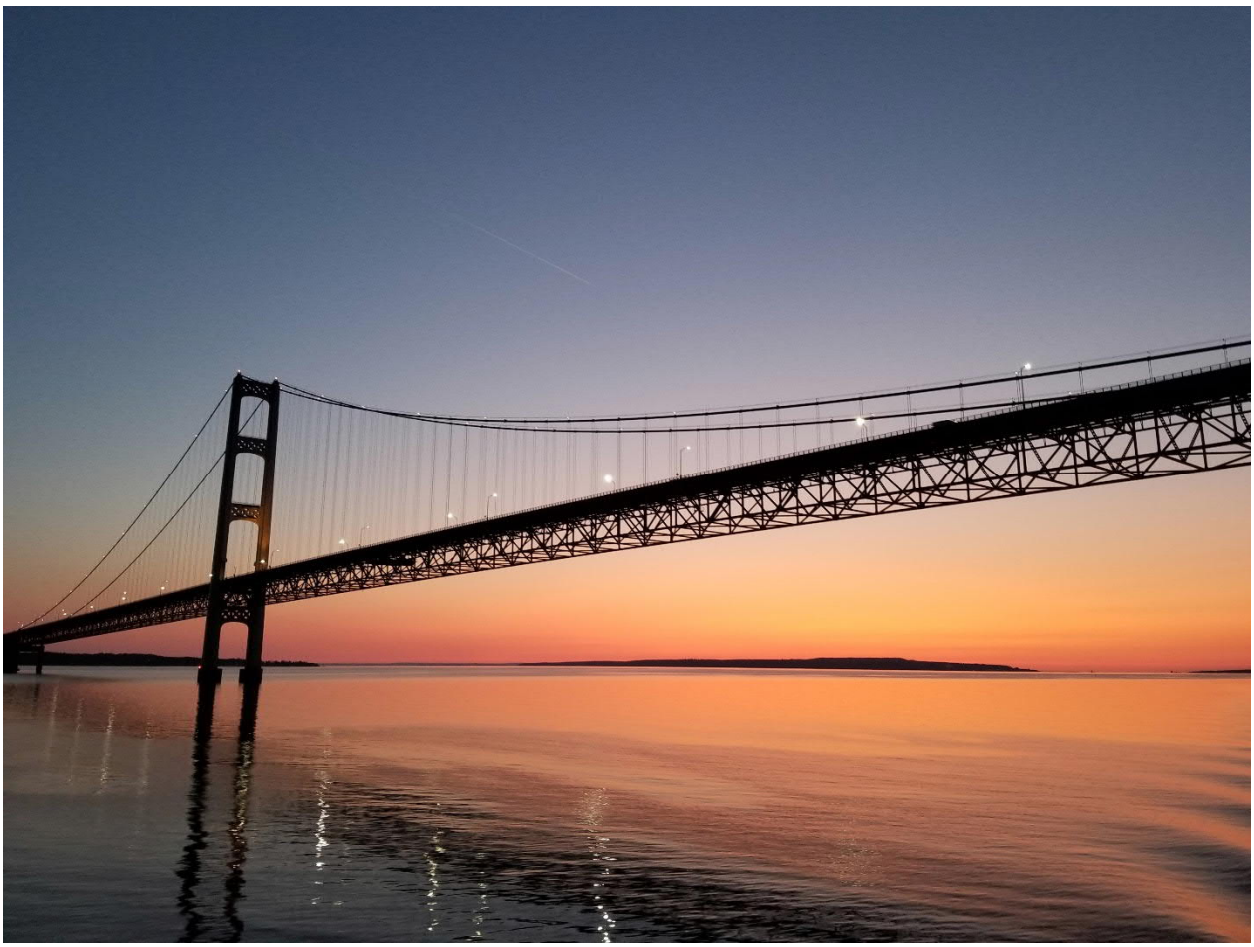
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

LINE 5 REPLACEMENT AND TUNNEL PROJECT

GEOTECHNICAL DATA REPORT

MARCH 09, 2020



LINE 5 REPLACEMENT AND TUNNEL PROJECT

GEOTECHNICAL DATA REPORT

ENBRIDGE ENERGY, LIMITED PARTNERSHIP

VERSION 1.1.1

PROJECT NO.: 31402024.00
DATE: MARCH 09, 2020

WSP
GUARDIAN BUILDING, SUITE 2600
500 GRISWOLD STREET
DETROIT, MI 48226

TEL.: +1 313 963-5760
FAX: +1 313 963-6910
WSP.COM

[Page Intentionally Left Blank]

SIGNATURES

PREPARED BY

Alex Williams, P.E.
Project Manager

REVIEWED BY

Elizabeth Dwyre, P.E.
Senior Technical Principal

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 General 1

1.2 Purpose and Limitations 1

2 GEOLOGIC SETTING 2

2.1 Regional Geology 2

2.2 NRCS SOIL SURVEY MAPPING 3

2.3 Surficial Soils Overlying the Bedrock Formation 4

2.4 Bedrock Geology 4

2.5 Potential for Karstic Conditions 7

2.6 Seismicity 9

2.7 Hydrology and Hydrogeology 9

3 HISTORICAL DATA AND PREVIOUS INVESTIGATIONS 10

4 GEOTECHNICAL INVESTIGATION PROGRAM 11

4.1 Introduction 11

4.2 Survey Datum, Coordinate System, and Measurement Units 11

4.3 Participants 11

4.4 Development of Subsurface Investigation Program 13

5 FIELD INVESTIGATION BORINGS 14

5.1 Introduction 14

5.2 Exploratory Borings 14

5.2.1 Onshore Borings 14

5.2.2 Nearshore Borings 17

5.2.3 Deepwater Borings 20

5.2.4 Storage of Samples 22

5.3 Environmental Program 22

5.3.1 Gas Monitoring 22

6 IN-SITU TESTING 24
6.1 Introduction 24
6.1.1 Pressuremeter Testing 25
6.1.2 Downhole Seismic Survey 25
6.1.3 Televiewing and Caliper Logs 26
6.1.4 Natural Gamma 27
6.1.5 Electrical Potential and Resistivity Logs 27
6.1.6 Temperature and Fluid Conductivity 27
6.1.7 Cone Penetration Test 28
7 HYDROGEOLOGIC TESTING 29
7.1 Packer Testing 29
7.2 Slug Testing 29
7.3 Aquifer Testing 30
7.4 Groundwater Sampling 30
7.4.1 Sampling Preservation and Handling 31
7.4.2 Equipment Calibration 31
7.4.3 Decontamination of Equipment 31
7.4.4 Laboratory Methods 32
7.4.5 Results 32
7.5 Long-Term Groundwater Observation Wells 32
8 LABORATORY TESTING PROGRAM 33
8.1 Geotechnical Program 33
8.2 Soil Testing 33
8.3 Rock Testing 33
9 REFERENCES 36

TABLES

TABLE 4.1: GEOTECHNICAL INVESTIGATION ROLES AND RESPONSIBILITIES 12
TABLE 5.1: ONSHORE BORING PROGRAM 16
TABLE 5.2: OBSERVATION AND PUMPING WELL CONSTRUCTION DETAILS 17
TABLE 5.3: NEARSHORE DRILLING PROGRAM 19
TABLE 5.4: DEEPWATER DRILLING PROGRAM 21
TABLE 5.5: GX-2009 MANUFACTURER DATA 23
TABLE 6.1: SUMMARY OF IN-SITU TEST PERFORMED 24
TABLE 7.1: GROUNDWATER SAMPLING TOLERANCES 31

FIGURES

FIGURE 1: MAP OF THE SUBMERGED MACKINAC VALLEY COLORIZED 3
FIGURE 2: GENERALIZED STRATIGRAPHIC COLUMN OF SILURIAN AND DEVONIAN ROCKS IN THE MACKINAC STRAITS REGION 4
FIGURE 3: MAP OF MACKINAC STRAITS REGION SHOWING ZONE OF COLLAPSE AND EXPOSURES OF MACKINAC BRECCIA 6
FIGURE 4: A PORTION OF ST. ANTHONY'S ROCK, AN EXAMPLE OF A SOLIDLY INDURATE MACKINAC BRECCIA OUTCROP 6
FIGURE 5: LOCATION MAP OF BRECCIA FEATURES ON MACKINAC ISLAND 7
FIGURE 6: MAP OF KARST FEATURES IN THE SILURIAN-DEVONIAN AQUIFER 8
FIGURE 7: SILURIAN-DEVONIAN AQUIFER IN MICHIGAN 8
FIGURE 8: SEISMIC HAZARD MAP OF THE UNITED STATES (USGS) 9
FIGURE 9: ROV SWEEP PATTERN FOR HAZARDS AND UTILITIES 18

APPENDICES

A MAPS

A-1 Project Location Map

A-2 Boring Location Plan

A-3 NRCS Soil Survey Maps

B EXPLORATORY BORINGS

B-1 As-Drilled Coordinates and Boring Elevations

B-2 Boring Logs

B-3 Observation Well Construction Logs

C SAMPLE PHOTOGRAPHS

C-1 Soil Sample Photographs

C-2 Rock Core Photographs

C-3 Deepwater Core Photographs

D IN-SITU TESTING

D-1 In-Situ Testing Excluding Deepwater Pressuremeter and Cone Penetrometer Tests

D-2 Deepwater Pressuremeter and Cone Penetrometer Tests

E LABORATORY TESTING

E-1 Soil Test Results

E-2 Rock Test Results

F HYDROGEOLOGY DATA

F-1 Packer Test Data

F-2 Slug Testing Data

F-3 Groundwater Sampling

F-4 Aquifer Test Report

F-5 Depth to Groundwater Measurements

1 INTRODUCTION

1.1 GENERAL

Line 5 is a 30-inch diameter petroleum pipeline owned and operated by Enbridge Energy, Limited Partnership (Enbridge) that has been in operation since 1953. The line runs 645 miles from Superior, Wisconsin, through Michigan's Upper Peninsula, crossing the Straits of Mackinac (Straits), then southeast to Port Huron where the pipeline crosses under the St. Claire River to Sarnia, Ontario. Where Line 5 traverses the Straits, the pipeline divides into two (2) 20-inch diameter pipelines. At the north and south ends of the crossing, where the water depth is shallow, the 20-inch lines are buried approximately 15 feet below the lake bed. Where the water depth in the Straits reaches approximately 65 feet, the pipelines run along the lake bottom.

The Line 5 Replacement and Tunnel (L5RT) Project replaces the existing dual 20-inch pipeline crossing the Straits with a new 30-inch pipeline in an approximately 4-mile long tunnel. The tunnel is anticipated to be excavated using a tunnel boring machine, and lined with precast concrete segments. Once the 30-inch pipeline is installed in the tunnel, the existing dual 20-inch pipelines will be decommissioned. The general project location is shown in Appendix A-1, Project Location Map. Figure A-1 also shows the land use features of the project area as of the date of the base map (USGS, 2017).

The geotechnical exploration for the L5RT Project was authorized by Enbridge under two separate contracts, the Onshore/Nearshore Contract and Deepwater Contract. The Onshore/Nearshore Contract was awarded to a team consisting of WSP USA, Inc. (WSP) as prime, with subcontractors Cascade Environmental Services, LLC and Colog, Inc. as well as several other supporting subcontractors. The Deepwater Contract was awarded to a team consisting of Fugro USA Marine, Inc. (Fugro) as prime, subcontractors WSP USA Inc. and Tidewater Inc., and several other supporting subcontractors. The Onshore/Nearshore program was authorized under contract L5SM-2-9-02 and the Deepwater program was authorized under contract L5SM-2-9-01. The geotechnical exploration was performed to obtain geotechnical data pertinent to the design and construction of the L5RT Project. This Geotechnical Data Report (GDR) presents the data obtained from this geotechnical investigation.

1.2 PURPOSE AND LIMITATIONS

This GDR prepared by WSP for the L5RT Project presents the results of the Subsurface Exploration and Laboratory Testing program. The GDR references previous geotechnical investigations performed by others for this project as well as relevant available historical geotechnical investigations.

The purpose of this GDR is to present:

- A description of general site conditions and geologic setting for the L5RT Project.
- A description of the field and laboratory methods and procedures used for the geotechnical investigation program.
- A compilation of available data from investigations performed under the supervision of WSP.

This GDR does not attempt to interpret the data or provide conclusions regarding design recommendations or construction considerations.

The data presented in this GDR represents site conditions during the time period in which the work was performed. Groundwater and lake conditions may vary seasonally and over time. The data obtained during this investigation is from a necessarily limited number of observations, borings, samples, and tests and is specific to the locations explored. The data does not completely define subsurface conditions throughout the project site, which may vary within short distances.

2 GEOLOGIC SETTING

2.1 REGIONAL GEOLOGY

The project area is in the northern portion of the Michigan Basin, which is an elliptical feature extending from approximately the north edge of the eastern part of the Upper Peninsula of Michigan into Indiana and Ohio to the south, and from eastern Wisconsin well into the Ontario peninsula to the east. It covers an area of approximately 80,000 square miles, and the sedimentary rocks comprising the basin reach a maximum thickness of 16,000 feet. The basin is bounded by the Canadian Shield to the north and northeast, and structural arches defining the rest of the perimeter: The Wisconsin and Kankakee Arches to the west and southwest, and the Findlay and Algonquin Arches to the southeast and east. The rocks comprising the basin all dip toward the center of the basin at about one degree or less (Gillespie, Harrison, & Grammer, 2008).

The Michigan Basin began forming during the Late Cambrian or Early Ordovician when a marine environment covered most of lower Michigan. The shallow sea covering the region was partially surrounded by highland areas from which some clastic sediment was eroded and deposited into the basin. In addition, the region was in an arid environment that allowed for a high rate of evaporation. The evaporation of the seawater concentrated dissolved minerals into a supersaturated solution. Thick layers of limestones, dolomites, halite, gypsum, and anhydrite were deposited in the basin in addition to layers of fine-grained sediments. The weight of the accumulating sediments began to warp the earth's crust downward, and created the basin in which additional sediment and evaporites were deposited.

Deposition in the Michigan basin continued through at least the Jurassic era. No rocks more recent than the middle Jurassic are present in the Michigan basin, either because none were deposited, or because the sediment that was deposited has since been eroded. Only scattered Jurassic age rocks are present in the center of the basin.

The project area and surrounding region was affected by at least six major glacial advances during Pleistocene time (beginning around 2.4 million years ago). The glacial advances carved out and subsequently enlarged the basins that form the Great Lakes; however, regional structure and paleo-drainage patterns influenced the current configuration. The Canadian Shield rocks were folded during the Precambrian time forming a northeast-southwest trending regional syncline, which helped funnel advancing glacial ice southwestward, scouring and deepening the basin further, and forming Lake Superior, while the area to the east was controlled by joint patterns in the rock. Generally, Lakes Michigan and Huron conform to the outcrop pattern of the soft limestones and shales of the Upper Silurian, Ordovician, and Devonian ages.

The most recent glacial episode was the Wisconsinan, which began between 79,000 and 65,000 years ago. The ice completely covered the Michigan Basin 22,000 years ago, and remained until it began to retreat beginning 18,000 years ago. Four minor re-advances of the ice occurred between 15,500 and 10,000 years ago; the region was completely ice-free by 9,000 years ago.

During the glacial period, proglacial lakes occupied portions of the Great Lakes basin. These lakes were fed by glacial meltwater during the retreat of the ice. They expanded, and sometimes merged with one another. Lake levels fell after further retreat of the ice opened new drainage channels. One of these retreats resulted in the carving of the Mackinac Valley, the submerged channel of the Mackinac River present within the Straits area, allowing water to flow from an early Lake Michigan (Lake Chippewa) to the Lake Huron basin (Lake Stanley). Figure 1 presents a colorized map of the submerged channel of the Mackinac River through the Straits area and was included in a field guide to Mackinac Island from the 2007 AIPG Annual Meeting.

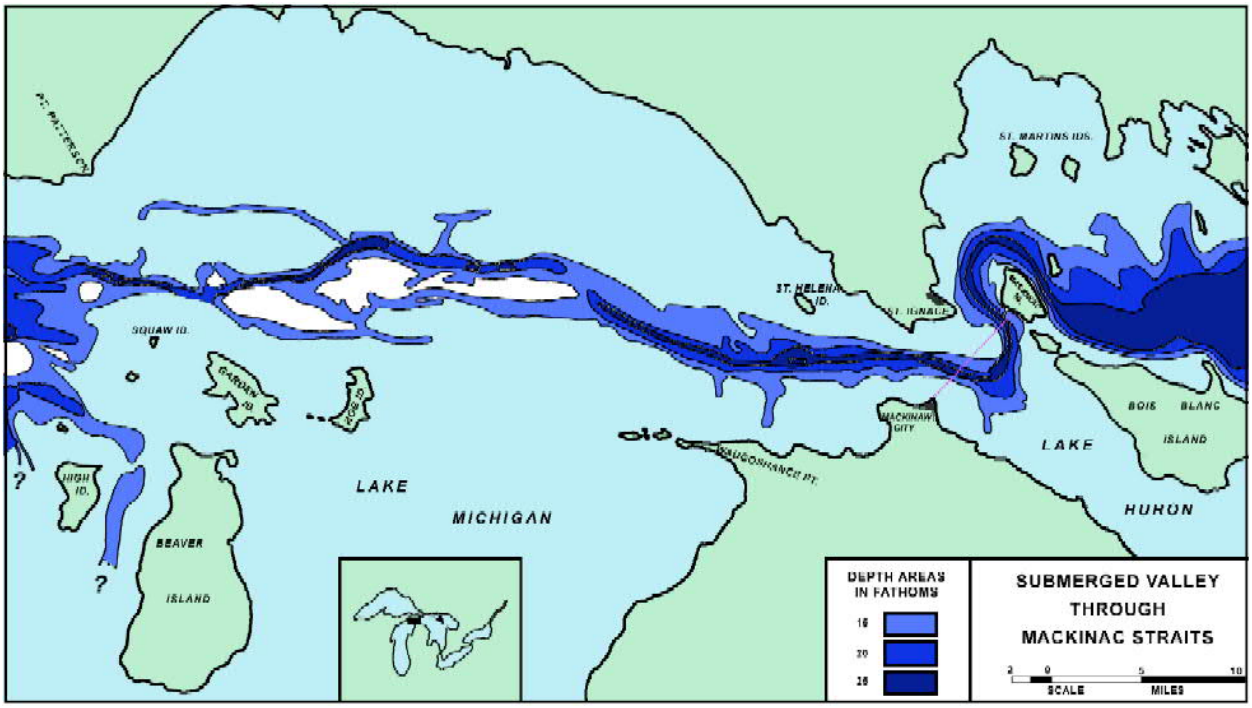


Figure 1: Map of the Submerged Mackinac Valley colorized after (Stanley, 1938)

The carving of the Mackinac Valley occurred in the low-water period between glacial Lake Algonquin and glacial Lake Nipissing (about 9,500 years ago). After the glacial ice had melted from the area, the removal of the overlying weight of ice allowed isostatic rebound of the land surface to the south to occur, raising the outlet channel elevation of the glacial lakes and allowing Lakes Michigan and Huron to fill to their present-day elevations.

The shorelines surrounding the lakes have wave-cut terraces and other features at different elevations based on glacial lake elevations. At least two separate levels of wave-cut terraces are present on nearby Mackinac Island, and two are present in the project area on the south side of the Straits.

2.2 NRCS SOIL SURVEY MAPPING

Soil survey maps prepared by the U.S. Department of Agriculture, Natural Resources Conservation Services (NRCS), formerly the Soil Conservation Service, for Mackinac and Emmet Counties provide information about the surficial soils in the project area. A copy of the maps and soil descriptions for soils identified on the maps are provided in Appendix A-3 NRCS Soil Survey Maps. The NRCS mapping is focused primarily on the uppermost approximately 6 feet of soil for land use and agricultural purposes.

Three soil types are mapped on the south side of the Straits. The southern area, from approximately the base of a wave-cut terrace south to the south end of the project area, is mapped as St. Ignace stony sandy loam, 2 to 6 percent slopes. This soil is described by the NRCS as well drained with moderately high to highly permeability and typically 16 to 18 inches thick overlying the fractured limestone bedrock. The area from the base of the wave-cut terrace to the edge of the lake is mapped as Alpena gravelly loamy sand, sandy variant, 0 to 6 percent slopes. This soil is described by the NRCS as excessively drained with high to very high permeability, and typically at least 80 inches thick. The lake area, extending from the edge of the lake to within about 50 feet north of the shoreline is mapped as stony lake beaches.

Five soil types are present on the north side of the Straits. The southern area, from the lake shore north to the “neck” of the peninsula, is mapped as Udipsamments and Udorthents, nearly level. This soil is described by NRCS as well to excessively drained, having a very high permeability, and is typically at least 80 inches thick. The soil in the northwestern part of the area is mapped as Alpena gravelly loamy sand, 0 to 15 percent slopes. This soil is described by NRCS as excessively drained, with moderately high to high permeability, and typically at least 80 inches thick. The soil in the north-central part of the area

is mapped as Esau-Zela complex, 0 to 3 percent slopes. This soil is described by NRCS as somewhat poorly drained, having moderately high to high permeability, and typically at least 80 inches thick. The soil in the northeastern part of the area is mapped as Markey and Carbonate mucks. This soil is described as very poorly drained with moderately high to high permeability. The soil on the east edge of the area is mapped as Histosols and Aquents, ponded. This soil is described as very poorly drained, having moderately high to high permeability, and typically at least 80 inches thick.

2.3 SURFICIAL SOILS OVERLYING THE BEDROCK FORMATION

Based on regional geologic mapping, surficial soils on the south shore are anticipated to be primarily sands of beach, littoral, and aeolian depositional origins. Other soils of glacial depositional origin are anticipated below the sands, based on the regional geologic setting. On the north shore, the map, "Quarternary Geology of Northern Michigan" (Farrand & Bell, 1982) shows the north shore soils as thin to discontinuous glacial till over bedrock.

The map "Quaternary Geology of Southern Michigan" (Farrand & Bell, Quarternary Geology of Northern Michigan, 1982), shows that the surficial soil on the southern part of the project area is composed of pale brown to reddish-brown fine to medium-grained sand, which commonly includes beds or lenses of small gravel. The sand is chiefly quartz sand, but the gravel is rich in igneous and metamorphic rocks. These soils occur primarily as former beach and near-offshore littoral deposits of the glacial Great Lakes, and may include intercalated lacustrine clay. These deposits are often locally veneered by discontinuous sheets or dunes of aeolian sand, and may include considerable areas of organic soils. Regionally, these deposits are typically 30 feet to 100 feet thick (Farrand & Bell, Quarternary Geology of Northern Michigan, 1982).

The same quaternary geology map also shows that pale brown, well sorted, fine- to medium-grained sand deposits are present in areas near and primarily east of the Southern part of the project area. The sand is mostly quartz, with some heavy minerals. It occurs chiefly in massive dune ridges parallel to present leeward shorelines, but also as parabolic dunes on former (Late Wisconsinan) lake and outwash plains. It is subject to continued movement in blowouts where vegetation is disturbed, especially near present-day coasts. Regionally, the dune sand ranges from 3 feet to 100 feet thick (Farrand & Bell, Quarternary Geology of Northern Michigan, 1982).

2.4 BEDROCK GEOLOGY

A generalized stratigraphic column for the area was prepared for the construction of the Mackinac Bridge by W. N. Melhorn (1959) and is presented below as Figure 2.

SYSTEM	SERIES	NAME OF UNIT	THICKNESS (ft)	DESCRIPTION	REMARKS
DEVONIAN	MIDDLE	DUNDEE FORMATION		MOSTLY LIMESTONE	NO BRECCIA
					EROSIONAL UNCONFORMITY
		DETROIT RIVER GROUP		LIMESTONE, DOLOMITE, SOME CHERT	
					EROSIONAL UNCONFORMITY
		BOIS BLANC FORMATION	325-400	ENTIRELY CHERTY LIMESTONE OR DOLOMITE	LOWER ONONDAGA FAUNA.
					EROSIONAL UNCONFORMITY
	LOWER	GARDEN ISLAND FORMATION	0-25	DOLOMITE OR DOLOMITIC SANDSTONE	PATCHY DISTRIBUTION. ORISKANY FAUNA.
					EROSIONAL UNCONFORMITY
SILURIAN	UPPER	ST. IGNACE FORMATION	200-300	DOLOMITE AND SHALE	
		POINTE AUX CHENES FORMATION	500-600	RED AND GREEN SHALE, THIN BEDS OF DOLOMITE, IRREGULAR MASSES AND STRINGERS OF GYPSUM.	SHALE EQUIVALENT TO "G" UNIT OF SALINA FORMATION IN MICHIGAN BASIN

"MACKINAC BRECCIA"

Figure 2: Generalized stratigraphic column of Silurian and Devonian rocks in the Mackinac Straits Region after (Melhorn, 1959)

The map, “Bedrock Geology of Southern Michigan” (Wilson & Milstein, 1987), shows that the uppermost bedrock unit below the southern part of the project area is the Early Devonian aged Bois Blanc Formation. The Bois Blanc Formation consists of sandy dolomite and cherty limestone which was deposited in an offshore marine environment. Some anhydrite or gypsum is also present in the Bois Blanc. The climate at the time of the deposition of the Bois Blanc Formation was arid or semiarid, and streams flowing into the sea provided abundant silica that was deposited as beds within the dolomite or as nodules within limestone offshore. The Bois Blanc Formation ranges in color from white and gray, to browns and blue (Dorr & Eschman, 1970). It dips southward an average of 55 feet per mile (Steinman, 1956).

The Garden Island Formation is a thin, Middle Devonian limestone that is stratigraphically between the Middle Devonian Bois Blanc Formation and Upper Silurian St. Ignace Formation. The Garden Island Formation is only known to outcrop on Garden Island, which is approximately 36 miles west of the Straits. If not eroded to the southwest of Garden Island, it may form the bed of Lake Michigan. The formation is not exposed in the Straits area, but several outcrops indicate that this formation was eroded prior to the deposition of the Bois Blanc Formation.

The Garden Island Formation is a light buff dolomitic sandstone containing a few frosted quartz grains, and a very hard buff gray to dark gray dolomite with a few chert nodules. The formation is restricted to a narrow zone, has a maximum thickness of 25 feet, and an average thickness of about 15 feet (Landes, 1945).

Beneath the Garden Island Formation is the St. Ignace Formation, which is a Late Silurian aged dolomite. It is present beneath the Straits area, and most of the project area. The St. Ignace Formation is evenly bedded, light gray, cream colored, and light buff dolomite. Some of the upper portion of this formation contains some thick bedded oolitic dolomite. The St. Ignace Dolomite typically ranges from 250 to 300 feet in thickness (Ehlers & Kesling, 1957). It dips southward an average of 52 feet per mile (Steinman, 1956).

The Pointe Aux Chenes Shale is the oldest formation encountered in this investigation and is stratigraphically below the St. Ignace Dolomite, and is Middle to Late Silurian in age. While it underlies the entire project area, it is only exposed around the Northern part of the area, and is encountered in borings drilled in the northern half of the alignment. It consists of green and red shale, thin beds of dolomite, thick layers of halite, and small irregular masses and thin beds of gypsum. The thickness of the formation ranges from 500 to 600 feet. The Pointe Aux Chenes Shale is interpreted to be a deltaic deposit that spread into the Michigan basin from a Northern source of land (Gillespie et al., 2008).

Each of the three bedrock formations (as well as additional early Devonian rocks that are no longer present in the area) also was affected by and contributed to the formation of the Mackinac Breccia. The Mackinac Breccia was formed during the middle Devonian when halite and gypsum layers within the Pointe Aux Chenes formation were dissolved, forming large subsurface voids. The collapse of these subsurface voids resulted in a jumbled mass of broken rock ranging from small fragments to large pieces 30 or more feet in diameter. The collapsed mass of rock was subsequently recemented into the breccia by secondary limestone deposition; however, the degree of cementation comprises a full spectrum, from minimal to complete. The assemblage of fragments ranges from solidly indurate formations, such as Castle Rock on the St Ignace peninsula and Arch Rock on Mackinac Island, to non-indurated masses where the fragments are effectively loose (Landes, 1945).

The extent of the Mackinac Breccia in the region encompasses more than the vicinity of the project. The Mackinac Breccia is present on the St. Ignace Peninsula, Mackinac Island, Round Island, Bois Blanc Island, parts of Beaver Island, and in a few places on the north part of the Southern Peninsula (Landes, 1945).

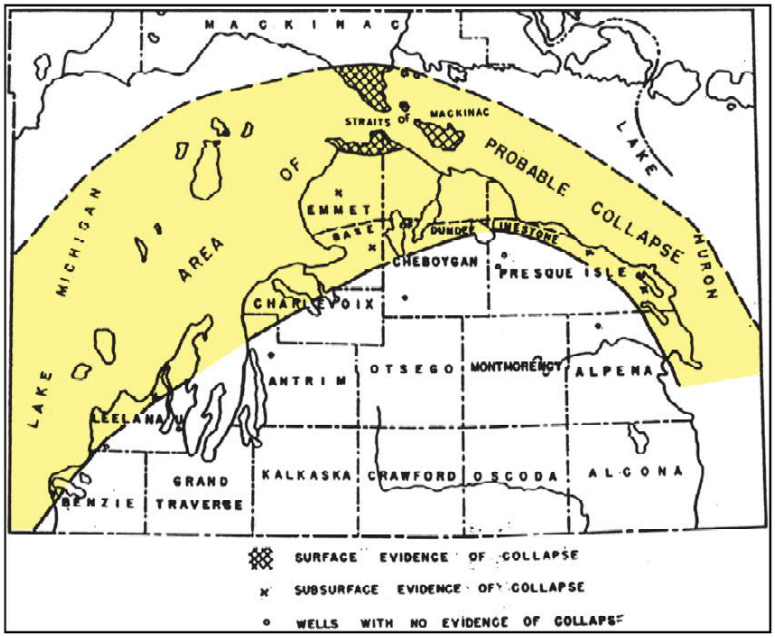


Figure 3: Map of Mackinac Straits Region Showing Zone of Collapse and Exposures of Mackinac Breccia after Landes, 1945

Figure 3 depicts the probable area of extent of the Mackinac Breccia. The map is based on surface outcrops of the breccia as well as subsurface evidence from wells drilled.

Locations on the St. Ignace Peninsula where the breccia is found in outcrops or exposures include Gros Cap, St. Anthony's Rock, Castle Rock, and the road cuts north of the toll plaza for the Mackinac Bridge.

Figure 4: A Portion of St. Anthony's Rock, An Example of a Solidly Indurate Mackinac Breccia Outcrop

Figure 5 shows the locations of the many exposures of breccia features on Mackinac Island. This figure originates from Porter and Nelhiebel (1984) and was included in a field guide to Mackinac Island from the 2007 American Institute of Professional Geologists (AIPG) Annual Meeting.

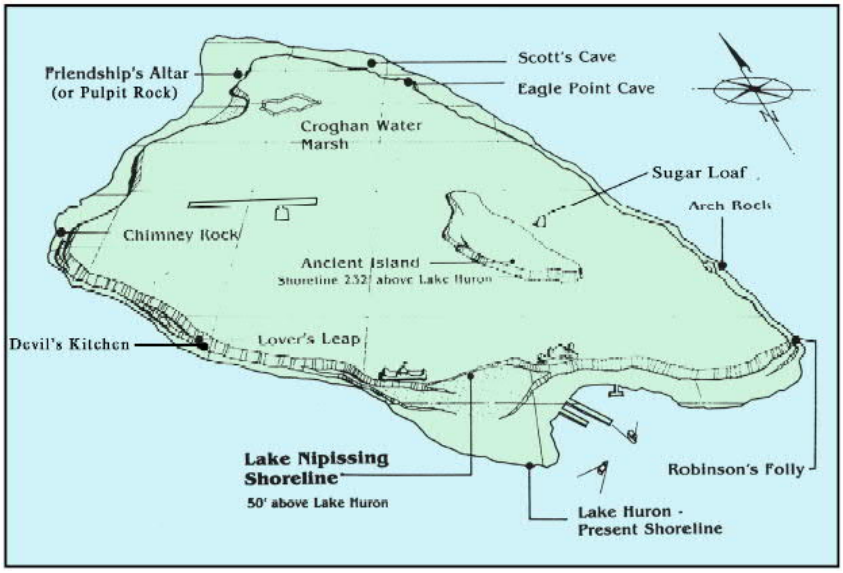


Figure 5: Location Map of Breccia Features on Mackinac Island (Porter & Nelhiebel, 1984)

The Mackinac Breccia is also present in places on the northern part of the Southern Peninsula; however, the thickness of the breccia is typically thin. A field guide from the Michigan Basin Geological Society (MBGS) from 1959 discusses an eight-inch thick layer of limestone breccia within the Upper Bois Blanc Formation. This location is about two miles south and one mile east of Mackinaw City. The Calcite Quarry in Rogers City, Michigan reportedly reached a layer of brecciated Detroit River Group rocks approximately 24 feet thick in the bottom of the pit, but the breccia had been covered over. The breccia was described as "small to large angular blocks of buff dolomite and then bedded to laminated dark bluish-gray limestone in a matrix of dark bluish-gray shale and comminuted limestone." The breccia was also present on the bottom of Lake Huron in the harbor for the quarry, and large blocks of dolomite were dredged from water.

2.5 POTENTIAL FOR KARSTIC CONDITIONS

Regionally Karst conditions have been mapped and are discussed in literature as being north and south of the L5RT Project site. The *Ground Water Atlas of the United States, Iowa, Michigan, Minnesota, and Wisconsin HA 730-J*, provides several figures describing the extent of Karst in the Silurian-Devonian Aquifer. Specifically, Figure 79, reproduced below as Figure 6, shows Karst in the upper and lower peninsulas of Michigan, to the north and south of the project site.

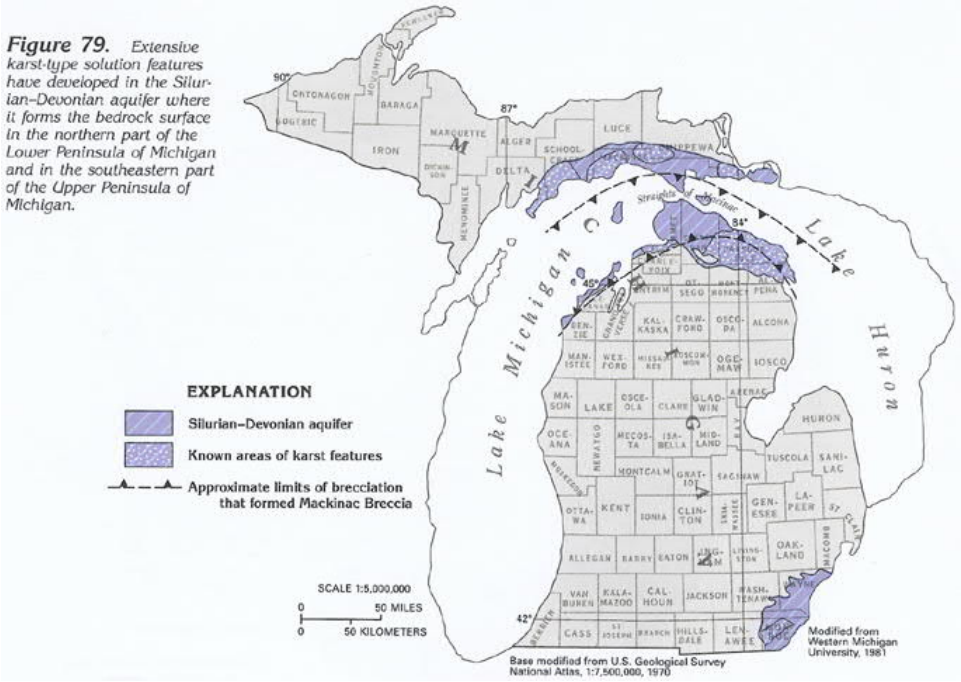


Figure 6: Map of Karst Features in the Silurian-Devonian Aquifer

The above referenced report also includes Figure 76, reproduced below as Figure 7, provides a general lithology of the Silurian-Devonian Aquifer. This lithology shows that the Mackinac Breccia extends from the Detroit River Group down to the Salina Group. The known karst features mapped are in the Traverse Group (above/South) and Niagara Group (below/North).

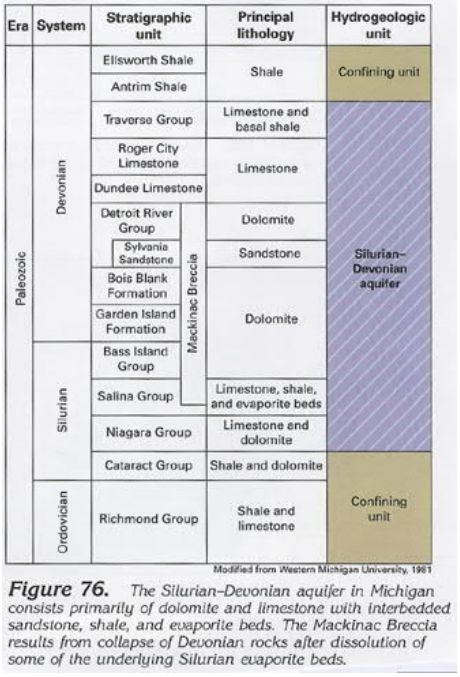


Figure 76. *The Silurian–Devonian aquifer in Michigan consists primarily of dolomite and limestone with interbedded sandstone, shale, and evaporite beds. The Mackinac Breccia results from collapse of Devonian rocks after dissolution of some of the underlying Silurian evaporite beds.*

Figure 7: Silurian-Devonian Aquifer in Michigan

2.6 SEISMICITY

The project site is not near any known active seismic fault lines. The USGS Earthquake Hazards Program provides National Seismic Hazard Maps of the United States at http://earthquake.usgs.gov/hazards/conterminous/index.php#2014. The Peak Ground Acceleration (PGA) with a two percent probabilistic return in 50 years map is reproduced below as Figure 8.

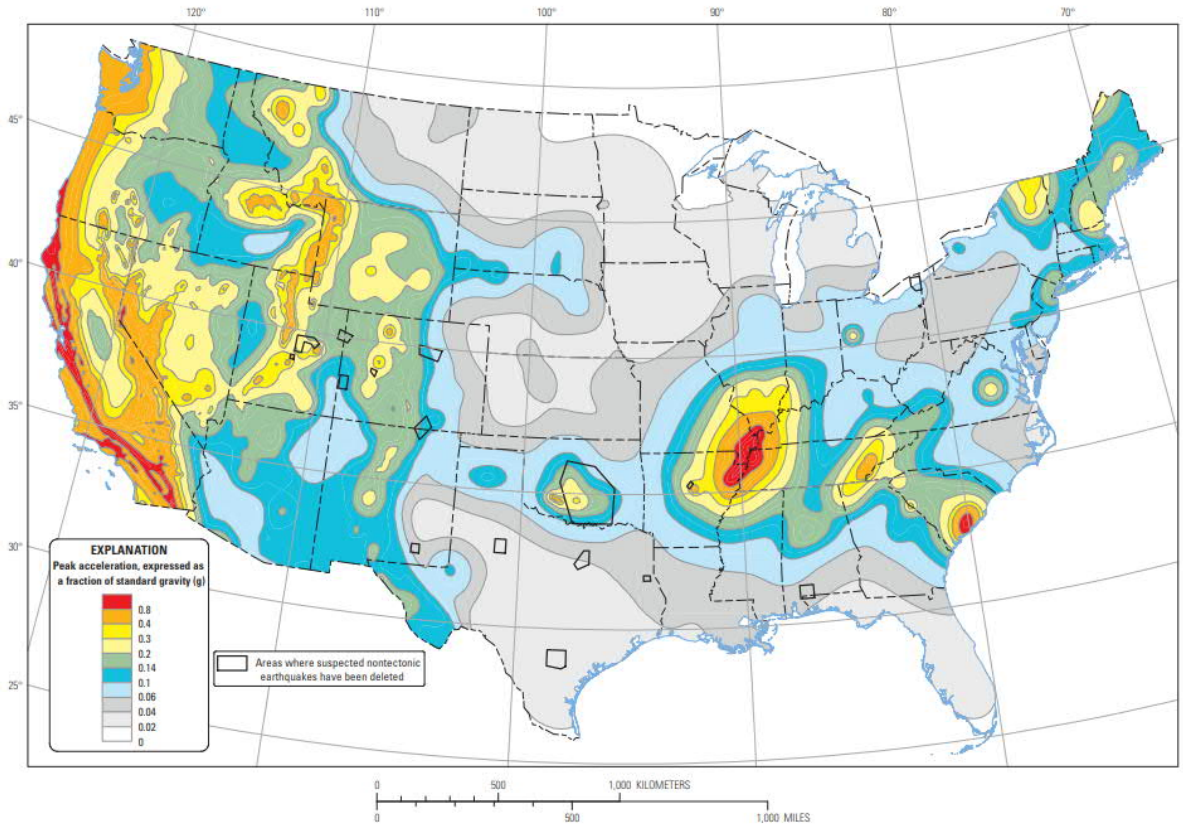


Figure 8: Seismic Hazard Map of the United States (USGS)

The site is mapped as being in a zone where the expected peak ground acceleration for this return period is 0.02g, the second lowest category. Note that design values for seismic design depend on several factors, including ground conditions and facility category and may be greater than the base value given by the seismic hazard map.

2.7 HYDROLOGY AND HYDROGEOLOGY

The project area is situated within the Northern Lower and Southeastern Upper Peninsula Hydrologic Province as defined by the U.S. Geological Survey. This region is characterized by relatively thin glacial-lacustrine sand that overlies Silurian and Devonian limestone and dolomite. The bedrock aquifers are the primary source of most groundwater supplies, however, glacial deposits (where sufficiently thick) are sometimes used for domestic supply (Rheaume, 1991).

Surface water in the project area drains toward Lake Michigan. The direction of groundwater flow in the unconsolidated glacial materials above the bedrock is generally toward Lake Michigan.

3 HISTORICAL DATA AND PREVIOUS INVESTIGATIONS

Historical data was available from the construction of the Mackinac Bridge. D.B. Steinman conducted a review of a total of sixty-one (61) borings, two (2) from the American Bridge Field office on the north shore, forty-nine (49) borings from the investigation for the Mackinac Bridge, and ten (10) historic borings provided by the Michigan Highway Department. Using the reviewed borings and inspections of nearby outcroppings, D.B. Steinman issued the "Final Geologic Report" in 1956 regarding the condition of the bedrock investigated. However, the borings completed did not investigate the area of the Straits shipping channel.

Two field explorations were conducted for the L5RT Project prior to the investigation covered by this GDR.

Between March 8th and May 21st, 2018, Materials Testing Consultants (Mateco) conducted a geotechnical investigation to provide information for the L5RT feasibility study. Mateco completed two borings, one on the north side and one on the south side of the Straits near the proposed alignment. The investigation included soil and rock logging, permeability testing, downhole geophysics, and laboratory testing.

Between September 10th and September 25th, 2018, Golder Associates, Inc. (Golder) conducted a geophysical investigation along the proposed L5RT alignment. The geophysical investigation focused on a marine seismic survey using seismic reflection and refraction. The recovered data was used to develop the interpreted lakebed elevation and top of bedrock elevation.

4 GEOTECHNICAL INVESTIGATION PROGRAM

4.1 INTRODUCTION

The geotechnical investigation program consisted of a review of existing information and subsurface data, a field explorations, and laboratory testing. Portions of the investigation described in this GDR include drilling, sampling, soil sample and rock core logging, field monitoring for toxic and combustible gases, groundwater testing, in-situ testing, groundwater observation well installations, water level measurements, aquifer testing, and laboratory testing of soils and rock.

4.2 SURVEY DATUM, COORDINATE SYSTEM, AND MEASUREMENT UNITS

The L5RT Project vertical datum is the International Great Lakes Datum (IGLD) 1985. The horizontal control for the L5RT Project is the North American Datum of 1983 (NAD83) Zone 16N, US Foot, Central Meridian 87°W.

During the drilling program, onshore borings were measured in feet with depth starting at the ground surface. Nearshore borings were measured in feet with depth starting at the top of casing. Deepwater borings were measured in meters with depth starting at the mudline.

The geotechnical work and data was primarily conducted in U.S. customary units. The deepwater phase of the field investigation was conducted in SI units, which were converted to US customary units for this GDR. In general, references in SI units have been converted on all data sheets, with the exception of rock core photographs from the deepwater exploration, which are labeled within the photo image in meters.

4.3 PARTICIPANTS

The geotechnical investigation program was divided into three phases, onshore, nearshore, and deepwater. The participants and their roles and responsibilities are summarized in Table 4.1.

Table 4.1: Geotechnical Investigation Roles and Responsibilities

INVESTIGATION PHASE	FIRM	ROLE AND RESPONSIBILITY
Onshore	WSP USA, Inc.	Prime responsible for inspection of drilling, sampling, sample logging, and hydrogeologic testing.
	Cascade Environmental	Subcontractor to WSP responsible for drilling operations.
	Colog, Inc.	Subcontractor to WSP responsible for downhole in-situ testing.
	Job Site Services Inc.	Subcontractor to Cascade responsible for site logistics
	TriMedia	Subcontractor to Cascade responsible for utility locates
	GeoTesting Express, Inc.	Laboratory contracted by WSP to perform laboratory testing of soil and rock samples
	Fibertec Environmental Services, Inc.	Laboratory contracted by WSP to perform laboratory testing of groundwater samples
Nearshore	WSP USA, Inc.	Prime responsible for inspection of drilling, sampling, sample logging, and hydrogeologic testing
	Cascade Environmental	Subcontractor to WSP responsible for drilling operations
	Andrie Transportation Group, Inc.	Subcontractor to Cascade Environmental responsible for providing and operating the jack-up barge
	Durocher Marine, a division of Kokosing, Inc.	Subcontractor to Cascade Environmental who provided marine support for jack-up barge operations (e.g. positioning and supplying the jack-up barge, crew transfers, etc.)
	Colog, Inc.	Subcontractor to WSP responsible for downhole in-situ testing
	GeoTesting Express, Inc.	Laboratory contracted by WSP to perform laboratory testing of soil and rock samples
	Fibertec Environmental Services, Inc.	Laboratory contracted by WSP to perform laboratory testing of groundwater samples
Deepwater	Fugro USA Marine, Inc.	Prime responsible for drilling operations and pressuremeter testing. Fugro staff jointly conducted hydrogeologic testing with WSP inspectors
	WSP USA, Inc.	Subcontractor to Fugro responsible for inspection of drilling, sampling, and sample logging. WSP inspectors jointly conducted hydrogeologic testing with Fugro staff
	Tidewater, Inc.	Subcontractor to Fugro who owned and operated the dynamically positioned vessel, Highland Eagle
	Durocher Marine, a division of Kokosing, Inc.	Subcontractor to Fugro who provided marine support for the Highland Eagle
	Colog, Inc.	Subcontractor to WSP responsible for downhole in-situ testing except for pressuremeter testing
	GeoTesting Express, Inc.	Laboratory contracted by WSP to perform laboratory testing of soil and rock samples
	Fibertec Environmental Services, Inc.	Laboratory contracted by WSP to perform laboratory testing of groundwater samples

4.4 DEVELOPMENT OF SUBSURFACE INVESTIGATION PROGRAM

The subsurface exploration program was developed by Hatch, Ltd in 2018. Enbridge obtained permits for the proposed south shore borings and on-water borings at specified coordinates, with permit provisions for a limited number of additional on-water borings to be performed in unspecified locations. Due to permitting considerations on the north shore, the 2019 investigation omitted activities on the North shore of the Straits.

Enbridge solicited proposals for the planned subsurface exploration program, selected teams led by WSP and Fugro as described in the preceding section, and finalized the details of the program in consultation with the selected firms. Seven borings were performed onshore; three were performed with a combination of sonic drilling and high-speed rock coring, four were performed with a combination of sonic drilling and SPT soil sampling. Three observation wells for the aquifer pumping test were constructed on the south shore and were logged geotechnically as a matter of course. Six borings were performed from a jack-up barge in up to about 70 feet of water depth by a combination of sonic and high-speed coring methods. Fourteen borings were performed from a dynamically positioned drill ship using high-speed coring methods. Boring depths on the South shore ranged from 4.5 feet to 150 feet, and depths ranged from 67.5 feet to 336 feet below the lake mudline for nearshore and deepwater borings. The boring inclinations were vertical, with the exception of one boring on the south shore (BH19-08) and one nearshore boring (BH19-07) which were drilled at an inclination of 20° from vertical. In addition to soil and rock sampling, the subsurface exploration program included in-situ testing, hydrogeologic testing, and laboratory soil and rock testing, as described in the following section.

5 FIELD INVESTIGATION BORINGS

5.1 INTRODUCTION

The field exploration program for the L5RT Project began on May 21, 2019 with the onshore phase of the investigation followed by the commencement of the nearshore phase of the investigation on June 11, 2019 and the deepwater phase of the investigation on July 10, 2019. The onshore and nearshore phases of the investigation were completed on July 27, 2019 and July 28, 2019 respectively. The deepwater phase of the investigation was completed on November 19, 2019. The field explorations consisted of drilling and sampling methods and in–situ testing methods as described in this section.

Experienced geotechnical engineers and/or geologists from WSP provided oversight of the boring and testing activities in the field. WSP inspectors were responsible for visually classifying the recovered soil samples and rock core, maintaining field boring and coring logs, and determining the location and type of samples to be obtained.

5.2 EXPLORATORY BORINGS

Data from the borings drilled for the L5RT Project are presented in this GDR. Of the total borings, seven were performed onshore on the south side of the Strait, six were performed nearshore from a jack-up barge, and fourteen were performed in deepwater using a dynamically positioned drill ship. Three observation wells for the aquifer pumping test were constructed on the south shore and were logged geotechnically as a matter of course. Boring locations are shown in Appendix A-2 Boring Location Map. Appendix B-2 contains the boring logs for each of the borings arranged in numerical order. The boring logs for the observation wells are included in Appendix B-3. Soil samples and rock core are stored in an Enbridge-owned facility.

5.2.1 ONSHORE BORINGS

Table B, provided in Appendix B-1 summarizes the as-drilled coordinates and boring elevations for the ten total onshore borings including the surveyed location, reference point elevation, total boring depth, end of boring elevation, the driller, and the inspector. The borings included six borings performed with a combination of sonic drilling and rock core drilling (three include an immediately adjacent Standard Penetration Tests), one boring for a pumping well, three observation wells to install piezometers. One of the borings was drilled at a 20° inclination from vertical, and the remaining boring inclinations were vertical. Sonic drilling and rock core drilling were generally performed in accordance with ASTM D6914 and ASTM D2113 respectively.

Prior to the commencement of drilling Cascade and WSP reviewed the boring locations based on the utility marking provided by Miss Dig and the results of 4-way sweep conducted by TriMedia Environmental and Engineering Services. When necessary, locations were offset for utility conflicts, or due to access constraints for drilling equipment. Additionally, stakes and caution tape were placed delineating areas where vehicles and equipment should not cross the existing pipeline. Finalized boring locations were in the general vicinity of the proposed locations.

ONSHORE DRILLING AND SAMPLING

Borings were performed using a truck-mounted Boart Longyear 600T drill rig for all onshore borings.

Borings BH19-08 through BH19-14 generally extended to depths of about 10 feet below the elevation of the L5RT Project tunnel excavation. Boring depths ranged from 17 to 113 feet below ground surface. BH19-12 was extended by sonic drilling methods from the initial depth of 90 feet to a depth of 150 feet below ground surface for an aquifer pumping test.

Borings BH19-08, BH19-09, and BH19-10 were advanced through overburden and the upper weathered rock with 4 x 6 (four-inch nominal core overridden by a six-inch casing) sonic drilling methods to depths of 10 to 19 feet, and continued in rock with wireline HQ3 coring (nominal core diameter of 61.1 mm) to the full depth. At selected locations, an NQ3 rock socket (nominal core diameter of 45.0 mm) was cored to facilitate performance of an in-situ pressuremeter test. The retrieved sonic, HQ3 core and NQ3 core were placed in plastic core trays.

Borings BH19-11 through BH19-14 were drilled with sonic drilling to full depth of 17 to 90 feet. It should be noted that the vibrations of sonic drilling methods do not provide intact rock core.

In general, borings were advanced without the need for casing installed independently of the sonic or wireline HQ3 coring. However, casing was used during advancement of BH19-10 and BH19-09. BH19-10 was sonic drilled to a depth of 17 feet, cleaned out and cored to a depth of 48 feet. Due to lost circulation and rock condition, coring was stopped and casing was advanced to 47 feet. Rock coring was resumed with full circulation to the final depth of 110 feet below ground surface. BH19-09 was advanced by SPT to a depth of about five feet, it was then cleaned out through sonic drilling to a depth of ten feet. The hole was then advanced with HQ3 core to a depth of 104 feet. Two NQ3 cored sockets were drilled to facilitate the in-situ pressuremeter tests. Due to instability of the hole at about 49 feet, the entire hole was reamed with the sonic drill and six-inch casing was installed to a final depth of 104 feet. the casing was pulled back to 55 feet below ground and was not removed further for the in-situ testing.

After completion of the drilling, the boreholes were backfilled by tremie grouting methods from the bottom of the borehole to the surface with ZEOGEL® (composed of attapulgite clay), except at BH19-08, BH19-09, and BH19-12 where the holes were left open to obtain water level observations, after which a permanent well for long-term water level observations was constructed.

In addition to extending BH19-12 to serve as the pumping well for the test, three groundwater observation wells were constructed, PZ19-40, PZ19-41, and PZ19-42. These wells were drilled by continuous sonic methods to completion.

At four of the boring locations, BH19-09, BH19-12A, BH19-13A, and BH19-14A, Standard Penetration Tests (SPT) borings were performed. At three of these locations, BH19-12A, BH19-13A and BH19-14A, the rig was offset approximately five feet in plan from the sonic boring. Continuous Standard Penetration Tests (SPT) samples were driven to split spoon refusal at depths of 4 to 7 feet below ground surface. SPT samples were collected in accordance with ASTM D1586. Samples were collected using a standard split barrel sampler with a two-inch OD and 1-3/8 -inch ID. The sampler was driven 24 inches into the ground using a 140-pound auto hammer free falling 30 inches. The number of blows required to advance the sampler in six inch increments was recorded to obtain the SPT N-Value. Representative SPT soil samples were placed in labelled glass jars where material was recovered. Boreholes BH19-12A, BH19-13A and BH19-14A were backfilled with soil cuttings.

The onshore drilling and sampling program is summarized below in Table 5.1

Table 5.1: Onshore Boring Program

BORING NUMBER	INCLINATION FROM VERTICAL AND AZIMUTH	SPT SAMPLING DEPTH (FT BGS)	SONIC DRILLING DEPTH (FT BGS)	ROCK CORING DEPTHS (FT BGS)	BOREHOLE BACKFILL OR WELL ABANDONMENT
BH19-08	21° / 23°	-	19	19-113	Permanent Well
BH19-09	0° / N/A	4.7	10	10-104	Permanent Well with VWP
BH19-10	0° / N/A	-	17	17-110	ZEOGEL®
BH19-11	0° / N/A	-	17	-	ZEOGEL®
BH19-12	0° / N/A	-	150	-	Permanent Well with VWP
BH19-12A	0° / N/A	4.9	-	-	Cuttings
BH19-13	0° / N/A	-	60	-	ZEOGEL®
BH19-13A	0° / N/A	6.7	-	-	Cuttings
BH19-14	0° / N/A	-	17	-	ZEOGEL®
BH19-14A	0° / N/A	4.5	-	-	Cuttings
PZ19-40	0° / N/A	-	100	-	Permanent Well
PZ19-41	0° / N/A	-	100	-	Permanent Well
PZ19-42	0° / N/A	-	50	-	Permanent Well

ONSHORE SAMPLE LOGGING

Sonic drilling soil samples and SPT soil samples from the onshore borings were classified and logged in the field by WSP inspectors. Classifications were performed in accordance with ASTM D2488 and recorded on the boring logs. Soil descriptions on the boring logs generally represent the field classifications, or, where further laboratory testing was performed, soil descriptions were reviewed and modified appropriately based on the data. Sample type, depth, recovery, boring location, drilling and sampling equipment, and drilling observations were also recorded on the boring logs.

In addition to the sample description and classification, hand held pocket penetrometer (PP) readings for cohesive soils are shown where taken. The PP is an index test providing an approximation or relative value of unconfined compressive strength. The PP readings are shown on the logs after the classification in tons per square foot.

Sonic drilling rock samples retrieved from the onshore borings were logged by WSP inspectors to record recovery and general lithology, but because the sampling method results in significant disturbance, no attempt was made to log rock discontinuities.

Rock core retrieved from the onshore borings was described in the field by WSP inspectors. WSP inspectors recorded run length, recovery, and Rock Quality Designation (RQD) in accordance with ASTM D6032. Additionally, WSP inspectors described discontinuities by characterizing joint surfaces for alteration, roughness, and infilling. Where rock became extremely fractured, individual fractures were not recorded. The extremely fracture zone's depth was indicated with the range of fracture angles, joint alterations, and joint roughness present.

In general, where core recovery was less than 100%, it was not possible to determine the actual depth of core loss, and it was assumed to be at the bottom of the run for logging purposes to determine depths of discontinuities. Where possible, Acoustic Televiewer Data was used to determine the actual depth of core loss. Rock type, strength, degree of weathering, color (Munsell, 2011), geologic formation, boring location in latitude and longitude, drilling equipment, and other drilling observations were also recorded on the boring logs. Boring logs for onshore borings are presented in Appendix B-2, together with a key to the logs.

The SPT sample boxes and the sonic and rock core boxes (plastic core trays) were labeled and transported to the core storage location.

ONSHORE PIEZOMETER CONSTRUCTION

Six onshore borings were converted into open-standpipe piezometers in general accordance with ASTM D5092, to monitor water levels and perform aquifer testing in the piezometers. The piezometers were constructed with two-inch-diameter Schedule 40 PVC with a ten foot long screened interval and 0.010 inch sized slots. The sand filter ranged in length from 20-98 feet bgs. The piezometers were installed in the HQ3 portions of borings BH19-08 (inclined) and BH19-09 (also known as PZ19-09 for the aquifer testing program). PZ19-40, PZ19-41, and PZ19-42 were installed in sonic boreholes. A piezometer was constructed in sonic borehole BH19-12 (also known as PW19-12 for the aquifer testing program) after aquifer testing was completed. All borings were completed with an eight-inch, flush mounted surface casing. Construction details for each of the piezometers are summarized in the Table 5.2

Table 5.2: Observation and Pumping Well Construction Details

OBSERVATION WELL	GROUND SURFACE ELEVATION (FT.)	TOP OF SCREEN DEPTH (FT. BGS)	TOP OF SCREEN ELEVATION (FT. MSL)	BOTTOM OF SCREEN DEPTH (FT. BGS)	BOTTOM OF SCREEN ELEVATION (FT. MSL)	TOP OF FILTER PACK DEPTH (FT. BGS)	TOP OF FILTER PACK ELEVATION (FT. MSL)	BOTTOM OF FILTER PACK DEPTH (FT. BGS)	BOTTOM OF FILTER PACK ELEVATION (FT. MSL)
BH19-08	584.3	70	518.5	80	509.1	10	574.9	108	482.8
BH19-09/PZ19-09	619.2	85	534.2	95	524.2	33	586.2	104	515.2
PZ19-40	652.2	85	567.2	95	557.2	50	602.2	95	557.2
BH19-12/PW19-12	652.1	130	522.1	140	512.1	50	602.1	150	502.1
PZ19-41	652.3	85	567.3	95	557.3	50	602.3	95	557.3
PZ19-42	621.4	40	581.4	50	571.4	30	591.4	50	571.4

The aquifer testing program is described in Section 7.3, and piezometer construction diagrams are included in Appendix B-3 at the end of this GDR. Data from automatic piezometers was downloaded by an Enbridge representative regularly. Manual observation wells were read intermittently by an Enbridge representative.

5.2.2 NEARSHORE BORINGS

Table B, provided in Appendix B-1 summarizes the as-drilled coordinates and boring elevations for the six nearshore borings including the surveyed location, reference point elevation, height of the reference point above lake level, total boring depth from reference point, end of boring elevation, the driller, and the inspector. The six nearshore borings were performed with a combination of sonic drilling and rock core drilling. One of the borings, BH19-07, was drilled at a 20° inclination from vertical, and the remaining boring inclinations were vertical. Sonic drilling and rock core drilling were generally performed in accordance with ASTM D6914 and ASTM D2113 respectively.

Nearshore borings were performed in the general vicinity of their proposed locations. Due to the nature of the nearshore work, utility markings provided by Miss Dig were unavailable. However, the Miss Dig notification served as a notification to the utility owners of the intended boring locations and a request for as-built information to be reviewed. As an additional measure to check that the boring location was clear of utilities, WSP inspectors conducted a series of visual sweeps of each boring area utilizing a remotely operated vehicle, Blue Robotics BlueROV 2 Heavy. The visual sweep pattern of the lake bottom utilized is shown in Figure 9.

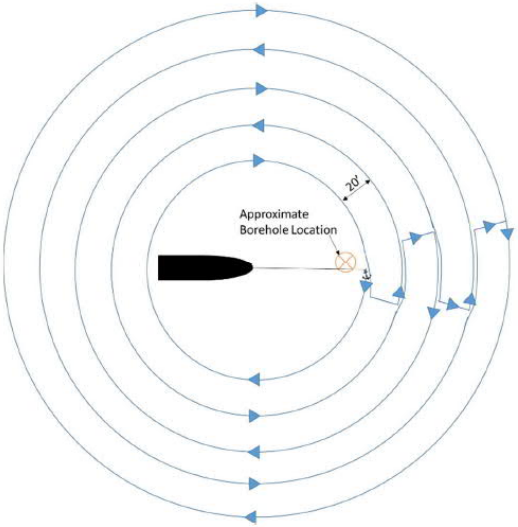


Figure 9: ROV Sweep Pattern for Hazards and Utilities.

Under the power of the Tug Nancy Anne and guided by HYPACK® GPS navigation, the barge was generally positioned within 10 feet of the proposed location. However, the top of casing location for BH19-07 was adjusted towards shore such that the mudline was intercepted at the proposed location coordinates. The jack-up barge legs were temporally lowered to the lakebed to secure the barge in location. WSP inspectors then verified the location with construction-grade Global Navigation Satellite System (GNSS) survey equipment. WSP inspectors conducted an additional visual ROV sweep to check that the jack-up barge legs were clear of obstructions and were on the lake bed prior to the jack-up barge jacking out of the water.

NEARSHORE DRILLING AND SAMPLING

The nearshore borings were performed using a track-mounted Boart Longyear 600C drill rig temporarily mounted to the jack-up barge. Borings BH19-15, 16, 17, 37, and 38 were drilled vertically. BH19-07 was drilled with a 20° incline from vertical. Groundwater levels were not measured or monitored.

Drilling was initiated with the placement of a seven-inch nominal casing embedded to a shallow depth below the mudline (about 15 feet). Drilling fluids and cuttings were required to be contained throughout drilling and sampling. As Cascade was lowering the mudline casing to the mudline, WSP inspectors lowered an anchor and line near the mudline casing's intercept with the mudline. The ROV was secured to the anchor line and left on station near the mudline throughout drilling to observe the mudline for inadvertent drilling fluid (water and soil/rock cuttings) release.

The mudline casing was suspended with the bottom of casing at the mudline to determine depth to mudline before embedment. Once embedded, WSP inspectors surveyed the top of the casing as the reference point. The four-inch nominal sonic core (sonic core) with sampling shoe was then lowered into the mudline casing and advanced to ten feet below the mudline. A six-inch nominal casing (over-core casing) was then advanced over the sonic core to stabilize the borehole and the sonic core was removed. The samples were removed from the sonic core and placed in a polyethylene sleeve. The recovered material was characterized by WSP inspectors and placed in sonic core boxes. The empty sonic core was lowered back into the borehole and the process was repeated, advancing the sonic core followed by the over-core casing in ten foot intervals to rock.

Every twenty feet, sonic drilling was stopped and a split spoon sampler was lowered to the bottom of the sonic core to obtain split spoon samples. Split spoon sampling consisted of Standard Penetration Testing (SPT) in accordance with ASTM D-1586. Samples were collected using a standard split barrel sampler with two-inch OD and 1-3/8 inch ID. The sampler was driven 24 inches into the ground using a 140-pound auto hammer free falling 30 inches. The number of blows required to advance the sampler in six inch increments was recorded to obtain the SPT N-Value. Representative SPT soil samples were placed in labelled glass jars where material was recovered.

When rock was encountered, sonic drilling and sampling continued until the sonic core and over-core casing were advanced ten to fifteen feet into rock. The sonic core and was removed from the borehole and PQ size casing with a casing shoe was then advanced back to the bottom of the borehole to facilitate rock coring.

Following the installation of the PQ casing into the borehole, a high-speed drill head was installed onto the sonic drill rig and rock coring began using wireline, HQ3 size tools. Coring was typically completed in five-foot runs using water from Lake Michigan (without additives) as the drilling fluid. At select depths, the HQ3 coring tooling was removed from the borehole and replaced with a HQ3 casing with casing shoe, and coring resumed for typically ten feet using NQ3 tooling to facilitate in-situ pressuremeter testing. At the completion of the pressuremeter testing, the HQ3 casing with casing shoe was advanced to the end of the NQ3 coring depth and then removed from the borehole. The HQ3 tooling with coring bit was lowered back into the borehole and HQ3 size coring resumed to termination.

Following completion of the boring, boreholes were generally backfilled by tremie grouting from the bottom of the borehole to the mudline with a cement-bentonite grout. Additional backfill notes can be found on the boring logs.

The nearshore drilling and sampling program is summarized below in Table 5.3.

Table 5.3: Nearshore Drilling Program

BORING NUMBER	INCLINATION FROM VERTICAL AND AZIMUTH	SONIC DRILLING DEPTH (FT BELOW TOC)	ROCK CORING DEPTHS (FT BELOW TOC)	BOREHOLE BACKFILL OR ABANDONMENT
BH19-07	19° / 219°	50-70	70-203	Cement-Bentonite Grout
BH19-15	0° / N/A	30-110	110-228	Cement-Bentonite Grout
BH19-16	0° / N/A	55-120	120-328.5	Cement-Bentonite Grout
BH19-17	0° / N/A	80-120	120-378	Cement-Bentonite Grout
BH19-37	0° / N/A	72-150	150-248.4	Cement-Bentonite Grout
BH19-38	0° / N/A	52.5-120	120-203	Cement-Bentonite Grout

NEARSHORE SAMPLE LOGGING

Sonic drilling soil samples and SPT soil samples from the nearshore borings were classified and logged in the field by WSP inspectors. Classifications were performed in accordance with ASTM D2488-09A and recorded on the boring logs. Soil descriptions on the boring logs generally represent the field classifications, or where further laboratory testing was performed, soil descriptions were reviewed and modified appropriately based on the data. Sample type, depth, recovery, boring location, drilling and sampling equipment, and drilling observations were also recorded on the boring logs.

In addition to the sample description and classification, hand held pocket penetrometer (PP) readings for cohesive soils are shown where taken. The PP is an index test providing an approximation or relative value of unconfined compressive strength. The PP readings are shown on the logs after the classification in tons per square foot.

Rock core retrieved from the nearshore borings was described in the field by WSP inspectors. WSP inspectors recorded run length, recovery, and RQD in accordance with ASTM D6032. Additionally, WSP inspectors described discontinuities by characterizing joint surfaces for alteration, roughness, and infilling. Where rock became extremely fractured, individual fractures were not recorded. The extremely fracture zone's depth was indicated with the range of fracture angles, joint alterations, and joint roughness present. Rock type, strength, degree of weathering, color (Munsell, 2011), geologic formation, boring location in latitude and longitude, drilling equipment, and other drilling observations were also recorded on the boring logs. Boring logs for the nearshore borings are presented in Appendix B-2, together with a key to the logs.

The sonic and rock core boxes (plastic core trays) were labeled and transported to the core storage location.

DEVIATIONS FROM WORKPLAN

Generally, the nearshore borings were drilled in accordance with the project specific work plan; however, BH19-16 and BH19-17 encountered geologic conditions that required deviations from the project specific work plan. At BH19-16, sonic casing was advanced to a depth of 250 feet below top of casing to stabilize a sand layer encountered between 240 and 249 feet. Borehole geophysical testing was omitted within the cased portion of the borehole above 250 feet. At BH19-17, the sequence of drilling, testing and grouting as well as the packer diameters was modified to manage caving conditions. Packer testing was completed throughout BH19-17 excluding local caving zones and the depth interval from 251 to 203 feet. Borehole geophysical testing was not performed in the depth interval from 267 to 309 feet due to the obstruction of the packer assembly, and was omitted above a depth of 221 feet due to weather conditions. Further details are included on the boring logs.

5.2.3 DEEPWATER BORINGS

Table B, provided in Appendix B-1 summarizes the as-drilled coordinates and boring elevations for the fourteen deepwater borings including the surveyed location, the reference point elevation, depth of the reference point below lake level, total boring depth from the reference point, end of boring elevation, the driller, and the inspector.

Deepwater borings were performed in the general vicinity of their proposed locations. The Highland Eagle generally positioned itself within 10 feet of the proposed location. While on location the Highland Eagle's position was continuously surveyed with onboard GPS and maintained using dynamic positioning thrusters. Due to the nature of the offshore work, utility markings provided by Miss Dig were unavailable. However, the Miss Dig notification served as a notification to the utility owners of the intended boring locations and a request for as-built information to be reviewed. Once the Highland Eagle reached the proposed boring location and was maintaining its position, a visual and sonic survey was performed to confirm the boring location was clear of utilities.

DEEPWATER DRILLING AND SAMPLING

The deepwater borings were performed using a Fugro R-30 marine drill mounted on the Highland Eagle. All deepwater borings were drilled vertically, and groundwater levels were not measured or monitored.

Drilling was initiated by lowering a clamping frame to within sight of the lakebed. A camera mounted on the clamping frame was then used to observe the area of the proposed boring to verify that no utilities or other obstructions were visible. The Highland Eagle was then moved forward and the frame was lowered to the lakebed. A seven-inch nominal diameter L80 steel casing was lowered through the lakebed clamp and advanced into the overburden. Drilling fluids and cuttings were required to be contained throughout drilling and sampling. The camera mounted on the clamping frame observed the mudline throughout drilling for inadvertent drilling fluid release.

Following the embedment of the casing into the mudline, coring of the soil began using wireline, Geobor-S triple barrel size tools and bentonite-water drilling fluid. Geobor-S triple barrel size tooling has an outer diameter of 146 mm that produces core samples with a diameter of 102 mm. Coring with the Geobor-S was utilized for both the overburden and rock. In instances where coring was to begin at a specified elevation, a Non-Coring Device (NCD) was used to drill to the desired elevation. While using the NCD, no samples are recovered. Additionally, the NCD was occasionally used between Geobor-S sampled runs to accelerate the coring process.

While in the overburden for select borings, coring was temporarily stopped. The Geobor-S core barrel was removed and a Cone Penetration Test (CPT) was performed. At the completion of each CPT stage, NCD drilling advanced the boring to the end of the completed CPT stage. The NCD was removed and another CPT stage was completed. Once CPT testing was compete, coring resumed using the Geobor-S core barrel.

At select depths, the Geobor-S core barrel was removed and T6-101 sized tooling with an outer diameter of 101 mm that produces a 72 mm diameter core, was lowered through the Geobor-S string. The T6-101 sized tooling was then utilized to drill a 9.84 ft long socket to facilitate in-situ pressuremeter testing. Pressuremeter testing for the deepwater phase was performed by Fugro. At the completion of the pressuremeter testing, the T6-101 sized tooling was removed from the borehole and drilling resumed using the Geobor-S triple barrel tooling to termination.

The deepwater drilling and sampling program is summarized below in Table 5.4.

Table 5.4: Deepwater Drilling Program

BORING NUMBER	INCLINATION FROM VERTICAL AND AZIMUTH	SOIL DEPTHS DRILLED (FT BELOW MUDLINE)	ROCK DEPTHS DRILLED (FT BELOW MUDLINE)	BOREHOLE BACKFILL OR ABANDONMENT
BH19-19	0° / N/A	0-63.5	63.5-200.3	Cement-Bentonite Grout
BH19-21	0° / N/A	0-49.2	49.2-52.7	Cement-Bentonite Grout
BH19-23	0° / N/A	0-155.6	155.6-245.2	Cement-Bentonite Grout
BH19-24	0° / N/A	0-155.5	N/A	Cement-Bentonite Grout
BH19-24A	0° / N/A	0-225.4	225.4-316.3	Cement-Bentonite Grout
BH19-25	0° / N/A	0-303.0	303.0-326.4	Cement-Bentonite Grout
BH19-26	0° / N/A	0-320.5	320.5-336.3	Cement-Bentonite Grout
BH19-27	0° / N/A	0-282.5	282.5-328.4	Cement-Bentonite Grout
BH19-28	0° / N/A	0-161.9	161.9-249.7	Cement-Bentonite Grout
BH19-31	0° / N/A	0-132.2	132.2-265.7	Cement-Bentonite Grout
BH19-32	0° / N/A	0-92.4	92.4-197.2	Cement-Bentonite Grout
BH19-33	0° / N/A	0-112.8	112.8-217.6	Cement-Bentonite Grout
BH19-35	0° / N/A	0-155.8	155.8-231.3	Cement-Bentonite Grout
BH19-36	0° / N/A	0-123.8	123.8-221.5	Cement-Bentonite Grout

DEEPWATER SAMPLE LOGGING

Geobor-S soil samples from the deepwater borings were classified and logged in the field by WSP inspectors. Classifications were performed in accordance with ASTM D2488-09A and recorded on the boring logs. Soil descriptions on the boring logs generally represent the field classifications, or where further laboratory testing was performed, soil descriptions were reviewed and modified appropriately based on the data. Sample type, depth, recovery, boring location, drilling and sampling equipment, and drilling observations were also recorded on the boring logs.

In addition to the sample description and classification, hand held pocket penetrometer (PP) readings for cohesive soils are shown where taken. The PP is an index test providing an approximation or relative value of unconfined compressive strength. The PP readings are shown on the logs after the classification in tons per square foot.

Rock core retrieved from the deepwater borings was described in the field by WSP inspectors. WSP inspectors recorded run length, recovery, and RQD in accordance with ASTM D6032. Additionally, WSP inspectors described discontinuities by characterizing joint surfaces for alteration, roughness, and infilling. Where rock became extremely fractured, individual fractures were not recorded. The extremely fracture zone's depth was indicated with the range of fracture angles, joint alterations, and joint roughness present. Rock type, strength, degree of weathering, color (Munsell, 2011), geologic formation, boring location in latitude and longitude, drilling equipment, and other drilling observations were also recorded on the boring logs. Boring logs for the deepwater borings are presented in Appendix B-2, together with a key to the logs.

The Geobor-S core boxes (wood core boxes) were labeled and transported to the core storage location.

5.2.4 STORAGE OF SAMPLES

ONSHORE BORING SAMPLES

At the end of each shift, soil samples, sonic boxes, and rock cores were stored at Enbridge's Mackinaw Station, and were subsequently transported to the core storage facility. Once at the core storage facility, WSP inspectors registered recovered samples with a bar code, took high resolution photographs of the sonic boxes and rock core boxes, as well as designated rock and soil samples for laboratory testing. The samples designated for testing were wrapped, packaged, and shipped to the laboratory. Soil and rock samples were preserved and transported in general accordance with ASTM D4220 and D5079. For samples sensitive to changes in engineering properties upon drying, only samples which had been wrapped were submitted for testing.

NEARSHORE BORING SAMPLES

Soil samples, sonic core boxes, and rock core boxes were temporarily stored on the jack-up barge until weather conditions and timing were favorable. When weather and timing permitted, soil samples, sonic boxes, and rock cores were lowered via crane onto the crew boat and transported to shore. Upon reaching the shore, the samples were transported by WSP inspectors to the core storage facility. Once at the core storage facility, WSP inspectors registered recovered samples with a bar code, took high resolution photographs of the sonic boxes and rock core boxes, as well as designated rock and soil samples for laboratory testing. The samples designated for testing were wrapped, packaged, and shipped to the laboratory. Soil and rock samples were preserved and transported in general accordance with ASTM D4220 and D5079. For samples sensitive to changes in engineering properties upon drying, only samples which had been wrapped were submitted for testing.

DEEPWATER BORING SAMPLES

Onboard the Highland Eagle, WSP inspectors registered the recovered samples with a barcode, took high resolution photographs of the core boxes, as well as designated rock and soil samples for laboratory testing. The core boxes and laboratory samples were stored inside a refrigerated, 1 TEU (twenty-foot equivalent unit) intermodal container on the Highland Eagle until the ship returned to port in Rogers City, MI. Once docked in port, the samples and core boxes were unloaded. WSP inspectors transported the samples and core boxes to the core storage facility. The samples designated for testing were wrapped, packaged, and shipped to the laboratory. Soil and rock samples were preserved and transported in general accordance with ASTM D4220 and D5079. For samples sensitive to changes in engineering properties upon drying, only samples which had been wrapped were submitted for testing.

5.3 ENVIRONMENTAL PROGRAM

During drilling and sampling, environmental field testing consisted of gas monitoring for the onshore borings using a GX-2009 gas monitoring unit. The unit was mounted near the casing and checked for calibration at the beginning of each shift.

5.3.1 GAS MONITORING

GX-2009 gas monitoring readings were performed by Cascade during drilling operations of the onshore borings. The GX-2009 contains sensors that utilize catalytic combustion, electrochemical, and galvanic sensor technologies. Table 5.5 presents the manufacturer provide specifications regarding type of sense detection, range, accuracy, and the user set alarms that were set during monitoring. At all of the onshore borings, gas readings were taken near the casing and no alarms went off during the process.

Table 5.5: GX-2009 Manufacturer Data

GAS DETECTED	COMBUSTIBLE GASES (METHANE AS STANDARD)	OXYGEN (O2)	HYDROGEN SULFIDE (H2S)	CARBON MONOXIDE (CO)
Detection Principle	Catalytic Combustion	Galvanic Cell	Electrochemical Cell	
Detection Range (increments)	0 ~ 100% LEL (1% LEL)	0 ~ 40.0% Vol. (0.1% Vol.)	0 ~ 100.0 ppm (0.5 ppm)	0 ~ 500 ppm (1 ppm)
Accuracy Statement	± 5% of greater reading or ± 2% LEL *(whichever is greater)	± 0.5% O2	± 5% of reading or ± 2 ppm H2S	± 5% of reading or ± 5 ppm CO (whichever is greater)
User Set Alarms	1st Alarm 10% LEL 2nd Alarm 20% LEL	Low Alarm 19.5% High Alarm 23.5%	1st Alarm 10 ppm 2nd Alarm 15 ppm	1st Alarm 35 ppm 2nd Alarm 200 ppm

6 IN-SITU TESTING

6.1 INTRODUCTION

All in-situ testing with the exception of High Pressure Dilatometer Testing and Cone Penetration Testing (CPT) of the deepwater borings was conducted by Colog. The High Pressure Dilatometer Testing and Cone Penetration Testing (CPT) testing was performed by Fugro. The testing methodology and equipment utilized by Colog and Fugro are discussed in Appendix D-1 and D-2 respectively. The type of in-situ testing performed for the investigation consisted of:

- Pressuremeter Testing (PM)
- Downhole Seismic Survey (DSS)
- Optical and/or Acoustic Televiewing (OTV and ATV respectively)
- Caliper Logging
- Natural Gamma Logging
- Electric Log Tests (ELOG)
  - Spontaneous Potential
  - Instantaneous Potential
  - Short (16”) and Long (64”) Normal Resistivity
- Fluid Temperature and Conductivity (FTC)
- Cone Penetration Testing (CPT)
- High Pressure Dilatometer testing (HPD)

Table 6.1 lists the depths in-situ tests were performed in each boring. For complete results of in-situ tests, see Appendix D-1 and Appendix D-2.

Table 6.1: Summary of In-Situ Test Performed

BORING	PM	DSS	OTV	ATV	CALIPER	NATURAL GAMMA	ELOG	FTC	CPT	HPD
BH19-07	NT	76-160 168-194	65-169	69-168 171-203	48-203	45-203	71-203	0-203	NT	NT
BH19-08	38 110	23-79	21-97	21-96	20-90	4-89	23-90	2-91	NT	NT
BH19-09	44 102	23-42 50-84	10-50 55-90	21-96	9-95	6-93	34-94	30-95	NT	NT
BH19-10	107	69-97	47-101	62-101	45-108	3-106	71-108	68-109	NT	NT
BH19-15	149 206	104-217	146-228	105-227	5-230	17-226	110-226	20-228	NT	NT
BH19-16	294	248-310	254-277	254-324	254-319	7-138	252-319	240-322	NT	NT
BH19-17	NT	119-197 213-259 297-367	111-187 210-265 299-379	121-198 221-264 310-375	115-265 297-376	5-375	120-193 220-263 310-376	120-265 300-378	NT	NT
BH19-19	NT	58-116	NT	NT	0-128	0-128	70-127	58-119	NT	NT

BORING	PM	DSS	OTV	ATV	CALIPER	NATURAL GAMMA	ELOG	FTC	CPT	HPD
BH19-21	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
BH19-23	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
BH19-24	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
BH19-24A	NT	222-303	NT	226-307	5-310	5-313	218-313	220-306	NT	NT
BH19-25	NT	299-313	NT	305-325	1-324	1-324	287-325	3-323	NT	NT
BH19-26	NT	NT	NT	322-335	0-333	0-333	NT	NT	95-100	NT
BH19-27	NT	NT	NT	290-328	0-328	0-328	278-327	279-328	115-120	NT
BH19-28	NT	164-238	NT	167-250	150-250	0-247	160-248	0-250	NT	NT
BH19-31	NT	132-252	NT	135-265	0-265	126-264	127-264	126-200 180-267	NT	NT
BH19-32	NT	94-192	NT	93-198	0-196	0-196	95-198	89-196	NT	NT
BH19-33	NT	113-201	119-139	119-212	0-213	0-210	108-211	115-213	NT	148
BH19-35	NT	156-220	NT	158-232	0-231	0-229	150-230	115-231	NT	NT
BH19-36	NT	130-211	NT	131-221	0-222	0-220	116-220	11-222	NT	NT
BH19-37	NT	148-236	151-248	151-248	140-246	7-246	152-246	140-248	NT	NT
BH19-38	131	116-164	5-179	125-174	116-176	4-172	116-174	11-175	NT	NT

NT = Not Tested

6.1.1 PRESSUREMETER TESTING

Prior to testing, the inflatable probe was calibrated for pressure (by inflating the probe in an unconfined condition) and volume (by inflating the probe in a fixed volume condition). Once placed in the borehole, the probe was radially expanded by introducing equal increments of increasing water volume, and collecting pressure-volume data. Once the tests were complete, the data was plotted to determine the deformability and shear modulus of the rock mass at the tested zone. Onshore and nearshore pressuremeter testing was conducted utilizing a RocTest PROBEX dilatometer. Deepwater pressuremeter testing was conducted utilizing a Cambridge Insitu Limited 95mm High Pressure Dilatometer (HPD95).

Results from the onshore and nearshore rock pressuremeter testing are included in Appendix D-1, and result from the deepwater rock pressuremeter testing is included in Appendix D-2.

6.1.2 DOWNHOLE SEISMIC SURVEY

Colog performed downhole seismic surveys to measure velocity of compression (P) and shear (S) waves in the rock portion of boreholes.

A mechanical dipole source was used to create a pressure wave that propagates parallel and normal to the borehole walls. Two in-line motion-detecting hydrophones record from the motion in the borehole fluid. Measurements were taken in static conditions at approximately 3-foot intervals. The captured P- and S-wave data is then processed to identify P- and S-waves velocities. The downhole seismic survey was conducted utilizing a Robertson Geologging Digital PS, PS Suspension Logger.

The downhole seismic surveys are included in Appendix D-1.

6.1.3 TELEVIEWING AND CALIPER LOGS

OPTICAL TELEVIEWER

The Optical Televiewer (OTV) log provides a 360 degree visual image of the borehole wall. The OTV probe has a window section that facilitates an internal camera to view the borehole wall reflected off a conical mirror. The tool can be used in a dry hole, or fluid-filled hole. However, the fluid filling the boring must be clear and not murky. At a given depth, the camera captures an image of the borehole wall off the conical mirror. As the images are being captured, the position of the image is being recorded by an onboard orientation sensor. The orientation sensor measures the direction and dip of the boring. Using the orientation data, the images from each interval are stacked on top of each other as the tool passes through the hole. This builds a three-dimensional image of the hole. After logging, image features such as fractures and bedding planes are mapped for their orientation, strike and dip, and aperture. For the Nearshore and Onshore borings, an LIM OPTV Optical Televiewer was utilized, for the Deepwater borings a Mount Sopris Instruments QL40-OBI Optical Televiewer was utilized for optical imaging.

The OTV logging results are included in Appendix D-1.

ACOUSTIC TELEVIEWER

The Acoustic Televiewer (ATV) log provides an acoustic image of the borehole wall. A rotating acoustic source within the ATV tool emits a sonic pulse which is reflected off the borehole wall to a receiver housed in the ATV probe. The tool requires a fluid-filled hole to provide a medium to transport the acoustic pulse to and from the tool and the borehole wall. The amplitude and travel time of the return pulse is recorded at the probe for the full circumference of the borehole at a given depth. As each pulse is being captured, the position of the pulse is being recorded by an onboard orientation sensor. The orientation sensor measures the direction and dip of the boring. Using the orientation data, the results of each interval are stacked on top of each other as the tool passes through the hole. This builds a three-dimensional image of the hole. After logging, image features such as fractures and bedding planes are mapped for their orientation, strike and dip, and aperture. For the Nearshore and Onshore borings, an LIM BTHV Acoustic Televiewer was utilized, for the Deepwater borings, a Mount Sopris Instruments QL40-ABI Acoustic Televiewer was utilized for acoustic imaging.

The ATV logging results are included in Appendix D-1.

DIRECTIONAL SURVEY

As discussed above, the position of the OTV and/or ATV logging tool is recorded by an onboard orientation sensor for the duration of the logging. The onboard orientation sensor measures the orientation (azimuth), dip (inclination), and strike (direction of dip) of the tool using magnetometers and accelerometers. After logging is complete, the position data is processed and can be used to generate a plan view or three-dimensional view of the actual borehole trajectory.

Directional survey results are included in Appendix D-1,

CALIPER LOG

The caliper log measures the average borehole diameter along the length of the borehole. Spring-loaded caliper arms are connected through a resistor. As the tool is raised from the bottom of the borehole, the arms open or close in response to changes in the hole diameter, causing variations in the measured voltage. The voltage is calibrated to borehole diameter using calibration rings and the data processing software converts the measured voltages to borehole diameter, in inches. Changes in the borehole diameter reflect the hardness of the rock and the amount of fracturing. Measured borehole diameter is usually constant and slightly larger than the drill bit size in hard rock, while in softer rock the measured diameter may, at times, be enlarged due to washout by the drill operations. Zones may also be enlarged due to fracturing or dissolution features in the rock. Caliper logging was conducted utilizing a Robertson Geologging LACS 3-Arm Caliper / Gamma Probe combo.

Caliper log results are included in Appendix D-1

6.1.4 NATURAL GAMMA

Natural gamma probes (tools) measure the amount of naturally-occurring gamma radiation in rocks and soils. The natural gamma logging can be conducted in open or cased holes, both above and below the water table. The sources of the gamma radiation are the naturally-occurring elemental isotopes. Isotopes of potassium, uranium, and thorium are the most common isotopes measured by a natural gamma logging tool.

A natural gamma logging tool measures gamma ray activity using scintillation crystals and photomultiplier tubes in units of counts per second (CPS). A gamma ray passing through a scintillation crystal causes a light pulse to be generated. The light is detected by the photomultiplier tube and is converted to an electric current. The strength of the current is proportional to the number of gamma rays striking the crystal. Natural Gamma logging was conducting utilizing a Robertson Geologging ELXG

Results of the natural gamma measurements are included in Appendix D-1.

6.1.5 ELECTRICAL POTENTIAL AND RESISTIVITY LOGS

The spontaneous potential single-point resistivity, and 16/64 inch, short/long, normal resistivity logs are collectively referred to as the electric logs. An electric current is passed through the formation and the electric response is measured. The electric logging tools (probes) can only be run in open holes containing water or drilling fluid. The tools read resistance in units of Ohms. Electric potential and resistivity logging was conducting utilizing a Robertson Geologging ELXG

SPONTANEOUS POTENTIAL

The spontaneous potential is the measured electrical potential between an electrode on the logging tool and a reference electrode at the ground surface or work platform, for nearshore and deepwater borings. The potential, measured in millivolts, will be higher where there is a contrast in the conductivity of the formation water compared to the fluid, generally water, in the borehole. The contrast is most pronounced in permeable zones, where a variance from the baseline can be observed. In cases where there is little or no electrical contrast between the formation water and the borehole water, the spontaneous potential log will not be useful.

SINGLE-POINT RESISTIVITY

The single-point resistivity is the resistance of the formation measured at an electrode on the tool referenced to the tool body. Because the spacing between these is so short, the tool is sensitive to contacts between formations of differing resistance. Rocks and soils vary in their resistance to electrical current.

NORMAL RESISTIVITY

The 16/64 inch normal resistivity log is similar to the single-point resistivity except that resistivity is measured between two electrodes on the tool. This allows the tool to “see” deeper into the formation beyond the borehole wall than single-point resistivity. 16/64 refers to the spacing in inches between the electrode pairs. The 64-inch electrode spacing sees deeper into the formation than the 16-inch spacing, thus yielding a more representative reading of formation resistivity. Normal resistivity probes measure the overall, or total, electric resistivity of the zone investigated, and as a result, formation permeability and chemistry of the groundwater and drilling fluid will affect the resistivity log by adding to or subtracting from the measured formation values.

Results of the electric log results are included in Appendix D-1.

6.1.6 TEMPERATURE AND FLUID CONDUCTIVITY

Temperature and fluid conductivity logs are measures of water quality. Changes in water quality with depth can often be correlated with inflow or outflow zones in the subsurface. High fluid conductivity indicates greater salinity in the groundwater. For optimum results the tool should be run after the well has set undisturbed for several days to allow the

drilling water in the well to come into equilibrium with the formation water. This was not possible during the investigation due to borehole stability issues and schedule constraints. As a result, natural groundwater conditions and flows that might otherwise be indicated by the probe survey may be masked in this case due to insufficient dilution and dissemination of the drill water by and through the groundwater. Temperature and fluid conductivity were logged utilizing a Robertson Geologging TCDS fluid temperature and resistivity probe.

Results of the temperature and fluid conductivity tests are included in Appendix D-1.

6.1.7 CONE PENETRATION TEST

The cone penetration test (CPT) involves the measurement of the resistance of soil to steady and continuous penetration of a cone penetrometer equipped with internal sensors. Measurement penetration depth, cone resistance, sleeve friction and, optionally, pore pressure and inclination from vertical. These measurements permit interpretation of ground conditions. Cone penetration testing was completed utilizing a Wison MKV Cone Penetration System.

Results of the CPT testing are included in Appendix D-2

7 HYDROGEOLOGIC TESTING

7.1 PACKER TESTING

Packer testing was conducted in 18 boreholes to measure hydraulic conductivity in rock. Testing was typically performed from the bottom of the boring to the top of rock capable of sealing a packer. A total of 105 tests were performed in the following borings:

- BH19-07 (11 tests)
- BH19-08 (6 tests)
- BH19-09 (3 tests)
- BH19-10 (3 tests)
- BH19-15 (10 tests)
- BH19-16 (4 tests)
- BH19-17 (17 tests)
- BH19-19 (1 test)
- BH19-24A (5 tests)
- BH19-25 (1 test)
- BH19-27 (2 tests)
- BH19-28 (7 tests)
- BH19-32 (7 tests)
- BH19-33 (2 tests)
- BH19-35 (6 tests)
- BH19-36 (7 tests)
- BH19-37 (8 tests)
- BH19-38 (5 tests)

Packer testing was performed in general accordance with ASTM D4630. A double pneumatic packer system connected by a perforated pipe was used to seal approximately ten-foot long sections of borehole. A vibrating wire transducer within the perforated pipe test zone was used to measure water pressures before and during the tests for onshore and nearshore tests. For deepwater test, the water pressure was measured using a pressure gauge at the surface. Water was pumped into the boring to raise the down-hole pressure to the desired test pressure. The pressure was maintained by adjusting a by-pass valve that reduced or increased the flow by opening or closing the valve respectively. An electronic flow meter was installed at the ground surface or on the drill rig deck to measure the flow rate correlating to different pressure intervals within each test interval.

Each packer test included a sequence of five pressure stages at approximately 15, 30, 45, 30, and 15 psi above measured hydrostatic pressure. Total flow was recorded at approximately 0, 1, 3, 5, 10, and 15 minutes after reaching equilibrium during each of the five pressure steps. The average flow rates were used to calculate hydraulic conductivity values using the United States Bureau of Reclamation (USBR) hydraulic conductivity calculation (U.S. Department of the Interior, Bureau of Reclamation, 2001). Results of the packer tests are presented in Appendix F-1.

7.2 SLUG TESTING

A falling head slug test was performed in general accordance with ASTM D4044 on June 26, 2019 for the following onshore borings and in piezometers boreholes: PZ19-09, BH19-10, BH19-12, PZ19-40, PZ19-41, and PZ19-42. At boreholes BH19-10 and BH19-12, the slug test was performed in the open borehole in rock. At the piezometer borings, the slug test was

performed within the two-inch diameter PVC well casing. Refer to the section, 5.2.1 Onshore Borings, for details of the well construction.

For test inside the piezometers, a 1.5-inch diameter, four-foot long slug was used in the slug test. For BH19-10 and BH19-12, a four-inch diameter, three-foot long slug was used. The slugs were constructed of schedule 40 PVC pipe filled with concrete, into which an eye bolt was inserted to allow a rope or cord to be attached. The slugs displace a known volume of water resulting in rise in the static head within the borehole or piezometer. Measurement of the rate of re-equilibration to the original water level allows evaluation of the hydraulic conductivity at the screened or open test interval.

For each location, the slug was lowered to a point slightly above the static water table, which was measured immediately before conducting the slug test. A water level meter was lowered to be just above the slug. Once preparations were complete, the slug was dropped into the water column far enough to be completely immersed, and the water level meter was simultaneously lowered to the water table and water level readings were collected approximately every five seconds.

The slug test continued until the water level returned to the static water elevation, or within 0.01 feet and remained there for one minute. The duration of the slug tests was generally about five minutes. After the test was complete, the slug and water level meter were pulled out of the water.

7.3 AQUIFER TESTING

Aquifer testing was performed in bedrock near the south terminus to evaluate the hydraulic conductivity and potential for groundwater inflow into the Line 5 Tunnel southern terminus excavation. Pumping was conducted in open borehole BH19-12 (PW19-12), and water levels were recorded in nearby observation piezometers PZ19-09 (in BH19-09), PZ19-40, PZ19-41, and PZ19-42. Construction details are summarized in Section 5.2.1.

Background water level measurements were recorded in 10-minute intervals for approximately nineteen days using vibrating wire water pressure transducers. Subsequently, a step drawdown test was conducted in PW19-12 to determine the optimum pumping discharge rates for the constant rate aquifer test. The well was pumped at various rates, from 4.2, to 26.5 over several hours. Resultant water levels in the open borehole were recorded.

The constant rate pumping test was completed over 48 hours in general accordance with ASTM D5786. Groundwater was pumped from 137 feet bgs in PW19-12 at between 19.7 to 20.5 GPM. Pressure transducers recorded depth, temperature, and water pressure (in PSI) in PW19-12 and the observation wells PZ19-09, PZ19-40, PZ19-41, and PZ19-42. Temperature, specific conductance, pH, and oxidation-reduction potential were measured from the discharge water every hour, and confirmation water levels were manually recorded every four hours to compare against the vibrating wire transducer data. Water-level recovery data was recorded for approximately seven hours at the completion of testing. Barometric data and lake levels for Lake Michigan were also determined from weather buoys for the same interval of the entire aquifer testing program to correct the data for regional trends.

Detailed methods, analysis, results, and interpretations are presented in a separate report included in Appendix F-4 of this GDR.

7.4 GROUNDWATER SAMPLING

The piezometers and boreholes were sampled using low-flow sampling techniques. To help maintain groundwater sample integrity during sampling activities, WSP used a bladder pump to collect water samples from the open boreholes or from piezometers at low flow rates (approximately 200 to 500 ml/min). Geotechnical pneumatic bladder pumps operate with a unique air-driven action, ideal for low-flow purging and minimal agitation for representative sample collection. Driven by a mini-compressor, timed on/off cycles of compressed air alternately squeeze the flexible bladder to displace water out of the pump to the surface, and then exhaust the air allowing the pump to refill. Water enters and fills the pump through the fluid inlet check valve at the bottom of the pump body via hydrostatic pressure. Once filled with fluid, compressed air enters the space between the bladder and the interior of the pump housing, squeezing the bladder, and pushing the water to the surface. A drop-tube assembly was used to assist sampling; the intake screen was set at a depth corresponding to the tunnel horizon.

The bladder pump discharged water into a flow cell via ¼ inch diameter disposable polyethylene tubing; the flow cell was connected to a YSI 556 MPS meter that measures temperature, specific conductance, dissolved oxygen, pH, and redox

potential (ORP). Once the temperature, specific conductance, dissolved oxygen, pH, and ORP measurements (measured at three-minute intervals) all stabilized within acceptable tolerances listed in Table 7.1, for three consecutive intervals, it was considered formation water and a groundwater sample was collected. Table F-3.1 in Appendix F-3 summarizes the YSI 556 MPS meter readings prior to sampling for each sampling location. Additionally, BH19-12 was sampled on June 3rd, 2019, prior to converting the boring to the pumping well, PW19-12, for aquifer testing. After conversion to the pumping well, PW19-12 was sampled 3 additional times.

Table 7.1: Groundwater Sampling Tolerances

	SPECIFIC CONDUCTANCE	DISSOLVED OXYGEN	PH	OXYGEN-REDUCTION POTENTIAL
Tolerance	3%	10%	0.1 units	10 units

7.4.1 SAMPLING PRESERVATION AND HANDLING

Preservative was added to the sample containers by the analytical laboratory. The containers used for analysis of methane were pre-preserved with hydrochloric acid. The container for sulfide, needed for the hydrogen sulfide calculation, was pre-preserved with sodium hydroxide and zinc acetate. The container for phosphate was pre-preserved with sulfuric acid. The container for cations (calcium, magnesium, iron, sodium, and potassium) was pre-preserved with nitric acid. The container for total dissolved solids, specific conductance, alkalinity, chloride, and fluoride was unpreserved. Each groundwater sample was immediately placed in a cooler on ice (or in a refrigerator) and chilled to 4°C for transportation to the laboratory under appropriate chain-of-custody.

7.4.2 EQUIPMENT CALIBRATION

The YSI MPS meter requires periodic calibration to ensure that the readings are accurate. The instruments were checked prior to each sampling event to see whether the readings were within acceptable tolerances. The YSI's calibration cup was filled with "Confidence Solution", which has specific value ranges for conductance, pH, and ORP based on temperature. If the YSI read the parameter concentrations within the appropriate ranges, the "bump test" was deemed sufficient and no calibration of the instrument was required. If one or more of the parameters were outside the value ranges, a calibration was performed in accordance with the equipment instructions using laboratory-provided standards for the parameter(s) outside the range. After calibration, the instrument was checked against the Confidence Solution to ensure it was reading accurately.

7.4.3 DECONTAMINATION OF EQUIPMENT

To maintain sample integrity, strict decontamination procedures were followed during all sampling operations. These procedures included cleansing the sampling pump and screen with a solution of tap water and phosphate-free Alconox detergent followed by a rinse of tap water between each sampling interval. Disposable nitrile gloves were worn during the transfer of samples into the appropriate containers and while handling the water sampling equipment.

Disposable polyethylene tubing was used for each groundwater sampling location. The sample tubing was obtained from Geotech Environmental Equipment, Inc., which batch-tests the tubing before it is sold. The tubing is tested using a synthetic precipitation leaching procedure following Method 1312 (modified) using ultra-pure water of pH 4. No analytes were detected at concentrations exceeding method detection limits. The tubing was certified clean for metals, base-neutral-acid extractables, volatile organic compounds, diesel range organics, mineral oil, polynuclear aromatic hydrocarbons, and phthalates. The tubing is deemed acceptable for use for all parameters analyzed for this scope of work.

7.4.4 LABORATORY METHODS

Fibertec utilized field measurements provided by WSP for temperature, specific conductance, and pH to calculate the dissolved hydrogen sulfide concentration in groundwater. Fibertec used method GC/FID RSK-175 for methane, HACH 8131/Calculation SM 4500-S2 for hydrogen sulfide, EPA method 3005A/6020 for calcium, iron, magnesium, potassium, and sodium, EPA method 9050A for specific conductance, EPA method 9056A for chloride, fluoride, phosphate, and sulfate, HACH 8146 for ferrous iron, method SM 2320 B-2011 for alkalinity, and method SM 2540 C-2011 for total dissolved solids.

7.4.5 RESULTS

All groundwater samples were analyzed for dissolved methane and hydrogen sulfide (with the exception of PW19-12 during the aquifer test – these two samples were analyzed for total dissolved solids, specific conductance, sulfate, sulfide, phosphate, chloride, fluoride, bicarbonate, calcium, ferrous and ferric iron, magnesium, sodium, and potassium). Table F-3.2 in Appendix F-3 summarizes the results of the analyses performed on the groundwater samples. A copy of the Fibertec laboratory data and quality control reports for the sampling events are included in Appendix F-3.

Dissolved methane in groundwater was detected at concentrations exceeding method reporting limits of 2.6 µg/L in samples PZ19-12, BH19-17, BH19-38, and BH19-07. Concentrations of methane, where detected, ranged from 5 to 11 µg/L. Hydrogen sulfide in groundwater was not detected in any sample at concentrations above the laboratory method reporting limit of 20 µg/L during any of the sampling events.

Calcium, magnesium, sulfate, total dissolved solids, bicarbonate alkalinity, and specific conductance was present in both samples analyzed for those parameters at concentrations exceeding method detection limits. Ferric iron and sodium were present in only the PW19-12 (Initial) sample at concentrations exceeding method detection limits. Potassium, chloride, fluoride, ortho-phosphate, sulfide, and ferrous iron were not present in either sample at concentrations exceeding method detection limits.

7.5 LONG-TERM GROUNDWATER OBSERVATION WELLS

After the aquifer pumping test was completed, six long-term observation wells were installed on the south shore. At BH19-09 and BH19-12 automatic groundwater level observation equipment was installed. The system is comprised of Geokon unvented 350 kPa (51psi) vibrating wire piezometers installed in the standpipe observation wells. One piezometer was installed in each well, at a depth of 95 and 130 feet below ground surface in BH19-09 and BH19-12, respectively. The piezometers are connected to Geokon GeoNet Node 1-CH, VW, 900 MHz battery powered surface units, which communicate to a Geokon GeoNet Supervisor, RS-232, 900 MHz data acquisition system located in the Enbridge L5RT Project field office located on the south shore.

In addition to the automatic groundwater level observation equipment, as listed in Table 5.1 in a previous section, BH19-08, PZ19-40, PZ19-41 and PZ19-42 were fitted with steel surface mount covers and can be used to manually measure water levels or take groundwater samples.

8 LABORATORY TESTING PROGRAM

8.1 GEOTECHNICAL PROGRAM

Soil and rock samples recovered from the test borings were retained at the Enbridge owned storage facility. Throughout the course of the L5RT investigation, WSP assigned laboratory testing on representative soil and rock samples in accordance with the quantities and specifications included in the project specific work plan. Specific geotechnical laboratory tests were assigned to GTX. GTX self-performed all of the assigned laboratory tests.

8.2 SOIL TESTING

Soil testing for this project included the following:

- Particle size analyses (Sieve/Hydrometer);
- Liquid Limit, Plastic Limit, and Plasticity Index (Atterberg Limits),
- Moisture content, and
- Specific gravity tests.

Soil tests were performed on bulk samples and SPT split spoon samples. All soil testing was performed by GTX.

There are several systems that can be used to classify soils; the L5RT Project is using the Unified Soil Classification System (USCS). Classification methods require specific quantitative determination of the distribution of particle sizes in soil. The determination of particle sizes that are larger than the No. 200 Sieve (75 µm) are determined by sieving the soil, while the particle sizes smaller than the No. 200 Sieve (75 µm) are determined by a sedimentation process, using a hydrometer to obtain the necessary data. Particle Size Analyses (Sieve/Hydrometer) were performed in accordance with ASTM D422.

The Liquid Limit, Plastic Limit, and Plasticity Index of cohesive soils are more commonly referred to as the Atterberg Limits. The Liquid Limit is defined as the water content, in percent, of a soil at the arbitrarily defined boundary between the semi-liquid and plastic states, as defined by Albert Atterberg. The Plastic Limit refers to the water content, in percent, of a soil at the boundary between the plastic and semi-solid states. Lastly, the Plasticity Index is defined as the range of water content over which a soil behaves plastically. The Liquid Limit, Plastic Limit, and Plasticity Index (Atterberg Limits) tests were performed in accordance with ASTM D4318.

Unlike other materials that are completely homogeneous, soil and rock are multiphase materials – the matrix is composed of solids, liquids, and gas. To determine the relative mass of water to soil, the mass of a moist test specimen is first determined. Then, the specimen is dried in an oven until a constant mass is achieved. The loss of mass, due to drying, is considered to be the mass of water in the material. The water content is then calculated by using the mass of water to the mass of the dry specimen expressed in percent. Moisture Content tests were performed in accordance with ASTM D2216

As previously discussed for the moisture content, the matrix of soil is comprised of solids, liquids, and gases. The specific gravity test is performed by using a water pycnometer to determine the density of the soil particles. The Specific Gravity tests were performed in accordance with ASTM D854.

Results of all soil tests are presented in individual laboratory data sheets contained in Appendix E-1.

8.3 ROCK TESTING

Rock testing for this project included the following:

- CERCHAR Abrasivity Index,
- Direct Tensile Strength,

- Unit Weight,
- Petrographic Analyses,
- Point Load Index,
- Punch Penetration,
- Slake Durability,
- Splitting (Brazilian) Tensile Strength,
- Triaxial Compression, Elastic Moduli in Triaxial Compression, Unconfined Compression,
- Mohs Hardness,
- Pulse Velocity,
- Drillability (abrasion, brittleness, and drillability), and
- Soil Abrasivity testing.

Rock tests were performed on rock samples obtained from rock coring. All rock testing was performed in house by GTX.

One method of determining rock abrasivity is the CERCHAR Abrasivity Index test. The CERCHAR Abrasivity Index test is performed by measuring the wear on the tip of a steel stylus in the shape of a cone and known Rockwell Hardness caused by scratching against the rock surface for a prescribed distance of 10 millimeters. CERCHAR Abrasivity Index test was performed in accordance with ASTM D7625.

Rock is weaker in tension compared to compression. A method of measuring the tension of rock is through the Direct Tensile Strength test. The Direct Tensile Strength is performed by obtaining a rock core sample and cutting it to the appropriate lengths specified in ASTM D2936. Once the sample has been cut, each end is cemented to metal caps. The metal caps are then attached to the testing machine and the rock core is then loaded in tension until failure. The Direct Tensile Strength test was performed in accordance with ASTM D2936.

The compression of rock is typically determined by cutting a rock core specimen to the length specified in ASTM D7012. Once the specimen is cut to the required length, the specimen is placed in a loading frame (Unconfined Compression Strength) or in a loading chamber and subjected to a confining pressure (Triaxial Compression). The axial load that is applied to the specimen is then increased and measured continuously. For the Undrained Triaxial Compression test and Unconfined Compression Strength test, no deformation is measured. Deformation is measured for the Elastic Moduli of Rock in Triaxial Compression and is measured as a function of load until peak load and failure are obtained. The Undrained Triaxial Compression of Rock, Elastic Moduli of Rock in Triaxial Compression, and Unconfined Compression Strength of Rock tests were performed in accordance with ASTM D7012 Method A, ASTM D7012 Method B, and ASTM D7012 Method C, respectively.

Unit Weight tests are therefore performed to obtain the unit weight of the rock, porosity (percentage of voids), and specific gravity. This test is performed by obtaining the physical properties of the rock, e.g. water content, degree of saturation, porosity, void ratio, etc., and relating them to each other by interdependent equations. The Unit Weight test was performed in accordance with the ISRM Blue Book Standards (Ulusay & Hudson, 1974-2006).

For petrographic analysis, a thin section of rock is cut and placed under a petrographic microscope. From there, the petrographer determines the minerals presents within the rock, along with the grain size and texture. The Petrographic Analysis was performed in accordance with the ISRM Blue Book Standards (Ulusay & Hudson, 1974-2006).

The Point Load Index test serves as a means to classify rock strength and can be correlated to the Unconfined Compression Strength of rock. The Point Load Index test is performed by subjecting a rock to an increasingly, concentrated load in the axial (Point Load Axial Test) or diametral (Point Load Diametral Test) direction. When the rock specimen fails, the failure load is then recorded and used to obtain the uncorrected point load strength index. There are various methods for determining the size corrected Point Load Index that are further described in ASTM D5731. The Point Load Index test was performed in accordance with ASTM D5731.

The Colorado School of Mines developed the Punch Penetration test to try and assess the rock brittleness. For this test, the rock is placed under a load in which an indenter is pressed into the rock surface. From the indentation, an index is obtained. The Punch Penetration test was performed in accordance with Handewith (1970).

Slake durability is performed by obtaining ten (10) pieces of rock specimen and placing them in a wire mesh drum mounted in an apparatus where the drum is partially submerged in a trough filled with distilled water. The specimens are then rotated in the water for two cycles (each cycle being 10 minutes in length with a rotation speed of 20 rotations per minute). Once the first cycle is completed, the specimen is oven dried and the total mass of specimen retained in the drum is recorded. This process is repeated a second time to obtain the results of the second cycle. The Slake Durability Index is calculated using both recorded masses of test specimen. The Slake Durability test was performed in accordance with ASTM D4644.

The Splitting (Brazilian) Tensile Strength test is performed by obtaining rock samples from the rock core and cutting them perpendicular to the core axis to produce disk shaped specimens. The specimens are then placed in the testing machine with the diametral axis being coincidental with the loading axis of the testing machine. The sample is then loaded by applying an increasing compressive load until failure occurs. The Splitting (Brazilian) Tensile Strength test was performed in accordance with ASTM D3967.

To determine Mohs Hardness, a list of ten minerals were defined to have a set value in the Mohs Hardness scale. The hardness of a mineral is defined as the resistance of a material to being scratched. The Mohs Hardness test was performed in accordance with the American Geological Institute Geoscience Handbook Section 5.1.

Pulse Velocity testing yields compression and shear wave velocities, and ultrasonic values for the elastic constants of intact homogeneous isotropic rock specimens. The Pulse Velocity test was performed in accordance with ASTM D2845.

Drilling Rate Index (DRI) and Bit Wear Index (BWI) were developed by the Department of Geology at the Norwegian University of Science and Technology (NTNU). The Cutter Life Index (CLI) was developed by the Department of Building and Construction Engineering at NTNU. The Drilling Rate Index is assessed on the basis of two laboratory tests: Brittleness Value (S20) and Sievers' J-value (SJ). To determine the Brittleness Value (S20), samples are passed through a jaw crusher with an opening set to the mean value of the sieve interval, 13.6 mm for the 11.2-16 mm fraction. The material that is retained on the 11.2 mm sieve is then placed into a mortar. A weight is then dropped into the mortar from an average height of 25 cm, twenty (20) times. The percentage of material that passes the 11.2 mm mesh after the aggregate has been crushed by 20 impacts is the Brittleness Value (S20). The Sievers' Miniature Drill Test gives a measure for the resistance to indentation of the rock. A rock sample is clamped into place as a chuck with a tungsten carbide drill bit is drilled into the rock at 200 rpm. The Siever's J-Value is taken as the drill-hole depth after 200 revolutions of the miniature drill bit measured in 1/10 mm. Once both S20 and SJ values have been obtained, a chart is used to obtain DRI. Sievers' J-Value and the Abrasion Value of Steel (AVS) are used to determine the CLI through an equation. Drillability testing was performed in accordance with Bruland (1998) and Dahl (2003).

Results of all rock tests are presented in individual laboratory data sheets contained in Appendix E-2.

9 REFERENCES

ASTM D 5753A-05. (n.d.). Standard Guide for Planning and Conducting Borehole Geophysical Logging. *ASTM International*. West Conshohocken, PA.

ASTM D1586-18. (n.d.). Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils. *ASTM International 2018*. West Conshohocken, PA.

ASTM D2113-14. (n.d.). Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration. *ASTM International 2014*. West Conshohocken, PA.

ASTM D2216-19. (n.d.). Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. *ASTM International 2019*. West Conshohocken, PA.

ASTM D2488-17e1. (n.d.). Standard Practice for Description and Identification of Soils (Visual-Manual Procedures). *ASTM International 2017*. West Conshohocken, PA.

ASTM D2845-08. (n.d.). Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock (Withdrawn 2017). *ASTM International 2008*. West Conshohocken, PA.

ASTM D2936-08. (n.d.). Standard Test Method for Direct Tensile Strength of Intact Rock Core Specimens (Withdrawn 2017). *ASTM International 2008*. West Conshohocken, PA.

ASTM D3967-16. (n.d.). Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens. *ASTM International 2016*. West Conshohocken, PA.

ASTM D4043-17. (n.d.). Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques. *ASTM International*. West Conshohocken, PA.

ASTM D4044-15. (n.d.). Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers. *ASTM International*. West Conshohocken, PA.

ASTM D4104-17. (n.d.). Standard Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests). *ASTM International*. West Conshohocken, PA.

ASTM D4106-15. (n.d.). Standard Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method. *ASTM International*. West Conshohocken, PA.

ASTM D4220-14. (n.d.). Standard Practices for Preserving and Transporting Soil Samples. *ASTM International*. West Conshohocken, PA.

ASTM D422-63(2007)e2. (n.d.). Standard Test Method for Particle-Size Analysis of Soils (Withdrawn 2016). *ASTM International 2007*. West Conshohocken, PA.

ASTM D4318-17e1. (n.d.). Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. *ASTM International 2017*. West Conshohocken, PA.

ASTM D4630-19. (n.d.). Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test. *ASTM International*. West Conshohocken, PA.

ASTM D4644-16. (n.d.). Standard Test Method for Slake Durability of Shales and Other Similar Weak Rocks. *ASTM International 2016*. West Conshohocken, PA.

ASTM D4719-00. (n.d.). Standard Test Method for Prebored Pressuremeter Testing in Soils. *ASTM International*. West Conshohocken, PA.

ASTM D4750-87. (n.d.). Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well) (Withdrawn 2010). *ASTM International*. West Conshohocken, PA.

ASTM D5079. (n.d.). Standard Practices for Preserving and Transporting Rock Core Samples (Withdrawn 2017). *ASTM International*. West Conshohocken, PA.

ASTM D5092-16. (n.d.). Standard Practice for Design and Installation of Groundwater Monitoring Wells. *ASTM International*. West Conshohocken, PA.

ASTM D5731-16. (n.d.). Standard Test Method for Determination of the Point Load Strength Index of Rock and Application of Rock Strength Classifications. *ASTM International 2016*. West Conshohocken, PA.

ASTM D5786-17. (n.d.). Standard Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems. West Conshohocken, PA.

ASTM D6032-17. (n.d.). Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core. *ASTM International 2017*. West Conshohocken, PA.

ASTM D6914-16. (n.d.). Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices. *ASTM International 2016*. West Conshohocken, PA.

ASTM D7012-14e1. (n.d.). Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures. *ASTM International 2014*. West Conshohocken, PA.

ASTM D7625-10. (n.d.). Standard Test Method for Laboratory Determination of Abrasiveness of Rock Using the CERCHAR Method (Withdrawn 2019). *ASTM International 2010*. West Conshohocken, PA.

ASTM D854-14. (n.d.). Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer. *ASTM International 2014*. West Conshohocken, PA.

Bruland, A. (1998). Hard Rock Tunnel Boring - Drillability Test Methods. Norway: NTNU.

Dahl, F. (2003). DRI, BWI, CLI Standards. *NTNU/SINTEF*, 20.

Dorr, J. A., & Eschman, D. F. (1970). Geology of Michigan. University of Michigan Press.

Ehlers, G. M., & Kesling, R. V. (1957). Silurian Rocks of the Michigan and Their Correlation. In *Michigan Geological Society Guidebook for Annual Geological Excursion.*

Farrand, W. R., & Bell, D. L. (1982). Quarternary Geology of Northern Michigan. University of Michigan Department of Geological Sciences.

Farrand, W. R., & Bell, D. L. (1982). Quarternary Geology of Southern Michigan. University of Michigan Department of Geological Sciences.

Gillespie, R., Harrison, W. B., & Grammer, G. M. (2008). Geology of Michigan and the Great Lakes. Michigan Geological Repository for Research and Education, Western Michigan University.

Golder Associates Inc. (2019). *Marine Geophysics Investigation, Enbridge Line 5.*

Grant, R. P., & Pringle, C. H. (1943). Topographic Map of the Bedrock Surface of the Southern Peninsula of Michigan. *Miscellaneous Map Number 3585*. Michigan Department of Natural Resources, Geological Survey Division.

Landes, K., Ehlers, G., & and Stanley, G. (1945). Geology of the Mackinac Straits Region and Sub-Surface Geology of Northern Southern Peninsula. *State of Michigan Department of Conservation Geological Survey Division, Publication 44*(Geological Series 37), 82.

Materials Testing Consultants, Inc. (2018). *Summary of Subsurface Investigation and Laboratory Testing, Soil Borings-Line 5-Straits of Mackinac.*

Melhorn, W. N. (1959). Geology of Mackinac Straits in Relation to Mackinac Bridge. *The Journal of Geology, 67*(4), 403-416.

Munsell Color. (2010). Munsell Soil Color Charts : with Genuine Munsell Color Chips. Grand Rapids, MI.

Munsell Color. (2011). Geologic Rock-Color Chart : with Genuine Munsell Color Chips. Grand Rapids, MI.

Olcott, P. G. (2000). Ground Water Atlas of the United States. *Segment 9: Iowa, Michigan, Minnesota, Wisconsin*. U.S. Geological Survey.

Porter, P., & Nelhiebel, V. R. (1984). *The wonder of Mackinac: A guide to the natural history of Mackinac Island.* Mackinac Island State Park Commission.

Rheaume, S. J. (1991). *Hydrologic Provinces of Michigan.* Water Resources Investigation Report 91-4120, U.S. Geological Survey.

RocTest Limited. (2017). Borehole Dilatometer (Rock Pressuremeter) Model PROBEX Instruction Manual. *E10037-170214*.

Stanley, G. M. (1938). The Submerged Valley through Mackinac Straits. *The Journal of Geology, 46*(7), 966-974.

Steinman, D. B. (1956). *Mackinac Bridge Final Geologic Report.*

U.S. Department of the Interior, Bureau of Reclamation. (2001). Chapter 16: Water Testing for Grouting. In *Engineering Geology Field Manual; 2nd Ed., Vol. II* (p. 127).

U.S. Geological Survey. (2017). USGS US Topo 7.5-minute map for McGulpin Point, MI. USGS - National Geospatial Technical Operations Center (NGTOC).

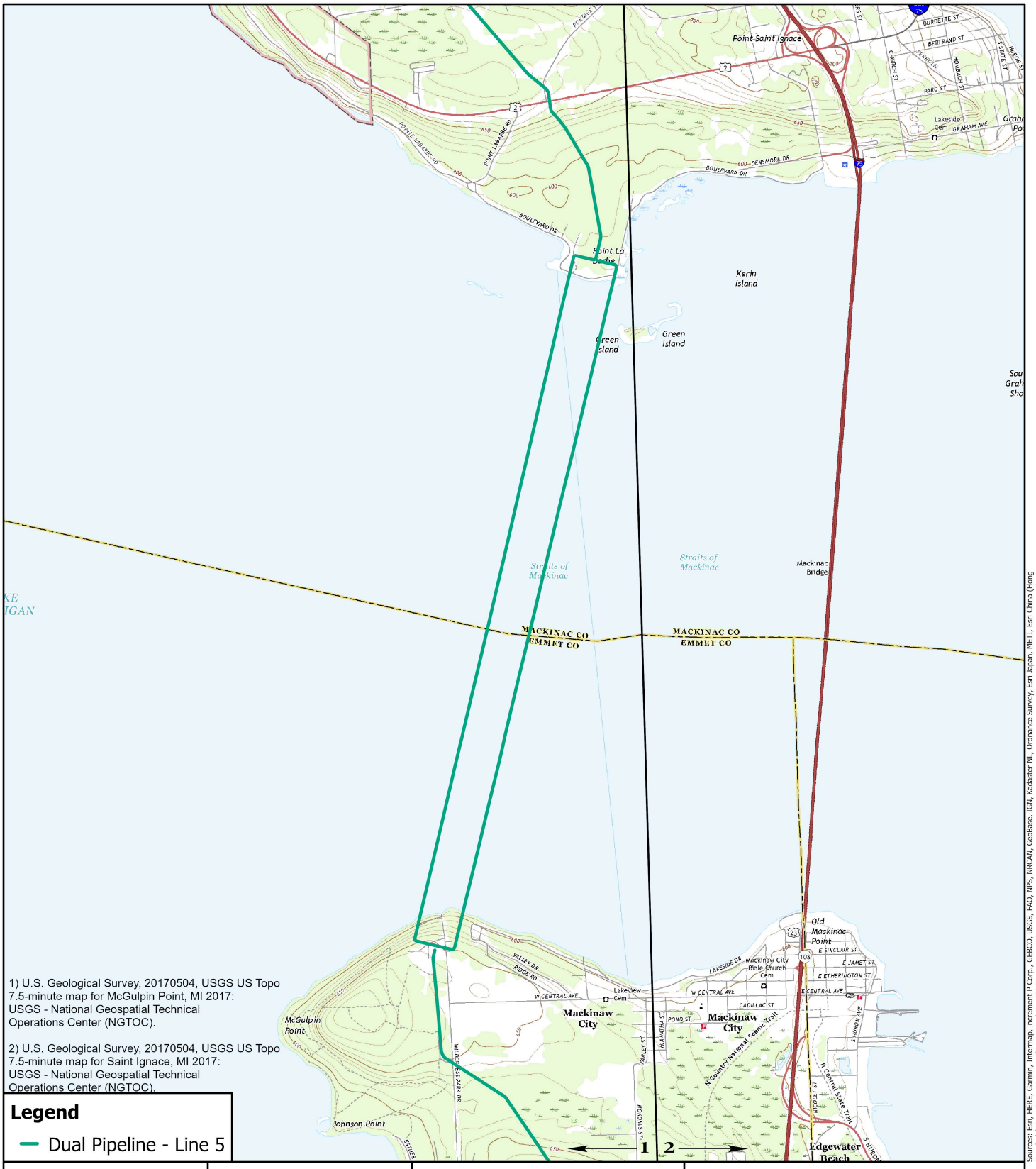
Wilson, S., & Milstein, R. L. (1987). Bedrock Geology of Northern Michigan. Michigan Department of Natural Resources, Geological Survey Division.

APPENDIX

A MAPS

APPENDIX

A-1 *PROJECT LOCATION MAP*



1) U.S. Geological Survey, 20170504, USGS US Topo 7.5-minute map for McGulpin Point, MI 2017: USGS - National Geospatial Technical Operations Center (NGTOC).

2) U.S. Geological Survey, 20170504, USGS US Topo 7.5-minute map for Saint Ignace, MI 2017: USGS - National Geospatial Technical Operations Center (NGTOC).

Legend

— Dual Pipeline - Line 5

Location Map

N

0 4,000

Feet

Date: December 2019

Project #: 31402024.00

APPENDIX A-1
PROJECT LOCATION MAP

LINE 5 REPLACEMENT AND TUNNEL PROJECT
STRAITS OF MACKINAC, MICHIGAN

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Path: C:\Users\tyczkaz\OneDrive - WSP O365\Straits of Mackinac\maps\Project-W-AMRV4-D-LBG10.aprx

APPENDIX

A-2 *BORING LOCATION PLAN*

wsp

Date: December 2019

Project #: 31402024.00

Location Map

N

0 1,500

Feet

Legend

- Monitoring Well
- Onshore Geotech Boring
- Nearshore Geotech Boring
- Deepwater Geotech Boring
- Dual Pipeline - Line 5

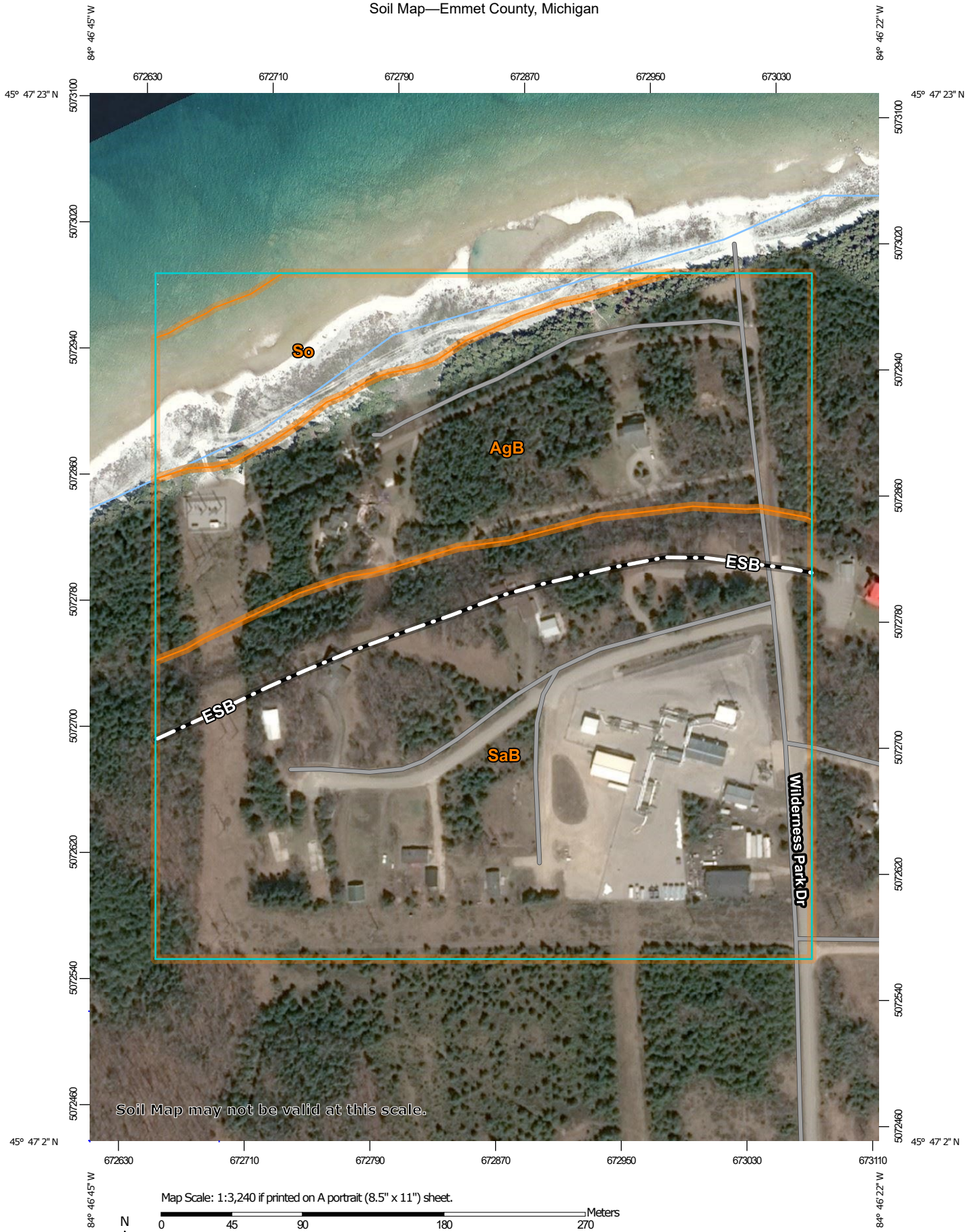
APPENDIX A-2
BORING LOCATION PLAN

LINE 5 REPLACEMENT AND TUNNEL PROJECT
STRAITS OF MACKINAC, MICHIGAN

Path: C:\Users\tyczkaz\OneDrive - WSP O365\Straits of Mackinac\maps\Project-W-AMRV4-D-LBG10.aprx

APPENDIX

A-3 *NRCS SOIL SURVEY MAPS*



Map Scale: 1:3,240 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 45 90 180 270

Feet: 0 150 300 600 900

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Emmet County, Michigan
Survey Area Data: Version 15, Sep 6, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jan 15, 1994—May 4, 2019

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AgB	Alpena gravelly loamy sand, sandy variant, 0 to 6 percent slopes	13.5	30.0%
SaB	St. Ignace stony sandy loam, 2 to 6 percent slopes	26.5	58.8%
So	Stony lake beaches	4.6	10.2%
Totals for Area of Interest		**45.1**	**100.0%**

Emmet County, Michigan

AgB—Alpena gravelly loamy sand, sandy variant, 0 to 6 percent slopes

Map Unit Setting

National map unit symbol: 6bzm
Elevation: 600 to 1,500 feet
Mean annual precipitation: 22 to 34 inches
Mean annual air temperature: 39 to 46 degrees F
Frost-free period: 70 to 150 days
Farmland classification: Not prime farmland

Map Unit Composition

Alpena and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alpena

Setting

Landform: Kames, lake terraces, eskers
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: 4 to 10 inches of sandy and loamy material over calcareous sandy and gravelly glaciofluvial deposits

Typical profile

H1 - 0 to 7 inches: gravelly loamy sand
H2 - 7 to 9 inches: gravelly loamy sand
H3 - 9 to 60 inches: very gravelly sand

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 20 percent
Available water storage in profile: Very low (about 3.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Roscommon

Percent of map unit: 5 percent
Landform: Depressions on drainageways, depressions on lake plains, depressions on outwash plains
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: Yes

East lake

Percent of map unit: 5 percent
Landform: Outwash plains, beach ridges
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Data Source Information

Soil Survey Area: Emmet County, Michigan
Survey Area Data: Version 15, Sep 6, 2018

Emmet County, Michigan

SaB—St. Ignace stony sandy loam, 2 to 6 percent slopes

Map Unit Setting

National map unit symbol: 6c1q
Elevation: 600 to 900 feet
Mean annual precipitation: 27 to 33 inches
Mean annual air temperature: 41 to 45 degrees F
Frost-free period: 110 to 150 days
Farmland classification: Not prime farmland

Map Unit Composition

St. ignace and similar soils: 93 percent
Minor components: 7 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of St. Ignace

Setting

Landform: Lake plains, lake terraces
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: 10 to 20 inches of loamy material over fractured limestone bedrock and/or breecia

Typical profile

H1 - 0 to 4 inches: stony sandy loam
H2 - 4 to 16 inches: flaggy sandy loam
R - 16 to 18 inches: bedrock

Properties and qualities

Slope: 2 to 6 percent
Depth to restrictive feature: About 16 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 50 percent
Available water storage in profile: Very low (about 1.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Hydric soil rating: No

Minor Components

Longrie

Percent of map unit: 7 percent
Landform: Beaches, lake terraces
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Data Source Information

Soil Survey Area: Emmet County, Michigan
Survey Area Data: Version 15, Sep 6, 2018

Emmet County, Michigan

So—Stony lake beaches

Map Unit Composition

Stony lake beaches: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Stony Lake Beaches

Setting

Landform: Beaches

Data Source Information

Soil Survey Area: Emmet County, Michigan
Survey Area Data: Version 15, Sep 6, 2018

Soil Map—Mackinac County, Michigan

Map Scale: 1:5,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters
0 50 100 200 300

Feet
0 200 400 800 1200

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Mackinac County, Michigan
Survey Area Data: Version 11, Sep 11, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 23, 2010—May 16, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
35	Histosols and Aquents, ponded	1.0	0.8%
36	Markey and Carbondale mucks	9.6	7.9%
116	Udipsamments and Udorthents, nearly level	40.2	33.0%
124D	Alpena gravelly loam, 0 to 15 percent slopes	12.2	10.0%
163B	Esau-Zela complex, 0 to 3 percent slopes	18.0	14.7%
Totals for Area of Interest		**121.9**	**100.0%**

Mackinac County, Michigan

124D—Alpena gravelly loam, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: fz6m
Elevation: 570 to 1,390 feet
Mean annual precipitation: 28 to 33 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 90 to 155 days
Farmland classification: Not prime farmland

Map Unit Composition

Alpena and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alpena

Setting

Landform: Eskers, outwash plains, beach ridges
Landform position (two-dimensional): Summit, shoulder, backslope, footslope
Landform position (three-dimensional): Side slope, base slope, crest, rise
Down-slope shape: Concave, convex, linear
Across-slope shape: Convex, concave, linear
Parent material: Sandy and gravelly glaciofluvial deposits

Typical profile

Oe - 0 to 2 inches: moderately decomposed plant material
A1 - 2 to 6 inches: gravelly loam
A2 - 6 to 9 inches: gravelly sandy loam
2C - 9 to 80 inches: extremely gravelly sand

Properties and qualities

Slope: 0 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 30 percent
Available water storage in profile: Low (about 3.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s

Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Esau

Percent of map unit: 8 percent
Landform: Beach ridges
Landform position (two-dimensional): Summit, shoulder, backslope, footslope
Landform position (three-dimensional): Crest, side slope, base slope
Down-slope shape: Concave, convex
Across-slope shape: Linear
Hydric soil rating: No

Shelter

Percent of map unit: 7 percent
Landform: Lake terraces, drumlins, till plains
Landform position (two-dimensional): Footslope, summit, backslope
Landform position (three-dimensional): Riser, tread, rise, talf
Down-slope shape: Linear, concave
Across-slope shape: Linear
Hydric soil rating: No

Data Source Information

Soil Survey Area: Mackinac County, Michigan
Survey Area Data: Version 11, Sep 11, 2018

Mackinac County, Michigan

163B—Esau-Zela complex, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: fz75
Elevation: 570 to 1,390 feet
Mean annual precipitation: 28 to 33 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 90 to 155 days
Farmland classification: Not prime farmland

Map Unit Composition

Esau and similar soils: 52 percent
Zela and similar soils: 43 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Esau

Setting

Landform: Beach ridges
Landform position (two-dimensional): Summit, shoulder, backslope, footslope
Landform position (three-dimensional): Crest, side slope, base slope
Down-slope shape: Concave, convex
Across-slope shape: Linear
Parent material: Gravelly beach sand

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 6 inches: extremely gravelly sandy loam
2Bw - 6 to 10 inches: extremely gravelly coarse sand
2C - 10 to 80 inches: very gravelly coarse sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: About 6 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 30 percent
Available water storage in profile: Very low (about 1.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A/D
Hydric soil rating: No

Description of Zela

Setting

Landform: Beach ridges, depressions
Landform position (two-dimensional): Backslope, footslope, summit, toeslope
Landform position (three-dimensional): Side slope, base slope, crest, dip
Down-slope shape: Concave, convex, linear
Across-slope shape: Linear
Parent material: Sandy and gravelly lacustrine deposits

Typical profile

Oa - 0 to 9 inches: muck
A - 9 to 12 inches: extremely gravelly loam
Cg - 12 to 35 inches: very gravelly sand
C - 35 to 80 inches: extremely gravelly sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 6.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum in profile: 30 percent
Available water storage in profile: Low (about 4.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

Minor Components

Markey

Percent of map unit: 3 percent
Landform: Depressions
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf, dip
Down-slope shape: Linear
Across-slope shape: Linear
Other vegetative classification: Tsuga-Thuja-Mitella (TTM)
Hydric soil rating: Yes

Water

Percent of map unit: 2 percent
Hydric soil rating: Unranked

Data Source Information

Soil Survey Area: Mackinac County, Michigan
Survey Area Data: Version 11, Sep 11, 2018

Mackinac County, Michigan

35—Histosols and Aquents, ponded

Map Unit Setting

National map unit symbol: fz93
Elevation: 570 to 1,390 feet
Mean annual precipitation: 28 to 33 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 90 to 155 days
Farmland classification: Not prime farmland

Map Unit Composition

Histosols, ponded, and similar soils: 47 percent
Aquents, ponded, and similar soils: 47 percent
Minor components: 6 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Histosols, Ponded

Setting

Landform: Marshes
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Dip, talf
Down-slope shape: Linear
Across-slope shape: Linear

Typical profile

Oa - 0 to 51 inches: muck
C - 51 to 80 inches: variable

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 6.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Available water storage in profile: Very high (about 20.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

Description of Aquents, Ponded

Setting

Landform: Marshes
Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear

Typical profile

C - 0 to 80 inches: variable

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very low
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8w
Hydric soil rating: Yes

Minor Components

Finch

Percent of map unit: 3 percent
Landform: Lake plains, outwash plains
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Talf, dip
Down-slope shape: Linear
Across-slope shape: Linear
Other vegetative classification: Tsuga-Maianthemum-Coptis/Tsuga-Maianthemum-Coptis, Vaccinium phase (TMC/TMC-V)
Hydric soil rating: No

Rubicon

Percent of map unit: 3 percent
Landform: Outwash plains, till plains
Landform position (two-dimensional): Shoulder, summit, footslope, backslope
Landform position (three-dimensional): Side slope, crest, base slope
Down-slope shape: Concave, convex
Across-slope shape: Linear, convex
Other vegetative classification: Acer-Quercus-Vaccinium/Quercus-Acer-Epigea (AQV/QAE)

Hydric soil rating: No

Data Source Information

Soil Survey Area: Mackinac County, Michigan
Survey Area Data: Version 11, Sep 11, 2018

Mackinac County, Michigan

36—Markey and Carbondale mucks

Map Unit Setting

National map unit symbol: fz94
Elevation: 570 to 1,390 feet
Mean annual precipitation: 28 to 33 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 90 to 155 days
Farmland classification: Not prime farmland

Map Unit Composition

Markey and similar soils: 45 percent
Carbondale and similar soils: 45 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Markey

Setting

Landform: Depressions
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf, dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Herbaceous organic material over sandy glaciolacustrine deposits

Typical profile

Oe - 0 to 3 inches: moderately decomposed plant material
Oa - 3 to 20 inches: muck
Cg - 20 to 80 inches: sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 6.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum in profile: 10 percent
Available water storage in profile: High (about 10.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6w
Hydrologic Soil Group: A/D

Other vegetative classification: Tsuga-Thuja-Mitella/Tsuga-Thuja-Sphagnum (TTM/TTS)
Hydric soil rating: Yes

Description of Carbondale

Setting

Landform: Depressions
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Dip, talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Woody organic material

Typical profile

Oa1 - 0 to 6 inches: muck
Oa2 - 6 to 23 inches: muck
Oa3 - 23 to 38 inches: muck
Oe1 - 38 to 68 inches: mucky peat
Oe2 - 68 to 80 inches: mucky peat

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 6.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Available water storage in profile: Very high (about 26.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6w
Hydrologic Soil Group: A/D
Other vegetative classification: Tsuga-Thuja-Mitella/Tsuga-Thuja-Sphagnum (TTM/TTS)
Hydric soil rating: Yes

Minor Components

Finch

Percent of map unit: 5 percent
Landform: Lake plains, outwash plains
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Talf, dip
Down-slope shape: Linear
Across-slope shape: Linear
Other vegetative classification: Tsuga-Maianthemum-Coptis/Tsuga-Maianthemum-Coptis, Vaccinium phase (TMC/TMC-V)
Hydric soil rating: No

Angelica

Percent of map unit: 5 percent
Landform: Till plains
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Dip, talf
Down-slope shape: Linear
Across-slope shape: Linear
Other vegetative classification: Tsuga-Thuja-Petasties (TTP)
Hydric soil rating: Yes

Data Source Information

Soil Survey Area: Mackinac County, Michigan
Survey Area Data: Version 11, Sep 11, 2018

Mackinac County, Michigan

116—Udipsamments and Udorthents, nearly level

Map Unit Setting

National map unit symbol: fz6d
Elevation: 570 to 1,390 feet
Mean annual precipitation: 28 to 33 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 90 to 155 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents and similar soils: 50 percent
Udipsamments and similar soils: 50 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents

Typical profile

C - 0 to 80 inches: variable

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Negligible
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydric soil rating: No

Description of Udipsamments

Typical profile

C - 0 to 80 inches: sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Very high (20.00 to 28.34 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 1.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Hydric soil rating: No

Data Source Information

Soil Survey Area: Mackinac County, Michigan
Survey Area Data: Version 11, Sep 11, 2018

APPENDIX

B EXPLORATORY BORINGS

APPENDIX

B-1 *AS-DRILLED COORDINATES AND BORING ELEVATIONS*

Table B - As-Drilled Coordinates and Boring Elevations
Geotechnical Data Report
Line 5 Replacement and Tunnel Project

Boring ID	As-Drilled Coordinates		Reference Point Elevation (ft)	Height/Depth of Reference Point Above/Below Lake Level (ft)	Drilled Depth (ft)	End of Boring Elevation (ft)	Drilled By	Inspected By
	Latitude	Longitude						
Onshore Borings[1]								
BH19-08	45.78830°N	84.77656°W	584.3	N/A	113.0	478.1	Cascade	WSP
BH19-09	45.78736°N	84.77692°W	619.2	N/A	104.0	515.2	Cascade	WSP
BH19-10	45.78545°N	84.77588°W	662.6	N/A	110.0	552.6	Cascade	WSP
BH19-11	45.78735°N	84.77692°W	619.7	N/A	17.0	602.7	Cascade	WSP
BH19-12	45.78680°N	84.77682°W	652.1	N/A	150.0	502.1	Cascade	WSP
BH19-12A	45.78679°N	84.77680°W	652.1	N/A	4.9	647.2	Cascade	WSP
BH19-13	45.78614°N	84.77599°W	659.4	N/A	60.0	599.4	Cascade	WSP
BH19-13A	45.78615°N	84.77600°W	659.5	N/A	6.8	652.7	Cascade	WSP
BH19-14	45.78537°N	84.77644°W	665.8	N/A	17.0	648.8	Cascade	WSP
BH19-14A	45.78539°N	84.77642°W	665.5	N/A	4.5	661.0	Cascade	WSP
PZ19-40	45.78667°N	84.77627°W	652.2	N/A	100.0	552.2	Cascade	WSP
PZ19-41	45.78671°N	84.77650°W	652.3	N/A	100.0	552.3	Cascade	WSP
PZ19-42	45.78712°N	84.77699°W	621.4	N/A	50.0	571.4	Cascade	WSP
Nearshore Borings[2]								
BH19-07	45.83808°N	84.75731°W	600.4	18.4	203.0	409.6	Cascade	WSP
BH19-15	45.83538°N	84.75837°W	598.6	16.8	228.0	370.6	Cascade	WSP
BH19-16	45.83164°N	84.76097°W	600.0	18.0	328.5	271.5	Cascade	WSP
BH19-17	45.82875°N	84.76084°W	599.7	17.8	378.0	221.7	Cascade	WSP
BH19-37	45.79428°N	84.77377°W	600.7	19.0	248.4	352.3	Cascade	WSP
BH19-38	45.79162°N	84.77478°W	598.2	15.3	203.0	395.2	Cascade	WSP
Deepwater Borings[3,4]								
BH19-19	45.82346°N	84.76282°W	446.5	-135.2	200.3	246.2	Fugro	WSP
BH19-21	45.82081°N	84.76382°W	351.4	-230.3	67.5	283.9	Fugro	WSP
BH19-23	45.81904°N	84.76448°W	345.9	-235.8	245.2	100.7	Fugro	WSP
BH19-24	45.81837°N	84.76592°W	339.5	-242.2	156.5	183.0	Fugro	WSP
BH19-24A	45.81814°N	84.76479°W	356.7	-225.0	316.3	40.4	Fugro	WSP
BH19-25	45.81727°N	84.76514°W	398.0	-183.7	326.4	71.6	Fugro	WSP
BH19-26	45.81661°N	84.76659°W	396.7	-185.0	336.3	60.4	Fugro	WSP
BH19-27	45.81551°N	84.76579°W	418.3	-163.4	328.4	89.9	Fugro	WSP
BH19-28	45.81439°N	84.76743°W	399.9	-181.8	249.7	150.3	Fugro	WSP
BH19-31	45.81090°N	84.76751°W	462.4	-119.3	265.7	196.7	Fugro	WSP
BH19-32	45.80755°N	84.76880°W	451.4	-130.2	197.2	254.2	Fugro	WSP
BH19-33	45.80489°N	84.76979°W	486.5	-95.1	217.6	268.9	Fugro	WSP
BH19-35	45.79960°N	84.77182°W	499.2	-82.5	231.3	267.9	Fugro	WSP
BH19-36	45.79716°N	84.77391°W	502.4	-79.3	221.5	280.9	Fugro	WSP

Notes:
1) The reference point elevation is the ground surface.
2) The reference point elevation is the top of casing.
3) The reference point elevation is the mudline.
4) Assumed Lake Level of 581.7 feet above Mean Sea Level (MSL).

APPENDIX

B-2 *BORING LOGS*

BORING LOG KEY

BORING NUMBER: BH19-##
SHEET NUMBER: # of #
PROJECT NUMBER: 31402024.00

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE				SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
			TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
1	2	3	4	5	6	7	8	9	10	11	12	13

COLUMN DESCRIPTIONS

1. DEPTH: Distance (in feet) below the ground surface (onshore borings) or the bottom jaws (nearshore boreholes).
2. GRAPHIC LOG: A graphic log of encountered material using symbols to represent each differing soil and rock types. Symbols are explained in the following section.
3. CASING: A column showing the amount of blows/feet.
4. SAMPLE TYPE: A column denoting the type of sample used to retrieve the sample during sample, e.g. U for Shelby Tube.
5. SAMPLE NO.: Number of the individual sample retrieved.
6. SAMPLE SYMBOL: A visual representation of the type of sampling method used to retrieve the sample.
7. DEPTH: Range (in feet) of the sample interval.
8. SOIL – 0/6: The number of blow counts it takes to advance the first 6 inches for the Standard Penetration Test (SPT).
   CORING – RUN: The length of the core run in inches.
9. SOIL – 6/12: The number of blow counts it takes to advance the second 6 inches for the Standard Penetration Test (SPT).
   CORING – REC.: The amount of the core run that was recovered in inches.
10. SOIL – 12/18: The number of blow counts it takes to advance the third 6 inches for the Standard Penetration Test (SPT).
    CORING – REC.: The amount of the core run that was recovered as a percentage.
11. SOIL – 18/24: The number of blow counts it takes to advance the fourth 6 inches for the Standard Penetration Test (SPT)
    CORING – L>4": The amount of core that is greater than 4 inches recorded in inches.
12. SOIL – REC.: The amount of the sample that was retrieve recorded as a percentage.
    CORING – RQD (ROCK QUALITY DESIGNATION): Amount (in percent) of intact core (pieces of sound core greater than or equal to 4 inches in length) in the coring interval. The value is calculated as the sum of lengths of intact core divided by the total run length.
13. FIELD CLASSIFICATION AND REMARKS: Lithologic description in the following order: color, soil/rock type, plasticity (soil), density (soil), strength, fracturing (rock), moisture content (soil), and other descriptive features.

SOIL PARTICLE SIZE IDENTIFICATION

Broad Group	Name	Size Limits: ASTM Sieve Number	Size Limits: mm
Coarse-Grained	Boulder	> 12 in.	> 305
	Cobble	12 in. to 3 in.	305 to 76
	Coarse Gravel	3 in. to 3/4 in.	76 to 19
	Fine Gravel	3/4 in. to No. 4 Sieve	19 to 4.75
	Coarse Sand	No. 4 to No. 10 Sieve	4.75 to 2.00
	Medium Sand	No. 10 to No. 40 Sieve	2.00 to 0.42
	Fine Sand	No. 40 to No. 200 Sieve	0.42 to 0.075
Fine-Grained	Silt and/or Clay	< No. 200 Sieve	< 0.075

Note: Particles finer than fine sand cannot be discerned with the naked eye at a distance of 8 inches (200 mm)

APPARENT DENSITY/COMPACTNESS OF GRANULAR SOILS

Description	Relative Density Dr (%) (approx.)	N-Value (approx.)	Penetration with 1/2" (13 mm) Reinforcing Rod
Very Loose		4	Easily pushed by hand
Loose	40	10	Easily driven by 5-lb. (2.3 kg) hammer
Medium Dense	70	30	Driven 1.0 ft (300 mm) by 5-lb (2.3 kg) hammer
Dense	90	50	Driven only few inches (centimeters) by 5-lb (2.3 kg) hammer
Very Dense			

WSP BORING LOG L5RTProject_20191216.GPJ WSP USA_20191216.GLB 12/16/19

BORING LOG KEY

BORING NUMBER: BH19-##
SHEET NUMBER: # of #
PROJECT NUMBER: 31402024.00

CRITERIA FOR DESCRIBING ANGULARITY OF COARSE-GRAINED PARTICLES

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have rounded edges.
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

CONSISTENCY OF FINE-GRAINED SOILS

Uncorrected Blow Count	Consistency	Unconfined Compressive Strength, qu tsf (kPa)	Results of Manual Manipulation
<2	Very Soft	<0.25 (<25)	Specimen (height = twice the diameter) sags under its own weight; extrudes between fingers when squeezed.
2-4	Soft	0.25 - 0.50 (25 - 50)	Specimen can be pinched in two between the thumb and forefinger; remolded by light finger pressure.
4-8	Medium Stiff	0.50 - 1.00 (50 - 100)	Can be imprinted easily with fingers; remolded by strong finger pressure.
8-15	Stiff	1.00 - 2.00 (100 - 200)	Can be imprinted with considerable pressure from fingers or indented by thumbnail.
15-30	Very Stiff	2.00 - 4.00 (200 - 400)	Can barely be imprinted by pressure from fingers or indented by thumbnail.
>30	Hard	>4.00 (>400)	Cannot be imprinted by fingers or difficult to indent by thumbnail.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

			Group Symbols	Typical Names
Coarse-grained soils More than half of material is larger than 0.075 mm sieve size	Gravels More than half of coarse fraction is larger than 4 mm sieve size		GW	Well graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
			GM	Silty gravels, poorly graded gravel-sand-silt mixtures
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures
	Sands More than half of coarse fraction is smaller than 4 mm sieve size		SW	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
			SM	Silty sands, poorly graded sand-silt mixtures
			SC	Clayey sands, poorly graded sand-clay mixtures
Fine-grained soils More than half of material is smaller than 0.075 mm sieve size	Silts and clays liquid limit less than 50		ML	Inorganic silts and very little sands, rock flour, clayey fine sands with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silt-clays of low plasticity
	Silts and clays liquid limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			Pt	Peat and other highly organic soils

WSP BORING LOG L5RTProject_20191216.GPJ WSP USA_20191216.GLB 12/16/19

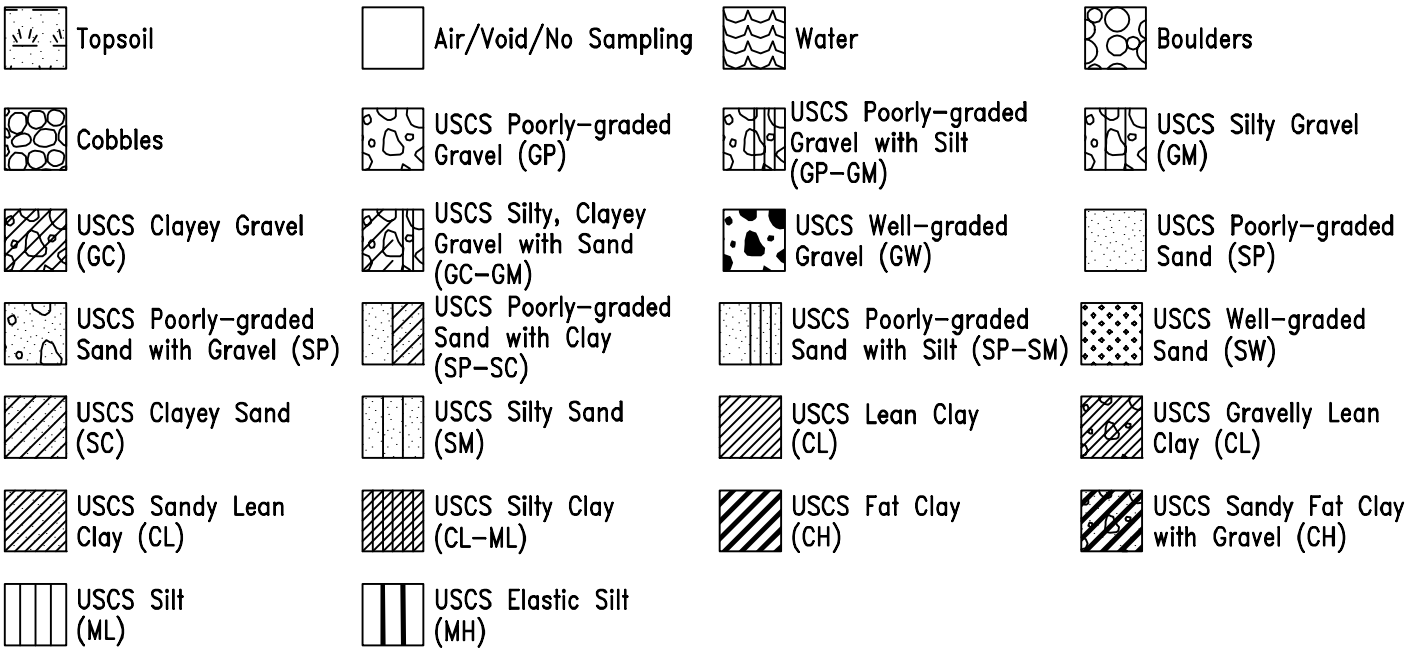
BORING LOG KEY

BORING NUMBER: BH19-##
SHEET NUMBER: # of #
PROJECT NUMBER: 31402024.00

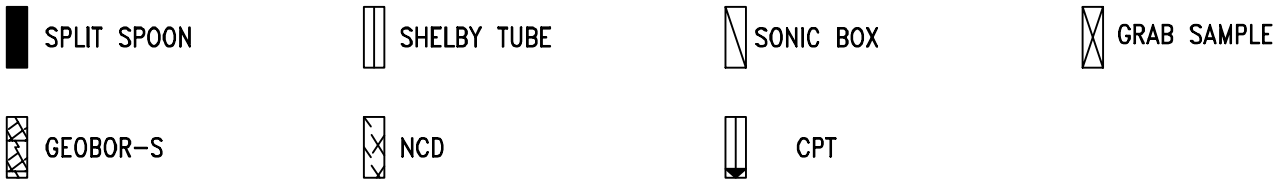
RANGE OF PERCENTAGES FOR SOIL DESCRIPTORS

Name	Range of Percentage
Trace	Particles are present but estimated to be less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

TYPICAL MATERIAL GRAPHIC SYMBOLS



TYPICAL SAMPLING SYMBOLS



ABBREVIATIONS

PSA:	Particle Size Analysis	PL:	Plastic Limit
SG:	Specific Gravity	PI:	Plasticity Index
w/MC:	Moisture Content	γ_d:	Dry Unit Weight
LL:	Liquid Limit		

REFERENCES

1. ASTM D1586-18. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils ASTM International 2018. West Conshohocken, PA.

2. ASTM D2487-17. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). ASTM International 2017. West Conshohocken, PA.

3. ASTM D2488-17e1. Standard Practice for Description and Identification of Soils (Visual-Manual Procedures) ASTM International 2018. West Conshohocken, PA.

WSP BORING LOG LSRTProject_20200219.GPJ WSP USA_20200219.GLB 02/19/20

CORING LOG KEY

BORING NUMBER: BH19-##

SHEET NUMBER: # of #

PROJECT NUMBER: 31402024.00

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

COLUMN DESCRIPTIONS

1. DEPTH: Distance (in feet) below the ground surface (onshore borings) or the bottom jaws (nearshore boreholes).
2. CORING RATE: Drilling rate for rock core runs (in ft/min).
3. GRAPHIC LOG: A graphic log of encountered material using symbols to represent each differing soil and rock types. Symbols are explained in the following section.
4. CORE RUN TYPE: A graphic explanation of the type of core retrieved during drilling. Symbols are explained in the following section.
5. CORE RUN NO.: Number of the individual coring interval.
6. ROCK BOX NO.: Number of the core box which contains core from the corresponding run.
7. RECOVERY: Amount (in percent) of core retrieved from the coring interval. Calculated as length of core retrieved divided by the run length.
8. RQD (ROCK QUALITY DESIGNATION): Amount (in percent) of intact core (pieces of sound core greater than or equal to 4 inches in length) in the coring interval. The value is calculated as the sum of lengths of intact core divided by the total run length.
9. ESTIMATED CORE LOSS: A graphic representation of zones of core lost during drilling. 'CL' indicates core loss zones.
10. DESCRIPTION AND REMARKS: Lithologic description in the following order: color, rock type, weathering, strength, fracturing, and other descriptive features. Description of weathering, strength, and fracturing determinations is included in the following section.
11. PACKER TEST ZONE: A graphic representation of the test intervals for each test zone of the packer.
12. WEATHERING: Value assigned to indicate degree of weathering. Description of weathering values is included in the following section.
13. STRENGTH: Value assigned to indicate strength of rock core. Description of strength values is included in the following section.
14. ANGLE: Dip of discontinuity (in degrees) measured relative to a plane normal to the core axis.
15. JOINT ROUGHNESS (JR): A measure of the roughness along the surface of the discontinuity based on the Q-System (Barton, Lien and Lunde, 1974).
16. JOINT ALTERATION (JA): A measure of the alteration along the surface of the discontinuity based on the Q-System (Barton, Lien and Lunde, 1974).
17. DEPTH: Depth or range of depths (in feet) at which discontinuities were observed.

ROCK WEATHERING

Term	Description	Grade
Unweathered	No visible sign of rock material weathering, perhaps slight discoloration on major discontinuity surfaces	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly Weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported	VI

DEFINITION OF ROCK WEATHERING TERMINOLOGY

Term	Description
Fresh	No visible sign of weathering of the rock material
Discolored	The color of the original fresh rock is changed. The degree of change from the original color should be indicated. If the color change is confined to particular mineral constituents, this should be mentioned.
Decomposed	The rock is weathered to the condition of a soil in which the original material fabric is still intact, but some or all of the mineral grains are decomposed.
Disintegrated	The rock is weathered to the condition of a soil in which the original fabric is still intact. The rock is friable, but the mineral grains are not decomposed.

CORING LOG KEY

BORING NUMBER: BH19-##
SHEET NUMBER: # of #
PROJECT NUMBER: 31402024.00

ROCK FRACTURING

Description	Criteria
Sound	Drill core stem >8" (>200 mm) pieces
Slightly Fractured	Drill core stem in 4"– 8" (100 – 200 mm) pieces
Moderately Fractured	Drill core stem in 1"– 4" (25 – 100 mm) pieces
Extremely Fractured	Drill core stem in pieces <1" (<25 mm)

JOINT ROUGHNESS

Rock Wall Contact Condition	Joint Description	Joint Roughness Number (Jr)
Rock wall contact along discontinuity surface	A. Discontinuous joints	4.0
	B. Rough or irregular, undulating	3.0
	C. Smooth, undulating	2.0
	D. Slickensided, undulating	1.5
	E. Rough or irregular, planar	1.5
	F. Smooth, planar	1.0
	G. Slickensided, planar	0.5
No rock wall contact along discontinuity surface	H. Zone containing clay minerals thick enough to prevent rock wall contact	1.0 (nominal)
	I. Sandy, gravelly, or crushed zone thick enough to prevent rock wall contact	1.0 (nominal)

JOINT ALTERATION

Rock Wall Contact Condition	Joint Description	Joint Alteration Number (Ja)
Rock wall contact, or coating <1/8 in. (3 mm) thick	A. Tightly healed, hard, non–softening, impermeable filling, i.e., quartz or epidote	0.75
	B. Unaltered joint walls, surface staining only.	1.0
	C. Slight altered joint walls. Non–softening mineral coatings, sandy particles, clay–free disintegrated rock, etc.	2.0
	D. Silty– or sandy–clay coatings, small clay–fraction (non softening).	3.0
	E. Softening or low friction clay mineral coatings, i.e., kaolinite, mica. Also chlorite, talc, gypsum, graphite, etc., and small quantities of swelling clays.	4.0
No rock wall contact, continuous coatings <1/4 in (5 mm) thick	F. Sandy particles, clay–free disintegrated rock, etc.	4.0
	G. Strong over–consolidation, softening, clay mineral fillings. (Continuous, <5 mm in thickness).	6.0
	H. Medium or low over–consolidation, softening, clay mineral fillings. (Continuous, <5 mm in thickness).	8.0
	J. Swelling clay fillings, i.e., montmorillonite (Continuous, <5 mm in thickness). Value of Ja depends on percent of swelling clay–size particles and access to water, etc.	8.0 – 12.0
No rock wall contact, continuous coatings >1/4 in (5 mm) thick	K. Crushed rock and clay (see G., H., J., for description of clay condition).	6.0 or 8.0
	L. Crushed rock and clay (see G., H., J., for description of clay condition).	8.0 – 12.0
	M. Zones or bands of silty– or sandy clay, small clay fraction (non–softening).	5.0
	N. Thick, continuous zones or bands of clay (see G, H, J for description of clay condition).	10.0 or 13.0
	O. Thick, continuous zones or bands of clay (see G, H, J for description of clay condition).	13.0 – 20.0

WSP CORING LOG L5RTProject_20191216.GPJ WSP USA_20191216.GLB 12/16/19

CORING LOG KEY

BORING NUMBER: BH19-##
SHEET NUMBER: # of #
PROJECT NUMBER: 31402024.00

ROCK STRENGTH

Term	Description	Grade	Approx. Range of Uniaxial Compressive Strength (psi)
Extremely weak	Indented by thumbnail	R0	40 – 150
Very weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	R1	150 – 700
Weak	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	R2	700 – 4,000
Medium strong	Cannot be scraped or peeled by a pocket knife, specimen can be fractured with single firm blow of geological hammer	R3	4,000 – 7,000
Strong	Specimen requires more than one blow of geological hammer to fracture it	R4	7,000 – 15,000
Very strong	Specimen requires many blows of geological hammer to fracture it	R5	15,000 – 36,000
Extremely strong	Specimen can only be chipped with geological hammer	R6	> 36,000

TYPICAL MATERIAL GRAPHIC SYMBOLS

Limestone
Argillaceous Limestone
Dolomitic Limestone
Dolomite
Argillaceous Dolomite
Claystone
Breccia
Gypsum
No Sample/Void

LITHOLOGICAL BOUNDARIES

Solid Line: Known contact between boundaries
Dashed Line: Inferred contact between boundaries

TYPICAL CORE RUN SYMBOLS

HQ3 Barrel
NQ3 Barrel
GEOBOR-S
NCD

ABBREVIATIONS

PLA: Estimated UCS value for Point Load Axial Strength based on Table 1 in ASTM D5731
PLD: Estimated UCS value for Point Load Diametral Strength based on Table 1 in ASTM D5731
PLL: Estimated UCS value for Point Load Lump Strength based on Table 1 in ASTM D5731

UCS: Uniaxial Compressive Strength
γ_d: Average dry unit weight
γ: Average bulk density

REFERENCES

1. ASTM D2113-14. Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration ASTM International 2014. West Conshohocken, PA.

2. Barton, N.R., Lien, R. and Lunde, J. Engineering Classifications of Rock Masses for Design of Tunnel Support, Rock Mech. 6(4), 189-239, 1974.

WSP CORING LOG LSRTProject_20200219.GPJ WSP USA_20200219.GLB 02/19/20

BORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 1 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You
BORING INCLINATION FROM HORIZONTAL: 69°/219°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.83808 N Long: 84.75731 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 600.4 feet
DATUM: IGLD 1985
START DATE: 7/22/19 TIME: 12:47 pm
FINISH DATE: 7/23/19 TIME: 10:30 am

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol	PQ	SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1																	AIR
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	WATER
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 2 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
26																	
27																	
28																	
29																	
30																	
31																	
32																	
33																	
34																	
35																	
36																	
37																	
38																	
39																	
40																	
41																	
42																	42-55: Not sampled
43																	
44																	
45																	
46																	
47																	
48																	
49																	
50																	
51																	
52																	
53																	
54																	
55		SB-001 50.0-60.0 ft.															Medium grained, POORLY GRADED SAND, (SP)
56																	G-2: PSA = 27.9% GRAVEL, 41.5% SAND, 30.6% FINES; SG = 2.65
57																	
58																	SILTY CLAYEY SAND, (SC-SM)
59																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 3 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61		SB-003 60.0-70.0 ft.	G	G-002		55.0 - 65.0											POORLY GRADED GRAVEL with SILT, few Silt, (GP)
62																	LEAN CLAY, very stiff, (CL)
63																	Becomes very dark gray to dark gray
64																	DOLOMITE, highly weathered with sand
65																	
66																	
67																	
68																	
69																	DOLOMITE, [SAINT IGNACE FORMATION - MACKINAC BRECCIA]
70																	Start Rock Coring at 70.0'
71																	
72																	
73																	
74																	
75																	
76																	
77																	
78																	
79																	
80																	
81																	
82																	
83																	
84																	
85																	
86																	
87																	
88																	
89																	
90																	
91																	
92																	
93																	
94																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 1 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You
BORING INCLINATION FROM HORIZONTAL: 69°/219°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.83808 N Long: 84.75731 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 600.4 feet
DATUM: IGLD 1985
START DATE: 7/22/19 TIME: 12:47 pm
FINISH DATE: 7/23/19 TIME: 10:30 am

CORE BARREL DATA:
TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: PQ

NOTES:
Depths and angles are shown in length along borehole
HQ3 (70-98', 117.7-158', 173-203')
NQ3 (98-117.7', 158-173')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
71	1.50			1		100	11		Light grayish brown, DOLOMITE, slightly weathered, medium strong, moderately to extremely fractured, with 60° bedding		II	R3	0-90	1.0	4.0	70.0-71.5
									[ST. IGNACE FORMATION - MACKINAC BRECCIA]				30	1.5	1.0	70.7
													80	1.0	2.0	70.0-72.0
72									Becomes moderately fractured, with dark brown, clay partings				30	3.0	2.0	72.0
													15	3.0	2.0	72.2
										P11			50	3.0	2.0	72.4
73									Becomes extremely fractured and locally crushed				50	2.0	2.0	72.9
													0-90	1.0	1.0	73.0-73.5
													0-90	1.0	4.0	73.5-74.8
74								CL	Becomes moderately to highly weathered, weak to medium strong, extremely fractured		III-IV	R2-R3				
									Mottled grayish brown and dark brown, LIMESTONE, laminated, moderately weathered, medium strong, slightly to moderately fractured, with 1-inch vugs and 30° bedding		III	R3				
75	1.25			2		95	28		Becomes moderately fractured				80	1.0	2.0	75.13
													30	1.5	1.0	75.53
													0-90	1.0	4.0	75.6-75.7
76					RB-001				Light gray, DOLOMITE, slightly weathered, weak, slightly to moderately fractured, with 20° bedding		II	R2	0	2.0	1.0	76.4
77													10	1.0	2.0	76.9
													20	1.0	0.75	77.5
													80	1.0	1.0	77.6-77.8
78									Becomes gray, moderately fractured				10	1.0	1.0	77.8
													0	2.0	1.0	78.3
													0	2.0	1.0	78.5
79									Light olive brown, LIMESTONE, moderately weathered, very weak, moderately to extremely fractured, with vugs up to 1/2-inch	P10	III	R1	0	1.5	1.0	79.0
													0-20	1.5	2.0	79.2
													20	1.5	2.0	79.5

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 2 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
													20	1.5	4.0	80.0
	1.00			3		100	13		Gray, DOLOMITE, unweathered to slightly weathered, medium strong, moderately fractured with mechanical breaks along bedding planes		I-II	R3	90	1.5	1.0	80.3
81									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				30	1.5	0.75	81.0
									80.9-81.2: PLA = 5,560 psi							
82													60	1.0	1.0	81.6-81.8
													20-30	1.0	2.0	82.1
													30	1.0	1.0	82.4
83													20	1.0	1.0	82.9
													10	1.0	1.0	83.1
													20	1.0	1.0	83.5-83.7
													50	1.0	1.0	83.7-84.0
84									Dark gray, DOLOMITIC LIMESTONE, laminated, slightly to moderately weathered, weak, slightly fractured to sound, argillaceous, locally clayey. Becomes slightly weathered and extremely fractured at 84.8'.		II-III	R2	30-60	1.0	4.0	84.2
85																
	1.00			4		100	18		Becomes light grayish brown, unweathered to slightly weathered, weak to medium strong, slightly fractured, not argillaceous		I-II	R2-R3	0-90	1.0	4.0	84.8-85.2
86													20	1.0	1.0	86.0
													30	1.0	1.0	86.2-86.6
87									Becomes moderately fractured, with vugs up to 3/4-inch				40	1.0	1.0	87.0-87.1
													70	2.0	2.0	87.1-87.6
88					RB-002				Becomes grayish brown, moderately weathered, weak, with calcite veins and dissolution along 30° bedding		III	R2	30	1.0	4.0	88.0-88.3
89									Becomes extremely fractured and crushed				60	3.0	2.0	88.8-89.2
									Becomes highly weathered, extremely weak, not argillaceous		IV	R0				
90									Gray and white, DOLOMITE, unweathered to slightly weathered, medium strong, slightly fractured, crushed	P9	I-II	R3				
	0.71			5		90	48		Becomes moderately weathered, weak, argillaceous, not crushed, with breccia clasts up to 3-inches below angular fracture		III	R2	20-70	2.0	1.0	90.5
91																
													20	1.5	8.0	91.5
92									Becomes slightly weathered, moderately fractured		II		20	1.0	1.0	92.1
													20	1.0	1.0	92.3
								CL					20	1.0	1.0	92.5
93									Becomes moderately weathered, extremely fractured and locally crushed at 93.6 ft.		III		0-90	1.0	3.0	93.0-93.6
													80	3.0	3.0	93.6-94.4

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 3 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Gray and white, DOLOMITE, moderately weathered, very weak, extremely fractured. Becomes slightly to moderately fractured at 94.4 ft.		III	R1	20	1.0	1.5	93.7
													20	1.0	1.5	93.8
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
95													60	1.0	2.0-3.0	94.2-94.9
	0.83			6		100	38		Dark gray, LIMESTONE, highly weathered, very weak, extremely fractured				20	2.0	3.0	95.4
96													50	2.0	3.0	96.0
											II	R2	60-90	1.5	1.0	96.0-96.8
									Becomes slightly weathered, weak, with 40° bedding				40	1.0	0.75	96.4
									Gray and white, DOLOMITE, highly to extremely weathered, extremely weak, locally crushed to a sand with clay and silt		IV-V	R0				
97													50	2.0	6.0	97.1-99.6
98					RB-003											
									Olive brown, LIMESTONE, slightly weathered, weak, extremely fractured, with vugs up to 1-inch and calcite precipitation along irregular fracture surfaces. At 98.6' becomes slightly to moderately weathered, very to extremely weak, sound to slightly fractured.		II	R2	30-50	3.0-4.0	3.0	98.0-99.6
99																
									Light grayish brown, DOLOMITE, slightly weathered, medium strong, sound, with 30° bedding		II	R3				
100										P8						
	0.83			7		100	37		Olive brown, LIMESTONE, slightly weathered, medium strong, moderately fractured, breccia clasts visible		II	R3				
101													30	1.5	4.0	100.8-101.8
									Light grayish brown, DOLOMITE, slightly weathered, medium strong		II	R3	10	1.5	1.0	101.8-102.1
102											II	R3	60	1.5	4.0	102.1-102.9
									Olive brown, LIMESTONE, slightly weathered, weak, slightly to moderately fractured, argillaceous, with brown breccia clasts							
103									NOTE: Switch from HQ to NQ at 103.0' for pressuremeter test		I-II	R3				
104								CL								
105																
	0.83			8		50	0		Light brownish gray, DOLOMITE, unweathered to slightly weathered, medium strong, moderately to extremely fractured, with caclite along fracture surfaces. Some clay on fractures 103.0-103.6'.				0-90	1.0	2.0-4.0	105.5-106.5
106													30	1.0	0.75	106.0
													45	1.0	0.75	106.4
107									Becomes extremely fractured				0-90	1.0	4.0	107.1-107.5
									Becomes moderately to extremely fractured				30-90	1.5	2.0	107.5-108.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 4 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, DOLOMITE, slightly weathered, medium strong to strong, extremely fractured with tight, black, calcite veins and pits (<1 mm), and 30° bedding [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3-R4	0-90	1.0	2.0	108.0-108.8
109									Becomes slightly fractured				30	3.0	2.0	108.8
													30	1.0	2.0	109.3
									30° 1.2-inch dissolution zone 109.6-109.7 ft.				30	1.0	2.0	109.6-109.7
110	0.83			9	RB-004	90	68						50	1.0	1.0	110.0
													12	1.5	2.0	110.1
													25	1.0	2.0	110.6
111																
112													30	1.5	2.0	111.7
								CL	NOTE: Switch from NQ to HQ at 113.0 ft.				20	1.5	2.0	112.4
113									Becomes unweathered to slightly weathered, medium strong		I-II	R3				
									113.0-113.3: ω = 0.82%; γ_d = 168 lb/ft^3; SG = 2.69; n = 0.041; PLA = 6,320 psi				30	1.0	0.75	113.3
									Becomes sound				30	0.75	1.0	113.5
114									114.3-114.5: Fracture infilled with LIMESTONE gravel				15	3.0	2.0	114.3-114.5
115	0.67			10		100	81			P7			30-40	1.0	0.75	115.1
													60	1.0	1.0	115.7
116													30	1.0	2.0	116.0
117									Moderately to extremely fractured, crushed with gravel (likely mechanical) 116.8-117.7'.				10	1.0	2.0	117.0
													90	2.0	2.0	117.4
118									With fractures adverse to bedding (both fractures and bedding at 30°)				25	1.0	1.0	118.1
									Becomes moderately fractured							
119									118.4-118.8: γ_d = 162 lb/ft^3				15	1.0	1.0	118.8
													30	1.0	0.75	119.1
													35	1.0	0.75	119.2
120	0.53			11		70	11		Olive gray, LIMESTONE, slightly weathered, weak, extremely fractured to a gravel, with trace clay and calcite dissolution along fracture surfaces possibly from drilling actvities		II	R2	0-90	3.0	4.0-6.0	119.6-121.4
121																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 5 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL								
123									Olive gray, LIMESTONE, moderately weathered, medium strong, moderately fractured, vuggy, with 60° bedding with some CALCITE recrystallization on vug surfaces [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R3	0-90	3.0	4.0-6.0	123.0-123.3
													30	3.0	2.0	123.5
124													5	3.0	2.0	124.0
													30	3.0	2.0	124.1
													20-60	2.0	0.75	124.3-124.5
125	0.40			12	RB-005	100	10		Becomes highly weathered, weak, extremely fractured to a gravel along 50° bedding		IV	R2	0-70	2.0	6.0	124.7-125.5
									Becomes dark gray, laminated, slightly fractured, argillaceous, possibly with turbidite texture				50	1.0	1.0	125.2
126									Becomes extremely weathered, extremely weak		V	R0				
													30	1.0	4.0	125.9
													35	2.0	2.0	126.0
													20	1.0	4.0	126.3-127.0
127	0.50			13		100	0		Light grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with clay and sand filled fractures (from drilling) and LIMESTONE up to 1.5-inches along 25° bedding		II	R3	30	1.0	1.0	127.0
													50	1.0	1.0	127.1
													40-50	3.0	2.0	127.2-127.7
128											IV	R1	65	3.0	2.0	127.3-127.7
								CL	Olive gray, LIMESTONE, highly weathered, very weak, extremely fractured and locally crushed	P6			20-70	3.0	2.0	128.3-128.5
129									Light grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with 30° bedding. Becomes extremely fractured at 129.4'.		II	R3	70-90	1.0	0.75	128.9-129.9
													20	1.5	0.75	129.6
130									Becomes slightly fractured with vugs (<1 mm) and dissolution along 30° bedding				20	1.5	0.75	129.7
	0.38			14		94	74						0-90	1.0	1.0	129.9-130.0
													30	1.0	0.75	130.1
													50	1.0	1.0	130.2
131													30	1.0	0.75	130.5
													30	1.0	0.75	130.8
													30	1.0	0.75	131.4
132													20	3.0	1.0	131.8
													20	1.0	0.75	132.0
													20	3.0	1.0	132.3
													30	1.0	0.75	132.4
133									Becomes strong, moderately fractured, with CALCITE infilling along fracture surfaces			R4				
													30	1.0	1.0	133.6
134													20	1.0	1.0	134.0
													10-30	3.0	1.0	134.3
									Becomes extremely fractured, without vugs				10-30	3.0	1.0	134.6
135													0-90	1.0	1.0	134.7-135.3
	0.50			15		100	48		Becomes moderately weathered, medium strong, with small gravel infilling fractures and chalky texture		III	R3	40	3.0	3.0	135.3-135.9

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 6 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, DOLOMITE, moderately weathered, medium strong, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R3	30	1.0	1.0	136.3
													15	2.0	1.0	136.6
137									Becomes laminated, with occasional SHALE, vugs, and 40° bedding at 136.9'				40	1.0	1.0	136.6
													40	1.0	1.0	136.9
									Becomes slightly weathered, strong, moderately fractured		II	R4	0-50	2.0	4.0	136.9-137.2
													10-30	2.0	2.0	137.2-138.0
138					RB-006				138.4-138.8: ω = 1.44%; γ_d = 166 lb/ft^3; SG = 2.66; n = 0.050				10	2.0	1.0	138.1
													30	1.0	1.0	138.3
										P5			10	1.0	1.0	138.7
139									Becomes extremely fractured along bedding							
													25	2.0	3.0	139.4
													0-90	3.0	6.0	139.4-140.0
140													90	1.0	1.0	140.0-140.5
	0.33			16		72	8						30	1.0	0.75	140.0-140.6
									Becomes light gray and tan							
141													25	1.0	1.0	140.8
													50	2.0	3.0	141.0
													10-50	3.0	6.0	141.0-141.6
142								CL								
143													15	1.0	1.0	143.0
													10-40	2.0	1.0	143.3-143.6
									Gray, LIMESTONE, highly weathered, very weak, extremely fractured, argillaceous, locally clayey, with 20° bedding		IV	R1				
144													30	2.0	4.0	144.0
									144.7-145.0: PLL = 2,900 psi				20	1.0	2.0	144.4
									Becomes weak			R2				
145									With solution cavities and vugs, crushed				0-90	3.0	6.0	144.8-145.1
	0.42			17		96	6									
									Light grayish brown, DOLOMITE, laminated, slightly weathered, medium strong, extremely fractured, locally crushed, with 25° bedding		II	R3	10	1.0	1.0	145.5
													70	2.0	1.0	145.5-145.8
146													25	1.0	1.0	146.0
													25	1.0	1.0	146.3
													90	3.0	6.0	146.5-147.2
													65	1.0	1.0	146.5-146.7
147													25	1.0	1.0	147.0
													25	1.0	1.0	147.1
													25	1.0	1.0	147.2
													25	1.0	1.0	147.3
148					RB-007			CL	Becomes moderately to extremely fractured				25	1.0	1.0	147.4
													25	1.0	1.0	147.7
													30	1.0	1.0	148.0
													10-30	1.0	1.0	148.4-148.6
149													30	1.0	1.0	148.7
										P4			30	1.0	1.0	148.8
									Becomes slightly to moderately fractured				30	1.0	1.0	148.9
													20	1.0	6.0	149.1

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 7 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with vugs and CALCITE veins		II	R3	20	1.0	1.0	149.4
	0.45			18		100	30		[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				10	1.0	2.0	150.1
													60	1.0	4.0	150.2-150.5
151													80	1.0	2.0	150.6
									Becomes laminated, with undulating bedding, without vugs, and a 4-inch thick zone with numerous needle-like grayish black features up to 7-mm long				20-60	1.0	2.0	150.8-151.0
													10	1.0	1.0	151.5
152													10	1.0	1.0	151.6
													10	2.0	6.0	151.8
													20	1.0	1.0	152.0
													20	1.0	1.0	152.3
153													20	1.0	1.0	152.6
									Becomes slightly weathered		II					
													0-90	2.0	1.0	153.3-153.9
													85	1.0	1.0	153.7-154.4
154										P3			30	1.0	1.0	154.0
									Becomes gray, possibly gradational contact with underlying LIMESTONE				25	1.0	1.0	154.1
													20	1.0	1.0	154.2
													70	1.0	6.0	154.4-154.7
155													25	1.0	1.0	154.7
	0.26			19		74	12		Gray, LIMESTONE, highly weathered, extremely weak, moderately fractured, locally crushed and clayey		IV	R0	30	1.0	4.0	155.0
													50	1.0	4.0	155.6
156													60	1.0	4.0	155.8
													25	2.0	8.0	156.0
													25	2.0	8.0	156.2
157								CL								
									NOTE: Switch from HQ to NQ at 158.0 ft. for pressuremeter test							
158									Light grayish brown, slightly weathered, strong		II	R4				
												R3				
159								CL								
160																
											II	R3				
	0.38			20	RB-008	50	12		Becomes gray, medium strong, moderately fractured, vuggy, with disturbed 45° bedding				85	2.0	1.0	160.5-161.0
161													20	1.0	1.0	160.7
													10	3.0	1.0	161.2
									Becomes increasingly vuggy 159.4-159.6 ft. With 25° bedding				10	3.0	1.0	161.4
162													15	3.0	4.0	161.9
													50	2.0	1.0	162.0
													25	1.0	1.0	162.1-162.5
													90	1.0	0.75	162.4-162.6
163									Light grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with 25° bedding				20	3.0	6.0	162.6
									Becomes slightly weathered, strong, sound		II	R4				
									Becomes moderately weathered, extremely fractured, locally crushed, with vugs up to 1/4-inch at 163.7 ft.		III					

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 8 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light gray, DOLOMITE, moderately weathered, strong, extremely fractured, locally crushed, with vugs up to 1/4-inch		III	R4	35	3.0	6.0	163.8
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				20	2.0	6.0	164.1
													30	3.0	8.0	164.3-164.5
165													10-70	2.0	6.0	164.7-164.9
													90	1.0	1.0	165.1
	0.28			21		80	40						30	1.0	0.75	165.3
													10	2.0	6.0	165.3-165.5
166									With occasional pits < 1 mm				40	3.0	8.0	165.5-165.7
													35	1.0	1.0	165.9
													50	1.0	1.0	166.2
													0	1.0	0.75	166.3
167													40	2.0	1.0	166.5
								CL								
168									Becomes crushed, only gravel-sized rock fragments recovered				0-90	1.0	1.0	168.0-168.7
								CL	Gray, LIMESTONE, extremely weathered, extremely weak, clayey, characterized by poor recovery		V	R0				
169									VOID							
170																
	0.42			22		10	0									
171																
172																
									NOTE: Switch from NQ to HQ at 173.0 ft.							
173									Light gray, DOLOMITE, slightly weathered, medium strong, extremely fractured, only gravel recovered		II	R3				
174									Greenish gray and gray, LIMESTONE, highly to extremely weathered, very weak, moderately fractured, locally clayey, with infilling of sand and clay, brecciated		IV-V	R1	30-50	1.0	6.0	174.0
									[ST. IGNACE FORMATION - MACKINAC BRECCIA]				0	1.0	6.0	174.7
175													0-60	1.0	6.0	175.2
	1.00			23	RB-009	94	31		Becomes slightly weathered, weak, sound		II	R2				
176																
													30	1.5	2.0	176.3
													30	1.5	2.0	176.5
									Becomes moderately fractured	P2			30	1.5	2.0	176.6
177													30	1.5	2.0	177.0-177.3
								CL					0	1.5	2.0	177.5

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 9 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
179									Greenish gray, CLAYSTONE, unweathered, medium strong, moderately fractured, locally clayey, calcareous [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		I	R3				
									178.0-178.8: ω = 3.31%; γ_d = 151 lb/ft^3; SG = 2.45; n = 0.087				0	1.0	6.0	178.8
													0	1.0	6.0	178.9
													0	1.0	6.0	179.0
180													0-30	1.0	3.0	179.8-180.0
	1.00			24		100	85									
181																
182													0-30	1.0	6.0	182.0
183													0-10	1.0	6.0	182.8
									Becomes weak, sound to slightly fractured		I	R2				
184									Becomes mottled greenish gray and reddish brown							
185																
	1.00			25		100	95									
186													0	1.5	1.0	185.6
													20	1.5	0.75	187.5
187																
188					RB-010								20	1.5	2.0	187.8
													20	1.5	2.0	188.0
189													5	1.0	2.0	188.9
190													35	1.5	1.0	190.0
									Extremely fractured (possible mechanical) 190.2-190.4 ft.	P1			0-90	1.0	4.0	190.2-190.4
	1.00			26		90	80									
191																
													0-15	1.0	4.0	191.5

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-07
SHEET NUMBER: 10 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond, C. Barden
INSPECTOR: K. Zeiger, X. You

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray and reddish brown, CLAYSTONE, unweathered, weak, sound to slightly fractured [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		I	R2				
								CL								
193									Becomes sound							
									Becomes very weak			R1				
194									194.2-194.9: γ_d = 125 lb/ft^3; PLL = 560 psi							
195	1.00			27		100	100									
196									Becomes greenish gray, slightly weathered		II		0-50	1.0	3.0	196.0
													0	1.0	6.0	196.7
197																
198					RB-011				Brown, DOLOMITE, slightly weathered, medium strong, extremely fractured along 30° bedding, with dark brown CALCITE laminations [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R3	0-90	1.0	2.0	197.8-198.0
													0-90	1.0	2.0	198.0-198.8
199									Becomes slightly to moderately fractured along bedding (possibly mechanical)				30	1.0	2.0	198.8
													50	1.5	2.0	198.9
													30	1.0	1.0	199.0
													30	1.0	1.0	199.3
200													30	1.0	1.0	199.4
													30	1.0	1.0	199.8
													30	1.5	2.0	200.0
	1.00			28		100	37						30	1.5	2.0	200.2
201													30	1.0	0.75	200.8
													30	1.0	2.0	201.5
202													30	1.0	2.0	202.2
													30	1.0	0.75	202.5
													30	1.0	0.75	202.8
													30	1.0	2.0	202.9
203									End of Boring at 203' The boring was backfilled with cement-bentonite grout to the mudline at 11:50 AM on 7/25/2019.							
204																
205																

BORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 70°/23°

DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78830 N Long: 84.77656 W
STN. NO.: OFFSET:
SURFACE ELEV.: 584.3 feet
DATUM: IGLD 1985

START DATE: 6/3/19 TIME: 7:45 am
FINISH DATE: 6/6/19 TIME: 8:40 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA				
Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1																	Brown, SILTY GRAVEL with SAND, little Sand, little Silt, trace Organics, (GM)
2																	Brown, SILTY SAND with GRAVEL, some Gravel, trace Cobbles, (SM)
3																	
4																	
5																	
6																	SANDY SILT with GRAVEL, some Sand, little Gravel, trace Cobbles, (ML)
7																	
8																	
9																	
10																	NOTE: Drilled from 0-19 ft. in 90 minutes.
11																	
12																	Light gray and tan, DOLOMITE, crushed [BOIS BLANC FORMATION]
13																	
14																	
15																	
16																	
17																	
18																	
19																	Start Rock Coring at 19.0'
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 70°/23°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78830 N Long: 84.77656 W
STN. NO.: OFFSET:
SURFACE ELEV.: 584.3 feet
DATUM: IGLD 1985
START DATE: 6/3/19 TIME: 7:45 am
FINISH DATE: 6/6/19 TIME: 8:40 pm

CORE BARREL DATA:
TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: " (")

NOTES:
Depths and angles are shown in length along borehole
HQ3 (19-105'), NQ3 (105-113')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown and white, DOLOMITE, slightly weathered, medium strong, extremely fractured [BOIS BLANC FORMATION - MACKINAC BRECCIA]		II	R3	10-30	1.5	2.0	19.0-19.5
													10	1.5	4.0	19.5-19.6
20									1-inch clay seam at 19.5-19.6 ft. Crushed to a gravel 19.9-20.1 ft.				75	1.0	3.0	20.2-20.7
									20.5: ω = 0.26%; γ_d = 144 lb/ft^3; SG = 2.31; n = 0.122 Clay-filled fracture at 20.7 ft.				10	2.0	6.0	20.7
21				1		75	8						5	3.0	2.0	21.0
									Becomes moderately fractured				0	3.0	4.0	21.4-21.5
22													40	1.0	2.0	22.0
								CL								
23								CL								
24									Becomes extremely fractured		IV		0-90	1.5	2.0	24.0-25.0
									NOTE: Drilled from 19.0-30.5 ft. in 120 minutes.				20	2.0	2.0	24.5
									Becomes moderately fractured				20	2.0	2.0	24.6
25				2	RB-001	75	0		Highly weathered, 1-inch clay seam at 24.0-24.1 ft.				20	2.0	6.0	25.2-25.6
													60	1.0	2.0	25.3-25.6
									Highly weathered, crushed to a sandy gravel with Fe staining 24.6-25.1 ft.				70	2.0	8.0	25.6-26.1
26										P6	IV					
													60	3.0	2.0	26.3-26.6
27									Highly weathered, 1-inch clay seam at 25.9-26.0 ft.				30	1.0	3.0	26.9
									Becomes moderately fractured				0-80	2.0	4.0	26.9-27.0
													0-90	1.5	2.0,4.0	27.0-27.7
28									27.4: ω = 0.22%; γ_d = 147 lb/ft^3; SG = 2.36; n = 0.137; PLA = 4,740 psi				0-5	2.0	2.0	27.7
													10	2.0	6.0	28.0-28.1
													90	1.0	2.0	28.1-28.5
				3		100	0		Crushed to a sandy gravel 28.8-29.1 ft.				5	2.0	8.0	28.8-29.1

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
30									Light grayish brown and white, DOLOMITE, slightly weathered, weak, extremely fractured, with occasional. Becomes moderately fractured at 29.9 ft. [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R2	70	1.0	1.0	29.1-29.3
													50	2.0	4.0	29.3-29.7
													70	2.0	6.0	29.7-30.0
													90	2.0	4.0	30.3-30.5
31				4		20	0	CL					5	2.0	1.0	30.5-30.6
32									32.6: γ_d = 153 lb/ft^3; UCS = 6,637 psi				0-90	3.0	4.0	31.5-32.8
33				5		100	38		NOTE: Drilled from 30.5-35.0 in 45 minutes. Becomes medium strong			R3	5	3.0	2.0	32.8
									Becomes slightly fractured				60	2.0	1.0	32.9-33.1
													30	2.0	2.0	33.2
													10	2.0	4.0	33.3
34																
35									NOTE: Switch from HQ to NQ at 35 ft. for pressuremeter test Becomes gray, strong, moderately fractured, with calcite veins and trace calcite-filled vugs			R4	20	1.5	1.0	34.7
													20	1.5	1.0	37.9
36									Becomes medium strong, slightly fractured	P5		R3	70	1.0	1.0	36.0
37				6	RB-002	76	21		NOTE: Drilled from 35.0-45.0 in 30 minutes.			R3-R4	90	2.0	2.0	37.7-38.1
38									Becomes grayish brown and white, medium strong to strong, extremely fractured Becomes moderately fractured				0	2.0	4.0	37.7-38.2
													90	2.0	1.0	38.5-38.8
39								CL								
40									Becomes extremely fractured				90	1.5	2.0	40.0-40.3
41				7		40	0	CL								
42								CL								

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
				8		45	0		Grayish brown and white, DOLOMITE, slightly weathered, weak, extremely fractured, locally crushed to a sand [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R2	0-90	2.0	6.0	43.1-43.6
													90	1.5	4.0	43.6-43.9
44												R3				
				9		70	50		Becomes medium strong, moderately fractured				10	1.5	1.0	44.2
								CL					90	1.5	2.0	44.3
45																
									45.2: ω = 0.54%; γ_d = 143 lb/ft^3; SG = 2.28; n = 0.163							
									Crushed to a gravel 45.5-45.7 ft.				30	1.5	6.0	45.5-45.7
46				10		100	43						60	2.0	2.0	45.9-46.1
													30	1.0	2.0	46.3
													90	1.0	1.0	46.5-47.1
47																
									Becomes dark gray, laminated, medium strong, crushed to a sandy gravel 48.1-48.2 ft.		II	R3	10	2.0	1.0	47.6-48.0
48													0	2.0	4.0	48.0
									Becomes grayish brown, weak, moderately to extremely fractured		II	R2	0-90	2.0	2.0	48.5-49.5
49				11		100	0									
													30	1.0	2.0	49.5
													30	1.0	1.0	49.7
50					RB-003				Becomes moderately fractured				55	1.0	4.0	50.0
													40	1.0	2.0	50.5
										P4			80	3.0	2.0	50.7-51.0
51									Becomes extremely fractured				30	1.0	2.0	51.2
													70	1.0	2.0	51.3-51.6
													0-90	2.0	1.0	51.5-52.8
52																
53									Becomes moderately fractured		II	R2				
54				12		90	13		Crushed to sandy gravel 53.8-54.2 ft.				10	3.0	8.0	53.8-54.2
													0	1.0	1.0	54.4
													0	1.0	1.0	54.5
55									55.3: PLD = 10,400 psi				0	1.0	1.0	54.7
									Becomes strong			R4	40	1.5	1.0	55.0
													80	2.0	1.0	55.5-55.7
									Crushed to sandy gravel 55.7-55.9 ft.	P3			50	2.0	8.0	55.7-55.9
56								CL								

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Grayish brown and white, DOLOMITE, slightly weathered, weak, moderately to extremely fractured. Becomes moderately fractured at 57.2 ft. [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R2	20	1.0	2.0	57.2
													30	1.5	1.0	57.4
				13		72	0						40	1.0	1.0	57.6-57.7
58													80	1.5	2.0	57.9-58.5
								CL								
59									Becomes medium strong		II	R3				
													0	1.5	1.0	59.2
									Becomes extremely fractured				45	1.0	1.0	59.4
60													0-90	2.0	2.0	59.5-60.5
													10	1.0	1.0	60.5
61									Becomes moderately weathered, weak, locally crushed		III	R2	20	3.0	6.0	60.8-61.7
				14		96	0									
62									Becomes slightly weathered, medium strong		II	R3	0-30	2.0	2.0	61.7-62.7
					RB-004											
63									Becomes laminated, with clay along wavy laminations				80	1.0	1.0	62.7-63.2
													10	2.0	2.0	63.2
													10	2.0	2.0	63.4
													10	2.0	2.0	63.7
64								CL								
									Becomes strong, moderately to extremely fractured			R4				
									Becomes moderately weathered, weak		III	R2	10	1.5	1.0	64.4
													20	1.5	2.0	64.4-65.4
65									Becomes slightly weathered, strong, moderately fractured		II	R4				
													40	1.0	2.0	65.4
													40	1.0	2.0	65.6
66													65	1.0	2.0	64.7
				15		100	14			P2			15	2.0	2.0	66.3
													15	2.0	2.0	66.5
67																
									NOTE: Drilled from 45.0-89.5 ft. in 225 minutes.				30	2.0	2.0	67.5
68									Becomes extremely fractured, locally crushed				30-50	3.0	4.0	67.8-68.8
69													30	2.0	3.0	68.9
													30	1.0	2.0	68.9-69.8
									Becomes moderately fractured							
70									Becomes dark gray and light gray, laminated, slightly weathered, medium strong, extremely fractured		II	R3	0-90	2.0	3.0	69.8-70.2
													50	1.0	4.0	70.4-70.7
									71.1: PLA = 15,600 psi				30	1.5	1.0	70.7-71.0

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark gray and light gray, DOLOMITE, laminated, slightly weathered, very strong, extremely fractured, with small CHERT inclusions. Possible turbidite texture 70.5-72.0' [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R5	30-40	1.5	1.0	71.0-71.7
				16		100	9						50	1.5	1.0	71.7-72.0
72									Becomes extremely fractured with Fe staining on fracture surfaces							
									Becomes moderately fractured				30	1.0	1.0	72.6
73													0-90	2.0	6.0	72.9-73.0
					RB-005								90	2.0	4.0	73.0-74.0
									Becomes extremely fractured and locally crushed, with sand infilling fractures							
74									Becomes strong, moderately fractured			R4				
													60	1.0	1.0	74.3-74.6
75																
													20	1.5	1.0	75.1
									Becomes extremely fractured				0-90	2.0	3.0	75.5-76.5
76																
				17		100	0									
									Becomes moderately fractured mostly along 30° laminations	P1			30	1.5	1.0	76.7
77													30	1.5	1.0	76.9
													30	1.0	1.0	77.1
													30	1.0	1.0	77.4-78.0
78									Becomes extremely fractured							
													0-90	1.5	1.0	78.5-79.7
79																
									Becomes weak, moderately fractured			R2	30	1.0	4.0	79.7-80.7
80				18		73	0						0-90	1.0	2.0	79.9-80.0
													0-90	1.5	2.0	80.0-80.7
81								CL								
									Becomes strong, extremely fractured			R4	10	2.0	1.0	81.5-82.5
82													60	1.0	1.0	81.5-82.5
									Moderately fractured zone 82.5-82.8 ft.							
				19		96	10		82.6: PP = 22,652 lbs				0-90	1.5	1.0	82.8-84.0
83									NOTE: Switched to a new diamond-impregnated bit at 84.5 ft.							
					RB-006											
84								CL								
				20		100	0						60	1.0	1.0	84.3

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown and white, DOLOMITE, slightly weathered, medium strong, extremely fractured, with small CHERT fragments and coral fossils up to 1.5-inches [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R3				
86													40	1.0	1.0	85.9
													30	1.5	2.0	86.0
									2.5-inch sand filled fracture at 86.5-86.7 ft.				70	1.5	1.0	86.2-86.3
													15	2.0	6.0	86.5-86.7
87				21		100	0						60	2.0	1.0	86.7-86.9
													30	2.0	2.0	86.9-88.5
88																
													70	2.0	2.0	88.5-89.5
89									2.5-inch crushed, sandy zone 88.9-89.1 ft.				15	2.0	6.0	88.9-89.1
									Becomes moderately fractured				40	1.0	1.0	89.5
90									89.5: ω = 0.95%; γ_d = 155 lb/ft^3; SG = 2.58; n = 0.060				90	2.0	2.0	90.0-90.6
									Becomes weak, extremely fractured and crushed			R2	0-90	3.0	6.0	90.6-91.5
91																
													60	1.0	2.0	91.5
92				22		94	6		Becomes medium strong, moderately fractured			R3				
													70	1.0	1.0	92.5-92.8
93									Becomes moderately weathered, weak, extremely fractured and crushed		III	R2	20	3.0	6.0-8.0	92.7-93.8
94									Becomes gray, slightly weathered, medium strong, with small CALCITE nodules along fracture surfaces		II	R3	90	2.0	4.0	93.8-94.5
								CL								
					RB-007				With Fe staining on fracture surfaces							
95																
				23		76	0		Becomes dark gray, highly weathered, weak, crushed		IV	R2	30	3.0	6.0-8.0	95.5-97.0
96																
								CL								
97									Becomes slightly weathered, strong, extremely fractured		II	R4				
									Brown, highly weathered, weak, 7.0-inch sandy zone 97.3-97.9 ft.		IV	R2	60	3.0	6.0	97.3-97.9
98									Becomes moderately weathered, medium strong, with sand and gravel filled fractures		III	R3	60-90	2.0	8.0	98.0-100.0
				24		67	0									

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL								
100									Grayish brown and white, DOLOMITE, slightly weathered, strong, moderately fractured, with small CHERT fragments and CALCITE nodules along fractures [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R4	0-90	1.5	1.0	100.0-100.6
													40	2.0	6.0	100.7-100.9
													30	1.5	1.0	100.7
101									2.5-inch zone crushed to a gravel 100.7-100.9 ft.				90	2.0	2.0	100.8-101.0
													30	1.0	2.0	101.1
									1-inch zone crushed to a gravel 101.7-101.8'				30	2.0	2.0	101.2
													20	2.0	2.0	101.3
102									NOTE: Drilled from 89.5-105.0 ft. in 45 minutes.				20	2.0	2.0	101.5
									Brown, 1-inch clay seam at 102.2-102.3 ft.				10	3.0	6.0	101.7-101.8
				25		80	0						10	3.0	6.0	102.2-102.5
									Becomes extremely fractured				70	2.0	1.0	102.5
103													10	1.0	1.0	103.0
									Becomes dark gray							
104																
								CL								
105									NOTE: Switch from HQ to NQ at 105.0 ft. for pressuremeter test				0-90	1.5	2.0	105.0-106.5
				26	RB-008	20	0	CL								
106																
									With Fe staining on fracture surfaces, with increasing abundance of white DOLOMITE, possibly brecciated and healed				30	3.0	1.0	106.6
107													25	3.0	1.0	106.7
													25	3.0	1.0	107.2
													30	3.0	1.0	107.5
108													30	3.0	1.0	107.7
				27		61	0						30	3.0	1.0	108.0
													90	3.0	1.0	108.5-108.7
109									NOTE: Drilled from 105.0-113.0 in 60 minutes.							
								CL								
110																
													0-90	1.5	2.0	110.3-111.5
111																
				28		45	0									
112								CL	NOTE: No recovery of soft material 111.5-113.0 ft.							

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-08
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
									End of Boring at 113' An open-standpipe piezometer was constructed in BH19-08 on 6/20/2019.							
114																
115																
116																
117																
118																
119																
120																
121																
122																
123																
124																
125																
126																

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: C. Barden
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: Auto

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78736 N Long: 84.77692 W
STN. NO.: OFFSET:
SURFACE ELEV.: 619.2 feet
DATUM: IGLD 1985

START DATE: 6/1/19 TIME: 2:00 pm
FINISH DATE: 6/7/19 TIME: 8:40 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
6/4/19	7:45 am	33.4	10.0	40.0
7/24/19	8:17 am	34.3	10.0	108.0

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1			SPT	1	■	0.0 - 2.0	3	8	6	5	14						TOP SOIL SILTY SAND, some Sand, trace Gravel, medium dense, (SM) 1.0: ω = 6.30%; γ_d = 134 lb/ft^3 3.0: ω = 6.03%; γ_d = 125 lb/ft^3
2																	
3			SPT	2	■	2.0 - 4.0	17	30	42	44	19						
4			SPT	3	■	4.0 - 4.8	9	50/3"			9						SILTY SAND with GRAVEL, some Sand, little Gravel, very dense, (SM)
5																	POORLY GRADED GRAVEL, very dense, (GP), up to 3 inches
6																	No sample from 4.8-10.0 ft.
7																	
8																	
9																	
10																	Start Rock Coring at 10.0'
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: Auto

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78736 N Long: 84.77692 W
STN. NO.: OFFSET:
SURFACE ELEV.: 619.2 feet
DATUM: IGLD 1985
START DATE: 6/1/19 TIME: 2:00 pm
FINISH DATE: 6/7/19 TIME: 8:40 pm

CORE BARREL DATA:
TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: " (")

NOTES:
HQ3 (10-40.5', 49.5-104')
NQ3 (40.5-49.5')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
6/4/19	7:45 am	33.4	10.0	40.0
7/24/19	8:17 am	34.3	10.0	108.0

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
11									Light grayish brown and white, DOLOMITIC LIMESTONE, slightly weathered, strong, moderately fractured, with some fossils [BOIS BLANC FORMATION - MACKINAC BRECCIA]		II	R4	0-90	1.5	2.0	10.0-10.2
													5-10	1.5	1.0	10.3
													5-10	1.5	1.0	10.5
													90	2.0	1.0	10.5-10.8
													5-10	1.5	1.0	11.0
													15	1.5	4.0	11.2
12				1		97	46						5	2.0	4.0	11.5
									12.1: ω = 1.17%; γ_d = 149 lb/ft^3; SG = 2.45; n = 0.08 12.6: PLD = 8,140 psi							
													5	2.0	1.0	12.5
13													15	2.0	1.0	12.8
													5	1.5	2.0	13.2
								CL	Becomes medium strong, extremely fractured			R3	0-5	1.5	1.0	13.5-14.3
													90	1.5	1.0	13.7-13.9
14					RB-001											
									Becomes moderately fractured Weak, extremely fractured zone 14.7-15.1 ft.			R2	10-80	2.0	1.0	14.7-15.1
15																
													20	1.0	1.0	15.4
16				2		84	18									
									Becomes weak, extremely fractured, locally crushed, with SILT and SAND infillings along fractures			R2	60	2.0	8.0	16.2-16.4
													70	2.0	8.0	16.6-16.8
17																
18								CL								
									Becomes very strong, moderately fractured with extremely fractured zones			R5	15	2.0	1.0	18.5
													15	2.0	1.0	18.8
19													85	1.5	1.0	19.0-19.2
													0-90	1.5	1.0	19.5-19.8

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with Fe staining along joint surfaces		II	R3	70	1.5	4.0	20.2-20.7
									[BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]				50	1.5	2.0	20.7-21.0
21				3		100	0						5	3.0	2.0	21.1
													60	1.0	2.0	21.5
22																
									Becomes strong, moderately fractured			R4				
23													40	2.0	1.0	22.7
					RB-002								15	1.0	2.0	23.1
									With CALCITE precipitation along bedding and fracture surfaces				15	1.0	2.0	23.4
24													90	1.5	4.0	23.4-23.5
													15	2.0	1.0	23.6
													90	1.5	1.0	23.6-24.1
													10	2.0	4.0	24.2
													5	1.5	1.0	24.4-25.1
25													60	1.0	4.0	24.9
									Highly weathered, crushed zone with SAND filled fractures 25.1-25.3 ft.		IV		10	3.0	8.0	25.1-25.3
													5-10	1.0-1.5	1.0	25.4
													5-10	1.0-1.5	1.0	25.6
26				4		100	20						5-10	1.0-1.5	1.0	25.8
									1-inch zone of dark yellowish brown, cemented SAND and rounded GRAVEL of Jasper up to 1/4-inch 26.0-26.1 ft.			R3				
									Becomes medium strong, moderately fractured							
									26.5: γ_d = 149 lb/ft^3; UCS = 5,766 psi				90	1.0	1.0	26.6-27.3
27																
													5	1.5	1.0	27.4
28																
									Becomes extremely fractured				0-90	1.5	1.0	28.5-29.3
29																
													90	2.0	1.0	29.3-29.8
									Becomes weak, locally crushed			R2				
30																
									With 10° bedding				10	1.5	4.0	30.1
									Highly weathered, crushed zone with SAND filled fractures 30.4-30.7 ft.		IV		5	1.5	4.0	30.4-30.7
31				5		92	0						0-90	1.0	1.0	30.7-31.5
									12.1: ω = 0.22%; γ_d = 152 lb/ft^3; SG = 2.44; n = 0.08				80	3.0	2.0	31.5
32																
									Becomes moderately fractured							
									32.5: BTS = 729 psi				30	1.0	1.0	32.3
													10	2.0	1.0	32.5
33									Becomes extremely fractured				20-30	2.0	3.0-4.0	32.6-33.1
								CL								
					RB-003								40	1.5	1.0	33.7-33.9

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Grayish brown and white, DOLOMITE, moderately weathered, medium strong, extremely fractured, with Fe staining along joint surfaces and irregular CHERT nodules up to 4-inches		III	R3	90	2.0	6.0	34.0-35.3
35									[BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]				50	1.0	1.0	34.9-35.1
													10	2.0	2.0	35.3
													10	2.0	2.0	35.6
36				6		100	12		Crushed to a GRAVEL 36.0-36.2 ft.				30	3.0	2.0	36.0-36.2
													70	1.5	1.0	36.2-36.4
									Becomes highly weathered, very weak		IV	R1	0	1.5	6.0	36.7-36.9
37									Becomes slightly weathered, strong, moderately fractured		II	R4	30	1.5	1.0	36.9-40.5
38									38.0: PP = 33,228 psi 38.5: PLA = 8,440 psi							
													10-30	1.5	1.0	38.8
39													10-30	1.5	1.0	39.0
				7		100	17		Becomes weak, moderately fractured with horizontal fractures			R2	10-30	1.5	1.0	39.1
40													0	1.0	1.0	39.3-40.2
									NOTE: Switch from HQ to NQ at 40.5 ft. for pressuremeter test				5	2.0	8.0	40.4-40.5
													40	2.0	6.0	40.5-40.7
41									Becomes slightly to moderately fractured				0-90	2.0	1.0	40.5-40.9
													5	1.0	1.0	41.0
													5	1.0	1.0	41.5
													5	1.0	1.0	41.7
42				8		83	17						15	2.0	1.0	41.8
													0	1.0	4.0	42.0
									42.5: CAI = 3.97				0	1.0	4.0	42.2
									Becomes extremely fractured and crushed				25	3.0	1.0	42.5
43								CL					0-90	2.0	2.0	42.6-43.0
													10	1.5	1.0	43.5-43.7
44					RB-004											
													30	1.0	1.0	44.4
													10	2.0	1.0	44.6
45				9		97	22						10	2.0	1.0	44.8
													70	1.0	4.0	44.8-45.6
46									Becomes highly weathered, weak, extremely fractured		IV	R2				
								CL	Becomes slightly weathered, medium strong, with moderately weathered, moderately strong		II	R3	0-90	1.5	2.0	46.5-47.3
47																
													90	1.0	4.0	47.3-47.7

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
				10		47	0	CL								
49																
									Grayish brown, DOLOMITE, slightly weathered, strong, moderately to extremely fractured, with highly weathered, Fe-stained zones around fractures		II	R4	90	1.0	1.0	49.7-50.1
50									[BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		V	R0	0	3.0	10.0	50.1-50.4
									Yellowish brown, extremely weathered, extremely weak, SAND 50.1-50.4 ft.		IV	R0	0	3.0	1.0	50.6-50.8
51				11		43	0		Yellowish brown, highly weathered, extremely weak, zone 50.6-50.8 ft.							
								CL								
52																
									Moderately weathered, medium strong, crushed zone 52.7-52.9 ft.		III	R3	30	1.0	2.0	52.7-52.9
53									53.5: γ_d = 159 lb/ft^3; UCS = 13,429 psi				20	1.0	4.0	53.1-53.4
									Becomes strong, sound			R4				
54									Becomes moderately fractured				5	1.5	1.0	54.1
													5	1.5	1.0	54.3
									Dark brown, extremely weathered, extremely weak, CLAY-filled fracture 54.6-54.9 ft.		V	R0	10	2.0	10.0	54.6-54.9
55				12		72	20		NOTE: Drilled from 49.0-61.0 ft. in 105 minutes.				5	1.0	1.0	55.0
													5	1.5	1.0	55.2
													10	1.0	1.0	55.6
56									Becomes moderately weathered, medium strong, extremely fractured, brecciated and healed, with small CHERT fragments		III	R3	0-90	2.0	2.0-6.0	55.8-57.5
								CL								
57									NOTE: Lost all fluid circulation at 57.0 ft.	P3						
					RB-005								0-90	1.5	2.0	57.5-58.3
58																
				13		65	0						5	1.0	1.0	58.6
59								CL					90	2.0	1.0	58.7-58.8
								CL			II	R4	0-90	2.0	2.0	59.5-60.7
60				14		47	0									
									Becomes slightly weathered, strong							
61																
									Becomes very strong, slightly fractured			R5	20	1.5	1.0	61.6

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Grayish brown and white, DOLOMITE, slightly weathered, strong, slightly fractured, with small CHERT fragments		II	R4	10	1.5	1.0	62.2
63									[BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]							
									Becomes extremely fractured				20	2.0	1.0	63.1
				15		70	28		Becomes dark gray and white, moderately fractured				60-90	2.0	2.0	63.4
													0	1.0	1.0	63.6
64									62.4: γ_d = 158 lb/ft^3				15	1.0	1.0	63.9
65								CL								
									NOTE: No recovery 59.5-66.0 ft. Circulation return at 66.0 ft.							
66									Becomes dark gray, laminated, moderately fractured with extremely fractured zones, and small CHERT fragments.				0	1.0	1.0	66.1
													0	1.0	1.0	66.4
									Extremely fractured 66.4-66.8'.				5	1.0	2.0	66.5
67													60	1.5	1.0	66.9-67.1
													10	1.0	1.0	67.5
68																
				16		93	18		Extremely fractured zone 68.4-68.9 ft.				15-30	1.5	2.0	68.4-68.9
69																
									Extremely fractured zone 69.3-69.6 ft.	P2			20	2.0	1.0	69.1
													20	2.0	1.0	69.3
									Becomes sound				60	1.0	1.0	69.3-69.5
70																
									Extremely fractured zone 70.25-70.65 ft.							
					RB-006			CL								
71													60	1.0	1.0	71.2-71.5
													10	1.5	2.0	71.7
72									Becomes extremely fractured				80	1.5	1.0	72.1
													10	1.0	1.0	72.2
									Extremely weathered, extremely weak, 2-inch CLAY Seam with high angles fractures at 72.7-73.0 ft.		V	R0	80	1.5	1.0	72.7
73													10	2.0	10.0	72.7-73.0
				17		93	37						90	1.0	1.0	73.0-74.1
74																
									Becomes moderately fractured with extremely fractured zones, porous				5	1.5	1.0	74.1
75													0-90	1.5	1.0	74.8-74.5
								CL					0	1.0	1.0	75.6

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark gray, DOLOMITE, laminated, slightly weathered, strong, extremely fractured, with small CHERT fragments. Moderately fractured 76.7-77.2 ft. [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R4	0-90	1.5	1.0	76.0-76.5
													70	1.0	1.0	76.5-76.7
77									NOTE: Drilled from 61.0-95.0 ft. in 75 minutes. 76.5: ω = 1.26%; γ_d = 156 lb/ft^3; SG = 2.58, n = 0.07				50	1.0	1.0	77.4-77.7
78																
				18		92	7						90	2.0	2.0	78.2-79.3
79																
													10	2.0	2.0	79.3-81.1
80									Becomes gray, medium strong			R3				
								CL	Becomes dark gray, weak, moderately fractured with locally crushed zones				75	1.5	2.0	80.5
81					RB-007				80.4: BTS = 711 psi 80.5: PLA = 2,350 psi	P1		R2	0	1.0	2.0	81.0
													0-90	2.0	2.0	81.3-82.3
82																
													10	1.0	2.0	82.5
													50	1.5	2.0	82.6
83													60	3.0	4.0	82.9
84				19		85	11		Crushed to a GRAVEL 84.1-84.5 ft.				90	2.0	2.0-4.0	83.7-84.5
													85	1.0	0.75	84.7-85.1
85													5	1.5	1.0	85.1
													90	2.0	4.0	85.1-85.5
									Becomes dark gray, moderately weathered, medium strong, locally crushed to a GRAVEL		III	R3	90	2.0	4.0	85.5-86.2
86																
								CL	NOTE: Driller inadvertently over drilled 1 ft. for Run 019.							
87																
													5	2.0	2.0	87.2
													5	2.0	2.0	87.3
													80	1.0	2.0	87.4-87.7
88													5	2.0	2.0	87.7
89													80	3.0	1.0	88.8-89.5
				20		72	0									

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
91					RB-008				Dark gray and white, DOLOMITE, slightly weathered, medium strong, extremely fractured, with small CHERT fragments and lamianted zones. At 90.5 ft. Becomes moderately to extremely fractured. [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R3	0-90	2.0	2.0	90.1-90.8
								CL					60	2.0	1.0	90.8
													10	2.0	4.0-6.0	90.9
92									Becomes extremely fractured, crushed				0-90	2.0	1.0	92.0-93.3
93																
				21		77	0		Becomes laminated, moderately to extremely fractured				60	3.0	2.0	93.3
													30	1.5	1.0	93.6
94									Becomes moderately fractured				85	2.0	2.0	93.6-93.8
													30	2.0	1.0	93.9
								CL								
95													30	2.0	1.0	94.8
									Becomes extremely fractured (only slightly weathered, strong DOLOMITE clasts up to 3-inches recovered)							
96																
97																
				22		10	0									
98								CL								
99					RB-009											
									NOTE: Drilled from 95.0-104.0 ft. in 75 minutes							
100									NOTE: Switch from HQ to NQ at 100 ft. for pressuremeter test				5	2.0	1.0	100.2
													70	3.0	2.0	100.3-100.8
101													5	2.0	1.0	100.9
													5	2.0	1.0	101.0
									Highly weathered, very weak, 101.5-101.7 ft., possibly argillaecous		IV	R1	0	2.0	4.0-6.0	101.2-101.5
102				23		75	17		Becomes dark gray, strong			R4	10	1.0	1.0	101.8
													90	2.0	2.0	102.1-102.6
													0-20	1.0	1.0	102.6-104.0
103								CL								

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-09
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
105									End of Boring at 104' An open-standpipe piezometer was constructed in BH19-09 on 6/22/2019.							
106																
107																
108																
109																
110																
111																
112																
113																
114																
115																
116																
117																

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: C. Barden
INSPECTOR: C. Fischer

BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600

HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78545 N Long: 84.77588 W
STN. NO.: OFFSET:
SURFACE ELEV.: 662.6 feet
DATUM: IGLD 1985

START DATE: 5/30/19 TIME: 10:00 am
FINISH DATE: 6/3/19 TIME: 11:00 am

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
6/8/19	11:00 am	71.7	47.0	110.0

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1																	Light brown, SANDY SILT, with Organics
2																	Light brown, SILTY SAND, little Gravel, trace Cobbles, (SM), gravel is subangular, cobbles are subrounded
3																	
4																	
5																	
6																	Light brown to tan, DOLOMITE, slightly to highly weathered [BOIS BLANC FORMATION - MACKINAC BRECCIA]
7																	
8																	
9																	
10																	
11																	
12																	
13																	Becomes light gray, slightly weathered, porous
14																	
15																	
16																	
17																	Start Rock Coring at 17.0'
18																	
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG L5RTPROJECT 20200219.GPJ WSP USA 20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 1 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78545 N Long: 84.77588 W
STN. NO.: OFFSET:
SURFACE ELEV.: 662.6 feet
DATUM: IGLD 1985
START DATE: 5/30/19 TIME: 10:00 am
FINISH DATE: 6/3/19 TIME: 11:00 am

CORE BARREL DATA:
TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: " (")

NOTES:
HQ3 (17-100')
NQ3 (100-110')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
6/8/19	11:00 am	71.7	47.0	110.0

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
18									Light grayish brown and white, LIMESTONE, slightly weathered, medium strong to strong, extremely fractured, locally filled with CLAY and coarse grained SAND [BOIS BLANC FORMATION - MACKINAC BRECCIA]		II	R3-R4				
									Highly weathered, with SAND infilling along fractures 18.0-18.5 ft.							
				1		67	0						90	2.0	8.0	18.7-19.2
19								CL								
20									Becomes moderately to extremely fractured, porous				90	1.5	6.0	20.0-20.3
													10	1.0	1.0	20.2
21					RB-001								5	1.0	2.0	20.9
													40	1.5	1.0	21.1
22													60	1.0	1.0	22.0
				2		87	0						30	2.0	6.0	22.5
													50	2.0	8.0	22.7
23									With irregular coral fossils				10	1.5	1.0	23.0
24									Becomes highly weathered, weak, locally crushed		IV	R2	0-90	1.5	2.0	23.8-24.0
								CL								
25									With Fe and/or Mn staining on fracture surfaces				0-90	1.5	3.0	25.0-28.0
26																
				3		39	0									

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 2 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL	Light grayish brown and white, DOLOMITE, slightly weathered, weak, extremely fractured, porous, with Fe staining on fracture surfaces [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R2				
28									NOTE: Drilled from 17.0-35.0 ft. in 90 minutes.				0-90	1.5	3.0	28.0-29.3
29									Becomes strong, moderately fractured			R4	60	1.5	1.0	29.4
				4	RB-002	71	10		NOTE: Lost all fluid circulation at 30.0 ft.				0	1.0	1.0	29.6
30									Becomes highly weathered, medium strong, extremely fractured, locally SANDY. Becomes crushed at 30.3 ft.		IV	R3	5	3.0	8.0	29.9
													20-30	3.0	8.0	30.3-30.6
31								CL								
									Becomes slightly weathered, strong		II	R4	0-90	2.0	2.0	31.5-31.9
32									31.8: ω = 1.95%; γ_d = 142 lb/ft^3; SG = 2.37; n = 0.12				20	1.0	1.0	31.9
									Becomes moderately weathered, locally crushed to a GRAVEL along fracture surfaces		III		20	1.0	1.0	32.2
33				5		83	0		Becomes slightly weathered, moderately fractured, porous, with increased weathering around joints		II		0-90	2.0	8.0	33.2-33.3
													55	2.0	8.0	33.6-33.8
34													55	2.0	8.0	33.9-34.1
								CL								
35									Becomes extremely fractured				0-90	1.5	1.0	35.0-35.5
													75	2.0	4.0	35.5-35.8
36									Extremely weathered, CLAYEY 36.0-36.2 ft.		V		0	2.0	8.0	36.0-36.2
				6		78	17		Extremely weathered, CLAYEY 36.4-36.6 ft.		V		0	2.0	8.0	36.4-36.6
													30	1.0	1.0	36.6
37													20	2.0	2.0	36.8-39.1
								CL								
38				7		100	0		Becomes moderately weathered, with a 5 mm zone of CHERT crushed to a gravel		III		0-90	1.5	1.0	38.0-38.7
													20	2.0	8.0	38.7-38.9
39									Becomes slightly to moderately weathered, moderately fractured, with local, highly weathered zones		II-III		15	1.5	1.0	39.1
													10	2.0	2.0	39.4
					RB-003				Moderately weathered, crushed zone 39.6-40.0 ft.		III		0-90	2.0	6.0	39.6-40.0
40									Moderately weathered, crushed zone 40.6-40.9 ft.				15	1.5	1.0	40.3
													80	1.5	1.0	40.3-40.5
				8		100	22				III		0-90	2.0	6.0	40.6-40.9

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 3 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown and white, DOLOMITE, slightly to moderately weathered, strong, moderately fractured [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II-III	R4	0	1.0	1.0	41.0
													0-90	2.0	6.0	41.4-42.5
42									41.1: PLA = 9,500 psi Moderately weathered, crushed zone 41.4-41.5 ft.							
									Becomes extremely weathered, extremely weak, to a poorly graded SAND		V	R0				
43																
				9		50	0		Becomes moderately to highly weathered, very weak		III-IV	R1				
44								CL								
45				10		100	0		NOTE: Lost all fluid circulation at 45.0 ft.							
									Light grayish brown, LIMESTONE, slightly weathered, strong, moderately fractured, trace DOLOMITE corestones, disturbed from drilling		II	R4	0-90	1.5	2.0	45.5-46.3
46									With fossils up to 2-inches				60	1.5	1.0	46.6
47				11		83	0						0	2.0	4.0	46.8
													0, 15	1.0	1.0	47.0-47.6
									With a 3-inch CALCITE-filled fossil cast 47.5-47.7 ft.							
48								CL								
									Light grayish brown and white, DOLOMITE, moderately weathered, very weak to weak, with crushed rock along joint surfaces		III	R1-R2	10	2.0	6.0	48.5-49.0
49													90	1.0	1.0	49.0-49.2
				12	RB-004	88	0						10-60	2.0	8.0	49.5-50.5
50								CL								
									Becomes slightly weathered, strong, moderately fractured, with 100% fluid circulation after advancing casing to 47'		II	R4	30	1.5	1.0	50.6
51													40	1.0	1.0	50.9
									Becomes moderately to extremely fractured				10-40	2.0	1.0	51.1-51.8
52									Becomes moderately fractured, with some calcite infilling on fracture surfaces				0	1.0	1.0	52.0
													10-30	1.5	1.0	52.3-53.0
53				13		90	0		Becomes extremely fractured				60	2.0	2.0	53.0-53.7
									Becomes moderately fractured				0-10	2.0	1.0	53.7-55.0
54																
													70	1.5	1.0	54.6-54.8

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 4 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL								
									Light grayish brown and white, DOLOMITE, slightly weathered, strong, extremely fractured, with Fe and/or Mn staining along fractures		II	R4	10-80	1.5	2.0	55.5-56.0
56									[BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]				0	1.5	1.0	56.0
													70	1.0	1.0	56.1-56.7
57									Crushed zone 57.0-57.7 ft.				10	1.5	2.0	56.8
													0-90	2.0	8.0	57.0-57.7
58				14		90	7		PP = 17,021 lbs Crushed zone 58.2-58.5 ft.				30	1.5	2.0	57.9
59													5	1.5	1.0	58.8
													90	2.0	2.0	58.9-59.7
60									59.8: ω = 0.69%; γ_d = 155 lb/ft^3; SG = 2.57; n = 0.04 Becomes moderately fractured							
								CL								
61					RB-005				Becomes extremely fractured, only GRAVEL-sized clasts recovered				0-90	1.5	1.0	60.5-61.9
									Becomes moderately weathered, weak, moderately to extremely fractured, with increasing Fe staining on fracture surfaces		III	R2				
62													10	1.0	1.0	61.9
													90	2.0	1.0	61.9-62.1
													0	1.5	2.0	62.2
													40	2.0	2.0	62.5
63				15		80	0						0-90	2.0	2.0	62.5-63.8
													80	1.5	1.0	63.8
64									Becomes slightly weathered, strong, without Fe staining on fracture surfaces		II	R4	70	2.0	2.0	64.0-64.3
													50	2.0	1.0	64.3
65								CL								
									Becomes moderately fractured with weak, crushed zones			R2	0-90	1.5	2.0	65.6
66													0-90	1.5	2.0	65.8
									Highly weathered, weak, crushed to a SANDY GRAVEL 66.1-66.3 ft.		IV	R2	20	2.0	8.0	66.1-66.3
													90	2.0	6.0	66.4-66.9
67									Highly weathered, weak, crushed to a GRAVEL 67.2-67.5 ft.		IV	R2	20	2.0	8.0	67.2-67.5
													10	2.0	1.0	67.7
68				16		100	7						20	2.0	1.0	68.0
													90	2.0	2.0	68.3
													70	1.0	1.0	68.5-68.8

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 5 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown and white, DOLOMITE, slightly weathered, medium strong, moderately to extremely fractured. Highly weathered, crushed zone 69.4-69.6'. [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]	P1	II	R3	90	2.0	4.0	69.0-69.3
											IV		10	2.0	8.0	69.4-69.6
70											II					
									70.2: PLA = 5,790 psi				10	2.0	8.0	70.0-70.6
					RB-006				Becomes moderately fractured							
													10	1.0	1.0	70.7
71													10	1.0	1.0	70.9
													30	1.5	1.0	71.2
													90	1.0	1.0	71.3-72.0
72																
													10	1.0	1.0	72.3
73				17		100	10						30	1.5	1.0	73.0
									Becomes extremely fractured, crushed along subvertical fractures							
74													80	3.0	10.0	74.0-75.3
75																
													10	1.5	1.0	75.3-75.5
									Becomes weak, with Fe staining on fractures surfaces			R2	60	1.5	1.0	75.5-77.5
76													0-90	1.5	2.0	75.5-80.5
													10	1.5	1.0	75.5-77.5
77																
									Fracure with quartz infilling at 77.5 ft.				90	1.5	6.0	77.5-78.4
78				18		88	0									
													0-90	2.0	2.0	78.4-79.5
79																
									Becomes extremely fractured, crushed to a gravel				80	2.0	1.0	79.5-80.5
80					RB-007			CL	Becomes moderately weathered, very weak	P2	III	R1				
81													10	1.5	6.0	81.0-81.5
									Becomes slightly weathered, moderately fractured		II					
82													60	1.0	1.0	81.8
													80	2.0	2.0	82.0
													70	2.0	6.0	82.6-83.0

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 6 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
				19		100	0		Light grayish brown and white, DOLOMITE, slightly weathered, weak, moderately to extremely fractured, locally crushed, possibly brecciated and healed [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R2				
													40	1.5	1.0	83.5
													30	2.0	2.0	83.7
84													15	2.0	8.0	83.9
													20	2.0	6.0	84.4-84.6
85									Becomes moderately fractured							
													10	1.0	1.0	85.5
													10	1.5	1.0	85.7
86																
													75	2.0	1.0	86.2-86.5
87									LIMESTONE, very weak, zone 86.8-87.1 ft. Becomes strong to very strong 87.1: PLA = 15,000 psi		III	R4	10	1.0	1.0	86.8
													10	1.0	1.0	87.7
88				20		100	15		Becomes slightly fractured							
													90	1.5	1.0	88.4-88.8
													10	2.0	6.0	88.8
89													10	1.5	1.0	89.2-89.3
													90	2.0	6.0	89.3-90.5
90					RB-008				Extremely fractured and crushed along subvertical fracture 89.8-90.5 ft.							
													0-90	1.5	2.0	90.5-91.6
91																
									Becomes moderately fractured	P3			10	1.5	1.0	91.6
92													5	1.5	2.0	92.0
													40	1.5	1.0	92.1
													10	1.0	1.0	92.3
													0	1.0	2.0	92.7
93				21		68	8		Becomes slightly to moderately weathered, very weak, extremely fractured and crushed		II-III	R1	0-90	2.0	6.0	92.8-95.5
94																
								CL								
95																
													10	2.0	6.0	95.7
96													70	2.0	2.0	95.7-96.3
									Becomes slightly weathered, medium strong, moderately fractured		II	R3	0	1.0	1.0	96.4
													70	1.5	1.0	96.6

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-10
SHEET NUMBER: 7 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden
INSPECTOR: C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown and white, DOLOMITE, slightly weathered, medium strong, moderately fractured. Becomes extremely fractured at 97.5 ft. [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]		II	R3	10	1.0	1.0	97.0
													0	1.0	1.0	97.3
				22	RB-009	89	8						0	1.5	1.0	97.6
98													90	2.0	8.0	98.1
													0	1.5	1.0	98.2
													70	2.0	6.0	98.2-98.5
99													0	1.0	1.0	98.8
								CL								
100									NOTE: Switch from HQ to NQ at 100.0 ft. for pressuremeter test.				15	1.0	1.0	100.0
									Becomes gray, moderately to extremely fractured				10	1.0	1.0	100.3
													20	1.5	1.0	100.6
101																
													0-90	2.0	6.0	101.2-102.0
102																
													0	1.0	2.0	102.0
				23		83	20						90	1.0	1.0	102.5-103.0
103																
									Becomes extremely fractured				30	1.5	1.0	103.5
104																
								CL								
105					RB-010								90	1.0	1.0	105.0-105.3
									Becomes moderately fractured				15	2.0	1.0	105.5
106													10	2.0	1.0	105.9
													10	1.0	1.0	106.4
													20	1.0	1.0	106.6
107									Becomes unweathered, strong, with increasing abundance of white dolomite		I	R4				
				24		100	52						80	2.0	1.0	107.2-107.5
108													70	2.0	1.0	108.0
													10	2.0	2.0	108.8
109													5	1.0	1.0	109.2
													15	2.0	2.0	109.8
110									End of Boring at 110' The boring was backfilled with cement-bentonite grout to the ground surface.							

WSP CORING LOG L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-11
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78735 N Long: 84.77692 W
STN. NO.: OFFSET:
SURFACE ELEV.: 619.7 feet
DATUM: IGLD 1985

START DATE: 6/1/19 TIME: 1:00 pm
FINISH DATE: 6/1/19 TIME: 2:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA				
Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
1		SB-001 0.0-7.0 ft.															POORLY GRADED GRAVEL, trace Cobbles, (GP), (TOPSOIL)
2																	POORLY GRADED GRAVEL, trace Cobbles, (GP)
3																	
4																	
5																	Brownish gray, LIMESTONE, moderately weathered
6																	
7																	
8																	
9																	
10		SB-002 7.0-17.0 ft.															
11																	
12																	
13																	
14																	
15																	
16																	
17																	End of boring at 17 feet.
18																	The boring was backfilled with bentonite grout to the ground surface..
19																	
20																	
21																	
22																	
23																	
24																	

BORING LOG

BORING NUMBER: BH19-12
SHEET NUMBER: 1 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78680 N Long: 84.77682 W
STN. NO.: OFFSET:
SURFACE ELEV.: 652.1 feet
DATUM: IGLD 1985

START DATE: 5/23/19 TIME: 3:00 pm
FINISH DATE: 5/28/19 TIME: 11:30 am

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.				4.00"		
O.D.				4.75"		
Length				10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1		SB-001 0.0-7.0 ft.															SILTY SAND, little Gravel, trace Cobbles, (ML)
2																	
3																	
4																	
5																	Tan, LIMESTONE, moderately to highly weathered, fossiliferous [BOIS BLANC FORMATION - MACKINAC BRECCIA]
6																	
7																	
8		SB-002 7.0-17.0 ft.															
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18		SB-003 17.0-27.0 ft.															
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200302.GPJ WSP USA_20200302.GLB 3/2/20

BORING LOG

BORING NUMBER: BH19-12
SHEET NUMBER: 2 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
26																	Tan, LIMESTONE, moderately to highly weathered, fossiliferous
27																	[BOIS BLANC FORMATION, continued]
28																	Becomes light tan to gray, slightly to moderately weathered, with white Calcite inclusions 27-30 ft.
29																	
30		SB-004 27.0-37.0 ft.															
31																	
32																	
33																	
34																	
35																	
36																	
37																	With occasional small chert inclusions
38																	
39																	
40		SB-005 37.0-47.0 ft.															
41																	
42																	
43																	
44																	
45																	
46																	
47																	Becomes light gray, slightly to moderately weathered, occasional CHERT inclusions
48																	
49																	
50		SB-006 47.0-57.0 ft.															
51																	
52																	
53																	
54																	
55																	
56																	
57																	Becomes light gray to tan, moderately weathered, occasional metal sulfides
58																	
59																	

BORING LOG

BORING NUMBER: BH19-12
SHEET NUMBER: 3 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61		SB-007 57.0-67.0 ft.															Light tan to tan, LIMESTONE, moderately weathered, fossiliferous, with occasional CHERT inclusions and metal sulfides [BOIS BLANC FORMATION - MACKINAC BRECCIA, continued]
62																	
63																	
64																	
65																	
66																	
67																	
68		SB-008 67.0-77.0 ft.															Becomes light tan to gray, LIMESTONE, brecciated and healed with light gray calcareous infilling, indurate [BOIS BLANC FORMATION - MACKINAC BRECCIA]
69																	
70																	
71																	
72																	
73																	
74																	
75																	
76																	
77																	
78		SB-009 77.0-90.0 ft.															
79																	
80																	
81																	
82																	
83																	
84																	
85																	
86																	
87																	
88																	
89																	
90																	Becomes gray, not brecciated, with occasional CHERT
91																	
92																	
93																	
94																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200302.GPJ WSP USA_20200302.GLB 3/2/20

BORING LOG

BORING NUMBER: BH19-12
SHEET NUMBER: 4 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
96		SB-010 90.0-107.0 ft.										
97												
98												
99												
100												
101												
102												
103												
104												
105												
106												
107												
108		SB-011 107.0-127.0 ft.										
109												
110												
111												
112												
113												
114												
115												
116												
117												
118												
119												
120												
121												
122												
123												
124												
125												
126												
127												
128												
129												

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200302.GPJ WSP USA_20200302.GLB 3/2/20

BORING LOG

BORING NUMBER: BH19-12
SHEET NUMBER: 5 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
131		SB-012 127.0-139.0 ft.															
132																	
133																	
134																	
135																	
136																	
137																	
138																	
139																	
140																	With occasional vugs up to 1/2 inch
141																	
142																	
143																	
144																	
145		SB-013 139.0-150.0 ft.															
146																	
147																	
148																	
149																	
150																	End of boring at 150 feet. An open-standpipe piezometer was constructed in BH19-12 on 7/27/2019..
151																	
152																	
153																	
154																	
155																	
156																	
157																	
158																	
159																	
160																	
161																	
162																	
163																	
164																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200302.GPJ WSP USA_20200302.GLB 3/2/20

BORING LOG

BORING NUMBER: BH19-12A
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic/SPT
RIG TYPE: Boart Longyear 600
HAMMER TYPE: Auto

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78679 N Long: 84.77680 W
STN. NO.: OFFSET:
SURFACE ELEV.: 652.1 feet
DATUM: IGLD 1985

START DATE: 5/29/19 TIME: 11:50 am
FINISH DATE: 5/29/19 TIME: 12:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.		1.375"	2.938"	4.00"		
O.D.		2"	3"	4.75"		
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1			SPT	1		0.0 - 2.0	1	2	2	4	6						Brown, SANDY SILT, with Gravel, (ML)
2																	Brown, SILTY SAND, with Gravel, (SM)
3			SPT	2		2.0 - 4.0	5	6	11	14	16						
4			SPT	3		4.0 - 4.9	23	50/5			11						Light brown, LIMESTONE, moderately weathered
5																	End of boring at 4.9 feet. This boring was backfilled with cuttings to the surface after drilling was completed.
6																	
7																	
8																	
9																	

WSP BORING LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

BORING LOG

BORING NUMBER: BH19-13
SHEET NUMBER: 1 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78614 N Long: 84.77599 W
STN. NO.: OFFSET:
SURFACE ELEV.: 659.4 feet
DATUM: IGLD 1985

START DATE: 5/22/19 TIME: 1:00 pm
FINISH DATE: 5/23/19 TIME: 5:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1		SB-001 0.0-7.0 ft.															Dark brown, Sandy, SILT, trace Gravel, Organics, (ML)
2																	Light tan, SILTY SAND, with Gravel, some Gravel, little Cobbles, (SM)
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	Light gray, LIMESTONE, highly weathered [BOIS BLANC FORMATION - MACKINAC BRECCIA]
11																	
12		SB-002 7.0-17.0 ft.															
13																	Light gray, LIMESTONE AND DOLOMITE, moderately weathered
14																	
15																	
16																	
17																	
18																	
19		SB-003 17.0-22.0 ft.															Becomes light gray, slightly weathered with moderately weathered zones
20																	
21																	
22																	
23																	
24		SB-004 22.0-27.0															

BORING LOG

BORING NUMBER: BH19-13
SHEET NUMBER: 2 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
26												Light gray, LIMESTONE AND DOLOMITE, slightly weathered with moderately weathered zones [BOIS BLANC FORMATION, continued]
27												With interbedded argillaceous zones of moderately to highly weathered LIMESTONE and DOLOMITE
28												
29												
30												
31												
32		SB-005 27.0-37.0 ft.										
33												
34												
35												
36												
37												
38		SB-006 37.0-41.0 ft.										
39												
40												
41												
42												
43												
44												
45		SB-007 41.0-51.0 ft.										
46												
47												Becomes increasingly argillaceous
48												
49												
50												
51												Becomes decreasingly argillaceous
52												
53												
54												
55		SB-008 51.0-60.0 ft.										
56												
57												
58												
59												

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

BORING LOG

BORING NUMBER: BH19-13
SHEET NUMBER: 3 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
61												End of boring at 60 feet. The boring was backfilled with bentonite grout to the ground surface on 5/23/2019. The water level was not before backfilling..
62												
63												
64												
65												
66												
67												
68												
69												
70												
71												
72												
73												
74												
75												
76												
77												
78												
79												
80												
81												
82												
83												
84												
85												
86												
87												
88												
89												
90												
91												
92												
93												
94												

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

BORING LOG

BORING NUMBER: BH19-13A
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic/SPT
RIG TYPE: Boart Longyear 600
HAMMER TYPE: Auto

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78615 N Long: 84.77600 W
STN. NO.: OFFSET:
SURFACE ELEV.: 659.5 feet
DATUM: IGLD 1985

START DATE: 5/23/19 TIME: 2:15 pm
FINISH DATE: 5/23/19 TIME: 3:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		
O.D.		2"	3"	4.75"		
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
0																	Dark brown, Sandy, SILT, with Sand, trace Organics, trace Gravel, (ML),[TOPSOIL]
1			SPT	1		0.0 - 2.0	1	1	1	2	12						Light brown, SILTY SAND, with Gravel, (SM)
2																	
3			SPT	2		2.0 - 4.0	WOH	8	23	34	16						
4																	
5			SPT	3		4.0 - 5.9	2	28	49	50/4.5"	16						
6			SPT	4		6.0 - 6.7	18	50/2.5"			6						With LIMESTONE fragments in sampler shoe
7																	End of boring at 6.7 feet. This boring was backfilled with cuttings to the surface after drilling was completed.
8																	
9																	

WSP BORING LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

BORING LOG

BORING NUMBER: BH19-14
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer

BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600

HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78537 N Long: 84.77644 W
STN. NO.: OFFSET:
SURFACE ELEV.: 665.8 feet
DATUM: IGLD 1985

START DATE: 5/22/19 TIME: 7:00 am
FINISH DATE: 5/22/19 TIME: 8:30 am

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1		SB-001 0.0-7.0 ft.															Dark brown, SILT, with Sand, trace Gravel, and Organics, (ML), [TOPSOIL]
2																	Light tan, SILTY SAND, little Gravel, trace Cobbles, (SM)
3																	
4																	
5																	
6																	Light gray, LIMESTONE, highly weathered [BOIS BLANC FORMATION - MACKINAC BRECCIA]
7																	
8		SB-002 7.0-17.0 ft.															Light gray, DOLOMITE, moderately weathered
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	End of boring at 17 feet. The boring was backfilled with bentonite grout to the ground surface on 5/22/2019. Groundwater was not encountered while drilling..
18																	
19																	
20																	
21																	
22																	
23																	
24																	

BORING LOG

BORING NUMBER: BH19-14A
SHEET NUMBER: 1 of 1
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: SPT
RIG TYPE: Boart Longyear 600
HAMMER TYPE: Auto

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78539 N Long: 84.77642 W
STN. NO.: OFFSET:
SURFACE ELEV.: 665.5 feet
DATUM: IGLD 1985

START DATE: 5/22/19 TIME: 8:30 am
FINISH DATE: 5/22/19 TIME: 11:00 am

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		
O.D.		2"	3"	4.75"		
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	CASING (Blows/ft)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1			SPT	1		0.0 - 2.0	1	1	11	21	20						Dark brown, SANDY SILT, trace Gravel, (ML), [TOPSOIL]
2																	Light brown, SILTY SAND, with Gravel, (SM), GRAVEL is subrounded
3			SPT	2		2.0 - 4.0	2	4	20	32	20						
4			SPT	3		4.0 - 4.5	57/5.5"										End of boring at 4.5 feet. The boring was backfilled with cuttings to the surface on 5/22/2019..
5																	
6																	
7																	
8																	
9																	

WSP BORING LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

BORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.83538 N Long: 84.75837 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 598.6 feet
DATUM: IGLD 1985
START DATE: 6/21/19 TIME: 2:00 pm
FINISH DATE: 6/22/19 TIME: 6:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol	PQ	SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1																	AIR
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	WATER
18																	
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
26																	
27																	
28																	
29																	
30																	Brown, fine grained, POORLY GRADED SAND, trace Gravel, (SP), gravel is fine to coarse [ALLUVIUM]
31																	
32																	
33																	
34																	
35		SB-001 30.0-40.0 ft.															NOTE: Bulk sample taken from SB-001, depth not recorded
36																	
37																	
38																	
39																	
40																	Brown and tan, POORLY GRADED SAND, trace Cobbles, (SP)
41																	
42																	
43																	
44																	
45		SB-002 40.0-50.0 ft.															
46																	
47																	
48																	
49																	
50																	
51																	
52																	
53																	
54																	
55		SB-003 50.0-60.0 ft.															With one round, 3-inch gravel clast at 55.0 ft.
56																	
57																	
58																	
59																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61			SPT	1		60.0 - 62.0	4	8	9	10	12						Light brown and light gray, fine to medium grained, POORLY GRADED SAND, few to trace Gravel, (SP), [ALLUVIUM, continued]
62																	
63																	
64																	
65																	
66																	NOTE: No recovery for SB-004; driller reported GRAVEL caught in trap door and material washed out into formation
67																	
68																	
69																	
70		SB-005 70.0-80.0 ft.	SPT	2		70.0 - 71.0	32	50/5.5"			9						70.0 - 72.0': PSA = 20.8% GRAVEL, 75.1% SAND, 4.1% FINES Brown, POORLY GRADED SAND with GRAVEL, (SP), gravel up to 9-inches
71																	
72																	
73																	
74																	
75																	
76																	
77																	
78																	
79																	
80			SPT	3		80.0 - 82.0	8	22	13	13	5						Contains fine to medium grained sand, gravel composed of limestone, chert, and quartz
81																	
82																	
83																	
84																	
85		SB-006 80.0-90.0 ft.															Reddish brown, SILTY CLAY, with trace Sand, trace Gravel, (CL-ML)
86																	
87																	
88																	Fine grained, POORLY GRADED SAND with GRAVEL, trace to little Gravel, (SP)
89																	
90																	Reddish brown, SILTY CLAY, some Gravel, (CL-ML), hard
91			SPT	4		90.0 - 92.0	8	15	20	25	17						Reddish brown, LEAN CLAY, trace to some Gravel, (CL), hard (PP> 4.5 tsf)
92																	Brown, GRAVELLY CLAY, trace Sand, trace Silt, (CL), very hard
93																	
94																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96		SB-007 90.0-100.0 ft.															Brown and gray, CLAYEY GRAVEL, (GC), with broken limestone COBBLES [ALLUVIUM, continued]
97																	
98																	
99																	Gray, SILTY CLAY, trace Gravel, trace Sand, very hard, (CL), [GLACIAL TILL]
100			SPT	5 6		99.0 - 100.0	50	50/2"			8						
101			G			100.0 - 100.7											100.0-100.7: PSA = 7.1% GRAVEL, 20.0% SAND, 72.9% FINES; ω = 13.3%; LL = 19, PL = 14, PI = 5,
102																	Gray, SILTY CLAY with SAND, little Sand, trace Gravel, very hard, (CL-ML), with occassional beige SILT partings
103																	
104		SB-008 100.0-107.0 ft.															Gray, DOLOMITE, recovered as crushed rock [ST. IGNACE FORMATION - MACKINAC BRECCIA]
105																	
106																	
107																	No sampling 107-110 ft.
108																	
109																	
110																	Start Rock Coring at 110.0'
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	
119																	
120																	
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 1 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.83538 N Long: 84.75837 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 598.6 feet
DATUM: IGLD 1985
START DATE: 6/21/19 TIME: 2:00 pm
FINISH DATE: 6/22/19 TIME: 6:00 pm

CORE BARREL DATA:

TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: PQ

NOTES:

HQ3 (110-148', 158-198', 218-228')
NQ3 (148-158', 198-208')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
111	1.25			1	RB-001	100	50		Dark olive gray, DOLOMITE, slightly weathered, strong, extremely fractured, with CALCITE-filled vugs, only gravel-sized clasts recovered [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R4	0-90	1.0-1.5	1.0	110.0-111.0
									Gray, LIMESTONE, laminated, highly weathered, strong, moderately fractured, locally clayey with 0-5° bedding		IV	R4	0	1.0	1.0	111.0-111.3
112									111.3 - 111.5': PLL = 11,040 psi				0	1.0	1.0	111.6
													0	1.0	1.0	112.0
													0	1.0	1.0	112.1
113									Becomes moderately weathered, extremely fractured		III		0	1.0	1.0	112.3
													0	1.0	1.0	112.5
													40	1.5	2.0	112.7
									Brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with CALCITE laminations along fractures		II	R3	5	1.5	2.0	113.5
114													80	1.0	2.0	112.6-113.0
													90	1.0	2.0	113.7-114.1
													0	1.5	2.0	114.2
													10	1.5	2.0	114.5
115													5	1.0	2.0	114.6
									Becomes gray, medium strong, with Fe staining on fracture surfaces			R3	5	1.0	2.0	114.8
													90	1.0	1.0	115.0-115.2
													10-40	1.0	1.0	115.2-116.6
116	3.00			2		100	0									
									Becomes moderately fractured, with CALCITE filled vugs up to 1 mm				0	1.0	1.0	116.6-117.2
117									Becomes extremely weathered, extremely weak, locally clayey	P10	V	R0				
118								CL	No recovery 118.0-118.8': driller noted temporarily plugged bit.							
119									Gray, LIMESTONE, highly weathered, weak, moderately fractured, argillaceous, possibly turbidite		IV	R2	0	4.0	0.75	119.0
													10	1.0	2.0	119.5

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 2 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
120	1.00			3		84	20		Dark gray, DOLOMITE, slightly weathered, strong, extremely fractured, with vugs up to 1/4-inch [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	0	1.0	2.0	120.1
													10	2.0	1.0	120.6
121													90	1.5	1.0	120.6-121.0
									Becomes grayish brown, highly weathered, very weak, locally crushed		IV	R1	0	1.5	2.0	121.5-123.5
122																
									Becomes dark gray, slightly weathered, strong		II	R4				
123					RB-002				Becomes gray, laminated, moderately weathered, weak, moderately fractured		III	R2				
									Crushed 123.0-123.3' and 123.7-124.2'				5	1.0	3.0	123.6
124																
									Gray, LIMESTONE, slightly weathered, medium strong, with disturbed bedding, possible debris flow		II	R3	0	1.0	6.0	124.5
125	1.00			4		100	15						0	1.0	2.0	125.1
													20	1.0	2.0	125.4
													90	1.0	2.0	125.6-125.9
126									Becomes light yellowish brown, moderately weathered, slightly DOLOMITIC		III	R2-R3				
									Light grayish brown, DOLOMITE, slightly to highly weathered, weak to medium strong, moderately fractured, with Fe staining on fracture surfaces		II-IV		45	1.0	3.0	126.5-126.8
127									Extremely fractured zones 125.6-126.2' and 126.4-126.5'				0	3.0	2.0	127.2
													10	1.0	2.0	127.6
128									Becomes unweathered, strong	P9	I	R4				
													45	1.0	1.0	128.5
129									Extremely fractured zones 129.1-130.6' and 130.8-131.2'				0	3.0	4.0	129.0
													0	1.0	3.0	129.2
130	1.25			5		90	13		Becomes slightly weathered		II		90	4.0	0.75	130.1
													0-45	3.0	2.0	130.2
													0	1.0	1.0	130.4-130.8
131																
													60	2.0	1.0	131.5-131.8
132									Becomes moderately weathered		III		10	1.0	4.0	131.7
								CL	No Recovery 132.5-133.0': driller noted soft material. Core ends in a 60° joint that matched next run.							
133					RB-003				132.2 - 132.5': PLA = 8,840 psi							
									Becomes extremely fractured				5	1.0	1.0	133.2

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 3 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
135	0.83			6		90	30		Light grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with Fe staining on fracture surfaces. Healed 90° fracture 134.4-134.6' [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3	5	2.0	3.0	134.6
													5	2.0	3.0	134.8
									Light gray, LIMESTONE, slightly weathered, medium strong, with vugs up to 1-inch, and cavities filled with clay and brown DOLOMITE		II	R3				
136													90	3.0	4.0	136.0-136.3
									Brown, DOLOMITE, highly weathered, weak, moderately fractured		IV	R2				
													90	3.0	6.0	136.5-137.0
137									Becomes dark gray, slightly weathered, medium strong, with grayish black, 0° laminations							
138											II	R3	90	1.0	1.0	138.0-138.2
													0	1.0	2.0	138.2-139.5
139										P8						
									Olive gray, LIMESTONE, slightly weathered, medium strong, moderately fractured, with vugs up to 1/2-inch		II	R3				
140	0.83			7		110	8						0	1.0	2.0	139.8-140.2
													45	1.0	2.0	140.3
141									Gray to brown, DOLOMITE WITH LIMESTONE, slightly weathered, medium strong, moderately fractured, with CALCITE precipitation along fracture surfaces		II	R3	90	1.0	1.0	141.0-141.9
142																
													0	1.0	2.0	142.4-142.5
143					RB-004				Becomes gray, extremely fractured				0	1.0	1.0	143.1-143.3
													0	1.0	1.0	143.2
													5	1.5	1.0	143.7
144									Becomes moderately fractured, with CALCITE veins with vertical offset				5	1.0	1.0	143.9
													0	1.5	1.0	144.0
													0	1.0	1.0	144.5
145													0	1.0	1.0	144.9
													0	1.5	1.0	145.2
	0.83			8		94	33		Possible debris flow 145.5 - 146.5'				0	1.0	1.0	145.4
146													0	1.0	7.0	145.8
									Becomes light grayish brown, laminated				0	1.0	6.0	146.3
									Extremely fractured zone 146.6-147.5'							
147																
									NOTE: Switch from HQ to NQ at 148.0' for pressuremeter test							
								CL								

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 4 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light brown, LIMESTONE, slightly weathered, weak, extremely fractured. Becomes moderately fractured at 149.0'		II	R2	0	1.0	1.0	148.0-148.9
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				0	1.0	8.0	148.7-148.9
149									Wide joint with SILT infilling 148.7-148.9'	P7			0	1.5	6.0	149.0
													70	1.0	1.0	149.6
150									Becomes dark gray and very dark gray, laminated, medium strong, locally weathered to a CLAY along laminations, with trace vugs up to 1/2-inch			R3	0	1.0	6.0	149.9
	0.71			9		97	44									
151									Becomes argillaceous with clay laminations with to 1/8-inch				0	1.5	3.0	151.2
									Light brown, DOLOMITE, laminated, moderately weathered, weak, moderately fractured, calcareous, with weathered fractured surfaces		III	R2	0	1.0	1.0	151.3
152													40	1.0	6.0	151.6
					RB-005											
153								CL	Becomes light gray, slightly weathered, medium strong, not calcareous		II	R3	0	1.5	3.0	153.1
													80	1.5	1.0	153.3-154.1
													0	1.0	3.0	153.3
154													0	1.0	1.0	153.7
													70	1.0	1.0	153.9-154.3
									Dark gray and very dark gray, LIMESTONE, moderately weathered, weak, extremely fractured		III	R2	20	1.0	0.75	154.4
155													45	1.0	3.0	154.8
													0	1.5	1.0	154.9
	1.00			10		100	52						0	1.0	1.0	155.0-155.1
									Light brown, DOLOMITE, moderately weathered, weak, moderately fractured, calcareous, with vugs up to 1/2-inch. Becomes extremely fractured at 156.1'.		III	R2	0	1.0	1.0	155.6
156																
									Gray, LIMESTONE, moderately weathered, weak, with irregular, healed CALCITE veins		III	R2				
157									Light brown, DOLOMITE, moderately weathered, weak to medium strong, moderately fractured, with CALCITE veins		III	R2-R3	0	1.5	1.0	157.3
													0	1.0	1.0	157.4
													0	1.0	3.0	157.6
158									NOTE: Switch from NQ to HQ at 158.0'		III	R1	20	1.0	6.0	158.0-159.0
									Dark gray, LIMESTONE, moderately weathered, very weak, extremely fractured along 20° bedding							
159																
								CL	VOID							
										P6						
160									Dark olive brown, LIMESTONE, slightly weathered, strong, extremely fractured along 20° bedding		II	R4				
	0.77			11		84	7						0-80	1.5	3.0	160.2-161.3
161																
													0	1.0	3.0	161.7

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 5 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
													0	1.0	1.0	162.0
									Light grayish brown, DOLOMITE, slightly weathered, strong, slightly fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4				
163					RB-006								0	1.0	2.0	163.3
													0	1.0	1.0	163.6
164													0	1.0	1.0	163.9
									165.9 - 166.2': PLA = 7,300 psi 165.6 - 165.9': ω = 1.06%; γ_d = 157 lb/ft^3; SG = 2.57; n = 0.04 166.3 - 166.7': γ_d = 166 lb/ft^3; UCS = 16,259 psi				0	1.0	1.0	164.3
165													0	1.0	1.0	165.1
	0.83			12		100	71						0	1.0	1.0	165.3
166									Becomes strong			R4				
									Becomes very strong			R5				
167													0	1.0	1.0	166.9
													0	1.0	3.0	167.0
168													45	1.0	1.0	167.8
									Extremely fractured zone 168.8-169.5', with black CALCITE infilling of fractures and voids, faint bedding laminations throughout.							
169													40	1.0	1.0	169.0
													0	2.0	4.0	168.8-169.5
170									Becomes sound	P5						
	0.80			13		100	74						70	1.0	1.0	170.2
171									Becomes moderately fractured							
													0	1.0	2.0	171.3
													50	1.0	1.0	171.6
172									Becomes sound				50	1.0	1.0	171.7
													0	1.0	2.0	171.8
173					RB-007											
									Becomes moderately fractured				0	1.0	1.0	173.8
174													20	1.0	1.0	173.9
													0	1.0	1.0	174.0
													0	1.0	1.0	174.2
175									Becomes sound				0	1.0	1.0	174.5
	0.83			14		100	63						70	2.0	3.0	174.8

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 6 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light yellowish brown, DOLOMITE, slightly weathered, strong, sound, with CALCITE precipitations along fracture surfaces. Highly weathered, very weak, crushed zone 176.6-177.4'.		II	R4				
											IV	R1	10	1.0	1.0	176.6
177									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				90	1.0	1.0	176.7
													10	1.0	1.0	177.4
178									Becomes gray, at a 30° angle contact with overlain material							
									Dark gray and very dark gray, LIMESTONE, slightly weathered, very strong, sound, brecciated, crushed at contact 178.7-178.8'		II	R5	20	1.0	1.0	178.6
179													15	2.0	8.0	178.7-178.9
													10	1.0	1.0	179.3
180	0.80			15		100	85			P4						
181													40	1.0	4.0	180.9
									Light grayish brown, slightly to moderately weathered, weak to medium strong, moderately fractured, with 2-mm thick black CALCITE fracutres. Becomes extremely fractured at 182.5' without CALCITE layers.		II-III	R2-R3				
182					RB-008								90	1.5	1.0	182.6-183.0
183									Dark gray and very dark gray, LIMESTONE, laminated, slightly weathered, medium strong, moderately fractured to a breccia with deformed bedding		II	R3				
													10	2.0	2.0	183.8
184													10	2.0	2.0	184.0
									Light grayish brown, DOLOMITE, slightly weathered, strong, moderately fractured, with CALCITE precipitation along fracture surfaces		II	R4	0	1.0	1.0	184.7
185									Becomes sound, with horizontal laminations				10-45	2.0	8.0	184.9-185.1
	0.83			16		100	62									
186									With CALCITE filled vugs up <1 mm							
187																
188									Becomes slightly weathered, medium strong, moderately fractured		II	R3	60	1.0	2.0	187.9-188.4
									LIMESTONE, moderately weathered, 188.4-188.7'		III		10	1.5	2.0	188.4-188.6
189																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 7 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.83			17		100	40		Light brown, DOLOMITE AND LIMESTONE, laminated, slightly weathered, medium strong, moderately fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3				
191										P3			70	1.0	2.0	190.9
													0	1.0	1.0	191.2
192																
													45	1.0	1.0	192.3
					RB-009								0	1.0	2.0	192.4
193									LIMESTONE, 193.0-193.4'							
									NOTE: Lost all circulation at 193.0'; ~25-50% fluid return below 193.0'				0	1.0	2.0	193.3
													0-10	1.0	2.0	193.6
194									Becomes dark grayish brown and dark gray, laminated, calcareous, with black CALCITE-filled pores				0-50	2.0	1.0	194.1
									Becomes highly weathered, very weak		IV	R1				
195									Becomes slightly to moderately weathered, medium strong		II-III	R3				
	1.00			18		98	50						0	1.0	1.0	195.4
196									Extremely fractured zone 195.8-196.4'				0	1.0	2.0	195.8
									Becomes moderately weathered, medium strong		III	R3	0	1.0	1.0	196.4
197																
									Gray, LIMESTONE, slightly weathered, weak, moderately fractured		II	R2	0	1.0	1.0	197.4
198								CL					0	1.0	1.0	197.6
									NOTE: Switch from HQ to NQ at 198.0' for pressuremeter test							
199								CL								
									Light brown, DOLOMITE, laminated, slightly weathered, strong, slightly fractured along wavy and planar laminations, with CALCITE veins		II	R4				
200													0	1.0	1.0	200.0-202.0
	0.83			19		90	47									
201													50	1.0	1.0	200.8-200.9
										P2			60	1.0	1.0	201.4-201.6
													70	1.5	1.0	201.6-202.0
202																
													80	1.0	1.0	204.2-203.0
203					RB-010											
													50	1.5	1.0	203.2
									Becomes slightly to moderately fractured				0	1.0	1.0	203.6

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 8 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light brown, DOLOMITE, laminated, slightly weathered, strong, slightly fractured, calcareous [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	0	1.0	1.0	203.8
													0	1.0	3.0	204.3-204.9
205																
	0.50			20		98	57		With numerous, black, needlike features up to 1-mm wide and 7-mm long				10	1.0	1.0	205.2
206													10	1.0	2.0	205.9
207													0	1.0	3.0	206.9
									NOTE: Switch from NQ to HQ at 208'				80	1.0	1.0	207.2-207.6
208								CL	Becomes moderately fractured				70	4.0	0.75	208.2
									Becomes dark gray, weak, sound, brecciated with a CALCITE cement		III	R2	0	1.0	4.0	208.3
209																
210									Brown, LIMESTONE, laminated, highly weathered, very weak, extremely fractured, brecciated with CALCITE cement and filled vugs up to 1/2-inch, and abundant dissolution along laminations		IV	R1	0	4.0	2.0	210.0-211.0
	0.83			21		100	73									
211									Light brown, DOLOMITE, laminated, slightly weathered, strong, slightly fractured, with vugs up to 2-mm		II	R4	0	1.0	1.0	211.5
212										P1			0	1.0	1.0	212.1
213					RB-011								20	1.5	1.0	213.0
									Becomes moderately fractured				0	1.0	2.0	213.5-214.0
214													0	1.0	2.0	214.0
													0	1.0	2.0	214.5
215													0	1.0	2.0	214.8
	0.83			22		100	47						0	1.0	2.0	214.9
													0	1.0	3.0	215.0
									Becomes medium strong, moderately to extremely fractured			R3	0	1.0	1.0	215.2
216													0	1.0	1.0	215.4
													0	1.0	1.0	215.6
													0	1.5	1.0	215.8
													30	1.5	1.0-2.0	216.2-217.0
217																
													20	1.0	1.0	217.0
									Dark gray, LIMESTONE, slightly weathered, medium strong, moderately fractured		II	R3	5	1.0	1.0	217.7

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-15
SHEET NUMBER: 9 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden and S. Parks
INSPECTOR: K. Williams, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
219									Dark gray, LIMESTONE, highly weathered, medium strong, slightly fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		IV	R3				
									Becomes weak			R2	0	1.5	1.0	219.1
									219.2 -219.3': PLA = 1,610 psi				0	1.0	1.0	219.8
220	0.71			23		100	98									
221									221.3 - 221.8': γ_d = 131 lb/ft^3							
222													0	1.0	1.0	221.6
									NOTE: 0.3' of Run 23 recovered with Run 24				0	1.0	1.0	222.5
223					RB-012				Greenish gray, CLAYSTONE, moderately weathered, weak, slightly fractured, calcareous [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		III	R2	0	2.0	2.0	223.2
224									Fissured zone 223.8-225.0'				45	1.0	1.0	224.2
225	0.83			24		100	66		Becomes moderately to extremely fractured				45 0 45	1.0 3.0 1.0	2.0 1.0 1.0	224.8 225.0 225.2
226													45	1.0	1.0	225.9
227																
228									End of Boring at 228' The boring was backfilled with cement-bentonite grout to 10' below the mudline at 5:30 PM on 6/26/2019.							
229																
230																
231																

BORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600

HAMMER TYPE: Auto

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.83164 N Long: 84.76097 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 600.0 feet
DATUM: IGLD 1985

START DATE: 6/27/19 TIME: 10:57 am
FINISH DATE: 7/4/19 TIME: 12:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol	PQ	SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1																	AIR
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	WATER
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
26																	
27																	
28																	
29																	
30																	
31																	
32																	
33																	
34																	
35																	
36																	
37																	
38																	
39																	
40																	
41																	
42																	
43																	
44																	
45																	
46																	
47																	
48																	
49																	
50																	
51																	
52																	
53																	
54																	
55		SB-001 55.0-60.0 ft.															Dark brown, fine grained, POORLY GRADED SAND, few Gravel, trace Cobbles, trace Silt, wet, (SP)
56																	
57																	
58																	
59																	

BORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61		SB-002 60.0-70.0 ft.															Dark brown, fine grained, POORLY GRADED SAND, few Gravel, trace Cobbles, trace Silt, wet, (SP)
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69			G	3	☒	69.0 - 70.0											69-70: ω = 15.6%; SG = 2.74; Atterberg Limits = NP
70																	
71		SB-004 70.0-80.0 ft.															
72																	
73																	
74																	
75																	
76																	
77																	
78																	
79																	
80			SPT		■	80.0 - 82.0	14	22	12	12	NR						
81																	
82																	
83																	
84																	
85		SB-005 80.0-90.0 ft.															
86																	
87																	
88																	
89																	
90																	
91			SPT	4	■	90.0 - 92.0	8	15	20	25	17						90-92: PSA = 96.1% SAND, 3.9% FINES; SG = 2.71
92																	
93																	
94																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96		SB-006 90.0-100.0 ft.															
97																	
98																	
99																	
100																	Gray and brown, SILTY SAND, with little Silt, little Clay, and few Gravel, (SM), very dense
101			SPT	7		100.0 - 101.7	19	42	29	50/2"	17						Tan and gray, fine grained, POORLY GRADED SAND, with some Silt, (SP)[RESIDUAL SOIL]
102																	Brown, fine, POORLY GRADED GRAVEL, with some Sand, and Silt, (GP)
103		SB-008 100.0-110.0 ft.															ω = 8.8%
104																	
105																	
106																	
107																	
108																	
109																	
110																	Gray, highly to completely weathered LIMESTONE [ST. IGNACE FORMATION - MACKINAC BRECCIA]
111																	
112																	
113																	
114																	
115		SB-009 110.0-120.0 ft.															
116																	
117																	
118																	
119																	
120																	Start Rock Coring at 120.0'
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 1 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600
HAMMER TYPE: Auto

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.83164 N Long: 84.76097 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 600.0 feet
DATUM: IGLD 1985
START DATE: 6/27/19 TIME: 10:57 am
FINISH DATE: 7/4/19 TIME: 12:00 pm

CORE BARREL DATA:

TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: PQ

NOTES:

HQ3 (120-238.5', 248.5-288.5', 298.5-328.5')
NQ3 (238.5-248.5', 288.5-298.5')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
120									Dark greenish gray, LIMESTONE, slightly weathered, medium strong, extremely fractured, with light brown banding, 0° bedding, and CALCITE precipitation along fracture surfaces		II	R3	80	1.0	2.0	120.0-121.0
													10	1.0	1.0	120.0-121.0
121									[ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R3				
				1		69	0		Dark grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with CALCITE and Fe precipitation on fracture/bedding surfaces				20	1.0	1.0	121.3
122													20	1.0	1.0	122.1
													80	1.0	2.0	122.1
123								CL								
									Light brown gray, LIMESTONE, slightly weathered, medium strong, with vugs up to 2 mm, and abundant CALCITE precipitation (possible vein)		III	R3	0-90	3.0	2.0	123.5-124.1
124									Gray, DOLOMITE, laminated, slightly weathered, strong, extremely fractured, with CALCITE and Fe precipitation on fracture/bedding surfaces		II	R4				
125	0.3			2	RB-001	68	0						80	2.0	2.0	124.8
													30	1.0	1.0	125.0
126													80	2.0	2.0	125.8
127								CL								
128	0.4			3		55	0		With light brownish gray, LIMESTONE, thinly bedded, zones				0-90	1.0	1.0	127.5-129.5
129								CL								
													80	2.0	1.0	129.5-130.0
													5	1.0	1.0	

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 2 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with CALCITE precipitation along fracture/bedding surfaces [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3				129.7
131													10	2.0	2.0	130.6
													70	2.0	1.0	130.8-130.9
	1.0			4		75	0		Pale brown, LIMESTONE, laminated, moderately weathered, weak, extremely fractured, locally crushed to a SAND/GRAVEL, argillaceous		III	R2				
132									Sand and gravel filled fracture 131.7-132.1 ft.				80	1.5	8.0	131.7-132.1
									132.2-132.5: PLL = 1,420 psi				10	1.0	1.0	132.1-133.5
133								CL								
									Light brownish gray, DOLOMITE, slightly weathered, medium strong, extremely fractured with CALCITE precipitation along 10° bedding planes		II	R3				
134									133.6-133.8: PLL = 1,820 psi				10	1.0	1.0	133.8
													10	1.0	1.0	134.0
135									Pale brown, LIMESTONE, laminated, moderately weathered, very weak, extremely fractured		III	R1	50	2.0	8.0	134.9
									Pale brown and light gray, DOLOMITE, moderately to highly weathered, very weak to weak, extremely fractured		III-IV	R1-R2	10-80	2.0	2.0	135.2-138.5
136	0.8			5		58	0		Pale brown, LIMESTONE, laminated, moderately weathered, very weak, extremely fractured		III	R1				
									Light brownish gray, DOLOMITE, slightly weathered, medium strong, extremely fractured with CALCITE precipitation along 10° bedding planes		II	R3				
137								CL								
138																
139									Clay seam 139.3-139.6 ft.				40	1.5	8.0	139.3-139.6
									Becomes very dark gray, slightly weathered, weak, slightly fractured, argillaceous, with CALCITE veins		II	R2	40	1.0	1.0	139.6-139.8
140									140.0-140.2: PLL = 250 psi							
									140.2-140.4: ω = 3.14%, γ_d = 145 lb/ft^3, SG = 2.33, n = 0.085		III	R2	20	2.0	1.0	140.4
141	0.8			6	RB-002	64	56		Dark gray, LIMESTONE, moderately weathered, weak, slightly to extremely fractured, with a 1-inch clay seam at 140.4 ft.		II	R1	20	2.0	1.0	140.9
													10-30	1.0	8.0	141.1-143.5
									Light gray, DOLOMITE, slightly weathered, very weak, extremely fractured, with SANDY SILT along fracture surfaces							
142																
143								CL								
									Dark olive gray, LIMESTONE, slightly weathered, medium strong, extremely fractured, with very dark gray		II	R3	30	1.5	2.0	143.5-144.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 3 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									CALCITE		II	R4	5	1.0	2.0	144.2
									Dark gray, LIMESTONE, slightly weathered, strong, extremely fractured, with very dark gray CALCITE. Highly altered joint surface with irregular, locally euhedral				80	1.5	1.0	144.6-145.0
145									CALCITE 144.6-145.0 ft.		II	R4	50-70	2.0	1.0	145.0-146.0
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
									Grayish brown, DOLOMITIC LIMESTONE, slightly weathered, strong, extremely fractured				5	1.0	2.0	145.5
146				7		62	0						10	1.5	8.0	145.6
									Dark gray, LIMESTONE, highly weathered, very weak, extremely fractured, argillaceous		IV	R1				
													5	1.0	2.0	146.6
147								CL								
148																
									Grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with partially dissolved		II	R3				
149									CALCITE veins and trace vugs up to 1/2-inch				80	1.0	2.0	149.0
													10	1.0	2.0	149.1
													30	1.0	1.0	149.2
150													90	1.0	1.0	149.6-150.0
									Becomes extremely fractured							
									Dark gray, LIMESTONE, slightly weathered, medium strong, extremely fractured. Becomes moderately fractured at 150.6 ft.		II	R3				
151	0.6			8		84	0						20	2.0	1.0	150.8
													5	1.0	1.0	151.0
									Grayish brown, DOLOMITE, slightly weathered, strong, moderately fractured, with calcite healed fractures along bedding planes, breccia clasts evident		II	R4	0	1.0	2.0	151.3
													30	2.0	2.0	151.5
152													50	1.0	1.0	151.8
									Becomes extremely fractured				50	1.5	1.0	152.2-152.4
153					RB-003			CL								
									Light gray, LIMESTONE, laminated, slightly weathered, medium strong, extremely fractured, with local DOLOMITE blocks, discontinuous CALCITE veins, and 10° bedding, brecciated		II	R3	0-90	1.5	1.0	154.5
154									Becomes gray, weak, argillaceous, crushed			R2	70	1.0	8.0	154.5
155									Becomes moderately fractured				10-20	1.0	6.0	155.3-155.5
156	1.0			9		84	6						10	1.0	1.0	155.8
													20	1.0	1.0	156.2
													30	2.0	1.0	156.5
157									Becomes moderately weathered, extremely fractured, crushed Becomes mottled gray and yellowish brown		III					

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 4 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL	Mottled light gray and grayish brown, LIMESTONE, moderately weathered, weak, extremely fractured, locally crushed. Becomes light gray, slightly weathered, strong, with abundant calcite precipitation at 158.5 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R2				
											II	R4				
159											I-II	R3	20	1.0	1.0	159.2
									Grayish brown, DOLOMITE, laminated, unweathered to slightly weathered, medium strong, moderately fractured along bedding				20	1.0	1.0	159.4
													10	1.0	1.0	159.6
160													15	1.0	1.0	159.8
													20	1.0	1.0	160.1
													20	1.0	1.0	160.3
													15	1.0	1.0	160.5
161	0.60			10		62	0		Extremely fractured 160.9-161.2 ft.				10	1.0	1.0	160.7
													10-40	1.5	2.0	160.9-161.2
													20	1.0	1.0	161.3
162													20	1.0	1.0	161.4
													20	1.0	1.0	161.5
								CL								
163																
									Becomes weak, sandy material on core			R2				
164													5	1.0	1.0	163.8
													5	1.0	1.0	164-164.4
165													40	1.0	1.0	164.8
									Driller reports fast drilling 165-167 ft.							
166	1.30			11		30	0									
								CL								
167																
168																
					RB-004				Dark olive gray, LIMESTONE, slightly weathered, weak, extremely fractured, with reduced fluid circulation		II	R2				
											I-II	R3				
169									Grayish brown, DOLOMITE, laminated, unweathered to slightly weathered, medium strong, extremely fractured				80	1.0	1.0	169.0-169.3
											III	R3	0-90	3.0	2.0	169.3-176.0
	0.80			12		40	4		Dark olive gray, LIMESTONE, slightly weathered, weak, extremely fractured							
170								CL								
171									Becomes moderately weathered, medium strong, extremely fractured, with rough, irregular CALCITE dissolution vugs up to 1-inch along fracture surfaces							

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 5 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
173	0.80			13		16	0	CL								
174	0.60			14		93	0		Dark olive gray and yellowish brown, LIMESTONE, moderately weathered, medium strong, extremely fractured, with rough, irregular CALCITE dissolution vugs up to 1-inch along fracture surfaces, some breccia clasts evident [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued] Run 14 recovered as irregular fragments of LIMESTONE - gravel to cobbled sized		III	R3				
175																
176								CL					0-90	2.0	1.0	176.0-177.2
													0-90	3.0	1.0	176.0-177.2
									Light brownish gray, DOLOMITE, moderately weathered, weak, locally clayey 176.6-177.0 ft.		III	R2				
177	0.60			15		100	28		Dark gray, LIMESTONE, slightly weathered, weak, slightly fractured, argillaceous, with rough, irregular CALCITE dissolution vugs up to 1-inch along fracture surfaces, 40° bedding/laminations		II	R2	40	1.0	1.0	177.1
													40	1.0	1.0	177.6
178																
179	0.80			16		80	37		177.2-177.4: ω = 2.86%, γ_d = 156 lb/ft^3, SG = 2.48, n = 0.026 177.4-177.5: PLL = 2,580 psi				0-90	3.0	1.0	178.5-179.2
									Becomes highly weathered, very weak, crushed		IV	R1	10	1.0	6.0	179.6-179.7
180									Brownish gray, DOLOMITE, laminated, slightly weathered, medium strong, extremely fractured with CALCITE precipitation on fracture surfaces		II	R3	15	1.0	2.0	179.9-180.6
													70	1.0	2.0	180.0-180.7
181									Dark gray, LIMESTONE, slightly weathered, weak, moderately fractured. Becomes extremely fractured, highly weathered along a CALCITE dissolution zone 181.2-181.6 ft.		II	R2				
													20	2.0	2.0	181.2-181.6
182									Gray, DOLOMITE, slightly weathered, strong, with irregular, black CALCITE bands 2-5 mm-thick on 20° bedding		II	R4	20	2.0	2.0	181.6
													20	1.0	2.0	182.0
													20	1.0	2.0	182.2
183					RB-005			CL								
184									Becomes extremely fractured, with trace LIMESTONE corestones at top of run				5-10	1.0	1.0	183.5-184.0
													10-70	1.0	1.0	184.0
													5	1.0	1.0	184.2
													40	1.0	1.0	184.5
185									Becomes slightly fractured							

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 6 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.70			17		100	62		Gray, DOLOMITE, slightly weathered, strong, extremely fractured, with CALCITE precipitation on fracture surfaces. Becomes slightly fractured at 186.9 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	10-20	1.0	1.0	186.0-186.2
													30	1.5	2.0	186.5-186.6
187													10	1.0	1.0	186.6-186.8
									Clay seam 186.5-187.9 ft.				30	1.5	8.0	187.5-187.7
188																
									Becomes moderately fractured				10	1.0	1.0	188.4
													10	1.0	1.0	188.5
189													5	1.0	1.0	188.6
									Becomes laminated 189.3-189.9 ft.				5	1.0	1.0	188.8
													5	1.0	1.0	188.9
													20	1.0	1.0	189.5
190													15	1.0	1.0	189.9
													10	1.0	1.0	190.3
													10	1.0	1.0	190.5
191	0.80			18		100	25						10	1.0	1.0	190.7
													10	1.0	1.0	191.2
									2-inch zone of black, needle-like features, 1 mm wide and 5 mm long				10	1.0	1.0	191.3
192													10	1.0	1.0	191.9
									Becomes extremely fractured with crushed rock along fracture surfaces				80	1.5	2.0	192.3-193.5
193					RB-006											
													20	1.0	1.0	193.6
194													60	1.5	1.0	193.9
	0.50			19		80	0		Dark gray, LIMESTONE, moderately weathered, medium strong, extremely fractured, locally crushed		III	R3	0-90	1.5	1.0	194.5-194.8
195																
								CL								
196									Lost all fluid circulation at 196.0 ft.							
									Becomes laminated, slightly weathered, sound, with zones of pure CALCITE		II					
197	0.80			20		100	29									
													60	2.0	2.0	197.8
198									Becomes mottled grayish brown and light brown, highly weathered, very weak, up to 60% pure CALCITE, with intermittent fluid circulation		IV	R1	10	1.0	1.0	198.0-198.5
											II	R3	15-20	1.0	1.0	198.5-200.0
199									Grayish brown, DOLOMITE, laminated, slightly weathered, medium strong, moderately to extremely fractured, locally crushed, with CALCITE veins							

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 7 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with CALCITE laminations and intermittent fluid circulation		II	R3	30	1.0	1.0	200.1
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				5	1.0	1.0	200.6
201	0.80			21		76	8		Extremely fractured 201.0-201.3 ft.				5	1.0	1.0	200.7
									Becomes brown, with dark gray, irregular CALCITE veins.				70	1.0	1.0	201.0-201.3
													5	1.0	2.0	201.4
202													60	1.0	1.0	201.5-201.7
203								CL								
									Becomes brown and gray, weak, moderately fractured, with black CALCITE veins and no fluid circulation			R2	10	1.5	1.0	203.5-204.0
204																
													5	1.0	1.0	204.5-205.0
205									Becomes laminated							
									Becomes gray, strong, moderately fractured with CALCITE precipitation along fractures			R4	20	1.0	1.0	205.5-206.0
206	1.00			22	RB-007	82	16						90	1.5	3.0	206.0-206.5
									Dark gray, LIMESTONE, highly weathered, weak, moderately fractured, argillaceous, with irregular zones of CALCITE		IV	R2				
207													5	1.5	6.0	207.1
									Becomes very weak to weak			R1-R2	10	1.5	2.0	207.3
208								CL	207.4-207.5: PLL = 699 psi							
													5	1.5	1.0	208.6
209									Becomes laminated, very weak, extremely fractured along laminations, with dark brown CALCITE			R1	15	1.0	1.0	209.0-209.8
													90	1.5	4.0	209.8-210.2
210													30	1.4	4.0	210.0
													10	1.0	1.0	210.2-210.3
211	1.00			23		64	9									
									Light brown, DOLOMITE, slightly weathered, medium strong, extremely fracured locally crushed to a sand, with 5 mm black CALCITE layers		II	R3				
212																
								CL								
213																
									With CALCITE filled vugs				15	1.5	6.0	213.5-214.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 8 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
215									Light brownish gray, LIMESTONE, laminated, moderately weathered, medium strong, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R3	80	1.5-2.0	2.0	214.6-215.2
216	1.00			24		90	22		Light brown, DOLOMITE, slightly weathered, strong, slightly fractured, slightly DOLOMITIC, with CALCITE filled vugs up to 1/4-inch		II	R4				
217									Becomes moderately fractured				40 5 5	2.0 1.0 1.0	1.0 1.0 1.0	216.8 217.1 217.4
218								CL								
219									Extremely fractured 218.6-219.0 ft. Dark gray, LIMESTONE, moderately weathered, weak, moderately to extremely fractured		III	R2	5-20	2.0	1.0	218.6-219.0
220					RB-008				Extremely fractured 219.7-220.2 ft.				10-40	2.0	2.0	219.7-220.0
221	1.00			25		90	40		Becomes moderately fractured, with irregular zones of CALCITE Becomes extremely fractured and locally crushed				90 15 15 15 20	2.0 2.0 2.0 2.0 2.0	1.0 2.0 2.0 2.0 6.0	220.2-220.4 220.4 220.6 220.8 221.0-221.1
222													15 70	1.5 1.5	2.0 2.0	222.0 222.3
223								CL								
224	0.90			26		70	0		Slightly weathered, medium strong, 223.5-224.0 ft.		II	R3	0-90	1.5	3.0	224.0
225								CL								
226									Becomes moderately fractured				40	3.0	4.0	226.5
227	1.00			27		100	41		Gray, CLAYSTONE, moderately weathered, weak, slightly to moderately fractured, likely mechanical		III	R2	5-15 5-15 5-15 5-15	2.0 2.0 2.0 2.0	1.0 1.0 1.0 1.0	226.7 227.1 227.2 227.3
									[See next page]							

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 9 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark gray, DOLOMITE, moderately weathered, medium strong, slightly to moderately fractured, brecciated and healed with clay. Becomes greenish gray and light grayish brown at 228.5 ft.		III	R3	30	2.0	6.0	227.7-228.2
229									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				10	2.0	1.0	229.0
									Extremely fractured, crushed zone 229.7-230.0 ft.				20	2.0	6.0	229.7-230.0
230													0-90	1.5	2.0	230.0
231	1.00			28		76	44									
232					RB-009								15	2.0	6.0	231.8-231.9
233								CL								
									Becomes greenish gray, slightly weathered, weak		II	R2				
234									Becomes very weak			R1				
									PLL = 644 psi				15	2.0	2.0	234.0
													10	3.0	1.0	234.5
													10	3.0	1.0	234.6
235													10	3.0	1.0	234.8
													10	2.0	1.0	234.9
									Becomes highly weathered, extremely fractured, locally crushed		IV	R2	10-15	1.5	6.0	235.1
236	0.70			29		84	45						0	2.0	6.0	236.0
													0	2.0	8.0	236.2-236.4
													10-15	1.5	1.0	236.6
237													10-15	1.5	1.0	236.8
													10-15	1.5	1.0	236.9
													90	2.0	3.0	237.2-238.0
									NOTE: Switch from HQ to NQ at 238.5' for pressuremeter test.							
238								CL	NOTE: Switch from HQ to NQ at 238.5' for pressuremeter test							
									Olive brown, LIMESTONE, slightly weathered, weak, extremely fractured		II	R2				
239									Greenish gray, CLAYSTONE, slightly weathered, weak, extremely fractured		II	R2	10	1.0	1.0	238.7
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
240									SAND AND GRAVEL, After drilling to 242.5', borehole filled with Sand and Gravel (based on driller description). Sonic casing was advanced to 250'. 3-feet of rounded GRAVEL of BASALT, QUARTZ, GRANITE, and DIORITE were recovered with sonic core 240-243'. No fluid circulation; material placed in sonic box BH19-16-BAG-001. No geophysical or packer testing 120-250' due to the sonic casing. Reddish brown and greenish gray mottling is also present on gravel recovered.							
241	0.80			30		16	5									

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 10 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
243									Dark gray, LIMESTONE, slightly weathered, medium strong, moderately fractured		II	R3				
									[ST. IGNACE FORMATION - MACKINAC BRECCIA]		I	R5				
244									Light brown, DOLOMITE, unweathered, very strong, with irregular CALCITE nodules				60	1.0	1.0	243.9
									Dark gray, CLAYSTONE, moderately weathered, weak, moderately fractured, with breccia clasts in clayey matrix		III	R2				
245									[ST. IGNACE/POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]				60	1.0	0.75	245.3
246	1.20			31		40	22									
247								CL								
248													30	2.0	2.0	248.3
									NOTE: Switch from NQ to HQ at 248.5'; 248.5-250' drilled with sonic and sealed with 6-inch casing.							
249									Becomes mottled reddish brown and greenish gray, slightly fractured		III	R2				
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
250									Becomes laminated							
													20	1.0	1.0	250.7
251													20	1.0	1.0	251.2
252	2.90			32	RB-010	90	80		Light grayish brown, DOLOMITE, laminated, moderately weathered, weak, extremely fractured, with CLAY and SAND along fracture surfaces		III	R2	20	1.0	2.0	252.2
									[ST. IGNACE FORMATION - MACKINAC BRECCIA]							
253								CL								
													10-40	2.0	6.0	253.5-254.0
254								CL								
255									Becomes slightly weathered, medium strong, with abundant fractures along laminations		II	R3	0-10	1.0	2.0	255.0-256.1
													90	2.0	4.0-6.0	255.1-255.6
									Becomes brown, moderately weathered, weak		III	R2				

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 11 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	1.00			33		58	0		Light brown, DOLOMITE, moderately weathered, weak, extremely fractured along laminations [ST. IGNACE FORMATION - MACKINAC BRECCIA]		III	R2	10-40	2.0	2.0	256.0-256.3
257								CL								
258										P4						
									NOTE: Only DOLOMITE gravel recovered from Run 34. Possible VOID 260.0-260.1'.				0-90	2.0	2.0	258.5-263.5
259									With some black partings on gravel pieces - bedding laminations							
260																
261	1.20			34		26	0									
262								CL								
263																
									Becomes dark gray, extremely weathered, extremely weak, with fragments of slightly weathered, strong DOLOMITE		V	R0				
264																
265																
266	1.20			35		68	10	CL								
267																
268													10-40	2.0	2.0	268.0-270.0
									Becomes laminated, moderately weathered, very weak	P3	III	R1				
269																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 12 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark grayish brown, DOLOMITE, slightly weathered, strong, extremely fractured, with sand and clay infilling along fractures		II	R4	60	3.0	3.0	270.0
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				90	3.0	3.0	270.1
271	0.90			36		82	22									
													90	2.0	6.0	271.3-271.5
									Becomes medium strong, moderately fractured			R3	10	1.0	6.0	271.1
272					RB-011								30	2.0	1.0	271.8-272.0
													50	1.5	2.0	272.0-272.6
									270.4 - 270.9': γ_d = 168 lb/ft^3, UCS = 14,422 psi							
273								CL	270.9 - 271.2': ω = 1.75%, γ_d = 197 lb/ft^3, SG = 3.16, n = 0.047							
									Mottled reddish brown and greenish gray, CLAYSTONE, moderately weathered, weak, extremely fractured		III	R2	10-30	2.0	6.0	273.5-274.5
274									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
									Becomes unweathered, strong, sound		I	R1				
275																
276	1.00			37		100	78									
277									With some breccia pieces							
278																
									NOTE: all fractures are possibly mechanical	P2						
279													10	1.0	2.0	279.5
280													5	1.5	2.0	280.4
281	0.90			38		100	95						15	1.5	2.0	281.3
									With minor GYPSUM pods							
282													5	1.5	2.0	282.5
283					RB-012								10	1.5	1.0	283.5-283.6

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 13 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Mottled reddish brown and greenish gray, CLAYSTONE, unweathered, strong, sound		I	R4	10	1.5	1.0	283.9
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				15	1.0	1.0	284.1
285																
													10	1.5	2.0	285.3
286	0.90			39		100	100		Becomes very weak Becomes mostly reddish brown							
287									PLL = 600 psi				0	2.0	2.0	286.9
													20	1.5	2.0	287.5
288									NOTE: Switch from HQ to NQ at 288.5' for pressuremeter test.							
									Becomes extremely weathered, extremely weak, loose gray sand (possibly slough)		V	R0				
289																
	0.50			40		100	56		Becomes slightly weathered, medium strong, with DOLOMITE breccia pieces	P1	II	R3				
290													5	1.0	1.0	290.3
291									BRECCIA, slightly to moderately weathered, very weak to weak, moderately fractured, composed of DOLOMITE, LIMESTONE, and CLAYSTONE, with CALCITE cementation [MACKINAC BRECCIA]		II-III	R1-R2				
292																
293																
	1.00			41	RB-013	100	100		Light brown, DOLOMITE, slightly weathered, very weak to weak, with 50° bedding and vugs up to 1/2-inch [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R1-R2	45	1.0	1.0	293.6
294									Mottled gray and brown, BRECCIA, highly to extremely weathered, very weak, possibly SHALEY, with 0° bedding and 4-inch clats of LIMESTONE		IV-V	R1				
295									Mottled reddish brown and greenish gray, CLAYSTONE, slightly weathered, weak, slightly fractured, with cemented breccia clasts		II	R2				
296									Becomes very weak, slightly fractured, brecciated and healed			R1				
													5	2.0	2.0	296.5
297	1.60			42		100	100									
									[See next page]				15	1.0	1.0	297.5

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 14 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Mottled reddish brown and greenish gray, BRECCIA, slightly weathered, weak to medium strong, moderately fractured, composed of CLAYSTONE, DOLOMITE, and CHERT up to 1/2-inch, with CALCITE cementation [MACKINAC BRECCIA, continued]		II	R2-R3				
299													30	1.0	1.0	299.1
									Mottled reddish brown and greenish gray, CLAYSTONE, slightly to highly weathered, very weak to medium strong, slightly fractured, with DOLOMITE fragments up to 8-inches (slightly weathered, moderately strong)		II-IV	R1-R3	30	1.0	6.0	299.5
300													10	2.0	6.0	300.0-300.1
301	1.00			43		70	15		Becomes highly weathered, very weak, extremely fractured, locally crushed		IV	R1	0-90	2.0	6.0	301.0-302.0
302								CL								
303					RB-014											
304									Highly fractured 303.7-306.7' Becomes slightly weathered, medium strong, sound		II	R3	0	2.0	2.0	303.6
305													30	1.5	4.0	304.9-305.1
306	2.00			44		68	32		Becomes extremely fractured				15 15-20 40-60	3.0 2.0 2.0	6.0 2.0 2.0	305.4 305.6 305.6-308.5
307								CL								
308																
309									Light brown and greenish gray, BRECCIA, slightly to highly weathered, extremely weak to strong, extremely fractured, composed of CLAYSTONE, DOLOMITE, and LIMESTONE		II-IV	R0-R4	0-90	1.0-3.0	1.0-6.0	308.5-313.5
310									Gray, DOLOMITE, slightly to moderately weathered, medium strong, extremely fractured, brecciated and healed		II-III	R3				
311	2.00			45		86	25									

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 15 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL	Light brown and greenish gray, BRECCIA, moderately to highly weathered, extremely weak to strong, extremely fractured, composed of CLAYSTONE, DOLOMITE, and LIMESTONE		III-IV	R0-R4				
									[MACKINAC BRECCIA, continued]		V	R0				
313	1.00			46	RB-015	100	22		Light gray, DOLOMITE, extremely weathered, extremely weak, to a POORLY GRADED SAND							
314									Becomes moderately weathered, medium strong, moderately fractured		III	R3				
													30	1.0	2.0	314.3
													30	1.5	8.0	314.3-314.6
315									Becomes slightly weathered, strong, with crushed zones and 50° bedding		II	R4	0-90	1.0	3.0	315.0
									Light brown and greenish gray, BRECCIA, highly weathered, very weak, extremely fractured, composed of CLAYSTONE, DOLOMITE, and LIMESTONE		IV	R1				
316	1.10			47		100	38		DOLOMITE corestone with 75° bedding 316.2-316.5'							
									CALCEROUS CLAYSTONE corestone 316.5-317.1'				0-90	1.5	2.0-4.0	316.5
317									DOLOMITE corestone 317.1-317.9'							
318									Becomes very weak 317.5 - 317.6': PLL = 240 psi			R1				
									Mottled reddish brown and greenish gray, CLAYSTONE, highly weathered, medium strong, slightly fractured, brecciated and healed with LIMESTONE and DOLOMITE corestones		IV	R3				
319													10	1.5	2.0	319.2
									Angular LIMESTONE corestone 319.5-319.8'							
320									Mottled reddish brown and greenish gray, CLAYSTONE, highly weathered, medium strong, slightly fractured, brecciated and healed with LIMESTONE and DOLOMITE corestones				0-90	1.5	2.0-4.0	319.8
													10	2.0	6.0	320.2-320.3
													10	2.0	2.0	320.4
321	1.00			48		82	24						20	1.5	2.0	321.0
322									Slightly weathered, weak, DOLOMITE corestone with 50° bedding 322.0-322.5'		II	R2	60	1.0	10.0	322.0
323								CL								
					RB-016				Becomes moderately fractured				10	3.0	2.0	323.6
324													10	1.0	2.0	324.4
													10-20	2.0	8.0	324.7-324.9
325													10	1.0	2.0	325.2

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-16
SHEET NUMBER: 16 of 16
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: S. Parks, M. Bond, J. Levy
INSPECTOR: KW, CF, AH, XY

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
326	1.00			49		100	70		Mottled reddish brown and greenish gray, CALCEREOUS CLAYSTONE, slightly weathered, weak, moderately fractured, brecciated and healed with LIMESTONE and DOLOMITE corestones [MACKINAC BRECCIA, continued]		II	R2				
327													10-30	3.0	8.0	327.1-327.4
328													30	2.0	2.0	328.3
									End of Boring at 328.5' The first batch of cement-bentonite grout backfilled the borehole to 297 feet. Second batch of grout backfilled the borehole to 290 feet. Subsequently, 30lb of bentonite pellets were used to backfill the boring to 280 feet. A third batch of grout backfilled the borehole to 240 feet before collapsing at 221 feet. A final batch of grout backfilled the boring to the mudline by midday 7/4/2019.							
329																
330																
331																
332																
333																
334																
335																
336																
337																
338																
339																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.82875 N Long: 84.76084 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 599.7 feet
DATUM: IGLD 1985
START DATE: 7/4/19 TIME: 7:35 pm
FINISH DATE: 7/8/19 TIME: 4:45 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol	PQ	SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1																	AIR
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	WATER
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												
54												
55												
56												
57												
58												
59												

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61																	
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69																	
70																	
71																	
72																	
73																	
74																	
75																	
76																	
77																	
78																	
79																	
80																	Brown, fine grained, SILTY SAND, wet, (SM)
81			G	2		80.0 - 82.0											Brown, FAT CLAY, hard, wet, (CH)
82																	Fine grained, POORLY GRADED SAND, little Silt, few Gravel, (SP)
83																	
84																	
85		SB-001 80.0-90.0 ft.															
86																	
87																	
88																	
89																	
90																	SILTY CLAYEY SAND, (SC-SM), with some fines
91																	
92																	
93																	
94			G	4		94.0 - 95.0											94.0-95.0: ω = 14%, SG = 2.78

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96		SB-003 90.0-100.0 ft.															
97																	
98																	
99																	
100			SPT	5		100.0 - 100.2	50/2"										NOTE: SPT attempted at 100.0' encountered refusal. No Recovery.
101																	Fine grained, POORLY GRADED SAND, little Clay, few Gravel, (SP), of LIMESTONE lithology, slightly weathered, extremely fractured from drilling
102																	
103																	
104																	
105		SB-006 100.0-110.0 ft.															LEAN CLAY, some Gravel, (CL)
106																	
107																	DOLOMITE, highly to completely weathered, slightly to completely pulverized by drilling [ST. IGNACE FORMATION - MACKINAC BRECCIA]
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115		SB-007 110.0-120.0 ft.															Becomes highly to completely weathered
116																	
117																	
118																	
119																	
120																	Start Rock Coring at 120.0'
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 1 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - North side of Strait
COORD. Lat: 45.82875 N Long: 84.76084 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 599.7 feet
DATUM: IGLD 1985
START DATE: 7/4/19 TIME: 7:35 pm
FINISH DATE: 7/8/19 TIME: 4:45 pm

CORE BARREL DATA:
TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: PQ

NOTES:

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
120									Gray, DOLOMITE, slightly weathered, medium strong, extremely fractured, with numerous black, needlike features 1 - 2 mm wide, up to 1 cm long [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R3	0-90	1.0	1.0	120.0-120.8
													60	1.0	1.0	120.7
121	1.50			1		100	44		Very dark gray, LIMESTONE, moderately weathered, very weak, moderately fractured, argillaceous, with abundant CALCITE veins		III	R1	60	2.0	1.0	121.3
122									Light brown, zone 121.5-121.6 ft.							
									Becomes mechanically broken from drilling							
123									Light grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, locally vuggy, with numerous black, needlike features 1 - 2 mm wide, up to 1 cm long		II	R3	5-10	1.0	1.0	123.5-123.9
124									Becomes highly weathered, very weak		IV	R1	70	1.0	1.0	124.4
125	0.38			2	RB-001	50	0	CL	Becomes dark gray							
126																
127																
128									Becomes slightly weathered, medium strong, extremely fractured, with subvertical joints, and black clay partings on fracture surfaces		II	R3				
129									With vertical joints	P17			80-90	1.0	1.0	129.0-130.6

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 2 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
131	1.00			3		100	8		Dark gray, DOLOMITE, slightly weathered, medium strong, extremely fractured, with vertical joints and vugs up to 1mm [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued] Becomes very dark gray, laminated		II	R3				
132																
133									Mottled dark gray and pale brown, LIMESTONE, laminated, highly weathered, very weak, moderately fractured, argillaceous, with mechanical breaks along 0° bedding		IV II	R1 R3	15	1.0	2.0	132.9
134									Light grayish brown, DOLOMITE, slightly weathered, weak, extremely fractured, with vertical joints and vugs up to 1mm. Moderately weathered 133.6-133.9'.		III		80	1.0	2.0	133.6-134.0
135	1.00			4		98	0		Becomes laminated, weak, moderately fractured, with fractures along laminations/bedding With 2-inch zone of abundant, needlelike features, 1 mm wide and 1 cm long			R2	90	1.0	1.0	135.5
136																
137													80	1.0	1.0	137.0-137.5
138					RB-002			CL	LIMESTONE, highly to extremely weathered, extremely weak, argillaceous Grayish brown, DOLOMITE, slightly weathered, weak to medium strong, extremely fractured		IV-V II	R0 R2-R3				
139									Dark gray, LIMESTONE, moderately weathered, very weak, sound, with irregular CALCITE precipitation zones up to 5mm 139.7-140.2: PLL = 320 psi		III	R1	0-90	4.0	2.0	139.0-141.5
140	1.25			5		100	43			P16						
141													0	1.0	1.0	140.7
142									Becomes extremely fractured, crushed Grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with vertical joints, irregular CALCITE precipitation and local dissolution, with some vugs up to 4 mm		II	R3	90	1.0	2.0	142.0-143.0
143									Gray, LIMESTONE, moderately weathered, weak, extremely fractured, abundant vugs, slightly dolomitic		III	R2	90	1.0	2.0	143.5-144.6

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 3 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
145	1.00			6	RB-003	98	35		Dark gray, LIMESTONE, slightly weathered, medium strong, sound, argillaceous, abundant vugs and CALCITE precipitation, and subvertical fractures [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3	55	1.0	2.0	144.5
146													90	2.0	3.0	146.3-148.0
147									Becomes highly weathered, very weak		IV	R1				
148								CL	Becomes laminated, moderately weathered, weak, argillaceous, with mechanical breaks on 0° laminations		III	R2	10	1.0	6.0	148.0-149.1
149																
150	1.00			7		100	50			P15			60	1.0	1.0	150.3
151									Grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, with vugs up to 5 mm and dissolution along fractures		II	R3	80-90	4.0	2.0	151.0-153.0
152									Becomes gray							
153									Slightly weathered, weak to medium strong, moderately fractured, with vugs up to 3/4-inch		II	R2-R3				
154													5	2.0	1.0	153.6
155	1.00			8		92	28		Becomes dark gray, extremely fractured, with CALCITE veins				50 40 85	1.0 2.0 1.0	1.0 1.0 1.0	154.8 155.0 155.0-55.9
156									Dark gray, LIMESTONE, laminated, moderately weathered, weak, moderately to slightly fractured, argillaceous, zones of abundant CALCITE precipitation		III	R2				
157								CL					10	2.0	1.0	157.3

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 4 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
159					RB-004				Dark gray, LIMESTONE, laminated, slightly weathered, strong, moderately fractured, argillaceous, zones of abundant CALCITE precipitation [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4				
											II	R4	60	1.0	2.0	158.7
													50	1.0	2.0	158.9
									Grayish brown, DOLOMITE, slightly weathered, strong, moderately fractured, with argillaceous LIMESTONE seems and CALCITE precipitation				30	1.0	2.0	159.0
									159.2-159.7: γ_d = 166^3, PLL = 8,190 psi				30	1.0	2.0	159.3
160													0	1.0	2.0	159.8
									Becomes crushed from drilling				60	1.0	0.75	160.0-160.2
	1.00			9		100	16									
161										P14			55	3.0	1.0	160.8
													5	1.0	0.75	160.9-161.1
									Grayish brown, LIMESTONE, moderately weathered, weak, moderately fractured, argillaceous, with numerous black, needlike features 1 - 2 mm wide, up to 3 - 4 mm long		III	R2	90	2.0	4.0	161.6-162.2
162																
									Becomes gray, extremely weak to weak, slightly fractured, not argillaceous, locally crushed from drilling			R0-R1				
163																
													0	1.0	2.0	163.4
164													0	1.0	2.0	163.8
													85	1.0	1.0	164.0-164.5
													0-10	2.0	6.0	164.4
									Becomes light brownish gray, with vugs up to 1/2-inch							
165																
	1.00			10		83	35		Grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with narrow LIMESTONE zones		II	R3				
166																
									Becomes extremely fractured, slightly vuggy with vugs up to 1-inch, 10-20° bedding, and wavy laminations				30	2.0	1.0	166.2
167																
								CL								
168					RB-005								0	1.0	1.0	168.0
													25	1.0	1.0	168.1
									Dark gray, LIMESTONE, moderately weathered, very weak to weak, slightly fractured, locally crushed from drilling, with CALCITE veins and 20-30° bedding		III	R1-R2	0	1.0	1.0	168.4
169																
									Very weak, crushed zone 169.3-169.6 ft.			R1				
									Becomes weak, slightly fractured, with mechanical breaks, some breccia clasts visible			R2				
170													50	1.0	2.0	169.8
	0.83			11		76	38									
171																
									Becomes highly weathered, very weak	P13	IV	R1				

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 5 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL								
173									Gray, LIMESTONE, slightly weathered, medium strong, moderately fractured, with sparse vugs up to 1-inch		II	R3				
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				30	3.0	1.0	173.6
174									Becomes highly to extremely weathered, extremely weak		IV-V	R0	20	1.0	1.0	173.9
									Grayish brown, DOLOMITE, slightly weathered, medium strong, moderately to extremely fractured, with CALCITE veins		II	R3-R4	10	1.0	1.0	174.6
175													10	1.0	3.0	174.8
	1.00			12		100	35		Extremely fractured zone 175.2-176.5 ft.				80	1.0	1.0	175.2-175.5
													5	3.0	1.0	175.7
176													5	3.0	1.0	175.8
													20	2.0	1.0	176.4
													0	1.0	1.0	176.7
177									With abundant mechanical fractures along bedding				0	1.0	1.0	176.8
													80	1.0	1.0	176.9-177.6
									Becomes extremely fractured				15	1.0	1.0	177.6
178					RB-006								0-90	2.0	1.0	178.0-178.9
179													90	1.0	1.0	179.0-179.1
180									Becomes slightly fractured				70	1.0	1.0	180.0
	1.00			13		90	7						15	2.0	1.0	180.2
								CL								
181									Becomes dark gray, moderately weathered, very weak to weak, extremely fractured, locally crushed, with some calcereous clay infillings along fracture surfaces		III	R1-R2				
182													90	1.0	1.0	182.2-182.6
183										P12	V	R0				
184									Becomes grayish brown, extremely weathered, extremely weak, gravel-sized fragments recovered				80	1.0	2.0	184.0-184.6
185	0.55			14		80	13		Becomes slightly weathered, medium strong, moderately fractured, with CALCITE infilling along joint surfaces.		II	R3	5	1.0	1.0	185.4

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 6 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
187									Grayish brown, DOLOMITE, slightly weathered, strong, moderately fractured, LIMESTONE (dark gray, slightly weathered, medium strong) 186.4-186.6 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3	0	1.0	1.0	186.1
													0	1.0	1.0	186.2
													50	1.0	1.0	186.8
													0	1.0	1.0	186.9
188					RB-007				With vugs up to 1-inch				90	1.0	2.0	188.0-188.8
189																
190	1.00			15		100	49		Becomes gray, laminated, unweathered, medium strong, extremely fractured, with mechanical breaks along 0° laminations		I	R3				
													0	1.0	6.0	190.4
													30	1.0	2.0	190.7
191													60	1.0	1.0	191.1
192									Light gray, LIMESTONE, slightly weathered, weak, slightly fractured to sound, argillaceous		II	R2				
									Grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with CALCITE veins and vugs up to 3mm	P11	II	R3	10	1.0	2.0	192.6-192.8
193													80	1.0	1.0	193.0-194.0
													10	2.0	1.0	193.6
194									Becomes gray, laminated, highly weathered, very weak, locally weathered to a medium grained sand 194.2-194.6: PLL = 40 psi		IV	R0				
195									Becomes gray, laminated, slightly weathered, strong, slightly fractured		II	R4				
	1.00			16		96	43									
													20	1.0	6.0	195.8
196									Gray, LIMESTONE, slightly weathered, weak, slightly fractured, argillaceous, with 0° bedding, breccia fragments present		II	R2	0	1.0	1.0	196.3
197									Becomes pale brown, moderately weathered, weak, with weathered joint surfaces		III	R2	0	1.5	6.0	197.1
198					RB-008			CL	Becomes thinly bedded, weak to medium strong, with occasional vugs; 198.0-200.1 ft. recovered as GRAVEL. NOTE: To avoid the same issues encountered in BH19-16, packer testing and borehole geophysics were performed 130-195 ft. after drilling to 198 ft. Drilling and packer testing were advanced in a 10-foot interval (to 203.5 ft.). Because of persistent hole collapse at 194 ft., the boring was advanced with HQ to 288 ft. after a packer test at 193-203.5 ft.			R2-R3	0-90	1.0-2.0	1.0-2.0	198.0-200.1
199																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 7 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
201	1.00			17		76	6		LIMESTONE, thinly bedded, moderately weathered, weak to medium strong, slightly fractured, with occasional vugs and 0° bedding [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R2-R3	0 90	1.0 1.0	1.0 1.0	200.8-201.0 201.0-201.3
202								CL	Grayish brown, DOLOMITE, slightly weathered, strong, slightly fractured to sound, with CALCITE precipitation along fracture surfaces		II	R4				
203									Pale brown, LIMESTONE, slightly weathered, medium strong, extremely fractured, healed with CALCITE cementation		II	R3	0	1.0	1.0	203.4-203.6
204													0	1.0	1.0	204.1
205	0.91			18		88	17		Becomes slightly to moderately fractured Becomes unweathered, strong		I	R4	30	1.5	2.0	205.3-205.9
206									Becomes extremely weathered, extremely weak, to a FAT CLAY		V	R0	10 70	2.0 1.0	2.0 2.0	205.9 206.0
207					RB-009			CL	Becomes dark olive gray, slightly weathered, medium strong, moderately to extremely fractured		II	R3				
208									Becomes pale brown, extremely weathered, extremely weak		V	R0				
209									Becomes slightly weathered, medium strong		II	R3	10-30	1.0	2.0	208.6
210	1.25			19		76	0		Pale brown, DOLOMITE, slightly weathered, medium strong, moderately fractured, with 0° bedding		II	R3	5-10 60	1.0 1.0	1.0 1.0	209.6-210.0 210.0-210.3
211									Becomes extremely weathered, extremely weak, extremely fractured		V	R0	70	2.0	1.0	210.9-211.2
212								CL								
213									Becomes slightly weathered, medium strong, slightly to moderately fractured		II	R3	90	1.0	1.0	213.5-214.3

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 8 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
214.5									Pale brown, LIMESTONE, moderately weathered, medium strong, slightly to moderately fractured, oolitic, with Mn staining along fracture surfaces. Becomes moderately weathered at 214.5 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R3				
													5-10	1.0	1.0	214.5-214.6
215													30	2.0	1.0	215.0
	1.67			20		92	57									
216													0	1.0	1.0	215.8
													30	1.0	6.0	216.3
													80	1.0	1.0	216.7-217.3
217																
													0-10	1.0	1.0	217.3
								CL	With black, CALCITE, on fracture surfaces							
218					RB-010				Becomes dark gray, weak, NOTE: Top of Run 21 recovered as pale brown, subrounded LIMESTONE GRAVEL up to 2-inches, driller noted soft conditions. No recovery assumed to be 218.3-220.0'			R2	0-90	2.0	1.0	218.0-218.3
219								CL								
220									Grayish brown, DOLOMITE, unweathered, strong, extremely fractured, with 0° laminations		I	R4				
	1.00			21		70	40									
221									Becomes sound				70	1.0	1.0	221.1
222									221.1-221.5: PLL = 12,200 psi							
223								CL	Becomes light gray, highly weathered, weak, moderately to extremely fractured, with local zones weathered to a SAND and slightly weathered, strong corestones		IV	R1				
224																
225																
	1.00			22		86	27		Dark olive gray, LIMESTONE, highly weathered, weak, moderately to extremely fractured, with disturbed bedding and breccia fragments possibly turbidite							
226													0	1.0	1.0	226.1
227									Becomes moderately weathered, weak, moderately fractured		III	R2	0	3.0	4.0	226.9
													20	2.0	2.0	227.5

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 9 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
					RB-011				Light gray, DOLOMITE, moderately weathered, weak, moderately fractured		III	R2				
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				10	1.0	2.0	228.7
229									Brown and gray, LIMESTONE, moderately weathered, very weak, moderately fractured				10	2.0	6.0	229.0-229.1
									Brown, DOLOMITE, laminated, highly weathered, very weak, extremely fractured, crushed to a gravel		III	R1	0	1.0	4.0	229.5
230													40	1.0	1.0	229.5
	0.71			23		100	25		Grayish brown, LIMESTONE, slightly to moderately weathered, medium strong, extremely fractured, with vugs and dissolved CALCITE veins along laminations		II-III	R3	10	1.0	2.0	229.7
													0	1.0	1.0	229.8
231													0	1.0	1.0	230.1
													0	1.0	1.0	230.4
													70	1.0	1.0	230.4
													0	1.0	1.0	230.5
232									Light grayish brown, DOLOMITE, slightly weathered, strong, extremely fractured		II	R4	60	1.0	6.0	231.0-231.3
									Becomes slightly to moderately fractured				70	1.0	1.0	232.2-232.5
233									Becomes gray, slightly to moderately weathered, medium strong, moderately fractured		II-III	R3				
													10	1.0	1.0	233.3-233.5
234									Becomes light brown, slightly weathered, medium strong, moderately fractured, with fossils and vugs		II	R3	60	1.0	2.0	233.9
													5	1.0	1.0	234.0
													5	1.0	1.0	234.2
235	1.25			24		80	7		Becomes moderately weathered, weak		III	R2	0-90	2.0	2.0	235.0-236.0
													10-30	2.0	6.0	235.3-236.2
236									2-inch LIMESTONE clasts at 236.0 ft.							
									Grayish brown, laminated, slightly weathered, strong		II	R4				
													10	1.0	1.0	236.6
237													70	1.0	1.0	236.8-237.0
								CL								
238					RB-012				Becomes moderately to extremely fractured				0-90	2.0	1.0	238.0-238.7
													70	1.0	1.0	238.8
239									Becomes extremely fractured, increasingly calcareous							
													50	2.0	1.0	239.8
240													10	1.0	1.0	238.9-239.6
	1.00			25		100	13									
241									Becomes moderately fractured				70	1.0	1.0	241.1-241.6
									Becomes extremely fractured							

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 10 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Grayish brown, DOLOMITE, laminated, slightly weathered, strong, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	10	1.0	6.0	242.2-242.3
													70	1.0	1.0	242.3-242.9
													10	1.0	6.0	242.6-242.7
243									Becomes medium strong, NOTE: Lost all fluid circulation at 245.5 ft.			R3				
													0	1.0	2.0	243.7-243.9
244									Gray, LIMESTONE, highly weathered, very weak, extremely fractured, locally crushed, argillaceous, with 5° bedding		IV	R1	85	2.0	6.0	244.1-244.7
245	1.00			26		92	25		Becomes laminated, slightly weathered, medium strong, sound		II	R3				
246									Grayish brown, DOLOMITE, laminated, moderately weathered, medium strong, extremely fractured, with subvertical fractures		III	R3				
247																
248					RB-013			CL	Becomes unweathered to slightly weathered, with trace vugs up to 1/4-inch		I-II		10	1.0	2.0	248.0-248.6
249									250.0-250.3: PLL = 4,730 psi							
													70	1.0	2.0	249.4
250	1.00			27		96	7		Becomes moderately fractured							
													0	1.0	1.0	250.6
251										P10			0	1.0	1.0	250.7
													5	1.0	1.0	251.0
									Becomes moderately weathered, weak, with CALCITE dissolution and Mn along fracture surfaces. Continued no fluid circulation, breccia clasts evident - healed clasts and partial layering		III	R2	0	2.0	4.0	251.4
252													0	2.0	2.0	251.4-253.0
253								CL								
254									Becomes gray, extremely fractured							
255	1.25			28		74	22		Becomes unweathered to slightly weathered, medium strong		I-II	R3				

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 11 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
257									Dark gray, LIMESTONE, highly weathered, very weak to weak, sound, with 15° bedding and CALCITE precipitation, breccia/turbidite [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		IV	R1-R2				
258					RB-014				Becomes extremely fractured				0-90	2.0	1.0	257.5-257.8
259									With vugs up to 1/2-inch 258.8-259.0 ft.							
260	1.67			29		80	21	CL	Becomes light brown, slightly to moderately weathered, weak, moderately fractured	P9	II-III	R2				
261									Becomes laminated, moderately weathered, extremely fractured along laminations		III		70	1.0	1.0	261.0-261.5
262													70	2.0	2.0	262.0-262.5
													0	1.0	1.0	262.1
263													10	2.0	2.0	262.7
													10	2.0	2.0	262.8
264													10	1.0	2.0	263.8-264.3
									Light gray, DOLOMITE, slightly weathered, medium strong, extremely fractured		II	R3				
265	1.00			30		100	45		265.2-264.8: CALCITE infilling on fracture surface				70	6.0	6.0	264.5-264.8
266									Dark gray, LIMESTONE, slightly weathered, weak, sound, argillaceous		II	R2	0	1.0	2.0	265.7
267																
268					RB-015					P8			15	2.0	6.0	268.3
269																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 12 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
271	1.00			31		88	45		Gray, CLAYSTONE, moderately weathered, very weak, sound, calcareous [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		III	R1				
272																
273								CL								
274	1.00												70	2.0	1.0	273.4
													0	1.0	2.0	273.7
275													0-90	2.0	1.0	275.0-275.3
276				32	RB-016	100	80		Mottled greenish gray and reddish brown, slightly weathered, weak, with fissures 276.4-276.7 ft.	P7	II	R3	0-90	2.0	2.0	276.4-276.7
277																
278																
279	1.00															
280				33		100	40		280.0-280.5: PLL = 220 psi							
									Becomes moderately fractured				80	2.0	6.0	280.6-281.0
281													0	1.0	3.0	281.0
													50	1.0	1.0	281.4-281.4
									Becomes moderately weathered, extremely fractured, locally crushed		III		10	1.0	6.0-8.0	281.6-282.0
282									Becomes slightly weathered, medium strong		II	R3				
283																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 13 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
285	1.00			34	RB-017	100	80		Mottled greenish gray and reddish brown, CLAYSTONE, laminated, slightly weathered, medium strong, sound, with GYPSUM [POINTE AUX CHENES - MACKINAC BRECCIA, continued]		II	R3	20	1.0	1.0	284.5
286																
287									Becomes moderately fractured				10	2.0	6.0	286.6-286.7
									NOTE: Switch from HQ to NQ at 288.0 ft. for pressuremeter				0	1.0	1.0	287.3-287.5
288									Becomes light brown and gray	P6						
289																
290	0.50			35		20	0									
291								CL								
292																
293																
294	1.00			36		46	0		Light brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, argillaceous [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R3	0	1.0	1.0	293.7-194.0
295																
296								CL								
297																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 14 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, argillaceous. [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R3				
299	1.00			37		31	0	CL								
300					RB-018				Driller noted softer material; only SILTY SAND-coating on core barrel retrieved 300.5-303.0 ft. No fluid circulation.							
301																
302	1.00			38		0	0	CL								
303																
304																
305	1.00			39		50	17									
306																
307								CL	NOTE: Switch from NQ to HQ at 308.0 ft.							
308									Greenish gray, CLAYSTONE, laminated, slightly weathered, weak to medium strong, sound, with tight, vertical CALCITE veins [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		II-III	R2				
309									Becomes slightly to moderately weathered, weak							
									Becomes gray, unweathered, weak, moderately fractured to sound		I		30	2.0	1.0	309.5
310									Becomes slightly to moderately weathered, very weak, with mechanical breaks		II-III	R1				
	0.63			40		100	95						40	1.0	0.75	310.6-313.0
311																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 15 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray, CLAYSTONE, laminated, slightly to moderately weathered, weak, moderately fractured, with tight, vertical CALCITE veins and mechanical breaks		II-III	R2				
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
313					RB-019				Becomes slightly weathered, with local extremely fractured zones		II					
									313.0 - 313.8': PLL = 270 psi				50	3.0	6.0	313.4
314									Becomes unweathered, extremely fractured, crushed		I		20-30	3.0	6.0	314.0-315.5
									Becomes slightly weathered	P5	II					
315									314.9 - 315.5': γ_d = 129 lb/ft^3				10	3.0	6.0	314.8-314.9
	0.63			41		90	62						20	1.5	4.0	315.5
316									Becomes mottled greenish gray and reddish brown							
317													30	2.0	1.0	317.1
								CL					30	2.0	1.0	317.2
318									Becomes medium strong, extremely fractured			R3	20	2.0	1.0	318.3-318.5
													90	2.0	1.0	318.3-318.5
									Becomes weak, sound			R2	30	2.0	1.0	318.3-318.5
319																
320									Becomes moderately weathered, very weak, extremely fractured, clayey, with crushed rock infilling fractures		III	R1	10	3.0	6.0	320.0
	0.50			42		78	30						15	3.0	6.0	320.3
321													20	2.0	6.0	320.6-320.8
													60	2.0	6.0	321.4
322													10	2.0	6.0	321.6
								CL								
323					RB-020				Becomes gray, extremely weathered, extremely weak		V	R0				
									Light yellowish brown, LIMESTONE, moderately weathered, medium strong, extremely fractured, brecciated and healed, with vugs up to 1-inch, with completely weathered, extremely weak zones/filling [MACKINAC BRECCIA]		V	R0	40	1.0	1.0	323.6
324													30	1.0	1.0	324
									Becomes highly weathered, very weak		IV	R1				
325										P4						
	0.56			43		58	0		Greenish gray, CLAYSTONE, extremely weathered, extremely weak, extremely fractured		V	R0	60	3	6	325.4
													85	1.0	1.0	325.7

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 16 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
327								CL								
328	0.42			44	RB-021	28	0		Reddish brown with greenish gray, CLAYSTONE, moderately weathered, weak, extremely fractured, DOLOMITE breccia clasts evident in CLAYSTONE [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]	P3	IV	R1				
329									Becomes greenish gray, very calcareous							
330																
331								CL								
332									NOTE: Hole open until 333.0' after Run 44. Poor recovery due to material washing out.							
333	0.50			45		94	67		Becomes highly to extremely weathered		IV-V					
334																
335									Becomes very weak to weak, moderately fractured to sound			R1-R2				
336																
337									Becomes moderately to extremely fractured							
338								CL	Becomes slightly to moderately weathered, extremely weak, 338.0 - 338.5: PLL = 142 psi		II-III	R0				
339									Extremely fractured 338.7-338.9' Becomes highly to extremely weathered, clayey		IV-V		15	1.0	1.0	338.7-338.9

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 17 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.42			46		52	14		Reddish brown with greenish gray, CLAYSTONE, highly weathered, very weak, extremely fractured [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		IV	R1				
341																
342								CL								
343									Slightly weathered, weak, corestone 343.0-343.2'		II	R2				
									Becomes reddish brown, highly weathered, very weak, moderately fractured, CLAYEY		IV	R1	25	1.0	1.0	343.3
344													15	3.0	6.0	343.6
													15	3.0	6.0	344.6
345													10	3.0	6.0	345.2
	0.33			47		100	80						10	3.0	6.0	345.4
346										P2			10	3.0	6.0	346
347									Becomes greenish gray with reddish brown, mottling							
					RB-022								10	3.0	6.0	347.7
348									Becomes reddish brown with greenish gray, moderately weathered, very weak to weak		III	R1-R2	10	3.0	6.0	347.9
349													10	3.0	6.0	348.9
													10	3.0	6.0	349.1
													10	3.0	6.0	349.2
350									Extremely weathered, extremely weak, zone 350.0-350.3'		V	R0	10	3.0	6.0	349.9
				48		98	65									
351									Crushed zone 351.4-351.6'							
													0	1.0	1.0	351.7
352													5	3.0	6.0	351.9
													15	1.0	4.0	352.4
													5	1.0	4.0	352.6
353								CL	Becomes highly weathered, very weak, extremely fractured, crushed		IV	R1				
									Crushed to a gravel 353.8-354.1'							

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 18 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, extremely fractured, locally crushed		II	R2	10	3.0	6.0	353.8-354.1
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				5	3.0	6.0	354.4
													10	3.0	6.0	354.6-354.7
355									Becomes medium strong, moderately fractured			R3				
	0.46			49		84	32						10-30	2.0	1.0	355.1
356													50	2.0	1.0	356.0
													40	2.0	2.0	356.2
										P1			5	2.0	2.0	356.7
357													5	2.0	2.0	357.0
								CL								
358					RB-023				Becomes unweathered, moderately fractured		I					
													0	1.0	1.0	358.3
													50	1.0	3.0	358.5
													0	2.0	1.0	358.7
359													0	1.0	1.0	359
360													0	1.0	1.0	359.8
	0.46			50		100	82									
361													0	2.0	1.0	360.7
									Highly weathered, very weak, clayey zone 361.6-362.2'		IV	R1				
362																
									Becomes reddish brown, slightly weathered, weak		II	R2				
363									Becomes mottled greenish gray and reddish brown							
													5	3.0	3.0	363.5
364													15	1.0	1.0	363.9
													30	2.0	3.0	364.3
													0	1.0	1.0	364.4
365									Crushed zone 364.7-364.9' Becomes sound				40	3.0	3.0	364.7-364.9
	0.50			51		100	96									
366																
367																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-17
SHEET NUMBER: 19 of 19
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: C. Barden, M. Bond, S. Parks
INSPECTOR: KW, KZ, XY, CF

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Reddish brown, CLAYSTONE, slightly weathered, weak, moderately fractured		II	R2	15	1.0	1.0	368.1
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
369									Becomes moderately weathered, very weak		III	R1	30	1.0	3.0	368.9
													50	1.0	3.0	369.4
370													90	1.0	3.0	369.8
	0.38			52	RB-024	46	18		NOTE: Bit became plugged twice during Run 52, potentially washing out softer material							
371																
								CL								
372																
373									Becomes slightly fractured							
									373.0 - 373.5': PLL = 390 psi							
374													0	1.0	3.0	374.2
375									Becomes mottled greenish gray and reddish brown							
	0.42			53		62	58									
376													15	1.0	3.0	375.9
								CL								
377																
378									End of Boring at 378'							
									The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons of water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from bottom of boring to 300 feet on 7/9/2019. In situ testing was then performed from ~250-300. Prior to removing the packer from the borehole, a bolt sheared off and the packer was lost in the hole. Subsequently, 4.5 batches of grout backfilled the borehole to 250 feet. 60lbs of bentonite pellets backfilled the borehole to 240 feet. A final batch of grout was used to backfill to 143 feet. The borehole then collapsed to 115 feet, 30 feet below mudline by 14:20 AM on 7/13/2019.							
379																
380																
381																

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 1 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.82346 N Long: 84.76282 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 446.5 feet
DATUM: IGLD 1985
START DATE: 10/24/19 TIME: 11:45 am
FINISH DATE: 10/25/19 TIME: 12:15 pm

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S, HQ3
O.D.: Geobor-S, HQ3
I.D.: Geobor-S, HQ3
CASING SIZE: " (")

NOTES:
Mudline is 135.2 ft. (41.2 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
0									Mudline is 135.2 ft. (41.2 m) below lake level.							
1									NCD down to 55.1 ft. to obtain first coring interval. No sample obtained.							
2																
3																
4																
5																
6																
7																
8																
9																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 2 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 3 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
25																
26																
27																
28																
29																
30																
31																
32																
33																
34																
35																
36																
37																

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 4 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
39																
40																
41																
42																
43																
44																
45																
46																
47																
48																
49																
50																
51																

WSP CORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 5 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
53																
54																
55									Dark gray, LIMESTONE, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA]							
56																
57	0.14			1	RB-001	50	11		Light grayish brown, DOLOMITIC LIMESTONE, extremely fractured Dark gray, LIMESTONE, extremely fractured							
58																
59																
60									Becomes moderately weathered, very weak to weak, distorted bedding							
61	0.06			2	RB-002	100	28									
62																
63	0.20			3	RB-003	95	0		Light grayish brown, fine grained, DOLOMITIC LIMESTONE, slightly weathered, strong, extremely fractured, wih trace Fe staining on fracture surfaces							
64																
65											II	R4	0-90	1.0	1.0	64.96-69.88

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 6 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
67	0.41			4	RB-004	33	0		Light grayish brown, fine grained, DOLOMITIC LIMESTONE, slightly weathered, strong, extremely fractured, wih trace Fe staining on fracture surfaces [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
68								CL								
69																
70									Becomes slightly to moderately weathered, Soft, clayey zone 72.8-73.2 ft.		II-III					
71													30	1.0	2.0	71.19
72	0.49			5	RB-005	83	41						0	1.0	1.0	72.11
73																
74								CL								
75									Light grayish brown, fine grained, DOLOMITIC LIMESTONE, slightly weathered, strong, extremely fractured, wih trace Fe staining on fracture surfaces		II	R4				
76													0 90	1.0 1.0	1.0 1.0	75.66 75.66-76.44
77	0.25			6	RB-006	97	0						0	1.0	1.0	77.07
78									Highly weathered, extremely weak, clayey zone 77.9-78.4 ft.		IV II	R0 R4	0 0	1.0 1.0	8.0 1.0	77.92 78.02
79									Highly weathered, extremely weak, clayey zone 78.8-79.7 ft.		IV	R0	0	1.0	8.0	78.8
								CL			II	R4				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 7 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
81	0.16			7	RB-007	40	0	CL	LIMESTONE, slightly weathered, strong, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
82									Light grayish brown, fine grained, DOLOMITIC LIMESTONE, highly weathered, medium strong		IV	R3				
83	0.16			8	RB-008	100	20									
84									Dark gray, LIMESTONE, highly weathered, weak, argillaceous, thinly bedded		IV	R2				
85									Light grayish brown, DOLOMITIC LIMESTONE, slightly to highly weathered, weak to medium strong, moderately fractured, with occasional clayey zones Dark gray, LIMESTONE, at 85.3 ft., extremely fractured		II-IV	R2-R3				
86									Dark gray, LIMESTONE, at 86.3 ft., extremely fractured							
87	0.27			9	RB-009	87	0									
88									High-angle fracture 87.9-88.5 ft.				90	1.0	1.0	87.93-89.57
89								CL								
90									Light grayish brown, DOLOMITIC LIMESTONE, slightly weathered, medium strong, moderately fractured, with occasional clayey zones		II	R3				
91													60	1.0	1.0	90.55-90.88
92	0.23			10	RB-010	100	37		LIMESTONE, extremely weathered, extremely weak, zone with local LIMESTONE layer at 91.0-91.8 ft. DOLOMITIC LIMESTONE, slightly weathered, medium strong, moderately fractured, with occastional clayey zones. Highly Weathered, very weak zone 91.9-92.0 ft.		V II IV II	R0 R3 R1 R3				
93									Highly weathered, very weak, 1/2-inch clay zone at 92.7 ft. with dolomite pieces Becomes slightly weathered, medium strong		IV II	R1 R3	0 0	1.0 1.0	1.0 1.0	93.44

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 8 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									94.28: γ_d = 162 pcf, ω = 1.07%				0	1.0	1.0	93.73 94.06
95	0.23			11	RB-011	63	11		DOLOMITE, slightly weathered, very strong, moderately fractured. Becomes extremely fractured with smooth partings at 94.8 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	5 30 60	1.0 1.0 1.5	1.0 0.75 1.0-2.0	94.82 94.91 95.14-96.03
96													90 0	1.0 1.0	0.75 1.0	96.13-96.16 96.16
97								CL								
98	0.16			12	RB-012	100	82		Becomes dark gray, unweathered, with Fe staining on fracture surfaces		I					
99									Becomes moderately weathered, medium strong, sound Becomes light olive gray		III	R3				
100									Becomes light grayish brown, highly weathered, weak, extremely fractured		III	R2				
101									Slightly weathered, strong, crushed corestone 100.7-101.7 ft.		II	R4	85	0.8	1.0	101.05-101.38
102	0.21			13	RB-013	63	11		Light grayish brown, BRECCIA, highly to extremely weathered, very weak, with slightly weathered, angular corestones healed in a soft, clay matrix		IV-V	R1	10 10 0	1.0 1.0 1.0	1.0 1.0 4.0	101.7 102.03 102.36-102.69
103								CL								
104																
105									Light grayish brown, DOLOMITE, slightly weathered, very strong, extremely fractured, with Fe staining on fracture surfaces and trace, needle-like mineral concretions		II	R4	0-90	1.0	1.0	104.66-106.3
106									Light grayish brown, BRECCIA, slightly to moderately weathered, medium strong, with slightly weathered, angular corestones healed in a soft, clay matrix	P1	II-III	R3				
107	0.46			14	RB-014	37	0	CL								

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 9 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
109									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
									Only DOLOMITE clasts up to 4-inches recovered 109.2-109.5 ft.							
													0-90	1.0	1.0	109.25-109.51
110									Dark gray, fine grained, DOLOMITE, moderately weathered, medium strong, sound		III	R2				
111																
112	0.29			15	RB-015	43	35									
113								CL								
114																
									Becomes moderately fractured				70	1.0	1.0	114.37-114.5
115									Becomes slightly weathered, strong to very strong, extremeley fractured to a 1-inch gravel, with some LIMESTONE clasts		II	R4	0-90	1.0	1.0	114.5-115.48
									Becomes slightly fractured, with horizontal dissolution				55	1.0	1.0	115.48
116													0	3.0	1.0	115.81
	0.20			16	RB-016	89	27						70-75	1.0	1.0	116.47-117.35
117									Dark gray, fine grained, DOLOMITE, slightly weathered, strong to very strong, slightly fractured, with horizontal dissolution		II	R4				
													0-10	1.0	1.0	117.35
118													0-10	1.0	1.0	117.55
													0-10	1.0	1.0	117.78
													0-10	1.0	1.0	118.04
119								CL	Becomes very dark gray, with shale partings on some fractures							
									Dark greenish gray, CLAYSTONE, laminated, slightly weathered, medium strong, sound, with light and dark gray mottling		II	R1				
120									[POINTE AUX CHENES FORMATION]							
121																
	0.20			17	RB-017	100	100		Becomes weak		II	R1				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 10 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Clayey, fractured zone 121.8-121.9 ft. [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				15	2.0	4.0	122.05
123													5	1.0	1.0	123.55
124									Becomes very strong		II	R1				
									Calcareous, weathered zone 124.4-124.5 ft.				10	1.5	4.0	124.44-124.6
125																
126	0.14			18	RB-018	100	97									
127																
128																
													10	1.5	2.0	128.61
129									Becomes mottled with trace reddish brown			R4				
													10	2.0	1.0	129.59
130																
131				19	RB-019	100	100		Dark greenish gray, CLAYSTONE, laminated, slightly weathered, weak, sound, with light and dark gray mottling		II	R2				
132													10	1.5	2.0	131.89
													15	2.0	2.0	132.22
133																
134																
													30	2.0	1.5	134.51
135																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 11 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.16			20	RB-020	100	100		Dark greenish gray, CLAYSTONE, laminated, slightly weathered, weak, sound, with light and dark gray mottling [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				10	1.5	1.0	135.83
													15	1.5	1.0	136.48
137									136.81: γ = 147 pcf							
138																
139									Becomes weak			R5	10	3.0	1.0	138.78
									Becomes greenish gray and light gray, mottled							
140													10	1.5	1.0	140.09
	0.15			21	RB-021	89	79									
141																
142																
									Light brown, DOLOMITE, slightly weathered, strong, extremely fractured, crushed, with higher weathering around joints [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R4	15	1.5	4.0	142.39
143								CL								
144									Becomes strong			R4	70	1.0	6.0	143.7
													10	1.0	1.5	143.8
									Vertical fracture 144.2-146.6 ft.				15	1.0	1.0	143.9
													10	1.0	6.0	144.03
													15	1.5	1.5	144.13
145											II	R4	20	1.0	1.5	144.19
													75	1.0	6.0	144.49
									With extremely close fracture spacing at 145.3'.		III	R3				
146	0.22			22	RB-022	74	0									
147																
								CL								
148																
									Becomes highly weathered		III	R2-R3				
149																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 12 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
151	0.62			23	RB-023	27	0	CL								
152																
153																
154									Light brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, crushed, with higher weathering around joints, with coarse feldspar grains. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R3				
155																
156	0.82			24	RB-024	9	0	CL								
157																
158											II	R2				
159	0.07			25		100	0				II	R2				
160									Greenish gray and gray, CLAYSTONE, slightly weathered, weak, moderate to extremely close fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
161				26	RB-025	100	72									
162																
163																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 13 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
165									Greenish gray and gray, CLAYSTONE, slightly weathered, weak, moderate to extremely close fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
166	0.13			27	RB-026	97	97									
									166.54: PLA = 607 psi							
167																
168								CL	Becomes greenish gray and reddish brown, mottled		I-II	R2				
169									Becomes highly weathered, extremely close fracture spacing, moderately fractured		IV					
170									Becomes slightly weathered		II					
													0	1.0	1.0	170.21
													10	1.0	1.0	170.27
171				28	RB-027	100	98						0	1.0	1.0	171.06
172													0	1.0	1.0	171.91
									Becomes greenish gray and gray, laminated, weak to medium strong, moderate to close fracture spacing, at 172.6 ft.			R2-R3				
173											II	R2-R3				
													15	3.0	1.0	173.49
174																
													10	3.0	1.0	174.57
175																
	0.14			29	RB-028	100	100						10	3.0	1.0	175.49
176									176-181: Some Gypsum veining							
177																
													10	3.0	1.0	

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 14 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray and dark gray, CLAYSTONE, laminated, slightly weathered, weak to medium strong, moderate to close fracture spacing, sound		I-II	R2-R3	0	2.0	1.0	177.72 178.15
179									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0	3.0	1.0	179.13
180	0.14			30	RB-029	100	100									
181																
182																
183									Becomes greenish gray				5	3.0	1.0	183.07
184																
185									Becomes reddish brown							
186	0.16			31	RB-030	100	100						10 5	3.0 1.5	4.0 2.0	185.69 186.02
187											I-II	R2-R3	0	2.0	1.0	187.01
188									Becomes weak 187.99: γ = 146 pcf, PLL = 410 psi			R2				
189																
190	0.13			32	RB-031	100	73		Highly weathered, very to extremely weak, extremely fractured zone crushed to a gravelly clay 189.3-190.7 ft.		IV	R0-R1	10	1.5	4.0	189.96- 190.35
191									Becomes unweathered to slightly weathered, weak to medium strong		I-II	R2-R3	0 0	1.0 1.0	3.0 3.0	190.71 190.75

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-19
SHEET NUMBER: 15 of 15
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: KZ, CZ, CF, AM

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
193									Reddish brown, CLAYSTONE, laminated, unweathered to slightly weathered, weak to medium strong, wide fracture spacing, sound, most fractures possibly mechanical [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				5	1.0	2.0	192.45
194																
195																
196																
197	0.06			33		0	0	CL								
198																
199																
200																
201									End of Boring at 200.3' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). During grouting, several segments of NQ rod were sheared and grouted in place.The borehole was backfilled from the bottom of the boring to mudline.							
202																
203																
204																
205																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-21
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: C. Fischer, A. Moreland
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.82081 N Long: 84.76382 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 351.4 feet
DATUM: IGLD 1985
START DATE: 9/26/19 TIME: 8:00 am
FINISH DATE: 9/27/19 TIME: 12:00 pm

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1			NCD				0.0 - 13.6	163.78										Mudline is 230.3 ft. (70.2 m) below lake level.
2																		NCD down to 13.6 ft. to obtain first coring interval. No sample obtained.
3																		
4																		
5																		
6																		
7																		
8																		
9																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-21
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: C. Fischer, A. Moreland

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		Bentonite mud-seal obtained from core barrel.
15																		
16		0.11	G-S	1		RB-001	13.7 - 18.6	59.05	47.24	80								
17																		
18																		
19																		NCD down to 23.5 ft. to obtain next coring interval. No sample obtained.
20																		
21			NCD				18.6 - 23.5	59.05										
22																		
23																		(SM), NOTE: No Recovery. Driller reported SILTY SAND material.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-21
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: C. Fischer, A. Moreland

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25																		
26		0.33	G-S	2			23.5 - 28.4	59.05	0.00	0								
27																		
28																		Sandy, FAT CLAY, little Gravel, wet, (CH), cohesive, gravel is small and subrounded
29																		
30																		
31		0.16	G-S	3		RB-002	28.4 - 33.3	59.05	27.56	47								
32																		
33																		32.8: Field MC = 19.2% Reddish brown, FAT CLAY, wet, (CH), cohesive
34																		
35																		
36			G-S	4		RB-003	33.3 - 38.3	59.05	49.21	83								Reddish brown, ELASTIC SILT, little Gravel, wet, (MH), gravel is subrounded 36.1: Field MC = 38.0%
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-21
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: C. Fischer, A. Moreland

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		SANDY LEAN CLAY, little Gravel, wet, (CL), medium plasticity, gravel is subrounded
40																		
41			G-S	5		RB-004	38.3 - 43.2						59.05	49.21	83			41.0: Field MC = 24.3%
42																		
43																		Brown, LEAN CLAY, little Gravel, wet, (CL), medium plasticity, gravel is subrounded
44																		
45		0.25	G-S	6		RB-005	43.2 - 48.1						59.05	57.09	97			
46																		46.0: Field MC = 32.1%
47																		
48																		See Core Log. Brown, SANDY LEAN CLAY, little Gravel, wet, (CL)
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-21
SHEET NUMBER: 1 of 2
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: C. Fischer, A. Moreland
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.82081 N Long: 84.76382 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 351.4 feet
DATUM: IGLD 1985
START DATE: 9/26/19 TIME: 8:00 am
FINISH DATE: 9/27/19 TIME: 12:00 pm

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 230.3 ft. (70.2 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
49											II	R2				
50	0.08			7	RB-006	96	71		Reddish brown, CLAYSTONE, slightly weathered, weak to medium strong, wide fracture spacing, sound [POINTE AUX CHENES FORMATION]				0	1.50	1.00	50.59
51													30.00	1.50	1.00	51.57-51.67
52								CL								
53											II	R2				
54													30.00	1.50	1.00	54.2
55	0.06			8	RB-007	100	100						10.00 60.00	1.00 1.00	1.00 1.00	54.82 55.05-55.45
56									55.77: PLA = 1,400 psi				30.00	1.00	1.00	55.71
57													50.00 10.00	2.00 1.00	4.00 1.00	56.59 56.86
58											II	R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-21
SHEET NUMBER: 2 of 2
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: C. Fischer, A. Moreland

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
59									Reddish brown, CLAYSTONE, slightly weathered, weak to medium strong, wide fracture spacing, sound [POINTE AUX CHENES FORMATION, continued]				0	1.00	1.00	58.23
60	0.10			9	RB-008	100	100									
61									Becomes greenish gray							
62																
63									Becomes reddish brown, with occasional gypsum veins		II	R2				
64									0.25 in. gypsum-filled joint at 63.7 ft.							
65	0.11			10	RB-009	90	90		0.25 in. gypsum-filled joint at 64.3 ft. 64.63: PLL = 190 psi 0.25 in. gypsum-filled joint at 65.0 ft.							
66																
67								CL	0.25 in. gypsum-filled joint at 66.8 ft.							
68									End of Boring at 67.5' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
69																
70																
71																
72																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 1 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81904 N Long: 84.76448 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 345.9 feet
DATUM: IGLD 1985
START DATE: 8/11/19 TIME: 4:45 pm
FINISH DATE: 8/13/19 TIME: 6:00 pm

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
0																		Mudline is 235.83 ft. (71.9 m) below lake level. NCD down to 18.8'. No sample obtained.
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9			NCD	001			0.0 - 18.8	225.19										

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 2 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19			NCD	002			18.8 -	118.5										NCD down to 28.6' to obtain first coring interval. No sample obtained.
20																		
21																		
22																		
23																		

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 3 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25							28.6											
26																		
27																		
28																		
29																		GRAVEL, wet, (GW), mixed igneous, metamorphic, and limestone, subangular to subrounded
																		Reddish brown, LEAN CLAY, moist, (CL), slight plasticity
30																		
31			G-S	001		RB-001	28.7 - 33.6	59.05	27.95	47								
32																		
33																		
34																		NCD down to 53.3 ft. No sample obtained.
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 4 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39			NCD	003			33.6 - 53.3					236.22						
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47																		
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 5 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53																		
54		0.12	G-S	002			53.3 - 55.2	23.62	0.00	0								NOTE: No recovery.
55																		NCD down to 57.4 ft. No sample obtained.
56			NCD	004			55.2 - 57.4	25.59										
57																		NOTE: No recovery.
58																		
59																		
60		0.11	G-S	003			57.4 - 62.3	59.05	0.00	0								
61																		
62																		NCD down to 68.0'. No sample obtained.
63																		
64																		
65			NCD	005			62.3 - 68.0	68.9										

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 6 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		Reddish brown, SILTY SAND, with trace Gravel, wet, (SM), calcareous
69																		
70		0.98	G-S	004	RB-002		68.0 - 72.9	59.05	23.62	40								
71																		
72																		
73																		NCD down to 92.6'. No sample obtained.
74																		
75																		
76																		
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 7 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82																		
83			NCD	006			72.9 - 92.6	236.22										
84																		
85																		
86																		
87																		
88																		
89																		
90																		
91																		
92																		
93																		Reddish brown, SILTY CLAYEY SAND, with Fine Gravel, wet, (SC-SM), calcareous

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 8 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95		0.98	G-S	005	RB-003		92.6 - 97.5						59.05	48.42	82			Reddish brown, SILTY CLAYEY SAND, with Fine Gravel, wet, (SC-SM), calcareous
96																		
97																		
98																		NCD down to 107.4'. No sample obtained.
99																		
100																		
101																		
102			NCD	007			97.5 - 107.4						118.11					
103																		
104																		
105																		
106																		
107																		Red, SILTY SAND, wet, (SM), with poorly graded subangular to subrounded Gravel, sample was washed out

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 9 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		
110		0.98	G-S	006			107.4 - 112.3	59.05	0.00	0								Red, SILTY SAND, wet, (SM), with poorly graded subangular to subrounded Gravel, sample was washed out
111																		
112																		NCD down to 122.2'. No sample obtained.
113																		
114																		
115																		
116																		
117			NCD	008			112.3 - 122.2	118.11										
118																		
119																		
120																		
121																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 10 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		Red, SILTY SAND, with Gravel, wet, (SM), gravel contained mixed igneous, metamorphic, and limestone, angular to subrounded
124			G-S	007		RB-004	122.2 - 127.1	59.05	9.06	15								
125																		
126																		
127																		
128		0.33																Red, SILT, with Gravel, wet, (ML), gravel is poorly graded, contained mixed igneous, metamorphic, and limestone, angular to subrounded
129			G-S	008		RB-005	127.1 - 132.0	59.05	13.78	23								
130																		
131																		
132																		Reddish brown, SILTY SAND, with Gravel, wet, (SM), primarily igneous and metamorphic gravel clasts, few limestone, angular to subrounded
133																		
134		0.49	G-S	009		RB-006	132.0 - 136.9	59.05	21.65	37								
135																		

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 11 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137																		Reddish brown, SILTY SAND, with Gravel, wet, (SM), primarily igneous and metamorphic gravel clasts, few limestone, angular to subrounded
138																		GRAVEL, and Cobble, wet, (GP), mostly Limestone, some traces of silty sand matrix on gravel, angular to subrounded
139		0.49	G-S	010			136.9 - 141.8	59.05	0.00	0								
140																		
141																		
142																		
143																		
144		0.08	G-S	011		RB-007	141.8 - 146.8	59.05	9.84	17								
145																		
146																		
147																		Gray, COBBLE, and Boulders, wet, (GP), mostly limestone, but mixed igneous and metamorphic rocks present, angular to subrounded
148																		
149		0.09	G-S	012		RB-008	146.8 - 150.7	47.24	15.75	33								

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 12 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151																		
152																		
153		0.07	G-S	013	RB-009		150.7 - 155.6						59.05	10.63	18			Gray, COBBLE, and Boulders, wet, (GP), mostly limestone, but mixed igneous and metamorphic rocks present, angular to subrounded
154																		
155																		See Core Log.
156																		
157																		
158																		
159																		
160																		
161																		
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 1 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81904 N Long: 84.76448 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 345.9 feet
DATUM: IGLD 1985
START DATE: 8/11/19 TIME: 4:45 pm
FINISH DATE: 8/13/19 TIME: 6:00 pm

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 235.8 ft. (71.9 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
156	0.08			014	RB-010	100	100		Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, wide fracture spacing, sound, occasional gypsum inclusions, moderate fracture spacing [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		II	R2	30	3.0	3.0	156.33
157													20	2.0	1.0	157.08
158													20	2.0	1.0	157.77
159													0	2.0	1.0	158.95
160													0	2.0	1.0	159.64
161	0.07			015	RB-011	100	100		1-inch gypsum vein at 161.1 ft.				20	1.5	4.0	161.18
162													20	1.5	4.0	161.93
163									Becomes mostly greenish gray							
164									2-inch gypsum layer at 164.1 ft.				20	1.5	2.0	163.94

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 2 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray, CLAYSTONE, slightly weathered, weak, wide fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II III	R2 R1	0	1.5	2.0	165.22
166																
167													30	3.0	3.0	166.96
168	0.08			016	RB-012	63	47									
169								CL								
170																
171				017	RB-013	100	100									
172									Becomes reddish brown, very to extremely weak		II	R2				
173													20	3.0	2.0	173.39
174	0.08			018	RB-014	100	100		173.56: γ = 134 pcf, UCS = 1,262 psi							
175									0.4-inch gypsum layer at 175.2 ft.				0	2.0	2.0	175.23
176													0	2.0	2.0	175.75
177													20	3.0	2.0	177.23
178													30	3.0	2.0	178.02
	0.11			019	RB-015	98	98						20-40	3.0	2.0	178.57

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 3 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Becomes mostly greenish gray		II	R2	0	3.0	2.0	179.16
180									Greenish gray, CLAYSTONE, slightly weathered, very to extremely weak, wide fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
									180.12: PLA = 1,290 psi				10	3.0	2.0	180.04
													0	3.0	2.0	180.61
181								CL								
									Becomes weak, slightly fractured to sound			R2				
182																
									Becomes very to extremely weak			R2	10	3.0	2.0	182.18
183																
	0.08			020	RB-016	100	100									
184									Becomes mostly reddish brown							
													0	3.0	2.0	184.44
185													5	2.0	1.0	184.83
186																
											II	R2				
187									Gypsum veining, breccia clasts visible throughout the run							
									Becomes mostly greenish gray				0	1.5	1.0	187.03
188																
	0.06			021	RB-017	100	100									
189																
190																
									190.29: PLA = 1,300 psi				0	1.5	1.0	190.28
													0	2.0	1.0	190.81
191																
192													5	3.0	2.0	

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 4 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.08			022	RB-018	100	100		Greenish gray, CLAYSTONE, slightly weathered, very to extremely weak, wide fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2	5	3.0	2.0	192.74 193.20
194																
195									Extremely fractured 194.8-195.3 ft. 194.88: PLA = 2,630 psi NOTE: 2.3-inches of Run 22/Box 18 placed in Box 19.				0	3.0	2.0	195.56
196											II	R1-R2				
197																
198				023	RB-019	100	100		Becomes mottled greenish gray and reddish brown, close fracture spacing, moderately fractured, breccia clasts visible				20 20	3.0 3.0	1.0 1.0	198.29 198.61
199																
200																
201									Becomes extremely weak to weak			R0-R2				
202																
203				024	RB-020	100	83									
204																
									4-inch possible GNEISS corestone 204.5-205.8 ft.				5	1.0	1.0	204.49
205																
206									Dark gray, DOLOMITE, slightly weathered, weak, very close fracture spacing, argillaceous, extremely fractured [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA] 206.69: PLA = 3,870 psi		II	R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 5 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
208				025	RB-021	73	49		Dark gray, DOLOMITE, slightly weathered, weak, close fracture spacing, sound, possibly mechanical breaks 207.2-207.5 ft. [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued] Becomes wide fracture spacing, sound		II	R2	0	4.0	3.0	207.34
209																
210								CL								
211	0.08								Becomes medium strong, extremely close fracture spacing, extremely fractured		II	R2				
212									Becomes moderate fracture spacing, sound			R2				
213				026	RB-022	100	73									
214																
215									215.22: PLA = 1,610 psi							
216																
217									Mechanically broken zone 216.8- 217.7 ft. 216.86: PLA = 402 psi							
218	0.08			027	RB-023	100	83									
219													0	3.0	2.0	219.39
220									Becomes weak			R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 6 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark gray, DOLOMITE, slightly weathered, weak, close fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2	10	2.0	2.0	221.36
222																
223	0.08			028	RB-024	100	80		223: Increased gypsum veining.				0	3.0	2.0	222.83
224																
225									Extremely weathered, extremely weak, CLAY 224.6-225.0 ft.		V	R0	10	3.0	2.0	224.64
226									Becomes reddish brown, moderately weathered, very weak		III	R3				
227																
228	0.16			029	RB-025	97	7		Slightly weathered, medium strong, gray and black, Argillaceous DOLOMITE with some gypsum, horizontal bedding 228.0-229.0 ft. 228.67: PLA = 11,000 psi		II	R3				
229									Becomes extremely weathered, very weak, very close fracture spacing, LEAN CLAY, extremely fractured, locally crushed, with moderately weathered, angular DOLOMITE fragments		II	R3				
230								CL								
231																
232									Becomes dark gray, unweathered, weak, argillaceous, sound		I	R2				
233	0.09			030	RB-026	59	17									
234								CL	Becomes extremely weathered, very weak		V	R1				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-23
SHEET NUMBER: 7 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
236									Dark gray, DOLOMITE, thinly bedded, unweathered, strong, moderate fracture spacing, sound, with 45° bedding [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		I	R4				
									235.56: PLA = 4,490 psi, γ = 144 pcf, UCS = 3,903 psi							
237																
				031	RB-027	92	48		Becomes light gray, moderately weathered, very weak, with turbidite texture		I	R3				
238									Becomes highly weathered, extremely weak, very close fracture spacing, extremely fractured, locally crushed, with slightly weathered, weak DOLOMITE fragments		III	R1				
239																
240								CL								
											II-VI	R0-R2				
241																
242																
				032	RB-028	100	45									
243																
									Mottled greenish gray and reddish brown, CLAYSTONE, slightly weathered, very to extremely weak, sound, with occasional gypsum inclusions and some breccia clasts [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
244																
245																
									End of Boring at 245.18'							
246									The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
247																
248																

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 1 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81837 N Long: 84.76592 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 339.5 feet
DATUM: IGLD 1985
START DATE: 8/7/19 TIME: 12:00 am
FINISH DATE: 8/14/19 TIME: 12:00 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1			NCD	1			0.0 - 12.1	145.68										NOTE: Mudline is 242.2 ft. (71.9 m) below lake level. NCD down to 12.1'. No sample obtained.
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 2 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		Brown, medium grained, POORLY GRADED SAND, wet, (SP), with some fines, subangular to subrounded
13																		
14		0.11	G-S	001	RB-001		12.1 - 17.1	59.05	33.46	57								Reddish brown, LEAN CLAY with SILT, wet, (CL), calcareous
15																		
16																		
17																		NCD down to 22.0 ft. No sample obtained.
18																		
19			NCD	001			17.1 - 22.0	59.05										
20																		
21																		
22																		Reddish brown, LEAN CLAY with SILT, wet, (CL), calcareous
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 3 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25		0.08	G-S	002		RB-002	22.0 - 26.9						59.05	55.12	93			Reddish brown, LEAN CLAY with SILT, wet, (CL), calcareous
26																		NOTE: Trace gravel at end of Sample Geobor-S-002. Driller noted possible cobbles at end of run.
27			NCD															NCD down to 31.8 ft. No sample obtained.
28				002			26.9 - 31.8						59.05					
29																		
30																		
31																		
32		0.08	G-S	003		RB-003	31.8 - 36.7						59.05	0	0			POORLY GRADED GRAVEL, and Cobble, wet, (GP), mixed lithology, subangular to subrounded. Sand appeared to be washed out of sample.
33																		
34																		
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 4 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39		0.12	G-S	004			36.7 - 41.7	59.05	11.81	20								POORLY GRADED GRAVEL, and Cobble, wet, (GP), mixed lithology, subangular to subrounded. Sand appeared to be washed out of sample.
40																		
41																		
42			NCD	003			41.7 - 46.6	59.05										NCD down to 46.6 ft. No sample obtained.
43																		
44																		
45																		
46																		
47		0.22	G-S	005		RB-004	46.6 - 49.9	39.37	11.81	30								Reddish brown, POORLY GRADED GRAVEL, and Cobble, wet, (GP), angular to subrounded, mixed lithology
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 5 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53		0.15	G-S	006		RB-005	49.9 - 54.8	59.05	11.81	20								Reddish brown, POORLY GRADED GRAVEL, and Cobble, wet, (GP), angular to subrounded, mixed lithology
54																		
55																		NCD down to 64.6 ft. No sample obtained.
56																		
57																		
58																		
59																		
60			NCD	004			54.8 - 64.6	118.11										
61																		
62																		
63																		
64																		
65																		Reddish brown, SILTY CLAYEY SAND, trace Gravel, wet, (SC-SM)

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 6 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67		0.70	G-S	007		RB-006	64.6 - 69.6						59.05	47.24	80			Reddish brown, SILTY CLAYEY SAND, trace Gravel, wet, (SC-SM)
68																		
69																		
70			NCD	005			69.6 - 76.1						78.74					NCD down to 76.1 ft. No sample obtained.
71																		
72																		
73																		
74																		
75																		
76																		
77		0.33	G-S	008		RB-007	76.1 - 81.0						59.05	59.05	100			Reddish brown, SILTY SAND, wet, (SM), calcareous
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 7 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		Reddish brown, SILTY SAND, wet, (SM), calcareous
82																		
83																		
84		0.70	G-S	009		RB-008	81.0 - 86.0						59.05	49.21	83			
85																		
86																		NCD down to 95.8 ft. No sample obtained.
87																		
88																		
89																		
90																		
91			NCD	006			86.0 - 95.8						118.11					
92																		
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 8 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95																		
96																		Reddish brown, SILT, wet, (ML), calcareous
97																		
98		0.62	G-S	010		RB-009	95.8 - 100.7	59.05	47.24	80								
99																		
100																		
101																		NCD down to 110.6 ft. No sample obtained.
102																		
103																		
104																		
105			NCD	007			100.7 - 110.6	118.11										
106																		
107																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 9 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		
110																		
111																		Reddish brown, SANDY SILT, with trace Fine Gravel, wet, (ML)
112																		
113		0.22	G-S	011		RB-010	110.6 - 115.5						59.05	52.36	89			
114																		
115																		
116																		NCD down to 125.3 ft. No sample obtained.
117																		
118																		
119																		
120			NCD	008			115.5 - 125.3						118.11					
121																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 10 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		
124																		
125																		
126		0.31	G-S	012		RB-011	125.3 - 130.3	59.05	11.81	20								Reddish brown, SILTY CLAYEY GRAVEL with SAND, wet, (GC-GM)
127																		
128																		
129																		
130																		NOTE: reddish brown silty clayey gravel with sand
131		0.49	G-S	013		RB-012	130.3 - 135.2	59.05	15.75	27								
132																		
133																		
134																		
135																		Reddish brown, SILTY SAND, with little Gravel, wet, (SM)

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 11 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137		0.70	G-S	014		RB-013	135.2 - 140.1	59.05	59.05	100								
138																		
139																		
140		0.49	G-S	015		RB-014	140.1 - 145.0	59.05	45.28	77								
141																		
142																		
143																		
144																		
145		0.14	G-S	016		RB-015	145.0 - 146.7	19.68	19.68	100								Reddish brown, LEAN CLAY, little Sand, little Silt, wet, (CL), sand is fine grained, few gravel
146																		
147		0.14	G-S	017		RB-016	146.7 - 151.6	59.05	55.12	93								Gray, LEAN CLAY, wet, (CL), with subrounded gravel, occasional cobble, and medium-grained sand lenses
148																		
149																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24
SHEET NUMBER: 12 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: K. Smith, B. Postans
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151																		
152																		Brownish gray, SILTY CLAY, with Sand, with Gravel, wet, (CL)
153																		
154		0.16	G-S	018		RB-017	151.6 - 156.5	59.05	44.88	76								Brown, FAT CLAY, with Silt, wet, (CH)
155																		NOTE: wet, Gravel seam.
156																		NOTE: Greenish gray, gray and blue cobbles - mixed lithology.
157																		End of boring at 156.5 feet. The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline..
158																		
159																		
160																		
161																		
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 1 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81814 N Long: 84.76479 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 356.7 feet
DATUM: IGLD 1985
START DATE: 9/4/19 TIME: 12:10 pm
FINISH DATE: 9/8/19 TIME: 12:00 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1		0.24	G-S	1			0.0 - 2.8	33.86	0	0								Mudline is 225.0 ft. (68.6 m) below lake level.
2																		No recovery. Sample was washed out.
3																		NCD down to 19.7 ft. No sample was obtained.
4																		
5																		
6																		
7																		
8																		
9																		

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 2 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11			NCD				2.8 - 19.7	202.36										
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		Brown, Sandy, LEAN CLAY, soft, wet, (CL)
21																		
22			G-S	2		RB-001	19.7 - 24.6	59.05	51.18	87								
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 3 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
																		Brown, LEAN CLAY, soft, wet, (CL)
																		NCD down to 44.6 ft. No sample was obtained.
25																		
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35			NCD				24.6 - 44.6	240.15										
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 4 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40																		
41																		
42																		
43																		
44																		
45																		Reddish brown, SANDY SILTY CLAY, soft, wet, (CL-ML), low plasticity, calcareous
46																		
47		1.23	G-S	3		RB-002	44.6 - 49.5	59.05	59.05	100								
48																		
49																		
50																		NCD down to 67.3 ft. No sample was obtained.
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 5 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53			NCD				49.5 - 67.3						212.6					
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 6 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		Reddish brown, fine to medium grained, SILTY SAND, trace Gravel, wet, (SM), calcareous
69																		
70			G-S	4		RB-003	67.3 - 72.2	59.05	20.47	35								
71																		
72																		NCD down to 91.9 ft. No sample was obtained.
73																		
74																		
75																		
76																		
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 7 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82			NCD				72.2 - 91.9	236.22										
83																		
84																		
85																		
86																		
87																		
88																		
89																		
90																		
91																		
92																		Reddish brown, SILTY SAND, trace Gravel, wet, (SM), calcareous
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 8 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95		1.64	G-S	5		RB-004	91.9 - 96.8						59.05	56.69	96			Reddish brown, SILTY SAND, trace Gravel, wet, (SM), calcareous
96																		
97																		NCD down to 116.5 ft. No sample was obtained.
98																		
99																		
100																		
101																		
102																		
103																		
104																		
105																		
106			NCD				96.8 - 116.5						236.22					
107																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 9 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		
110																		
111																		
112																		
113																		
114																		
115																		
116																		
117		0.70	G-S	6		RB-005	116.5 - 121.4	59.05	59.05	100								Reddish brown, SILTY CLAYEY SAND, trace Gravel, wet, (SC-SM), calcareous
118																		
119																		
120																		
121																		NCD down to 141.1 ft. No sample was obtained.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 10 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		
124																		
125																		
126																		
127																		
128																		
129																		
130																		
131			NCD				121.4 - 141.1	236.22										
132																		
133																		
134																		
135																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 11 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137																		
138																		
139																		
140																		
141																		
142		0.82	G-S	7		RB-006	141.1 - 146.0	59.05	50.79	86								Reddish brown, SILTY SAND, trace Cobbles, moist, (SM)
143																		
144																		
145																		
146																		NCD down to 155.8 ft. No sample was obtained.
147																		
148																		
149																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 12 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151			NCD				146.0 - 155.8						118.11					
152																		
153																		
154																		
155																		
156		0.45	G-S	8		RB-007	155.8 - 160.8						59.05	29.13	49			Reddish brown, POORLY GRADED SAND, some Gravel, dense, wet, (SP)
157																		Reddish brown, CLAYEY SAND with Gravel, moist, (SC), occasional small Cobbles, calcareous
158																		
159																		
160																		
161																		NCD down to 169.9 ft. No sample was obtained.
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 13 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
165			NCD				160.8 - 169.9	110.23										
166																		
167																		
168																		
169																		
170																		Reddish brown, LEAN CLAY, with Gravel, stiff, moist, (CL), calcareous, gravel is subangular to rounded
171			G-S	9			169.9 - 173.5	43.31	14.57	34								
172																		
173																		
174						RB-008												Reddish brown, CLAYEY SAND with Gravel, moist, (SC), calcareous
175																		
176		0.41	G-S	10			173.6 - 178.5	59.05	21.65	37								
177																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 14 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
179																		Reddish brown, LEAN CLAY, some Fine To Coarse Grained Sand, little Fine To Coarse Gravel, stiff, moist, (CL), calcareous
180																		
181			G-S	11		RB-009	178.5 - 183.4						59.05	59.05	100			
182																		Reddish brown, LEAN CLAY, little Fine Sand, stiff, moist, (CL)
183																		
184																		Reddish brown, LEAN CLAY, trace Fine Sand, very stiff, moist, (CL)
185																		
186			G-S	12		RB-010	183.4 - 188.3						59.05	52.76	89			
187																		
188																		
189																		
190																		
191		0.21	G-S	13		RB-011	188.3 - 193.2						59.05	57.09	97			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 15 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
193																		Reddish brown, LEAN CLAY, trace Fine Sand, very stiff, moist, (CL)
194																		
195		0.26	G-S	14		RB-012	193.2 - 198.2						59.05	55.51	94			
196																		
197																		
198																		
199																		
200		0.31	G-S	15		RB-013	198.2 - 203.1						59.05	41.34	70			
201																		
202																		Reddish brown, fine to coarse grained, CLAYEY SAND, some Silty Clay, little Fine Gravel, wet, (SC)
203																		
204																		Reddish brown, LEAN CLAY, little Fine Sand, moist, (CL)
205		0.31	G-S	16		RB-014	203.1 - 208.0						59.05	49.61	84			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 16 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
207																		Reddish brown, LEAN CLAY, little Fine Sand, moist, (CL)
208																		
209																		
210		0.38	G-S	17		RB-015	208.0 - 212.9						59.05	55.51	94			
211																		Becomes with some Fine To Coarse Grained Sand, little Fine To Coarse Gravel, moist
212																		
213																		NOTE: No recovery for G-S 018; driller reported boulder obstruction.
214																		
215			G-S	18			212.9 - 217.8						59.05	0.00	0			
216																		
217																		
218																		Granite boulder piece
219																		NOTE: Driller reported slough from last run (mixed sand and gravel).
																		Grayish brown, LEAN CLAY, some Sand, little Gravel, medium stiff, moist, (CL)

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 17 of 17
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
221			G-S	19		RB-016	217.8 - 222.8	59.05	40.55	69								Mottled brown and gray, LEAN CLAY, some Sand, little Gravel, moist, (CL), occasional cobble and mudstone pieces
222																		See Core Log.
223																		
224																		
225																		
226																		
227																		
228																		
229																		
230																		
231																		
232																		
233																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81814 N Long: 84.76479 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 356.7 feet
DATUM: IGLD 1985
START DATE: 9/4/19 TIME: 12:10 pm
FINISH DATE: 9/8/19 TIME: 12:00 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S, HQ3
O.D.: Geobor-S, HQ3
I.D.: Geobor-S, HQ3
CASING SIZE: " (")

NOTES:
Mudline is 225.0 ft. (68.6 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
223									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]				5	3.0	2.0	223.09
224									Light brown and black, DOLOMITE, laminated, slightly weathered, medium strong, very close fracture spacing, with occasional calcite inclusions Shale parting at 224.4'		II	R3				
225				20	RB-017	100	89						10	3.0	2.0	225.26
226									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, occasional zones of iron staining Horizontal fracture/parting with thin layer of medium sand.				10	3.0	6.0	226.54
227											II	R2				
228											II	R2				
229													10	3.0	2.0	228.90
230				21	RB-018	100	93						0	3.0	2.0	230.05
231									230.97: γ_d = 139 pcf, UCS = 1,657 psi, ω = 3.25%				10	3.0	2.0	231.26

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
233									Light brown and black, DOLOMITE, laminated, slightly weathered, medium strong, very close fracture spacing, extremely fractured with horizotal fractures, CALCITE and Fe precipitation on fracture/bedding surfaces		II	R2	0	3.0	1.0	232.74
													0	1.0	1.0	233.00
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0	1.5	4.0	233.53-234.09
234									234.25: PLA = 2,450 psi							
													0	1.0	1.0	234.45
235	0.15			22	RB-019	99	85		Becomes moderately weathered, very weak, with gypsum inclusions		III	R1	0	1.0	1.0	234.91
									Greenish gray, CLAYSTONE, breccia, with piece of light grayish brown dolomite				0	1.0	1.0	235.30
236													0	2.0	1.0	235.69
237													0	2.0	1.0	236.87
								CL								
238													0	2.0	1.0	238.28
													0	2.0	1.0	238.51
239													0	2.0	1.0	238.71
													0	1.0	6.0	239.04
240	0.27			23	RB-020	88	14		Becomes highly weathered, extremely weak, brecciated and healed		IV	R0	0	1.0	6.0	239.37
													0	1.0	6.0	239.50
241																
									Becomes slightly weathered, weak		II	R2				
242								CL					0	1.0	1.0	241.66
									Brown, CLAYSTONE, laminated, slightly weathered, weak, very close fracture spacing, extremely fractured with horizontal fractures		II	R2				
243																
									243.11: γ = 142 pcf, UCS = 497 psi	P5	III-IV		10	1.0	6.0	243.17
244									Becomes gray, moderately to highly weathered, very close to moderate fracture spacing, moderately fractured, with subhorizontal bedding							
													10	3.0	3.0	244.26
													75	1.5	3.0	244.52
245	0.33			24	RB-021	57	28		Brownish gray, DOLOMITE, close fracture spacing, moderately fractured, medium to fine grained		III	R2	15	3.0	3.0	244.65
													30	3.0	3.0	244.94
													0	1.0	6.0	245.08
													5	3.0	4.0	245.24

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
247								CL	Greenish gray and reddish brown, CLAYSTONE, highly weathered, weak, very close to wide fracture spacing, [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0	1.0	6.0	247.37
248																
249																
250	0.19			25	RB-022	100	91		Becomes moderately to highly weathered, very weak to weak, very close to wide fracture spacing, locally brecciated and healed, with bedding 0-45° 249.34: PLA = 916 psi		III-IV	R1-R2				
251													0 20	3.0 3.0	4.0 3.0	250.95 251.11
252													10 0 10	3.0 1.0 1.0	3.0 6.0 6.0	252.03 252.29 252.36
253									Becomes gray, very to extremely weak, very close to moderate fracture spacing, dolomitic			R0-R1				
254													0	3.0	4.0	253.61
255	0.17			26	RB-023	99	57		Gray, DOLOMITE, slightly weathered, medium strong, very close to wide fracture spacing, slightly fractured to sound, locally brecciated and healed with occasional gypsum inclusions	P4			10 10	1.0 1.0	6.0 6.0	254.33 254.52
256											III-IV	R0-R1	10	1.0	6.0	256.33
257								CL	257.22: PLA = 1,800 psi		IV	R1	0	1.5	3.0	257.21
258													0	3.0	4.0	258.49
259	0.18			27	RB-024	100	100		Greenish gray and reddish brown, CLAYSTONE, moderately to highly weathered, weak, close to moderate fracture spacing, slightly fractured to sound, with angular DOLOMITE corestones and occasional calicite veins							

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
261									Greenish gray and reddish brown, CLAYSTONE, moderately to highly weathered, weak, close to moderate fracture spacing, slightly fractured to sound, with angular DOLOMITE corestones and occasional calicite veins [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0	3.0	4.0	260.89
262													0	1.5	4.0	261.81
									Becomes moderately to highly weathered, with wavy, thin bedding		III-IV		5	1.5	3.0	262.14
263																
264													5	1.5	3.0	263.78
				28	RB-025	100	100			P3						
265																
266													15	1.5	3.0	265.91
													40	3.0	3.0	266.53
267									With close to wide fracture spacing				5	3.0	3.0	267.06
													0	3.0	3.0	267.22
268													0	3.0	3.0	267.84
269													5	1.5	4.0	269.03
													35	3.0	4.0	269.26
				29	RB-026	100	90		269.69: PLA = 705 psi, γ = 139 pcf, UCS = 1,949 psi				25	3.0	3.0	269.78
270									Gray, CLAYSTONE, slightly to highly weathered, very to extremely weak, close to wide fracture spacing, moderately fractured to sound, locally brecciated and healed, with bedding 0-45°		III-IV	R0-R1				
271																
272													5	1.5	3.0	271.91
									Wide fracture spacing, slightly fractured				10	1.5	3.0	271.98
273																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
275	0.14			30	RB-027	100	94		[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]	P2						
276									Becomes gray, moderately weathered, weak, wide fracture spacing, sound		III	R2				
277									276.57: PLA = 1,660 psi				45	3.0	3.0	276.51
													0	3.0	3.0	276.57
													0	3.0	3.0	276.74
													5	3.0	3.0	276.90
278																
279	0.14			31	RB-028	100	100						0	3.0	2.0	279.26
280																
281																
282									Becomes white and light gray, laminated, medium strong, close to moderate fracture spacing, slightly fractured, with subhorizontal bedding			R3	0	3.0	3.0	281.82
									281.82: PLA = 5,960 psi				0	1.5	2.0	282.31
283									Gray, weak, wide fracture spacing, sound			R2	5	1.5	2.0	282.48
284	0.22			32	RB-029	100	97		Gray, CLAYSTONE, laminated, moderately weathered, weak, close to wide fracture spacing, sound	P1	III	R2				
285																
286																
287													0	1.5	2.0	286.74

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									288.06: PLA = 4,750 psi, γ = 140 pcf, UCS = 1,612 psi							
289	0.18			33	RB-030	100	100		Becomes gray and brown, laminated, moderately to highly weathered, very weak to weak, close to wide fracture spacing, sound, trace gypsum stringers [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		III-IV	R1-R2				
290													0	2.0	3.0	289.63
291													5	1.0	3.0	291.24
292	0.18			34	RB-031	100	100		Becomes reddish brown and greenish gray, wide fracture spacing, sound, with faint, subhorizontal bedding and occasional angular, DOLOMITE inclusions and gypsum veins				0	3.0	3.0	291.66
293													0	3.0	2.0	292.98
294													10	3.0	2.0	294.12
295													10	3.0	2.0	294.75
296													20	3.0	2.0	295.67
297	0.20			35	RB-032	100	100		296.59: PLA = 4,230 psi, γ = 142 pcf, UCS = 2,845 psi							
298									Reddish brown and greenish gray, CLAYSTONE, laminated, moderately to highly weathered, very weak to weak, close to wide fracture spacing, sound		III-IV	R1-R2				
299																
300									Becomes moderately weathered, weak, brecciated and healed with calcite		III	R2	5	3.0	2.0	300.13
301													40	3.0	3.0	301.08
									Light gray, DOLOMITE, thinly, slightly to moderately weathered, medium strong, MODERATE fracture spacing,		II-III	R3	20	1.5	3.0	301.51

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									sound				5	2.0	1.0	302.06
303									CLAYSTONE, moderately weathered, weak, wide fracture spacing, sound, with occastional DOLOMITE corestones [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		III	R2	0	1.5	1.0	302.92
304				36	RB-033	100	100									
											II-III	R3	0	1.5	1.0	304.72
305									Greenish gray, CLAYSTONE, moderately weathered, weak, close to moderate fracture spacing, slightly fractured		III	R2	15	3.0	3.0	305.21
306									306.10: PLA = 8,380 psi				30	3.0	2.0	306.20
									Becomes reddish brown and greenish gray, moderately to highly weathered, wide fracture spacing, sound, with subhorizontal bedding		III-IV					
307																
308																
													0	3.0	3.0	308.53
309				37	RB-034	97	86									
310																
									Close fracture spacing, moderately fractured 310.6-311.2'				5	3.0	3.0	310.59
311									311.02: PLA = 724 psi							
								CL	With moderate to wide fracture spacing				0	2.0	4.0	311.22
													0	2.0	6.0	311.41
312									Greenish gray, CLAYSTONE, moderately weathered, weak, moderate to wide fracture spacing, slightly fractured		III-IV	R2				
313													5	1.5	3.0	312.96
314	0.14			38	RB-035	99	99						25	3.0	4.0	314.04
315																
													0	3.0	3.0	315.65

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-24A
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL	End of Boring at 316.27' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). During grouting, several segments of NQ rod were sheared with some segments embedded in the borehole and some left on the lakebed. The borehole was backfilled from the bottom of the boring to mudline.				0	2.0	3.0	316.2
317																
318																
319																
320																
321																
322																
323																
324																
325																
326																
327																
328																
329																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 1 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81727 N Long: 84.76514 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 398.0 feet
DATUM: IGLD 1985
START DATE: 10/13/19 TIME: 12:00 am
FINISH DATE: 10/16/19 TIME: 12:00 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1																		Mudline is 183.66 ft. (55.98 m) below lake level. NCD down to 70.50'. No sample obtained.
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 2 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 3 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25			NCD				0.0 - 70.5	846.45										
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 4 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47																		
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 5 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53																		
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 6 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		
69																		
70																		
71		0.70	G-S	1		RB-001	70.5 - 75.5	59.05	13.78	23								Brownish gray, fine to medium grained, SILTY SAND, wet, (SM)
72																		
73																		
74																		
75																		74.6: Field MC = 14.7%
76																		NCD down to 85.3'. No sample was obtained.
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 7 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81			NCD				75.5 - 85.3						118.11					
82																		
83																		
84																		
85																		
86		0.70	G-S	2		RB-002	85.3 - 90.2						59.05	53.94	91			Reddish brown, LEAN CLAY with SAND, moist, (CL)
87																		86.9: Field MC = 19.0%
88																		
89																		
90																		
91																		NCD down to 95.1'. No sample was obtained.
92																		
93			NCD				90.2 - 95.1						59.05					

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 8 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95																		
96																		Brownish gray, fine to medium grained, CLAYEY SAND, wet, (SC), dense
97		0.98	G-S	3		RB-003	95.1 - 100.1						59.05	43.31	73			
98																		98.4: Field MC = 15.7%
99																		
100																		Reddish brown, SILTY SAND, wet, (SM), loose
101																		
102		1.23	G-S	4		RB-004	100.1 - 105.0						59.05	59.05	100			101.7: Field MC = 18.6%
103																		
104																		
105																		Reddish brown, SILT, with some, moist, (ML), fine to medium grained Sand
106																		
107			G-S	5		RB-005	105.0 - 109.9						59.05	56.30	95			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 9 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		Reddish brown, SILT, with some, moist, (ML), fine to medium grained Sand 108.3: Field MC = 19.7%
110		1.23	G-S	6		RB-006	109.9 - 114.8						59.05	38.19	65			Reddish brown, LEAN CLAY with SAND, with trace Gravel, wet, (CL), medium plasticity
111																		
112																		
113																		Reddish brown, SILTY SAND, wet, (SM) 113.2: Field MC = 18.2%
114																		
115		0.98	G-S	7		RB-007	114.8 - 119.8						59.05	33.07	56			
116																		116.5: Field MC = 16.2%
117																		
118																		
119																		
120																		Brown, SANDY SILTY CLAY, moist, (CL-ML), little subrounded Gravel, calcareous
121																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 10 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123		1.23	G-S	8		RB-008	119.8 - 124.7						59.05	5.91	10			
124																		124.3: Field MC = 16.3%
125		0.70	G-S	9		RB-009	124.7 - 129.6						59.05	57.09	97			
126																		
127																		127.3: Field MC = 18.5%
128																		
129																		
130		0.98	G-S	10		RB-010	129.6 - 134.5						59.05	59.05	100			
131																		131.2: Field MC = 14.0%
132																		
133																		
134																		
135																		Brown, SANDY SILTY CLAY, moist, (CL-ML), little subrounded Gravel, calcareous

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 11 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137		1.23	G-S	11		RB-011	134.5 - 139.4						59.05	59.05	100			
138																		
139																		138.8: Field MC = 14.0%
140																		Brown, CLAYEY SAND, moist, (SC), calcareous
141																		141.1: Field MC = 14.2%
142		0.49	G-S	12		RB-012	139.4 - 144.4						59.05	59.05	100			
143																		
144																		
145																		Brown, SANDY SILTY CLAY, moist, (CL-ML), with few fine to coarse subrounded Gravel
146																		146.3: Field MC = 14.0%
147			G-S	13		RB-013	144.4 - 149.3						59.05	59.05	100			
148																		
149																		Grades with little fine to coarse subrounded to subangular Gravel

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 12 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151		0.49	G-S	14		RB-014	149.3 - 154.2	59.05	59.05	100								Brown, SANDY SILTY CLAY, moist, (CL-ML), with little fine to coarse subangular Gravel, calcareous
152																		151.6: Field MC = 14.4%
153																		
154																		
155		0.62	G-S	15		RB-015	154.2 - 159.1	59.05	59.05	100								Brown, SANDY SILTY CLAY, moist, (CL-ML), with fine to coarse subrounded Gravel and Cobble, calcareous
156																		
157																		156.5: Field MC = 14.5%
158																		
159																		
160		0.98	G-S	16		RB-016	159.1 - 164.0	59.05	59.05	100								
161																		160.8: Field MC = 14.0%
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 13 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
165																		Brown, SANDY SILTY CLAY, moist, (CL-ML), with fine to coarse subrounded Gravel and Cobble, calcareous
166		0.62	G-S	17		RB-017	164.0 - 169.0						59.05	59.05	100			166.0: Field MC = 14.1%
167																		
168																		
169		0.49	G-S	18		RB-018	169.0 - 173.9						59.05	38.19	65			
170																		
171																		
172																		171.9: Field MC = 13.5%
173																		Brown, CLAYEY SAND, wet, (SC), with little fine to coarse Gravel and 4-inch thick Cobble. NOTE: Driller reports more cobble that may have impacted recovery.
174		0.49	G-S	19		RB-019	173.9 - 178.8						59.05	23.62	40			
175																		
176																		
177																		177.5: Field MC = 11.3%

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 14 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
179																		Brown, CLAYEY SAND, wet, (SC), with Gravel, calcareous Note: Driller reports encountering cobbles during drilling.
180																		
181		0.62	G-S	20		RB-020	178.8 - 183.7						59.05	3.94	7			
182																		
183																		NOTE: No recovery.
184																		
185																		
186		0.98	G-S	21			183.7 - 188.6						59.05	0.00	0			
187																		
188																		
189			NCD				188.7 - 190.3						19.68					NCD down to 190.3 ft. No sample obtained.
190																		Brown, SANDY LEAN CLAY, moist, (CL), with subangular to subrounded Gravel
191																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 15 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
		0.22	G-S	22		RB-021	190.3 - 193.6						39.37	39.37	100			Brown, SANDY LEAN CLAY, moist, (CL), with subangular to subrounded Gravel
193																		
194																		
195																		
196		0.27	G-S	23		RB-022	193.6 - 198.5						59.05	59.05	100			
197																		
198																		
199																		
200																		Brown, SANDY LEAN CLAY, moist, (CL)
201		0.25	G-S	24		RB-023	198.5 - 203.4						59.05	59.05	100			
202																		Grades with subangular to subrounded Gravel, calcareous
203																		
204																		
205																		
		0.62	G-S	25			203.4 -						59.05	52.36	89			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 16 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
						RB-024	208.3											Brown, SANDY LEAN CLAY, moist, (CL), with subangular to subrounded Gravel, calcareous
207																		
208																		
209																		
210																		
211		0.16	G-S	26		RB-025	208.3 - 213.3						59.05	43.31	73			Brownish gray, SILT, moist, (ML), stiff 211.6: Field MC = 25.2%
212																		
213																		
214																		
215		0.20	G-S	27		RB-026	213.3 - 218.2						59.05	59.05	100			Brown, CLAYEY SAND, wet, (SC), with some subangular to subrounded Gravel, very dense
216																		
217																		
218																		Brown, Silty, LEAN CLAY, moist, (CL), stiff to very stiff 217.4: Field MC = 26.1%
219																		

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 17 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
221		0.25	G-S	28		RB-027	218.2 - 223.1						59.05	59.05	100			Brown, Silty, LEAN CLAY, moist, (CL), stiff to very stiff
222																		221.5: Field MC = 17.3%
223																		
224																		
225		0.25	G-S	29		RB-028	223.1 - 228.0						59.05	55.12	93			
226																		
227																		
228																		
229																		
230			G-S	30		RB-029	228.0 - 232.9						59.05	59.05	100			230.6: Field MC = 34.0%
231																		
232																		
233																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 18 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
235		0.35	G-S	31		RB-030	232.9 - 237.9						59.05	59.05	100			Brown, Silty, LEAN CLAY, moist, (CL), stiff to very stiff
236																		235.6: Field MC = 15.5%
237																		
238																		
239																		
240		0.62	G-S	32		RB-031	237.9 - 242.8						59.05	55.12	93			
241																		
242																		
243																		Brown, Silty, LEAN CLAY, moist, (CL), with lenses of nonplastic Silt
244																		
245		0.41	G-S	33		RB-032	242.8 - 247.7						59.05	47.24	80			244.8: Field MC = 20.7%
246																		
247																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 19 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
249																		GRAVEL, wet, (GP-GM), mixed with angular to subrounded Limestone and Igneous/Metamorphic Clasts in a silt matrix
250		0.98	G-S	34		RB-033	247.7 - 252.6	59.05	1.97	3								
251																		
252																		
253																		GRAVEL, wet, (GP-GM), mixed with angular to subrounded Limestone and Igneous/Metamorphic Clasts in a silt matrix
254																		
255		0.62	G-S	35		RB-034	252.6 - 257.5	59.05	13.78	23								
256																		
257																		
258																		
259																		
260		0.98	G-S	36		RB-035	257.5 - 262.5	59.05	1.97	3								
261																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 20 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
263																		
264																		
265		0.62	G-S	37			262.5 - 267.4						59.05	0.00	0			NOTE: No recovery.
266																		
267																		
268																		NOTE: No recovery.
269																		
270			G-S	38			267.4 - 272.3						59.05	0.00	0			
271																		
272																		
273																		NCD down to 277.2'. No sample was obtained.
274																		
275			NCD				272.3 - 277.2						59.05					

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 21 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
277																		
278																		NCD down to 282.6'. No sample was obtained.
279																		
280			NCD				277.2 - 282.6	64.96										
281																		
282																		
283		0.44	G-S	39			282.6 - 287.1	53.15	1.97	4								GRAVEL, (GP-GM), and Diorite cobble, igneous and metamporphic cobbles present NOTE: Matrix was washed away.
284																		
285																		285.43: PLL = 8,710 psi
286																		
287																		Same as above
288																		
289		1.64	G-S	40			287.1 - 292.0	59.05	1.18	2								

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 22 of 22
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
291																		GRAVEL, (GP-GM), igneous and metamporphic cobbles present NOTE: Fines likely washed away.
292		0.41	G-S	41		RB-036	292.0 - 296.9						59.05	21.65	37			Contains some limestone fragments
293																		292.82: PLL = 11,020 psi
294																		
295																		
296																		
297		0.35	G-S	42		RB-037	296.9 - 301.8						59.05	19.68	33			
298																		
299																		
300																		300.52: PLL = 16,480 psi
301																		
302																		
303																		See Core Log.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 1 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81727 N Long: 84.76514 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 398.0 feet
DATUM: IGLD 1985
START DATE: 10/13/19 TIME: 12:00 am
FINISH DATE: 10/16/19 TIME: 12:00 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 183.7 ft. (56.0 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
304	0.08			43	RB-038	87	84		Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound, gypsum filled joints, moderately fracture spacing [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
305																
306																
307									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound, gypsum filled joints, moderately fracture spacing		II	R2				
308													10	2.0	1.0	307.58
309	0.16			44	RB-039	100	100		With gypsum filled joints 308.73: PLA = 758 psi				0	1.0	1.0	308.85
310									310.04: PLA = 373 psi				0	2.0	1.0	309.84
311													0	1.0	1.0	310.92
312										P1			0	1.0	1.0	312.20

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 2 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound, gypsum filled joints [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0	2.0	1.0	313.41
314	0.20			45	RB-040	100	100		Becomes moderately weathered, very weak to weak		III	R1-R2				
									Becomes slightly weathered, weak		II	R2				
315																
316									Becomes moderately weathered, very weak to weak		III	R1-R2				
											II	R2				
317													0	1.0	1.0	317.22
318																
319	0.16			46	RB-041	100	100									
320																
321																
322																
323									322.83: PLA = 311 psi							
324	0.18			47	RB-042	100	100									
325																
326																
									End of Boring at 326.44' The borehole was backfilled with cement-bentonite grout							

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-25
SHEET NUMBER: 3 of 3
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA			
													ANGLE (deg)	Jr	Ja	DEPTH (feet)
328									composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
329																
330																
331																
332																
333																
334																
335																
336																
337																
338																
339																
340																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 1 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81661 N Long: 84.76659 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 396.7 feet
DATUM: IGLD 1985
START DATE: 11/9/19 TIME: 11:00 pm
FINISH DATE: 11/16/16 TIME: 5:00 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1																		Mudline is 185.00 ft. (56.4 m) below lake level. NCD down to 95.1 ft. No sample obtained.
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 2 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 3 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25																		
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 4 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47			NCD				0.0 - 95.1	1141.72										
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 5 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53																		
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 6 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		
69																		
70																		
71																		
72																		
73																		
74																		
75																		
76																		
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 7 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82																		
83																		
84																		
85																		
86																		
87																		
88																		
89																		
90																		
91																		
92																		
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 8 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95																		Brown, SILTY SAND, wet, (SM)
96																		NOTE: CPT 1 was overcored by G-S 1.
97		0.98	CPT	1		RB-001	95.1 - 100.1						59.05	11.42	19			96.1: Field MC = 16.0%
98																		
99																		
100																		
101		1.64	G-S	2		RB-002	100.1 - 105.0						59.05	59.05	100			
102																		
103																		
104																		Brown, SILTY CLAY with Sand, wet, (CL-ML), slight plasticity
105																		With few Silt, low dilatancy, strong effervescence
106			ST	1			105.0 - 107.6						31.5	28.35	90			105.0: Field MC = 20.9%
107																		107.6: Field MC = 19.6%
																		NCD down to 109.9 ft. No sample was obtained.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 9 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		
110																		Brown, SANDY SILTY CLAY, wet, (CL-ML), slight plasticity
111																		
112		1.23	G-S	3		RB-003	109.9 - 114.8						59.05	59.05	100			With Gravel, up to 0.75-inches
113																		
114																		114.5: Field MC = 14.4%
115																		With little Gravel, no dilatancy, and rounded GRAVEL up to 0.75-inches
116																		
117		1.23	G-S	4		RB-004	114.8 - 119.8						59.05	51.18	87			
118																		
119																		119.1: Field MC = 15.5%
120																		With little Gravel, few Sand With 2-inch gravel clast at 36.65 m
121																		

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 10 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123		1.64	G-S	5		RB-005	119.8 - 124.7						59.05	51.18	87			Brown, SANDY SILTY CLAY, wet, (CL-ML), slight plasticity
124																		Brown, CLAYEY SAND, wet, (SC), moderate effervescence, slight plasticity 124.0: Field MC = 15.4%
125																		Brown, SANDY SILTY CLAY, little Gravel, wet, (CL-ML), gravel is rounded, slight plasticity
126																		
127		0.49	G-S	6		RB-006	124.7 - 129.6						59.05	45.28	77			Brown, SILT, little Gravel, trace Clay, wet, (ML), gravel is rounded, slight plasticity, hard
128																		128.3: Field MC = 11.4%
129																		
130																		Brown, fine, CLAYEY SAND, little Gravel, wet, (SC), gravel is rounded, strong effervescence
131																		Brown, fine, CLAYEY SAND, little Gravel, wet, (SC), gravel is rounded, strong effervescence 131.2: Field MC = 12.0%
132		0.49	G-S	7		RB-007	129.6 - 134.5						59.05	52.36	89			
133																		Brown, LEAN CLAY with SAND, little Gravel, wet, (CL), weak effervescence
134																		
135																		

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 11 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
			ST	2			134.5 - 137.8	39.37	11.42	29								Brown, LEAN CLAY with SAND, little Gravel, wet, (CL), weak effervescence
137																		
138																		NCD down to 139.4 ft. No sample was obtained.
139																		
140																		Grayish brown, SILT, trace Clay, wet, (ML), calcareous, possibly grading to a poorly graded SAND at end of run. Driller noted hard conditions. 139.4: Field MC = 16.2%
141																		Brown, LEAN CLAY with SAND, wet, (CL)
142		0.70	G-S	8		RB-008	139.4 - 144.4	59.05	32.28	55								
143																		
144																		
145																		
146																		Brown, CLAYEY SAND, wet, (SC), low plasticity
147		0.45	G-S	9		RB-009	144.4 - 149.3	59.05	59.05	100								147.6: Field MC = 18.3%
148																		
149																		Brown, SANDY LEAN CLAY, some Gravel, stiff, moist, (CL), gravel is fine to coarse grained, low plasticity

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 12 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151		0.29	G-S	10		RB-010	149.3 - 154.2	59.05	59.05	100								Brown, SANDY LEAN CLAY, some Gravel, stiff, moist, (CL), gravel is fine to coarse grained, low plasticity With little Gravel 151.4: Field MC = 17.5%
152																		
153																		
154																		
155		0.33	G-S	11		RB-011	154.2 - 159.1	59.05	59.05	100								156.2: Field MC = 13.4%
156																		
157																		
158																		
159																		Brown, CLAYEY SAND, little Gravel, wet, (SC), medium dense
160		0.15	G-S	12		RB-012	159.1 - 164.0	59.05	19.68	33								160.3: Field MC = 14.8%
161																		
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 13 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
165																		Brown, LEAN CLAY with SAND, little Gravel, stiff, wet, (CL)
166		0.16	G-S	13		RB-013	164.0 - 169.0					59.05	44.49	75				
167																		166.7: Field MC = 15.3%
168																		
169		0.25	G-S	14		RB-014	169.0 - 173.9					59.05	55.12	93				
170																		
171																		
172																		Moist, 171.9: Field MC = 15.8%
173																		
174		0.14	G-S	15		RB-015	173.9 - 178.8					59.05	55.12	93				
175																		
176																		176.2: Field MC = 16.1%
177																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 14 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
179																		Brown, LEAN CLAY with SAND, little Gravel, stiff, wet, (CL)
180																		
181		0.16	G-S	16		RB-016	178.8 - 183.7						59.05	59.05	100			180.4: Field MC = 14.3%
182																		
183																		
184																		Brown, LEAN CLAY with SAND, little Gravel, stiff, moist, (CL)
185		0.16	G-S	17		RB-017	183.7 - 187.7						47.24	47.24	100			
186																		
187																		
188																		Becomes stiff 187.7: Field MC = 14.1%
189																		
190		0.20	G-S	18		RB-018	187.7 - 192.6						59.05	59.05	100			
191																		Brown, LEAN CLAY, little Gravel, stiff, moist, (CL)

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 15 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
193																		
194																		
195		0.20	G-S	19		RB-019	192.6 - 197.5						59.05	56.30	95			192.6: Field MC = 22.0%
196																		
197																		196.9: Field MC = 18.4%
198																		With little Sand, fine grained
199																		
200		0.14	G-S	20		RB-020	197.5 - 202.4						59.05	52.76	89			With trace Gravel, subrounded
201																		
202																		With few Gravel, up to 0.5-inches 201.4: Field MC = 18.0%
203																		
204																		
205		0.14	G-S	21		RB-021	202.4 - 207.4						59.05	59.05	100			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 16 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
207																		Brown, LEAN CLAY, little Gravel, hard, moist, (CL)
208																		207.3: Field MC = 15.2%
209																		
210		0.11	G-S	22		RB-022	207.4 - 212.3	59.05	59.05	100								Brown, SANDY LEAN CLAY, little Gravel, hard, wet, (CL), calcareous, strong effervescence, low plasticity
211																		
212																		With decreasing gravel content 212.3: Field MC = 13.3%
213																		
214																		With gravel is subangular up to 0.25-inches
215		0.16	G-S	23		RB-023	212.3 - 217.2	59.05	51.18	87								Brown, LEAN CLAY, with Gravel, hard, moist, (CL), moderate effervescence, gravel is of mixed litholgoies, subrounded to subangular, up to 1-inch
216																		216.5: Field MC = 17.5%
217																		
218																		Brown, LEAN CLAY, trace Gravel, stiff, moist, (CL), gravel up to 0.5-inches, weak effervescense, high plasticity
219																		
		0.16	G-S	24		RB-024	217.2 - 222.1	59.05	59.05	100								

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 17 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
221																		Brown, LEAN CLAY, trace Gravel, stiff, moist, (CL), gravel up to 0.5-inches, weak effervescense, high plasticity
222																		222.1: Field MC = 17.9%
223																		
224																		
225		0.16	G-S	25		RB-025	222.1 - 227.0		59.05	59.05	100							
226																		
227																		227.0: Field MC = 17.4%
228																		
229		0.17	G-S	26		RB-026	227.0 - 232.0		59.05	57.87	98							229.7: Field MC = 20.8%
230																		
231																		
232																		Reddish brown, LEAN CLAY, few Gravel, stiff, moist, (CL), medium plasticity
233																		Becomes grayish brown

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 18 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
235		0.20	G-S	27		RB-027	232.0 - 236.9						59.05	59.05	100			Grayish brown, LEAN CLAY, few Gravel, stiff, moist, (CL), medium plasticity
236																		
237																		Without Gravel 236.9: Field MC = 20.8%
238																		
239		0.20	G-S	28		RB-028	236.9 - 241.8						59.05	59.05	100			
240																		239.8: Field MC = 20.0%
241																		
242																		
243																		242.8: Field MC = 20.0%
244		0.22	G-S	29		RB-029	241.8 - 246.7						59.05	59.05	100			
245																		
246																		
247																		Light brown, LEAN CLAY, some Silt, moist, (CL), low plasticity

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 19 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
249		0.49	G-S	30		RB-030	246.7 - 251.6	59.05	59.05	100								Light brown, LEAN CLAY, some Silt, moist, (CL), low plasticity 249.0: Field MC = 20.4%
250																		
251																		
252																		
253																		
254		0.55	G-S	31		RB-031	251.6 - 256.6	59.05	59.05	100								253.9: Field MC = 19.7%
255																		
256																		
257																		Light brown, SILT, little Gravel, wet, (ML), slight plasticity
258																		
259		0.35	G-S	32		RB-032	256.6 - 261.5	59.05	53.15	90								259.2: Field MC = 23.6%
260																		
261																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 20 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
263																		Light brown, SILT, little Gravel, wet, (ML), slight plasticity 262.5: Field MC = 21.2%
264		0.62	G-S	33		RB-033	261.5 - 266.4	59.05	59.05	100								Brown, Sandy, LEAN CLAY, Clay, moist, (CL)
265																		
266																		Brown, CLAYEY SAND, Sand, wet, (SC), fine grained zone 80.9 - 81.0 m Brown, SILT with SAND, moist, (ML), slight plasticity
267																		
268																		
269		0.55	G-S	34		RB-034	266.4 - 271.3	59.05	59.05	100								269.0: Field MC = 22.0%
270																		
271																		
272																		Brown, fine to medium, POORLY GRADED SAND, little Clay, trace Silt, wet, (SP)
273																		
274		0.49	G-S	35		RB-035	271.3 - 276.2	59.05	31.50	53								274.0: Field MC = 27.2%
275																		

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 21 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
277																		Brown, fine to medium, POORLY GRADED SAND, little Clay, trace Silt, wet, (SP)
278																		
279		0.55	G-S	36		RB-036	276.2 - 281.2	59.05	59.05	100								
280																		Brown, CLAYEY SAND, some Fine Sand, (SC), occasional fat clay pockets
281																		280.5: Field MC = 23.0%
282																		Brown, SILT, (ML)
283		0.70	G-S	37		RB-037	281.2 - 286.1	59.05	45.28	77								Brown, fine to coarse, POORLY GRADED SAND, loose, wet, (SP), occasional clay pockets
284																		282.8: Field MC = 16.9%
285																		Brown, fine to coarse, POORLY GRADED SAND, loose, wet, (SP), occasional clay pockets
286																		
287																		Brown, fine to coarse, POORLY GRADED SAND, loose, wet, (SP), occasional clay pockets
288		0.98	G-S	38		RB-038	286.1 - 291.0	59.05	43.31	73								
289																		289.7: Field MC = 23.7%

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 22 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
291																		Brown, POORLY GRADED SAND, wet, (SP), occasional clay pockets
292																		
293		0.98	G-S	39		RB-039	291.0 - 295.9						59.05	59.05	100			
294																		
295																		
296																		295.9: Field MC = 27.0%
297																		
298		1.23	G-S	40		RB-040	295.9 - 300.9						59.05	59.05	100			
299																		
300																		
301																		Grayish brown, Silty, SILTY SAND, some Silt, wet, (SM), no effervescence, noncohesive 300.9: Field MC = 22.4%
302																		
303		0.82	G-S	41		RB-041	300.9 - 305.8						59.05	34.25	58			Grayish brown, LEAN CLAY, moist, (CL), weak effervescence, with faint reddish brown stratifications,

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 23 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
305																		medium plasticity 303.5: Field MC = 19.0% With rounded gravel
306																		COBBLES with FAT CLAY, wet, (GC), cobbles are rounded, up to 6-inches of mixed litholgies (granite, diorite, quartzite, dolomite)
307																		
308		0.62	G-S	42		RB-042	305.8 - 310.7	59.05	23.62	40								
309																		
310																		310.37: PLL = 6,720 psi
311																		
312			G-S	43			310.7 - 314.3	43.31	19.68	45								
313																		Brown, COBBLES with FAT CLAY, (GC), strong effervescence, angular cobbles up to 4-inches in a strongly cemented sandy clay matrix
314																		COBBLES with FAT CLAY, (GC), cobbles are rounded, up to 6-inches of mixed litholgies (granite, diorite, quartzite, dolomite), 7-inches of gypsum
315		0.13	G-S	44		RB-043	314.3 - 315.6	15.75	15.75	100								
316																		315.94: PLL = 13,960 psi
317		0.27	G-S	45		RB-044	315.6 - 318.9	39.37	31.50	80								Quartzite boulder 316.9-317.6 ft., angular to subrounded

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 24 of 24
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
319																		
320		0.11	G-S	46			318.9 - 320.5						19.68	19.68	100			Granite boulder 319.9-320.5 ft. See Core Log.
321																		
322																		
323																		
324																		
325																		
326																		
327																		
328																		
329																		
330																		
331																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 1 of 2
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81661 N Long: 84.76659 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 396.7 feet
DATUM: IGLD 1985
START DATE: 11/9/19 TIME: 11:00 pm
FINISH DATE: 11/16/16 TIME: 5:00 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 185.0 ft. (56.4 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
					RB-045											
321	0.11			47		100	0		Light greenish gray, CLAYSTONE, highly weathered, very to extremely weak, moderately to extremely close fracture spacing, sound to extremely fractured, dolomitic, brecciated with slightly weathered, weak corestones [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
322									Light greenish gray, CLAYSTONE, highly weathered, very to extremely weak, moderately to extremely close fracture spacing, sound to extremely fractured, dolomitic, brecciated with slightly weathered, weak corestones		IV	R0-R1	0-90	1.0	3.0	322.50-326.60
323									Slightly weathered, weak		II	R2	0-90	1.0	1.0	323.49
324				48	RB-046	85	45									
325									Highly weathered, extremely weak, extremely fractured zone 325.5-326.1 ft.		IV	R0	0-90	1.0	1.0	324.80-325.13
									Becomes slightly weathered, weak		II	R2				
326								CL								
327									Becomes medium strong, extremely fractured, with calcite coated fracture surfaces, possibly brecciated and healed			R4	0-90	1.0	1.0	326.44-328.08
									Becomes moderately fractured, not brecciated							
328									Becomes highly weathered, very to extremely weak, extremely fractured		IV	R0-R1	0-90	1.0	2.0	328.41-336.94
329				49	RB-047	70	27		328.74: γ = 137 pcf, UCS = 652 psi Becomes slightly weathered, weak, moderately fracture spacing, sound		II	R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-26
SHEET NUMBER: 2 of 2
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
331								CL								
332									Light greenish gray and greenish brown, CLAYSTONE, slightly weathered, weak, moderately to extremely close fracture spacing, sound to extremely fractured, dolomitic, brecciated with slightly weathered, weak corestones, mottled [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		II	R2				
333													30	1.5	1.0	333.33
334				50	RB-048	73	73						10	1.5	1.0	334.15
335									With irregular gypsum zones							
336								CL								
337									End of Boring at 336.28' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
338																
339																
340																
341																
342																
343																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 1 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81551 N Long: 84.76579 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 418.3 feet
DATUM: IGLD 1985
START DATE: 10/29/19 TIME: 12:00 am
FINISH DATE: 11/1/19 TIME: 3:00 pm

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA				
Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1																		NOTE: Mudline is 163.4 ft. (49.8 m) below lake level. NCD down to 283.1 ft. No sample was obtained.
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 2 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 3 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25																		
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 4 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47																		
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 5 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53			NCD				0.0 - 109.9						1318.88					
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 6 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		
69																		
70																		
71																		
72																		
73																		
74																		
75																		
76																		
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 7 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82																		
83																		
84																		
85																		
86																		
87																		
88																		
89																		
90																		
91																		
92																		
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 8 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95																		
96																		
97																		
98																		
99																		
100																		
101																		
102																		
103																		
104																		
105																		
106																		
107																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 9 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		
110																		Brown, fine to medium grained, POORLY GRADED SAND, wet, (SP)
111			ST	1		ST-001/RB-001	109.9 - 113.2	39.37	36.61	93								Brown, Silty, LEAN CLAY, moist, (CL), medium plasticity, strong effervescence
112																		
113																		
114			NCD				113.2 - 114.8	19.68										NCD down to 114.8 ft. No sample obtained. 113.2: Field MC = 20.1%
115																		CPT 1 was performed from 114.8-119.8 ft. After CPT 1 was completed, the CPT was removed and the NCD was used to advance to 119.8 ft.
116																		
117			CPT	1			114.8 - 119.8	59.05										
118																		
119																		
120																		Brown, Silty, LEAN CLAY with SAND, some Gravel, moist, (CL), medium plasticity
121		0.82	G-S	1		RB-002	119.8 - 123.0	39.37	18.50	47								121.1: Field MC = 16.9%

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 10 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		Brown, Silty, LEAN CLAY with SAND, some Gravel, moist, (CL), medium plasticity
124																		Brown, Silty, FAT CLAY, little Sand, trace Gravel, moist, (CH), high plasticity
125		0.98	G-S	2		RB-003	123.0 - 128.0						59.05	55.12	93			
126																		
127																		127.6: Field MC = 15.2%
128																		Brown, SILTY SAND, little Gravel, moist, (SM) G-S 3 was from 128.0-132.9 ft. and occurred after ST 2 was obtained. G-S 3 came back with no recovery.
129			ST	2		ST-002	128.0 - 129.9						23.62	23.62	100			
130																		129.9: Field MC = 13.9%
131			G-S	3		RB-004	129.9 - 132.9						35.43	0.00	0			
132																		
133																		Brown, SILTY SAND, little Gravel, moist, (SM) 132.9: Field MC = 15.7%
134																		
135			G-S	4			132.9 - 137.8						59.05	59.05	100			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 11 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137																		Brown, Silty, FAT CLAY, little Gravel, moist, (CH), high plasticity
138																		With trace Gravel
139																		
140			G-S	5		RB-005	137.8 - 142.7						59.05	33.86	57			Olive brown, DOLOMITE, moist, slightly fractured, close to very close fracture spacing, slightly weathered, strong 140.1: Field MC = 15.2%
141																		
142																		
143																		Brown, SANDY LEAN CLAY, with Gravel, hard, moist, (CL), low plasticity, fine to coarse gravel up to 1/2-inch
144																		
145			G-S	6		RB-006	142.7 - 147.6						59.05	55.12	93			
146																		
147																		147.3: Field MC = 13.5%
148																		
149																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 12 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
150		0.20	G-S	7		RB-007	147.6 - 152.6	59.05	59.05	100								Brown, SANDY LEAN CLAY, with Gravel, hard, moist, (CL), low plasticity, fine to coarse gravel up to 1/2-inch
151																		
152																		152.6: Field MC = 12.1%
153																		
154																		
155		0.38	G-S	8		RB-008	152.6 - 157.5	59.05	59.05	100								
156																		
157																		157.5: Field MC = 12.5%
158																		
159																		
160		0.31	G-S	9		RB-009	157.5 - 162.4	59.05	57.09	97								
161																		161.4: Field MC = 12.6%
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 13 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
165		0.33	G-S	10		RB-010	162.4 - 167.3						59.05	32.68	55			With greenish gray and black, subangular to subrounded, GRAVEL, up to 1/2-inch, with limestone and claystone clasts up to 3-inches Brown, SANDY LEAN CLAY, some Gravel, some Sand, firm, moist, (CL), low plasticity, gravel and sand are fine to coarse 165.0: Field MC = 13.6%
166																		
167																		
168		0.33	G-S	11		RB-011	167.3 - 172.2						59.05	32.68	55			Brown, Silty, LEAN CLAY, some Gravel, some Sand, firm, moist, (CL), low plasticity, gravel and sand are fine to coarse 169.5: Field MC = 12.8%
169																		
170																		
171																		
172																		
173			G-S	12		RB-012	172.3 - 177.2						59.05	25.59	43			Brown, medium to fine grained, POORLY GRADED SAND, trace Gravel, trace Clay, wet, (SP) 174.2: Field MC = 28.0%
174																		
175																		
176																		
177																		Becomes medium grained

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 14 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
179			G-S	13		RB-013	177.2 - 182.1	59.05	31.50	53								Brown, POORLY GRADED SAND, with Gravel, wet, (SP), subangular to subrounded gravel up to 2.5-inches of diabase, basalt and dolomite lithologies
180																		
181																		
182																		NOTE: Driller noted soft and hard material in Core Run 14
183																		Brown, Sandy, LEAN CLAY, some Sand, very hard, moist, (CL), low plasticity, strong effervescence
184			G-S	14		RB-014	182.1 - 187.0	59.05	33.46	57								With angular, Gravel, up to 1/2-inch of mixed lithologies
185																		Brown, POORLY GRADED SAND, loose, wet, (SP)
186																		
187																		Brown, SANDY LEAN CLAY, little Gravel, very hard, moist, (CL), low plasticity, gravel is angular, up to 3/4 inch of mixed lithologies
188																		
189		0.29	G-S	15		RB-015	187.0 - 191.9	59.05	59.05	100								
190																		With increasing sand abundance at end of Core Run 15.
191																		191.7: Field MC = 13.0%

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 15 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
193																		Brown, SANDY LEAN CLAY, little Gravel, very hard, moist, (CL), low plasticity, gravel is angular, up to 3/4 inch of mixed lithologies With gravel up to 2-inches
194		0.49	G-S	16		RB-016	191.9 - 196.9	59.05	47.24	80								193.6: Field MC = 11.7% 4-inch limestone clast
195																		
196																		Brown, fine to medium grained, POORLY GRADED SAND, loose, wet, (SP) NOTE: No recovery. Driller noted soft and sandy material in the last 1 ft. of Core Run 16.
197																		
198		0.41	G-S	17		RB-017	196.9 - 201.8	59.05	59.05	100								Brown, LEAN CLAY, with Sand, and Gravel, hard, moist, (CL), low plasticity, calcareous, angular gravel
199																		
200																		Brown, Sandy, LEAN CLAY, little Gravel, little Sand, moist, (CL), low plasticity, angular gravel up to 1-inch of mixed lithologies
201																		With gravel up to 6-inches of granite
202		0.16	G-S	18		RB-018	201.8 - 204.2	29.53	29.53	100								Brown, Clayey, GRAVEL, wet, (GC), 85% gravel/cobbles up to 8-inches, gravel is angular consisting of dolomite, diorite, quartzite lithologies, basalt boulder 201.8: Field MC = 9.8%
203																		
204																		204.2: Field MC = 11.8% NOTE: little matrix recovered
205		0.25	G-S	19		RB-019	204.2 - 206.7	29.53	20.87	71								

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 16 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
207		0.21	G-S	20		RB-020	206.7 - 211.6						59.05	23.62	40			Brown, Clayey, GRAVEL, wet, (GC), 85% gravel/cobbles up to 8-inches, gravel is angular consisting of dolomite, diorite, quartzite lithologies, basalt boulder With subrounded to rounded cobbles, voids evident as multiple cobbles have angled coring surfaces on stem or incomplete coring marks indicating the cobbles moved/rolled during the coring process 207.5: Field MC = 13.7%
208																		
209																		
210																		With subrounded to rounded cobbles
211																		
212																		Brown, Clayey, GRAVEL, wet, (GC), subrounded to rounded cobbles, mixed limestone, igneous and metamorphic rock fragments
213																		
214			G-S	21		RB-021	211.6 - 216.5						59.05	27.56	47			
215																		
216																		
217																		With mostly dolomite cobbles
218			G-S	22		RB-022	216.5 - 219.0						29.53	24.80	84			
219																		Only cobbles recovered, angular to subrounded cobbles up to 4-inches, of mixed lithologies

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 17 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
			G-S	23		RB-023	219.0 - 221.5						29.53	12.99	44			Brown, Clayey, GRAVEL, wet, (GC), subrounded to rounded cobbles, mixed limestone, igneous and metamorphic rock fragments
221																		
222																		Subrounded to rounded cobbles, gravel is of mixed lithologies
			G-S	24			221.5 - 223.9						29.53	23.62	80			
223																		0.5 ft. of stiff to hard sandy silty clay with gravel up to 1.5-inches and a few cobbles at the bottom
224																		Only cobbles recovered, angular to subrounded cobbles up to 5-inches, of mixed lithologies
225			G-S	25		RB-024	223.9 - 226.4						29.53	5.91	20			
226																		
227		0.25																
			G-S	26			226.4 - 228.8						29.53	6.30	21			
228																		
229																		
230		0.25	G-S	27		RB-025	228.8 - 231.3						29.53	9.84	33			
231																		
232																		Brown, Sandy, LEAN CLAY, with Gravel, moist, (CL), medium plasticity
233																		
		0.25	G-S	28		RB-026	231.3 -						59.05	25.59	43			233.4: Field MC = 15.3%

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 18 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
235							236.2											Brown, Sandy, LEAN CLAY, with Gravel, moist, (CL), medium plasticity
236																		
237																		Brown, Sandy, LEAN CLAY, with Gravel, moist, (CL), medium plasticity
238																		
239		0.10	G-S	29		RB-027	236.2 - 241.1	59.05	59.05	100								
240																		Brown, LEAN CLAY, some Silt, trace Sand, moist, (CL), medium plasticity
241																		
242																		Brown, LEAN CLAY, moist, (CL), low plasticity 241.1: Field MC = 20.1%
243		0.13	G-S	30		RB-028	241.1 - 246.1	59.05	54.33	92								
244																		
245																		
246																		245.7: Field MC = 18.3%
247																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 19 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
249		0.16	G-S	31		RB-029	246.1 - 251.0						59.05	42.91	73			Brown, FAT CLAY, moist, (CH), high plasticity 249.5: Field MC = 23.5%
250																		
251																		
252																		
253			G-S	32		RB-030	251.0 - 255.9						59.05	55.51	94			
254																		
255																		255.6: Field MC = 19.1%
256																		
257																		
258			G-S	33		RB-031	255.9 - 260.8						59.05	55.12	93			
259																		
260																		260.5: Field MC = 19.1%
261																		Brown, LEAN CLAY, moist, (CL), low plasticity

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 20 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
263			ST	3		ST-003	260.8 - 263.5						31.5	31.50	100			Brown, LEAN CLAY, moist, (CL), low plasticity
264			G-S	34		RB-032	263.5 - 265.7						27.56	27.56	100			G-S 35 was from 260.8-265.7 ft. and occurred after ST 3 was obtained. G-S 35 came back with recovery shown. 263.5: Field MC = 18.0%
265																		Grayish brown, SILT, trace Clay, wet, (ML), medium to high plasticity
266																		Brown, Silty, FAT CLAY, (CH)
267																		267.1: Field MC = 21.5%
268			G-S	35		RB-033	265.8 - 270.7						59.05	37.40	63			Brown, SILT, trace Clay, wet, (ML)
269																		Brown, Sandy, LEAN CLAY, some Silt, some Gravel, moist, (CL), low plasticity
270																		
271																		Brown, Sandy, LEAN CLAY, some Silt, some Gravel, moist, (CL), low plasticity
272																		
273		0.82	G-S	36		RB-034	270.7 - 275.6						59.05	41.34	70			
274																		Brown, SILT, trace Clay, wet, (ML) 274.1: Field MC = 24.5%
275																		275.6: Field MC = 20.0%

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 21 of 21
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
277																		Brown, SILT, trace Clay, wet, (ML)
278		0.98	G-S	37		RB-035	275.6 - 280.5	59.05	4.33	7								
279																		
280																		
281																		
282																		Brown, SANDY SILT, wet, (ML)
283		0.82	G-S	38		RB-036	280.5 - 285.4	59.05	35.43	60								
284																		Brown, SANDY SILT, trace Clay, wet, (ML)
285																		See Core Log.
286																		
287																		
288																		
289																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81551 N Long: 84.76579 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 418.3 feet
DATUM: IGLD 1985
START DATE: 10/29/19 TIME: 12:00 am
FINISH DATE: 11/1/19 TIME: 3:00 pm

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 163.4 ft. (49.8 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
285									Reddish brown, CLAYSTONE, moderately weathered, very weak, moderate fracture spacing, moderately fractured, breccia, with angular dolomite clasts [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		IV	R0-R1				
286									Reddish brown, CLAYSTONE, moderately weathered, very weak, moderately fractured, breccia, with angular dolomite clasts							
287																
288	0.35			39	RB-037	100	35									
289									Becomes mostly greenish gray, slightly to moderately weathered, very weak, sound		II-III	R1				
290																
291									Becomes moderately weathered, very weak to weak, sound to slightly fractured		IV	R0-R1				
292									Extremely weathered, very weak to weak, crushed zone with small rock fragments 291.4-291.6 ft.		V	R0	0	3.00	6.00	291.44
293	0.20			40	RB-038	87	25		Extremely weathered, extremely weak, crushed zone with small rock fragments 292.9-293.1 ft. 292.98: PLA = 202 psi		V	R0	0	3.00	6.00	292.91
									Becomes greenish gray, slightly weathered, weak, sound		II	R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
295								CL	Reddish brown, CLAYSTONE, slightly weathered, very weak, moderately fractured, breccia, with angular dolomite clasts [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
									Becomes moderately weathered, with crushed zones along fractures		III-IV		30	3.00	4.00	295.60
296													45	3.00	4.00	296.10
									Becomes greenish gray and reddish brown, slightly weathered, medium strong		II	R3	20	3.00	4.00	296.33
297																
298				41	RB-039	100	54		Crushed rock filled fracture at 298.6 ft.							
									Breccia clasts throughout, some gypsum pods or veins	P1			5	3.00	4.00	298.56
299									Reddish brown, CLAYSTONE, extremely weathered, extremely weak, wide to close fracture spacing		V	R0				
300									Greenish gray, CLAYSTONE, weak, sound, breccia, gypsum pods and veins 300.20: PLA = 348 psi		II	R2				
301									With increasing reddish brown mottling				15	1.50	2.00	300.78
													60	1.00	0.75	301.67
302									302.17: PLA = 418 psi; γ = 131 pcf, UCS = 763 psi							
				42	RB-040	100	100						20	1.00	3.00	302.49
303																
304													10	3.00	2.00	304.30
305													5	3.00	2.00	304.95
306																
307				43	RB-041	100	92		Moderately weathered, weak, crushed to a gravel along 55 degree fracture 306.6-307.1 ft., breccia clasts throughout		IV-V	R0-R1	55	3.00	6.00	306.59
													5	3.00	4.00	307.41

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Greenish gray, CLAYSTONE, slightly weathered, weak, sound, breccia, gypsum pods and veins [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]	P2		R1				
											II	R1				
309									Becomes very weak, breccia with occasional gypsum and dolomite clasts				5	3.00	2.00	308.93
310									310.04: PLA = 6,140 psi				15	1.50	1.00	309.75
311																
312																
313	0.09			44	RB-042	90	89									
													10	1.50	1.00	313.49
314																
315									Becomes slightly weathered, weak, close fracture spacing			R2	20	1.50	1.00	314.87
316																
317									NOTE: very close fracture spacing, High Pressure Dilatometer test attempted 308.4-318.2 ft. abandoned due to wireline issue				10	1.00	2.00	316.61
318								CL								
									Gray and brown, DOLOMITE, slightly weathered, strong, lower part vuggy with 0.10 in. vug		II	R4				
											IV	R2	0	2.00	2.00	318.67
319									318.24: PLA = 11,200 psi				0	2.00	2.00	318.70
													0	2.00	2.00	318.73
													0	2.00	2.00	318.83
									Gray and olive, GYPSUM, slightly weathered, strong, with 15 degree laminations of up to 0.40 in.		II	R4	5	3.00	1.00	319.19
320													10	3.00	1.00	319.36
													5	3.00	2.00	319.55
321	0.13			45	RB-043	87	54									
									321.52: PLA = 518 psi				0	1.00	3.00	321.26
													0	1.00	2.00	321.39
													0	1.50	2.00	

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-27
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
323								CL	Gray and olive, GYPSUM, slightly weathered, strong, with 15 degree laminations of up to 0.40 in. [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R4	0 0 0	2.00 2.00 3.00	2.00 4.00 2.00	321.49 322.05 322.28 322.60
324									Dark gray and brown, DOLOMITE, slightly weathered, medium strong to strong, extremely fractured, extremely vuggy with pits and vugs up to 0.08 in. 323.82: PLL = 3,770 psi		III-IV	R3	10 5 40 40 0-90	1.00 2.00 3.00 3.00 3.00	2.00 2.00 2.00 2.00 2.00	323.79 324.31 324.80 325.26 325.30
325																
326				46	RB-044	77	0									
327											III	R3				
328								CL								
329									End of Boring at 328.41' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
330																
331																
332																
333																
334																
335																

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 1 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81439 N Long: 84.76743 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 399.9 feet
DATUM: IGLD 1985
START DATE: 10/19/19 TIME: 12:00 am
FINISH DATE: 10/19/19 TIME: 12:00 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
0																		Mudline is 181.8 ft. (55.4 m) below lake level. NCD down to 87.3 ft. No sample was obtained.
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 2 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 3 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25																		
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 4 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39			NCD				0.0 - 87.3	1047.24										
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47																		
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 5 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53																		
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 6 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		
69																		
70																		
71																		
72																		
73																		
74																		
75																		
76																		
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 7 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82																		
83																		
84																		
85																		
86																		
87																		
88		0.38	G-S	1		RB-001	87.3 - 92.2	59.05	15.75	27								Brown, Sandy, LEAN CLAY, hard, moist, (CL), some subrounded to subangular gravel, low plasticity
89																		
90																		
91																		91.5: Field MC = 11.3%
92																		NCD down to 97.1 ft. No sample obtained.
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 8 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95			NCD				92.2 - 97.1						59.05					
96																		
97																		Brown, SANDY LEAN CLAY, very stiff, moist, (CL), little subrounded to subangular gravel, low plasticity
98																		
99																		
100		0.18	G-S	2		RB-002	97.1 - 102.0						59.05	53.94	91			
101																		101.4: Field MC = 13.4%
102																		
103																		
104		0.70	G-S	3		RB-003	102.0 - 107.0						59.05	46.06	78			
105																		Brown, fine to medium grained, CLAYEY SAND, dense, wet, (SC), some subrounded to subangular gravel 105.0: Field MC = 9.9%
106																		
107																		GRAVEL, trace Gravel, (GP), No recovery. Driller reported gravel. Fine matrix likely washed out.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 9 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109		0.41	G-S	4			107.0 - 111.9						59.05	0.00	0			GRAVEL, trace Gravel, (GP), No recovery. Driller reported gravel. Fine matrix likely washed out.
110																		
111																		
112																		NOTE: subrounded to subangular, GRAVEL, (GP), Silty matrix present on gravel pieces, gravel is of mixed lithology
113																		
114			G-S	5		RB-004	111.9 - 116.8						59.05	3.94	7			
115																		
116																		
117																		GRAVEL, with Cobbles, (GP), gravel and cobbles are of mixed lithology, angular to subrounded
118																		
119			G-S	6		RB-005	116.8 - 121.7						59.05	11.81	20			
120																		
121																		Reddish brown, Silty, LEAN CLAY, trace Sand, moist, (CL), low plasticity

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 10 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		121.6: Field MC = 17.0% GRAVEL, with Cobbles, wet, (GP), gravel and cobbles are of mixed lithology, angular to subrounded
124			G-S	7			121.7 - 126.6	59.05	0.00	0								
125																		
126																		
127		1.23																
128																		
129			G-S	8			126.6 - 131.6	59.05	0.00	0								
130																		
131																		
132		1.23																
133																		
134			G-S	9			131.6 - 136.5	59.05	0.00	0								
135																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 11 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137		1.23	G-S	10			136.5 - 141.4						59.05	0.00	0			GRAVEL, with Cobbles, wet, (GP), gravel and cobbles are of mixed lithology, angular to subrounded
138																		
139																		
140																		
141																		
142		1.64	G-S	11		RB-006	141.4 - 146.3						59.05	15.75	27			Brown, POORLY GRADED SAND, wet, (SP), few subangular gravel
143																		
144																		
145																		145.3: Field MC = 28.0%
146																		
147		1.64	G-S	12			146.3 - 151.2						59.05	0.00	0			
148																		
149																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 12 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151		0.33	G-S	13		RB-007	151.2 - 156.2						59.05	48.42	82			Brown, POORLY GRADED SAND, wet, (SP), few subangular gravel
152																		Brown, SILTY CLAYEY SAND, little Gravel, wet, (SC-SM)
153																		
154																		GRAVEL, wet, (GP), 4" Gravel lens
155																		Brown, Silty, LEAN CLAY, few Fine Gravel, hard, moist, (CL), low plasticity 155.2: Field MC = 13.1%
156																		
157			G-S	14		RB-008	156.2 - 161.1						59.05	11.81	20			Reddish brown, SANDY SILTY CLAY, dense, wet, (CL-ML), little subrounded fine gravel
158																		
159																		NOTE: Driller reported pulling off bottom while drilling may have contributed to low recovery
160																		160.4: Field MC = 9.0%
161																		
162																		COBBLES, trace Sand, wet, gravel is subangular to angular, large cobbles were noticed at the end of run See Core Log.
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 1 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81439 N Long: 84.76743 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 399.9 feet
DATUM: IGLD 1985
START DATE: 10/19/19 TIME: 12:00 am
FINISH DATE: 10/19/19 TIME: 12:00 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S, HQ3
O.D.: Geobor-S, HQ3
I.D.: Geobor-S, HQ3
CASING SIZE: " (")

NOTES:
Mudline is 181.8 ft. (55.4 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
163				15	RB-009	90	77		Greenish gray and reddish brown, CLAYSTONE Greenish gray and reddish brown, CLAYSTONE, mottled, slightly weathered, weak, wide fracture spacing, with breccia clasts, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		II	R2				
164																
165									With gypsum infilling along healed fractures							
166								CL								
167									With gypsum clasts, gypsum pods outside the clasts							
168				16	RB-010	100	100						0	1.0	1.0	168.08
169																
170									With gypsum infilling along healed fractures				0	1.0	1.0	170.57
171									Becomes gray and brown, mottled, and contains occasional gypsum infills NOTE: extremely fractured zone 171.5-172.2 ft.				10	1.0	1.0	171.45

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 2 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
173	0.10			17	RB-011	89	75		Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued] 172.24: γ = 137 pcf, PLL = 320 psi	P7	II	R2	10	1.0	1.0	173.23
174																
175								CL								
176	0.11			18	RB-012	100	100						10	1.0	1.0	176.77
177																
178																
179																
180									Becomes sound, moderate to wide fracture spacing							
181	0.16			19	RB-013	100	100		Contains clasts (breccia)with thin gypsum veins	P6						
182																
183																
184																
185																

WSP CORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 3 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
187									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
188	0.21			20	RB-014	100	100		186.35: PLA = 202 psi With occasional gypsum clasts Becomes slightly weathered, weak, sound with moderate to wide fracture spacing							
189																
190																
191													10	3.0	2.0	191.17
192													10	2.0	2.0	191.76
193	0.19			21	RB-015	100	100		Becomes slightly weathered, weak, sound with moderate fracture spacing	P5			0	2.0	2.0	192.45
194																
195													10	3.0	1.0	195.17
196									Becomes greenish gray, slightly weathered, weak							
197																
198				22	RB-016	99	99									
199									Becomes reddish brown, with gypsum clasts							

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 4 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	DISCONTINUITY DATA: Jr	DISCONTINUITY DATA: Ja	DISCONTINUITY DATA: DEPTH (feet)
								CL	Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
201									200.46: PLL = 240 psi							
202									With slightly weathered, weak, grayish green breccia clasts in red-brown matrix, some gypsum clasts							
203				23	RB-017	100	100			P4						
204									NOTE: fractured zone 203.5-203.6 ft. Becomes sound							
205																
206																
207									Contains slightly weathered, weak, multiple gypsum veins up to 1 cm thick							
208				24	RB-018	100	100									
209																
210									210.30: PLA = 1,090 psi							
211																
212									Contains slightly weathered, weak, breccia clasts with some gypsum pods and veins							
213	0.14			25	RB-019	100	100			P3						

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 5 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
215									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
216	0.16			26	RB-020	100	100		215.55: PLA = 632 psi							
217																
218																
219																
220									Greenish gray and reddish brown, CLAYSTONE, mottled, slightly weathered, weak, occasional gypsum, sound, moderate to wide fracture spacing							
221																
222	0.20			27	RB-021	100	100			P2						
223																
224																
225																
226																
227	0.16			28	RB-022	100	95		Becomes moderately fractured to sound, moderate to wide fracture spacing							

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 6 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
229									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
230	0.20			29	RB-023	100	95		Becomes sound with wide fracture spacing, some gypsum pods 229.99: PLA = 631 psi	P1						
231									Contains breccia clasts							
232									Extremely fractured 231.6-231.9 ft.							
233																
234																
235									Greenish gray and reddish brown, CLAYSTONE, mottled, slightly weathered, weak, brecciated, occasional gypsum clasts or veins, sound, moderate to wide fracture spacing							
236									NOTE: slightly weathered, very weak, weaker zone			R1				
237				30	RB-024	100	100		Greenish gray and reddish brown, CLAYSTONE, mottled, slightly weathered, weak, brecciated, sound, moderate to wide fracture spacing			R2				
238																
239																
240									239.83: PLA = 771 psi, γ = 134 pcf, UCS = 522 psi							
241																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-28
SHEET NUMBER: 7 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M.Blight, M. Richards
INSPECTOR: A. Moreland, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
243				31	RB-025	100	100		Greenish gray and reddish brown, CLAYSTONE, slightly weathered, weak, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]		II	R2				
244																
245																
246																
247				32	RB-026	100	100									
248									247.70: PLA = 717 psi							
249																
250									End of Boring at 249.66' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
251																
252																
253																
254																
255																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 1 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81090 N Long: 84.76751 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 462.4 feet
DATUM: IGLD 1985
START DATE: 11/4/19 TIME: 12:00 am
FINISH DATE: 11/6/19 TIME: 11:30 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1					X													Mudline is 119.3 ft. (36.4 m) below lake level. NCD down to 131.2 ft. No sample obtained.
2					X													
3					X													
4					X													
5					X													
6					X													
7					X													
8					X													
9					X													

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 2 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 3 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25																		
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 4 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40																		
41																		
42																		
43																		
44																		
45																		
46																		
47																		
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 5 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53																		
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65			NCD				0.0 - 131.2	1574.78										

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 6 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		
69																		
70																		
71																		
72																		
73																		
74																		
75																		
76																		
77																		
78																		
79																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 7 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82																		
83																		
84																		
85																		
86																		
87																		
88																		
89																		
90																		
91																		
92																		
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 8 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95																		
96																		
97																		
98																		
99																		
100																		
101																		
102																		
103																		
104																		
105																		
106																		
107																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 9 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		
110																		
111																		
112																		
113																		
114																		
115																		
116																		
117																		
118																		
119																		
120																		
121																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 10 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		
124																		
125																		
126																		
127																		
128																		
129																		
130																		
131																		Gray, SANDY LEAN CLAY, with Gravel, moist, (CL), low plasticity, soft, gravel is dolomitic, angular, up to 0.5-inches 131.4: Field MC = 17.5%
132																		Grayish brown, DOLOMITE, highly weathered, extremely weak,[ST. IGNACE FORMATION - MACKINAC BRECCIA]
133																		See Core Log.
134																		
135																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 1 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.81090 N Long: 84.76751 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 462.4 feet
DATUM: IGLD 1985
START DATE: 11/4/19 TIME: 12:00 am
FINISH DATE: 11/6/19 TIME: 11:30 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S, HQ3
O.D.: Geobor-S, HQ3
I.D.: Geobor-S, HQ3
CASING SIZE: " (")

NOTES:
Mudline is 119.3 ft. (36.4 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
133	0.25			1	RB-001	66	0		Grayish brown, DOLOMITE, highly weathered, extremely weak,[ST. IGNACE FORMATION - MACKINAC BRECCIA]							
134																
135								CL								
136											IV	R0				
137	0.38			2	RB-002	100	60		Becomes slightly weathered, medium strong, close fracture spacing, moderately fractured, with dark brown lamination and concretions, weak effervescence when powdered		II	R4	30 10 70	1.5 2.0 1.0 1.0	4.0 4.0 1.0 0.8	137.8 138.1 138.3 138.4-138.5
138																
139													30	1.0	4.0	139.1
140									Extremely weathered, extremely weak, SILT/CLAY zone 137.1-140.0 ft., some fractured dolomite pieces Becomes moderately weathered, medium strong, with increasing dark brown laminations		V III	R0 R3	40 50	1.5 1.0	4.0 0.8	139.5 140.0
141									Very dark grayish brown, LIMESTONE, slightly weathered, strong, extremely close fracture spacing, extremely fractured, strong effervescence		II	R4	5	1.0	1.0	140.9

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 2 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
													45	3.0	3.0	141.9
													50	3.0	3.0	142.0
									Steep, crushed rock filled fracture 142.5-143.0 ft.				0-90	3.0	3.0	142.0-142.4
143	0.20			3	RB-003	71	21		Light grayish brown, DOLOMITE, slightly weathered, medium strong, close fracture spacing, moderately fractured		II	R3	55	1.0	4.0	142.5-143.0
														1.0	1.0	143.4
144									LIMESTONE, slightly weathered, strong, extremely fractured zone 143.7-143.9 ft. With dolomite pieces in silt matrix		V	R0				
145								CL								
146									With gravels and cobbles of mixed lithology, angular to subround							
				4		57	0									
147								CL								
148	0.21			5	RB-004	26	0	CL								
149																
150				6		67	0				II III	R3				
151								CL								
152	0.05			7	RB-005	100	90		Dark gray, LIMESTONE, slightly weathered, medium strong, medium to close fracture spacing, argillaceous, sound, strong effervescence With breccia, highly weathered joints with silty clay and crushed rock		II	R3	20	2.0	2.0	151.5
													15	2.0	4.0	151.9
153				8		46	0		Becomes highly weathered, very weak, extremely close to close fracture spacing		IV	R0				
								CL								
154									Light brown, DOLOMITE, slightly weathered, medium strong to strong, extremely close to close fracture spacing, slightly to extremely fractured, no effervescence		II	R3-R4				
155									Dark greenish gray, LIMESTONE, highly weathered, extremely weak, weak effervescence, pitted 155.5-155.8 ft.		IV	R0				

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 3 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
157				9	RB-006	67	8		Becomes moderately to close fracture spacing, extremely fractured Light grayish brown, DOLOMITE, slightly weathered, strong, extremely fractured, no effervescence, with clay and sand filled joints [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4				
158								CL	157.15: PLL = 2,760 psi							
159									159.12: PLL = 1,840 psi							
160	0.21			10	RB-007	67	13		Highly weathered, extremely weak, joint with fat clay infilling 160.1 ft.		III	R3	10 10	1.0 2.0	1.0 4.0	159.9 160.1
161									Joint with fat clay infilling 160.6 ft.				15 15	1.0 1.5	1.0 3.0	160.5 160.7
162									Joint with fat clay infilling 161.4-161.8 ft.							
163								CL								
164																
165	0.14			11		58	0		Becomes slightly weathered, medium strong			R3				
166								CL								
167	0.23			12	RB-008	47	14		166.34: PLL = 6,710 psi Becomes light greenish gray, moderately weathered, weak, close to extremely close fracture spacing		III IV	R2 R0	10	1.0	4.0	166.8
168								CL								
169											III-IV	R0-R1				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 4 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
171	0.41			13	RB-009	40	15		Grayish brown, DOLOMITE, moderately to highly weathered, weak, breccia, extremely fractured, no effervescence, with clay and sand filled joints [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4				
172								CL								
173																
174									Becomes slightly weathered, medium strong, fractured		II	R4				
175	0.38			14	RB-010	40	0		Becomes highly weathered, very weak, matrix of silty clay and rock		V	R0	10	1.0	1.0	174.65
176																
177								CL								
178																
179									Becomes light greenish gray, slightly weathered, strong		II	R4				
180	0.20			15	RB-011	76	47		Dark gray, LIMESTONE, highly weathered, extremely weak, extremely close fracture spacing, argillaceous, extremely fractured 180.12: γ = 145 pcf, PLL = 440 psi		IV	R0	<5	2.0	4.0	180.1
181																
182													10	2.0	1.0	181.9
183								CL								
									Light grayish brown, DOLOMITE, slightly weathered,		II	R3				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 5 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									medium strong, extremely close fracture spacing, extremely fractured, pitted							
185									Light greenish gray, DOLOMITE, slightly weathered, medium strong, extremely close fracture spacing, extremely fractured, pitted		II	R3				
186	0.42			16	RB-012	39	0		[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
187								CL								
188									With trace pits				0-90	1.0-1.5	1.0	188.6-189.5
189													5	1.0	1.0	189.5
190													40	2.0	1.0	189.9
													85	1.0	1.0	190.0-190.2
									Becomes greenish gray, highly weathered, extremely weak, close fracture spacing, argillaceous, sound, locally crushed		V	R0		4.0	4.0	190.4-190.7
191				17	RB-013	90	55		Dark gray, DOLOMITE, slightly weathered, weak, wide fracture spacing, argillaceous, sound		II	R2				
192																
193								CL					0-90	4.0	4.0	193.0
											II	R4				
194																
											IV	R1	5	1.0	4.0	194.5-194.6
195									DOLOMITE, highly weathered, very weak, close fracture spacing, argillaceous, sound, moderately fractured, locally laminated		IV	R1				
196				18	RB-014	100	73		Reddish brown, CLAYSTONE, slightly weathered, weak, wide fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA] 195.87: PLA = 268 psi							
197									Becomes medium strong, very close fracture spacing,			R3	0-90	1.0	2.0	197.7-197.9

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 6 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									extremely fractured				80	1.0	4.0	197.9-198.3
199									Reddish brown, CLAYSTONE, slightly weathered, weak, moderate fracture spacing, sound, with light laminations and healed fractures [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
									Becomes greenish gray, moderate fracture spacing, sound, with light laminations and healed fractures				25	3.0	4.0	199.6
200																
									Becomes reddish brown, slightly weathered, weak		II	R2				
201	0.16			19	RB-015	100	100									
													10	2.0	3.0	201.4
202											II	R2				
									202.10: PLA = 212 psi				20	3.0	3.0	202.2
203									203.08: PLL = 170 psi							
									Becomes greenish gray				45	1.0	3.0	203.2
204																
205																
													5	2.0	4.0	205.2
206	0.16			20	RB-016	100	73									
									Becomes moderately weathered, very to extremely weak, extremely close fracture spacing, extremely fractured, locally brecciated and healed		III	R0-R1	10	2.0	4.0	205.9
													90	3.0	3.0	205.9-206.3
														3.0	3.0	206.5-207.3
207									Becomes slightly weathered, medium strong		II	R3				
													5	3.0	3.0	207.3
208																
									Becomes moderate fracture spacing, moderately fractured to sound							
209													5	1.0	1.0	208.9
210																
													10	2.0	4.0	209.8
									210.30: γ = 136 pcf, PLL = 470 psi				5	2.0	4.0	210.4
211	0.16			21	RB-017	100	99									

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 7 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
213													15	1.0	4.0	212.4
													20	2.0	3.0	213.2
214									Grayish brown, DOLOMITE, moderately weathered, very weak to weak, close fracture spacing, extremely fractured, locally crushed		IV	R1-R2	0-30	1.0	2.0	213.9
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]					1.0	3.0	213.9-214.4
													70	1.0	4.0	214.5-214.8
215														1.0	4.0	214.8
									Becomes highly to extremely weathered, very to extremely weak, extremely close fracture spacing, locally crushed to a sand at 215.4 ft.		IV-V	R0-R1				
216									Grayish brown, DOLOMITE, highly weathered, very weak to weak, close fracture spacing, extremely fractured, locally crushed		IV	R1-R2	5	2.0	4.0	215.8
									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
217																
218	0.41			22	RB-018	31	6									
219																
220								CL	NOTE: Driller notes fast drilling 219.8-224.2 ft.							
221																
222																
223									With slightly weathered, medium strong, black shale partings				0-90	2.0	1.0	223.1-224.2
224									Becomes brown, extremely weathered, extremely weak, with some limestone fragments		V	R0				
225	0.62			23	RB-019	50	0						0-90	2.0	1.0	225.3-225.5

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 8 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
227								CL								
228									Grayish brown, DOLOMITE, slightly weathered, medium strong, close fracture spacing, slightly fractured [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0-90	2.0	1.0	228.0-229.0
229				24		60	13		Becomes slightly weathered, medium strong, slightly fractured		II	R3	<5 19	1.5 3.0	2.0 1.0	229.0 229.1
230					RB-020			CL								
231	0.11			25		100	89		Becomes moderate to close fracture spacing, moderately fractured to sound, contains gypsum vein 230.64: PLA = 5,450 psi 230.97: γ_d = 139 pcf, MC = 3.25 %				10 10	1.5 1.0	2.0 1.0	230.6 230.8
232													<5	1.5	1.0	231.9
233									Greenish gray, CLAYSTONE, slightly weathered, weak, sound to slightly fractured, with completely weathered, extremely weak zones		II	R2	10 15	1.5 1.0	2.0 2.0	232.5 233.4
234																
235				26	RB-021	100	73									
236													20	1.0	1.0	235.6
237													10 15	1.0 1.0	4.0 2.0	236.4 237.4
238									Becomes mottled reddish brown and greenish gray, slightly weathered, weak, moderate fracture spacing, with few gypsum veins							
239													<5	1.0	1.0	238.9

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 9 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
241	0.10			27	RB-022	91	91		Mottled reddish brown and greenish gray, CLAYSTONE, slightly weathered, weak, close fracture spacing, sound to slightly fractured, with completely weathered, extremely weak zones, few to some gypsum pods [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				15	1.5	2.0	240.6
242								CL								
243	0.10			28	RB-023	100	97				II	R3	<5	1.0	1.0	242.9
244																
245																
246																
247																
248	0.10			29	RB-024	100	99						<5	1.5	1.0	247.7
249													<5	1.0	1.0	249.4
250																
251																
252																
253													50	2.0	1.0	252.6

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-31
SHEET NUMBER: 10 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, R. Smith
INSPECTOR: K. Zeiger, C. Zhang

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
255	0.09			30	RB-025	100	93		Reddish brown, CLAYSTONE, slightly weathered, medium strong, close fracture spacing, sound to slightly fractured, with completely weathered, extremely weak zones [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]							
256																
257																
258									Becomes mostly reddish brown, medium strong, moderate to close fracture spacing, at 257.5 ft.		II	R3 R3				
259													<5	3.0	2.0	259.2
260	0.11			31	RB-026	100	96						<5 9	3.0 2.0	2.0 2.0	259.9 260.1
261													20 10	2.0 3.0	2.0 2.0	260.6 260.8
262									261.48: γ = 136 pcf, UCS = 904 psi							
263									Becomes unweathered, wide fracture spacing, sound		I					
264				32	RB-027	100	100		Becomes greenish gray							
265									Becomes reddish brown							
266									End of Boring at 265.74' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). A section of packer testing equipment could not be retrieved and was grouted in place in the boring. The borehole was backfilled from the bottom of the boring to mudline.							
267																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 1 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.80755 N Long: 84.76880 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 451.4 feet
DATUM: IGLD 1985
START DATE: 9/18/19 TIME: 10:45 pm
FINISH DATE: 9/19/19 TIME: 7:30 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
1																		Mudline is 130.2 ft. (39.7 m) below lake level. NCD down to 21.4 ft. No sample obtained.
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 2 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11			NCD				0.0 - 21.3	255.9										
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		Brown, Silty, LEAN CLAY, trace to some Gravel, trace Sand, soft to very soft, moist, (CL)
23			G-S	1	RB-001		21.3 -	59.05	46.46	79								

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 3 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
							26.2											21.3-26.2: Field MC = 25.1%
25																		
26																		NCD down to 45.9 ft. No sample obtained.
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36			NCD				26.2 - 45.9	236.22										
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 4 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40																		
41																		
42																		
43																		
44																		
45																		
46																		Brown, Silty, LEAN CLAY, trace to some Gravel, trace Sand, soft to very soft, moist, (CL)
47																		
48		0.98	G-S	2		RB-002	45.9 - 50.9	59.05	23.62	40								47.6-52.5: Field MC = 30.6%
49																		
50																		
51																		NCD down to 70.5 ft. No sample was obtained.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 5 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53			NCD				50.9 - 70.5						236.22					
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61																		
62																		
63																		
64																		
65																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 6 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		
68																		
69																		
70																		
71																		Medium to coarse, POORLY GRADED SAND, some Gravel, wet, (SP), NOTE: Partial wash out of sand, gravel is subangular to subrounded
72																		Brown, Silty, LEAN CLAY, some Gravel, trace Sand, moist, (CL), gravel is medium to fine grained
73			G-S	3		RB-003	70.5 - 75.5	59.05	22.44	38								Fine, GRAVEL, some Sand, wet, (GP) NOTE: Sample above clay washed out.
74																		
75																		
76																		Brown, Silty, LEAN CLAY, trace Fine Sand, trace Gravel, medium stiff to stiff, moist, (CL)
77																		Brown, medium, GRAVEL, some Clay, little Sand, wet, (GC), sand is fine grained Large 4" limestone cobble NOTE: GRAVEL, Material washed out. 75.5-80.4: Field MC = 24.1%
78		0.27	G-S	4			75.5 - 80.4	59.05	22.44	38								
79																		

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 7 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		Light brown, LEAN CLAY, some Sand, some Gravel, very hard, moist, (CL), sand is fine grained, trace cobble
82																		
83		0.33	G-S	5		RB-004	80.4 - 85.3						59.05	59.05	100			
84																		
85																		With trace Silt, with occasional interbedded seams of light gray brown weathered dolomite
86																		
87		0.41	G-S	6		RB-005	85.3 - 90.2						59.05	51.18	87			
88																		
89																		
90																		
91																		
92		0.33	G-S	7		RB-006	90.2 - 95.1						59.05	56.30	95			See Core Log.
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.80755 N Long: 84.76880 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 451.4 feet
DATUM: IGLD 1985
START DATE: 9/18/19 TIME: 10:45 pm
FINISH DATE: 9/19/19 TIME: 7:30 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 130.2 ft. (39.7 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
93	0.33			7	RB-006	95	11		Light grayish brown, DOLOMITE, slightly weathered, weak to medium strong, very close to close fracture spacing, sound, with angular corestones and clay coating on fracture surfaces		III	R2-R3	40	1.0	6.0	92.35
									[ST. IGNACE FORMATION - MACKINAC BRECCIA]				5	1.5	2.0	93.04
94									With silty clay seams containing angular DOLOMITE fragments, brecciated and healed		V	R0	40	1.0	6.0	93.37
													0	1.0	6.0	93.5
													0	1.5	2.0	93.73
													40	1.5	2.0	93.83
									Tan, silty CLAY with some fine to coarse sand and fine to medium gravel.				70	1.5	2.0	94.16
95								CL					20	1.0	6.0	94.26
	0.29								Becomes light grayish brown, moderately weathered, weak to medium strong, angular DOLOMITE corestones cemented with clay				0	1.0	6.0	95.14
													90	3.0	2.0	95.24
96													0	1.0	6.0	95.31
													45	1.0	6.0	95.47
97																
				8	RB-007	73	0									
98													0	1.0	6.0	97.83
													45	1.0	6.0	98
99								CL								
100									Tan, DOLOMITE, slightly weathered, medium strong, very close to close fracture spacing, with 0° bedding, very thinly bedded		II	R3	0	1.0	6.0	100.06
													0	1.0	3.0	100.26
101									100.4: PLA = 2,960 psi				35	1.0	6.0	100.75
									Contains extremely weathered, extremely weak, a mix of clay, silt, sand, gravels or corestones and DOLOMITE fragments				20	1.0	6.0	100.95
											II	R3				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
103	0.35			9	RB-008	93	10		Tan, DOLOMITE, slightly weathered, medium strong, very close to close fracture spacing, with 0° bedding, very thinly bedded							
104									Light gray to gray, moderately weathered, weak, DOLOMITE corestone 103.8-104.7 ft.		III	R2	70	1.0	6.0	103.8
													10	1.0	0.0	104.07
													85	1.0	6.0	104.33
								CL					70	1.0	6.0	104.66
105									Light grayish brown, DOLOMITE, highly weathered, extremely weak, fragments in sandy silty clay matrix							
106																
107				10	RB-009	85	18		DOLOMITE, slightly weathered, medium strong, close fracture spacing, horizontal bedding with clay infills at the joints	P8	II	R3	25	1.0	6.0	107.31
													90	3.0	3.0	107.77
108									Tan to light gray, extremely weathered, extremely weak, sandy silty CLAY with dolomite fragments				20	1.0	6.0	108.14
109																
								CL								
110																
111																
112				11	RB-010	91	0									
113																
114																
								CL								
115									Becomes light grayish brown and light gray, slightly weathered, weak to medium strong, moderate to very close fracture spacing, moderately fractured, brecciated and healed, with a sandy gravelly silty clay seams		II-III	R2-R3	5	1.0	6.0	115.29
													70	10.0	2.0	115.42
											II-III	R2-	10	3.0	2.0	

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									DOLOMITE, slightly weathered, medium strong, close fracture spacing, horizontal bedding with clay infills at the joints			R3	85	3.0	3.0	115.52
													50	1.0	2.0	115.81
																116.17
117	0.26			12	RB-011	100	59			P7			0	1.0	6.0	117.22
													0	1.0	6.0	117.39
118									Becomes extremely weathered, extremely weak, with angular DOLOMITE fragments		V	R0	0	1.0	6.0	117.78
119									Reddish brown and greenish gray, CLAYSTONE, mottled, slightly weathered, weak, moderate to close fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		III	R2	0	1.0	6.0	118.76
													0	3.0	3.0	119.26
120									Light gray and brown, DOLOMITE, slightly weathered, medium strong, moderate fracture spacing, extremely fractured, with 40° bedding [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R1-R3	0	1.0	6.0	119.75
121	0.07			13		60	27						35	1.0	6.0	120.57
								CL					0	1.0	6.0	121.23
122					RB-012				122.1: PLA = 6,180 psi				10	1.0	6.0	122.21
													30	1.0	2.0	122.47
123	0.14			14		68	0		Becomes extremely close fracture spacing, extremely fractured				20	1.0	6.0	122.7
124								CL								
125	0.10			15		63	23		Becomes light grayish brown, DOLOMITE, extremely fragmented			R3	5	1.0	6.0	124.93
													10	1.0	3.0	125.36
								CL					0	1.0	6.0	125.56
126									Becomes extremely close fracture spacing, very to extremely fractured, with 20 to 30° bedding				5	1.0	6.0	126.41
127					RB-013				127.2: γ = 166 pcf, UCS = 11,779 psi	P6						
	0.15			16		84	31		Becomes moderately close fracture spacing, sound				10	1.0	6.0	127.52
128													0	1.0	6.0	127.69
													30	1.0	6.0	127.82
													30	1.0	3.0	127.98
													30	1.0	3.0	128.08
129													0	1.0	2.0	128.28
								CL	Becomes extremely close fracture spacing, extremely fractured				0	1.0	6.0	128.48
									Brown to light gray, LIMESTONE, slightly weathered,		II-III	R3				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									medium strong, extremely close fracture spacing, extremely fractured, way bedding planes, locally weathered to clay, sand, and silt, with trace vugs							
131									Becomes dark gray, slightly weathered, weak, moderate fracture spacing, argillaceous, sound				20	3.0	6.0	131.07
													10	1.0	6.0	131.4
132	0.33			17	RB-014	67	19						20	3.0	6.0	132.09
													30	1.0	6.0	132.35
133									Becomes moderately weathered, very close to close fracture spacing, extremely fractured, some vugs up to 0.4-inches				30	1.0	6.0	132.87
								CL								
134																
135																
136									Light grayish brown, DOLOMITE, slightly weathered, medium strong, extremely close fracture spacing, extremely fractured, some clay between dolomite fragments	P5	III	R2				
137	0.41			18		41	0									
138								CL								
139																
140					RB-015											
141																
142	0.35			19		39	0									
143								CL								

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
											III	R2				
									Gray, DOLOMITE, laminated, slightly weathered, medium strong, extremely close fracture spacing, extremely fractured, calcareous		II-III	R3	0	1.0	6.0	144.36
													0	1.0	6.0	144.68
145													0	1.0	6.0	145.11
									Becomes dark greenish gray, CLAYSTONE, moderately weathered, weak, moderate fracture spacing, sound				30	1.0	6.0	145.18
													0	1.0	6.0	145.24
146																
										P4			0	3.0	4.0	146.39
147				20	RB-016	80	45									
									Light grayish brown, DOLOMITE, slightly to moderately weathered, medium strong, close fracture spacing, moderately to extremely fractured, up to 0.2-inches vugs, clay coating around fragments				30	1.0	6.0	147.08
148													0	1.0	6.0	147.5
													35	1.0	6.0	148.06
								CL								
149																
									Light brown, DOLOMITE, extremely weathered, extremely weak, moderate to very close fracture spacing, extremely fractured		II	R2				
150																
151																
152				21	RB-017	65	0		Dark greenish gray, CLAYSTONE, highly weathered, very weak, moderate fracture spacing, calcareous, dolomitic clasts (breccia), extremely farctured [POINTE AUX CHENES FORMATION - MACKIANC BRECCIA]		IV	R1				
153								CL								
154																
									Light brown, DOLOMITE, fragments							
									CLAYSTONE, highly to extremely weathered, very to extremely weak, close to wide fracture spacing		IV-V	R0-R1	20	1.0	6.0	154.53
155													0	3.0	4.0	154.79
													0	3.0	4.0	155.18
156													30	3.0	4.0	155.74
	0.20			22	RB-018	100	75			P3						
157											IV-V	R0-				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark greenish gray, CLAYSTONE, highly weathered, very weak, moderate fracture spacing, calcareous, dolomitic clasts (breccia), extremely farctured			R1	0	3.0	4.0	158.2
159									[POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued] Becomes highly weathered, very weak		II	R2	0	3.0	4.0	159.12
160									With light grayish brown, GYPSUM, pitted		II	R4	10	3.0	4.0	160.23
									Dark greenish gray, CLAYSTONE, slightly weathered, weak, close to wide fracture spacing, sound		II	R2	30	1.0	6.0	160.56
161	0.14			23	RB-019	93	80									
162																
163													0	1.0	6.0	162.92
													20	1.0	6.0	163.06
								CL	163.6: PLA = 789 psi				0	1.0	6.0	163.68
164									Becomes moderately weathered, very weak, with horizontal bedding		IV	R1	0	1.0	6.0	164.04
165													0	3.0	4.0	165.02
166	0.16			24	RB-020	100	97			P2						
167													0	3.0	4.0	166.6
168													0	3.0	4.0	167.71
169									Becomes greenish gray and reddish brown, mottled, close to moderate fracture spacing, moderately fractured, irregular bedding surfaces, minimal red brown coloration				10	3.0	4.0	168.96
170									169.46: γ = 141 pcf; UCS = 438 psi				0	3.0	1.0	169.85
													5	3.0	4.0	170.37
171	0.14			25	RB-021	87	54		Becomes close to moderate fracture spacing, moderately fractured				40	3.0	3.0	171.06
											IV	R1				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark greenish gray, CLAYSTONE, slightly weathered, weak, close to wide fracture spacing, sound [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, continued]				0	1.0	6.0	172.21
173													0	1.0	6.0	172.77
													10	3.0	3.0	173.06
								CL					0	1.0	6.0	173.23
174									Becomes greenish gray and reddish brown, mottled, highly weathered, very weak				50	0.0	0.0	174.18
175																
176	0.14			26	RB-022	100	62			P1			10	0.0	0.0	175.85
													70	0.0	0.0	176.11
													90	0.0	0.0	176.51
177																
178													75	0.0	0.0	177.59
													0	0.0	0.0	178.31
179									Moderate fracture spacing			R2	0	2.0	0.8	178.8
									Light grayish brown, DOLOMITE, slightly weathered, medium strong, very close fracture spacing, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA]		IV	R1				
180																
181	0.25			27		24	13									
182								CL								
183																
184	0.20			28	RB-023	100	0		Becomes grayish brown, moderately weathered, weak, extremely close fracture spacing, argillaceous, brittle		III-IV		20	3.0	3.0	184.38
185									Becomes brown, CLAYSTONE, extremely weathered, extremely weak, with gravel		IV-V		20	2.0	3.0	184.94
									Grayish brown, DOLOMITE, slightly to moderately weathered, very weak to medium strong, extremely close fracture spacing, gravel is angular		IV-V	R1				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-32
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
187	0.27			29		42	0	CL	Grayish brown, DOLOMITE, slightly to moderately weathered, very weak to medium strong, extremely close fracture spacing, gravel is angular [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
188																
189				30		20	0	CL	Becomes slightly weathered, medium strong, moderately fractured, possible calcite infill							
190																
191				31	RB-024	89	0	CL	Becomes moderately fractured, with pits							
192	0.26															
193													0	3.0	4.0	193.14
194				32		63	10	CL			IV	R1	0	3.0	4.0	193.24
195													0	3.0	4.0	193.57
196	0.11			33	RB-025	97	18	CL	Dark gray, CLAYSTONE, slightly to moderately weathered, weak, moderately fractured, with horizontal bedding, occasional thinly laminated seams, with 0.4-inches thick calcareous claystone vein or inclusion [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]				0	3.0	4.0	195.31
197									196.98: PLA = 1,520 psi End of Boring at 197.18' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.				0	3.0	4.0	195.6
198													0	3.0	4.0	195.86
199													0	3.0	4.0	196.42
													0	3.0	4.0	196.75

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 1 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.80489 N Long: 84.76979 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 486.5 feet
DATUM: IGLD 1985
START DATE: 7/14/19 TIME: 12:00 pm
FINISH DATE: 7/23/19 TIME: 2:45 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA				
Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
0																		Mudline is 95.1 ft. (29.0 m) below lake level. NCD down to 16.4 ft. No sample obtained.
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8			NCD	1			0.0 - 16.4	196.85										
9																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 2 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11																		
12																		
13																		
14																		
15																		
16																		
17		1.64	G-S	1		RB-001	16.4 - 21.3						59.05	59.05	100			Reddish brown, Silty, LEAN CLAY, little Gravel, trace Sand, soft, moist, (CL), calcareous 16.7: PP = 0.00 tsf 17.1: PP = 0.00 tsf 17.4: PP = 0.00 tsf 17.7: PP = 0.00 tsf 18.0: PP = 0.00 tsf 18.4: PP = 0.00 tsf 18.7: PP = 0.00 tsf 19.0: PP = 0.00 tsf 19.4: PP = 0.00 tsf
18																		
19																		
20																		20.0: Field MC = 25.7%
21																		
22																		
23		1.64	G-S	2		RB-002	21.3 -						59.05	59.05	100			23.0: TV=0.25 tsf 23.6: Field MC = 29.5%

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 3 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
							26.3											Reddish brown, Silty, LEAN CLAY, little Gravel, trace Sand, soft, moist, (CL), calcareous
25																		24.6: TV=0.25 tsf
26																		
27																		
28																		27.9: TV=0.50 tsf; Field MC = 28.0%
29		0.82	G-S	3		RB-003	26.3 - 31.2	59.05	43.31	73								
30																		29.5: TV=0.50 tsf
31																		
32																		Reddish brown, Silty, LEAN CLAY, some Gravel, some Sand, medium plasticity, stiff, moist, (CL), calcareous
33																		32.8: TV=0.50 tsf
34		0.15	G-S	4		RB-004	31.2 - 36.1	59.05	51.18	87								
35																		34.4: TV=0.50 tsf
36																		35.4: Field MC = 6.5% Two black and white dolomitic limestone cobbles at end of G-S 004, slight effervescence Reddish brown, Sandy, LEAN CLAY, some Gravel, stiff, moist, (CL), calcareous
37																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 4 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39		0.25	G-S	5		RB-005	36.1 - 41.0						59.05	37.40	63			Reddish brown, Sandy, LEAN CLAY, some Gravel, stiff, moist, (CL), calcareous 38.4: TV=1.00 tsf
40																		
41																		40.7: Field MC = 9.3%
42		0.18	G-S	6		RB-006	41.0 - 43.3						27.56	19.68	71			Brown, POORLY GRADED SAND, and Gravel, wet, (SP), calcareous, some subrounded clasts NOTE: Driller reported circulation loss at 43.3' and pulled core out. Cobble found at bottom of G-S 006.
43																		
44		0.44	G-S	7		RB-007	43.3 - 45.9						31.5	15.75	50			Brown, fine grained, POORLY GRADED SAND, and Gravel, wet, (SP), calcareous, some subrounded clasts
45																		
46		0.07	G-S	8		RB-008	45.9 - 46.3						3.94	3.94	100			Brown, Clayey, fine grained, CLAYEY SAND, with Gravel, wet, (SC), calcareous, gravel is fine NOTE: Material becomes more coarse grained.
47		0.09	G-S	9		RB-009	46.3 - 47.6						15.75	15.75	100			
48		0.18	G-S	10		RB-010	47.6 - 49.5						23.62	11.81	50			Brown, subrounded, POORLY GRADED GRAVEL, some Rock Fragments, wet, (GP), subangular to subrounded clasts, no matrix recovered
49																		
50		0.15	G-S	11		RB-011	49.5 - 50.9						15.75	9.84	62			NOTE: trace Rock Fragments, limestone fragments are subangular
51		0.10	G-S	12		RB-012	50.9 - 51.8						11.81	7.87	67			

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 5 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53		0.20	G-S	13		RB-013	51.8 - 54.8	35.43	27.56	78								NOTE: little Rock Fragments, limestone fragments are angular to rounded Brown, subrounded, POORLY GRADED GRAVEL, some Rock Fragments, wet, (GP), subangular to subrounded clasts, no matrix recovered
54																		
55		0.33	G-S	14		RB-014	54.8 - 58.1	39.37	23.62	60								Brown, fine to coarse grained, POORLY GRADED GRAVEL, some Rock Fragments, wet, (GP), sand is fine to coarse grained, little clay, stone fragments and gravel are angular to subrounded
56																		
57																		
58		0.41	G-S	15		RB-015	58.1 - 60.1	24.8	11.81	48								
59																		
60		0.26	G-S	16		RB-016	60.1 - 61.5	15.75	3.94	25								POORLY GRADED GRAVEL, trace Sand, wet, (GP), gravel consists of limestone fragments, angular to subrounded
61		0.41	G-S	17		RB-017	61.5 - 63.1	19.68	17.32	88								POORLY GRADED GRAVEL, some Sand, some Silty Clay, wet, (GP), gravel consists of limestone fragments, angular to subrounded
62																		
63		0.20	G-S	18		RB-018	63.1 - 65.1	23.62	19.68	83								Silty, LEAN CLAY, some Gravel, some Cobble, hard, moist, (CL), calcareous 63.9: PP>4.50 tsf
64																		
65																		

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 6 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67		0.41	G-S	19		RB-019	65.1 - 68.3						39.37	25.59	65			Silty, LEAN CLAY, some Gravel, some Cobble, hard, moist, (CL), calcareous
68																		
69		0.27	G-S	20		RB-020	68.3 - 70.0						19.68	9.84	50			POORLY GRADED GRAVEL, wet, (GP), gravel consists of primarily of limestone, some igneous and metamorphic rock fragments, subrounded
70																		
71		0.55	G-S	21		RB-021	70.0 - 73.3						39.37	9.84	25			
72																		
73																		With some Sand, one granite rock fragment, sand is fine to medium grained with some calcareous fines
74		0.41	G-S	22		RB-022	73.3 - 74.9						19.68	9.84	50			
75																		Brown, Clayey, fine to coarse grained, subangular, CLAYEY SAND, wet, (SC), trace dolomite fragments in the lower part of the run
76		0.24	G-S	23		RB-023	74.9 - 77.8						34.25	34.25	100			
77																		
78																		NOTE: calcareous, some limestone and granite fragments
79		0.26	G-S	24		RB-024	77.8 - 80.4						31.5	31.50	100			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 7 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		Subangular to round, POORLY GRADED GRAVEL, wet, (GP), NOTE: Matrix was washed out. Large piece of cobble in bottom of barrel prevented good recovery in G-S 025.
82																		
83		0.33	G-S	25		RB-025	80.4 - 85.3						59.05	11.81	20			
84																		
85																		
86																		Brown, fine to coarse grained, subangular to subrounded, SILTY SAND, some Gravel, wet, (SM), calcareous, gravel consists of limestone fragments angular to rounded
87																		
88		0.49	G-S	26		RB-026	85.3 - 90.2						59.05	51.18	87			
89																		
90																		
91																		Subangular to round, POORLY GRADED GRAVEL, wet, (GP), No matrix was recovered.
92		0.43	G-S	27		RB-027	90.2 - 93.7						41.34	19.68	48			
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 8 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95		0.18	G-S	28		RB-028	93.7 - 95.1						17.72	1.97	11			Subangular to round, POORLY GRADED GRAVEL, wet, (GP), No matrix was recovered.
96		0.12	G-S	29		RB-029	95.1 - 98.1						35.43	27.56	78			Brown, fine to coarse grained, subangular to subrounded, CLAYEY SAND, wet, (SC), calcareous, some calcareous clay mixed with gravel and some sand in the lower part of the run. NOTE: Cobbles contain limestone and granite fragments, fossils and occasionally basalt fragments.
97																		
98																		
99		0.14	G-S	30		RB-030	98.1 - 100.1						23.62	23.62	100			
100																		
101		0.23	G-S	31		RB-031	100.1 - 103.0						35.43	25.59	72			
102																		
103		0.39	G-S	32		RB-032	103.0 - 105.0						23.62	5.91	25			Subangular to round, POORLY GRADED GRAVEL, wet, (GP), No matrix was recovered.
104																		
105		0.21	G-S	33		RB-033	105.0 - 106.6						19.68	13.78	70			NOTE: No matrix was recovered.
106																		NOTE: No matrix was recovered.
107																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 9 of 9
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109		0.33	G-S	34		RB-034	106.6 - 109.9						39.37	23.62	60			Subangular to round, POORLY GRADED GRAVEL, wet, (GP), No matrix was recovered.
110		0.08	G-S	35		RB-035	109.9 - 111.1						13.78	9.84	71			Gray, COBBLE, and Gravel, wet, cobble is Limestone
111		0.10	G-S	36			111.1 - 111.6						5.91	0.00	0			
112		0.09	G-S	37		RB-036/RB-037	111.6 - 113.3						20.87	9.84	47			See Core Log.
113																		
114																		
115																		
116																		
117																		
118																		
119																		
120																		
121																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.80489 N Long: 84.76979 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 486.5 feet
DATUM: IGLD 1985
START DATE: 7/14/19 TIME: 12:00 pm
FINISH DATE: 7/23/19 TIME: 2:45 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S, HQ3
O.D.: Geobor-S, HQ3
I.D.: Geobor-S, HQ3
CASING SIZE: " (")

NOTES:
Mudline is 95.1 ft. (29.0 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
113	0.09			37	RB-036/RB-037	47			Light grayish brown, ARGILLACEOUS DOLOMITE, slightly weathered, medium strong, slightly fractured, some calcite veining, with wavy bedding planes, possible debris flow (turbidite) [ST. IGNACE FORMATION - MACKINAC BRECCIA]							
114	0.03			38	RB-038	88										
	0.09			39	RB-039	100					II	R3				
115	0.11			40	RB-040	100	20		Light grayish brown, DOLOMITIC LIMESTONE, highly weathered, medium strong, extremely fractured, with some slightly weathered, medium strong corestones With dark brown, calcareous shale partings		IV-V	R0-R2				
116																
117	0.01			41		100	0		Light grayish brown, DOLOMITIC LIMESTONE, thinly bedded, highly weathered, medium strong, moderately fractured, bedding evident		II	R4				
118				42	RB-041	73	0									
119																
120								CL								
121									Gray, CLAYSTONE, extremely weak to weak		II-IV	R0-R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
123	0.25			43	RB-042	93	18		Light grayish brown, fine grained, LIMESTONE, slightly weathered, medium strong, moderately to extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3				
									122.8: PLL = 9,150 psi 122.9: PLL = 6,100 psi		V	R0				
124									Extremely weathered, extremely weak, zone at 123.4 ft.		II	R3				
125								CL								
126	0.21			44		0	0	CL	NOTE: No core recovery in Run 44.							
127									Light grayish brown, DOLOMITE, slightly weathered, strong, moderately fractured, with trace clay infilling fractures [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4				
128	0.22			45	RB-043	80	0		Extremely fractured zone 127.8-128.5 ft.							
129																
130								CL								
131									Grayish brown, ARGILLACEOUS DOLOMITE, moderately weathered, medium strong, extremely fractured		III	R3				
132	0.29			46	RB-044	79	9		Grayish brown, DOLOMITE, highly weathered, medium strong, extremely fractured		IV					
133									Light grayish brown, DOLOMITE, slightly weathered, strong, slightly to moderately fractured		II	R4				
									133.6: γ = 162 pcf							
134								CL								
135									Becomes medium strong, with evident 10° bedding, iron staining at the fracture surfaces and black shale partings at base 135.2: PLA = 2,510 psi			R3	0	1.0	1.0	135.04
													10	1.0	1.0	135.69

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, DOLOMITE, slightly weathered, strong, slightly to moderately fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				50	1.0	1.0	136.55
137	0.20			47	RB-045	93	58		Dark gray and gray, ARGILLACEOUS LIMESTONE, slightly weathered, medium strong, with black shale partings at the base				0	1.0	1.0	137.01
													10	1.0	1.0	137.56
138									Brownish white, DOLOMITE, slightly weathered, medium strong, moderately fractured		II	R3				
139								CL			II	R3				
140									Becomes light grayish brown, strong, moderately to extremely fractured		II	R4				
141									Light gray, ARGILLACEOUS LIMESTONE, moderately weathered, very weak, with distorted bedding and brecciated clasts							
142				48	RB-046	90	29		0.2 ft. zone of discoloration							
									Grayish brown, DOLOMITIC LIMESTONE, slightly weathered, medium strong, extremely fractured				90	1.5	1.0	142.58
143									Becomes moderately weathered, very weak, moderately to extremely fractured, with clay on core surface							
													30	1.0	1.0	143.47
144								CL								
				49	RB-047	100	0									
145									Grayish brown, DOLOMITE, slightly weathered, medium strong				30	1.5	2.0	144.68
146									Gray, ARGILLACEOUS LIMESTONE, moderately weathered, very weak, moderately fractured		II-III	R1-R3				
147																
148	0.11			50	RB-048	100	40		Gray, LIMESTONE, moderately weathered, very weak, moderately fractured							
149																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
151									Gray, LIMESTONE, moderately weathered, very weak, moderately fractured [ST. IGNACE FORMATION, MACKINAC BRECCIA, continued]							
									Becomes light grayish brown, slightly weathered, weak, extremely fractured		II	R2				
152											II	R2				
153	0.31			051	RB-049	68	33		Gray, LIMESTONE, slightly weathered, weak, sound 153.1: PLL = 300 psi							
154																
155								CL								
156									Becomes slightly weathered, extremely weak to weak, slightly to moderately fractured, with breccia clasts, no laminations or layering			R0-R1				
157													0	1.0	1.0	156.76
													0	1.0	1.0	156.82
158	0.20			052	RB-050	93	59						0	2.0	2.0	157.58
													30	2.0	1.0	158.13
159									Extremely fractured zone 158.5-158.8 ft.							
160																
								CL	Light grayish brown, DOLOMITIC LIMESTONE, highly weathered, extremely weak		IV	R0				
161									Becomes slightly weathered, weak, slightly to moderately fractured		II	R2				
162																
163	0.38			053	RB-051	93	43									

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
165									Light grayish brown, DOLOMITIC LIMESTONE, slightly weathered, weak, [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				85	1.0	2.0	164.04
								CL								
166									Becomes medium strong, moderately fractured to sound, possible shale fragments or tiny chert nodules, bedding evident especially in the upper half		II	R3				
167													10	1.0	2.0	166.89
													20	1.0	2.0	167.09
168	0.33			054	RB-052	97	50						55	1.0	1.0	167.98
													60	1.0	1.0	168.53
169													45	1.0	1.0	168.83
									Laminated, 169.3-169.6 ft.				45	1.0	1.0	169.03
170													0	1.0	1.0	170.04
								CL					0	2.0	2.0	170.21
171													40	2.0	2.0	170.86
													0	1.0	1.0	171.03
													0	2.0	1.0	171.26
172									Becomes thinly bedded				0	1.0	1.0	172.41
173	0.35			055	RB-053	97	42		With clay infilling along fractures							
													60	2.0	2.0	173.65
174													0	2.0	2.0	173.98
175									Becomes moderately weathered, medium strong, calcareous CLAY with pieces of dolomitic limestone							
								CL	NOTE: Possibly calcareous claystone or breccia or turbidite		III	R1				
176									Gray, ARGILLACEOUS LIMESTONE, moderately weathered, very weak, argillaceous, moderately fractured to sound with breccia clasts, possible debris flow texture				0	1.0	1.0	176.41
177																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
179	0.14			056	RB-054	100	75		Gray, ARGILLACEOUS LIMESTONE, moderately weathered, very weak, [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				10	2.0	2.0	179.16
180									Extremely fractured zone 179.5-180.2 ft.		III	R1				
181									Becomes dark gray, extremely fractured, with vugs up to 0.2-inches			R2	10	1.5	2.0	181.10
182									Light grayish brown, DOLOMITIC LIMESTONE, moderately weathered, weak, extremely fractured		III	R2	10	1.5	2.0	181.43-183.07
183	0.25			057	RB-055	89	0		182.6: γ_d = 170 pcf; PLL = 8,690 psi							
184									With vugs, and dark brown, needle-like concretions of random orientations				80	1.5	1.0	183.40-183.48
185								CL								
186									Light grayish brown, DOLOMITE, thinly bedded, slightly weathered, weak, moderately fractured, with argillaceous partings		II	R2	45 80	1.5 2.0	2.0 1.0	186.02 186.02-186.68
187													15	1.0	1.0	187.33
188	0.25			058	RB-056	100	0						85	1.0	2.0	187.66-187.75
189																
190										P2						
191									Becomes grayish brown, moderately weathered, medium strong, possible debris flow with clasts from breccia		III	R3	0 90	1.0 1.0	8.0 1.0	190.61 191.27-191.60

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
193	0.20			059	RB-057	100	29		Light grayish brown, DOLOMITE, thinly bedded, moderately weathered, weak, moderately fractured, with argillaceous partings [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
194									Gray, CLAYSTONE, highly weathered, extremely weak to weak, calcareous, breccia clasts present in core		III	R3	10	1.5	8.0	193.57
195																
196	0.20			060	RB-058	73	7		Light grayish brown, LIMESTONE, highly weathered, extremely weak to weak							
197									With bedding in large clast at up to a 60° angle to horizontal							
198																
199								CL		P1						
200									Gray, LIMESTONE, slightly weathered, weak, argillaceous, extremely fractured, with DOLOMITE breccia clasts		II	R2				
201	0.14			061	RB-059	84	48		Dark gray, CLAYSTONE, slightly weathered, weak, slightly calcareous, few breccia clasts evident							
202								CL								
203									Tan to light brown, DOLOMITIC LIMESTONE, slightly weathered, weak, argillaceous, moderately fractured to sound, with pits				90	3.0	1.0	203.41
204									Light grayish brown, DOLOMITE, slightly weathered, weak, moderately fractured to sound, with pits							
205	0.21			062	RB-060	95	40				II	R2	90	1.0	1.0	204.72-205.05

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-33
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
207									Light grayish brown, DOLOMITE, slightly weathered, weak, moderately fractured to sound, with pits [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				10	3.0	1.0	206.69
													30	3.0	1.0	207.35
								CL								
208											II	R2				
209																
210	0.20			063	RB-061	100	73		Gray, ARGILLACEOUS LIMESTONE, slightly weathered, weak, argillaceous, sound, with faint bedding		II	R2				
211																
212													10	3.0	3.0	211.78-212.33
213													0-30	3.0	1.0	212.92-216.70
214																
215	0.16			064	RB-062	100	97		Becomes clayey, soft Light gray and white, slightly weathered, weak, zone 214.9-215.6 ft., bedding evident		IV II	R1 R2				
216									Becomes medium strong			R3				
217																
218									End of Boring at 217.62' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
219																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 1 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.79960 N Long: 84.77182 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 499.2 feet
DATUM: IGLD 1985
START DATE: 7/26/19 TIME: 2:30 pm
FINISH DATE: 7/27/19 TIME: 3:30 pm

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
																		Mudline is 82.5 ft. (25.1 m) below lake level.
1		0.36	G-S	001		RB-001	0.0 - 1.8	21.65	21.65	100								0.82: Field MC = 13.8% Reddish brown, Sandy, LEAN CLAY, with Gravel, wet, (CL), low plasticity
2																		POORLY GRADED GRAVEL, trace Sand, wet, (GP), subrounded to angular, and limestone cobble, matrix not recovered
3		0.28	G-S	002			1.8 - 4.6	33.46	33.46	100								
4																		
5		0.30	G-S	003		RB-002	4.6 - 6.4	21.65	17.72	82								POORLY GRADED GRAVEL, trace Sand, wet, (GP), generally subangular, some limestone cobbles
6																		
7		0.14	G-S	004			6.4 - 7.2	9.84	9.84	100								
8		0.14	G-S	005			7.2 - 8.4	13.78	0.00	0								POORLY GRADED GRAVEL, trace Sand, wet, (GP), subrounded to angular cobbles, angular limestone cobbles present
9																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 2 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
11		0.61	G-S	006		RB-003	8.4 - 12.6						51.18	33.46	65			
12																		POORLY GRADED GRAVEL, trace Sand, wet, (GP), subrounded to angular
13																		
14		0.59	G-S	007		RB-004	12.6 - 15.6						35.43	21.65	61			
15																		
16		0.30	G-S	008			15.6 - 17.1						17.72	17.72	100			POORLY GRADED GRAVEL, trace Sand, wet, (GP), rounded to subangular particles, large piece of brownish white limestone present
17																		POORLY GRADED GRAVEL, trace Sand, wet, (GP), subrounded to angular particles, fine sand at end of sample
18		0.20	G-S	009			17.1 - 19.7						31.5	17.72	56			
19						RB-005												
20		0.20	G-S	010			19.7 - 21.6						23.62	23.62	100			POORLY GRADED GRAVEL, trace Sand, wet, (GP), and limestone cobbles, subrounded to angular clasts
21																		
22		0.33	G-S	011			21.7 - 24.3						31.5	19.68	62			POORLY GRADED GRAVEL, trace Sand, wet, (GP), subrounded to subangular clasts
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 3 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25						RB-006												POORLY GRADED GRAVEL, trace Sand, wet, (GP), some subangular to very rounded clasts
26		0.25	G-S	012			24.3 - 26.7						29.53	19.68	67			
27																		NCD down to 35.4 ft. No sample obtained.
28																		
29																		
30																		
31			NCD	001			26.7 - 35.4						104.33					
32																		
33																		
34																		
35																		
36																		POORLY GRADED GRAVEL, trace Sand, wet, (GP), subrounded to subangular cobbles
37		0.55	G-S	013			35.4 -						59.05	19.68	33			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 4 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39						RB-007	40.4											
40																		
41																		NCD down to 49.2 ft. No sample obtained. Driller noted last 3 ft. of run was tough to drill through.
42																		
43																		
44																		
45			NCD	002			40.4 - 49.2		106.3									
46																		
47																		
48																		
49																		
50		0.41	G-S	014		RB-008	49.2 - 54.1		59.05	51.18	87							POORLY GRADED GRAVEL, trace Sand, wet, (GP)
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 5 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53																		Fine grained, SILTY SAND, wet, (SM), poorly consolidated with calcite
54																		Medium grained, POORLY GRADED SAND, wet, (SP), subrounded to angular particles, poorly consolidated with calcite
55																		NOTE: No recovery.
56		0.82	G-S	015			54.1 - 59.1						59.05	0.00	0			
57																		
58																		
59																		NCD down to 64.0 ft. No sample obtained.
60																		
61			NCD	003			59.1 - 64.0						59.05					
62																		
63																		
64																		POORLY GRADED GRAVEL, with Gravel, wet, (GP), gravel predominantly Limestone
65		0.15	G-S	016			64.0 - 66.4						29.53	14.57	49			

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 6 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67																		NCD down to 70.6 ft. No sample obtained.
68			NCD	004		RB-009	66.4 - 70.7						51.18					
69																		
70																		
71			G-S	017			70.7 - 72.3						18.9	8.27	44			Light gray and brown, COBBLES, with Gravel, wet, (GP), cobbles are Limestone, subroundedd to subangular clasts
72		0.20																
73			G-S	018		RB-010	72.3 - 74.2						23.62	12.60	53			
74																		NCD down to 77.2 ft. No sample obtained.
75			NCD	005			74.2 - 77.2						35.43					
76																		
77																		
78		0.22																COBBLES, trace Gravel, wet, (GP), cobbles are Limestone, subangular
79			G-S	019		RB-011	77.2 - 80.5						39.37	19.68	50			

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 7 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		POORLY GRADED GRAVEL, wet, (GP), mixed Limestone, granite, basalt, and chert, angular to subrounded
82		0.41	G-S	020		RB-012	80.5 - 83.8						39.37	15.75	40			
83																		
84																		
85		0.36	G-S	021		RB-013	83.8 - 87.4						43.31	27.56	64			
86																		
87																		
88		0.20	G-S	022		RB-014	87.4 - 89.3						23.62	7.87	33			
89																		
90		0.33	G-S	023			89.3 - 91.0						19.68	11.81	60			
91		0.20	G-S	024			91.0 - 92.0						11.81	10.63	90			
92																		
93						RB-015												

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 8 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95		0.41	G-S	025			92.0 - 96.1						49.61	16.54	33			POORLY GRADED GRAVEL, wet, (GP), mixed Limestone, granite, basalt, and chert, angular to subrounded
96																		
97		0.19	G-S	026		RB-016	96.1 - 97.4						15.75	13.39	85			
98																		
99		0.26	G-S	027			97.4 - 100.0						31.5	22.05	70			
100																		
101		0.27	G-S	028		RB-017	100.0 - 103.3						39.37	23.62	60			
102																		
103																		
104		0.21	G-S	029			103.3 - 105.0						19.68	14.96	76			
105																		POORLY GRADED GRAVEL, wet, (GP)
106		0.35	G-S	030			105.0 - 106.7						21.26	21.26	100			
107						RB-018												COBBLES, with Gravel, wet, (GP), cobbles consisted of limestone and basalt, matrix was washed out.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 9 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109		0.44	G-S	031			106.7 - 110.2						42.13	17.72	42			COBBLES, with Gravel, wet, (GP), cobbles consisted of limestone and basalt, matrix was washed out.
110																		
111		0.27	G-S	032		RB-019	110.2 - 113.2						35.43	35.43	100			NOTE: Light gray brown Limestone gravels and cobbles, some basalt gravel, subrounded to angular
112																		
113		0.26	G-S	033			113.2 - 115.5						27.56	15.75	57			
114																		
115		0.57	G-S	034		RB-020	115.5 - 117.8						27.56	13.78	50			
116																		
117		0.33	G-S	035			117.8 - 119.7						23.62	15.75	67			
118																		
119		0.46	G-S	036		RB-021	119.8 - 122.0						27.56	23.62	86			
120																		
121																		

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 10 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123		0.41	G-S	037			122.1 - 123.7	19.68	19.68	100								COBBLES, with Gravel, wet, (GP), Limestone gravel and cobble, breccia clasts evident
124		0.26	G-S	038			123.7 - 125.0	15.75	15.75	100								
125		0.39	G-S	039		RB-022	125.0 - 127.0	23.62	23.62	100								COBBLES, with Gravel, wet, (GP), Limestone containing vugs, few mixed metamorphic rocks, red quartzite and black slate
126																		
127																		
128		0.53	G-S	040		RB-023	127.0 - 131.2	51.18	27.56	54								
129																		
130																		
131																		COBBLES, with Gravel, wet, (GP), subangular to angular, light gray brown Limestone, Limestone pieces are vuggy, breccia pieces visible in large pieces
132		0.82	G-S	041		RB-024	131.2 - 133.7	29.53	21.65	73								
133																		
134																		
135		0.54	G-S	042		RB-025	133.7 - 137.5	45.28	31.50	70								

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 11 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
137																		COBBLES, with Gravel, wet, (GP), subangular to angular, light gray brown Limestone, Limestone pieces are vuggy, breccia pieces visible in large pieces
138		0.49	G-S	043		RB-026	137.5 - 139.4	23.62	23.62	100								
139																		
140		0.38	G-S	044			139.4 - 141.7	27.56	27.56	100								
141																		
142		0.62	G-S	045		RB-027	141.7 - 144.2	29.53	29.53	100								NOTE: Jaspillite bearing arkasic metacomglomerate encountered, 0.46 ft. thick.
143																		
144																		NOTE: 13" limestone boulder encountered.
145		0.47	G-S	046		RB-028	144.2 - 147.5	39.37	39.37	100								
146																		
147																		COBBLES, with Gravel, wet, (GP)
148																		
149		0.62	G-S	047		RB-029	147.5 - 150.6	37.4	35.43	95								

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 12 of 12
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
151			G-S	048		RB-030	150.6 - 152.9	27.56	21.65	79								COBBLES, with Gravel, wet, (GP)
152																		
153																		
154			G-S	049			152.9 - 155.8	35.43	15.75	44								
155																		See Core Log.
156																		
157																		
158																		
159																		
160																		
161																		
162																		
163																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 1 of 6
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.79960 N Long: 84.77182 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 499.2 feet
DATUM: IGLD 1985
START DATE: 7/26/19 TIME: 2:30 pm
FINISH DATE: 7/27/19 TIME: 3:30 pm

CORE BARREL DATA:

TYPE:
CORE SIZE: Geobor-S, HQ3
O.D.: Geobor-S, HQ3
I.D.: Geobor-S, HQ3
CASING SIZE: " (")

NOTES:

Mudline is 82.5 ft. (25.1 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
156									Light grayish brown, DOLOMITE, highly weathered, extremely weak, extremely fractured, brecciated [ST. IGNACE FORMATION - MACKINAC BRECCIA]		IV	R0				
157									Dark gray, LIMESTONE, slightly weathered, medium strong, with calcite along fracture surfaces		II	R3				
158				050	RB-031	87	7		Light grayish brown, DOLOMITE, highly weathered, extremely weak, extremely fractured		IV	R0				
159									Dark gray, LIMESTONE, moderately weathered, extremely weak, moderately fractured		III	R0				
160								CL			III-IV	R0-R2				
161									Light grayish brown, ARGILLACEOUS LIMESTONE, slightly weathered, extremely weak to weak, extremely fractured							
162																
163				051	RB-032	80	0		Dark gray, LIMESTONE, moderately weathered, weak, slightly to extremely fractured, with brecciated clasts and shale partings							
164																

CORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 2 of 6
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL								
166									Dark gray, LIMESTONE, moderately weathered, weak, slightly to extremely fractured, with brecciated clasts and shale partings		III	R1				
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
167									Gray, DOLOMITE, moderately to highly weathered, extremely weak to weak, sound, argillaceous	P6						
168				052	RB-033	100	0				III-IV	R0-R2				
169																
170																
171									Light grayish brown, DOLOMITE, slightly to moderately weathered, weak, extremely fractured		II-III	R2				
172																
173				053	RB-034	80	0		Becomes light brownish white, highly weathered, with clayey, calcareous zones		III	R2				
174																
175								CL								
176									Becomes light brownish gray, slightly weathered, extremely weak to weak, with highly weathered, clayey breccia zones		II-IV	R0-R2				
177									176.8: γ = 149 pcf, UCS = 19,609 psi	P5						
178				054	RB-035	87	15									

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 3 of 6
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
180								CL	Light brownish gray, DOLOMITE, slightly weathered, extremely weak to weak, extremely fractured, with highly weathered, clayey breccia zones [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
181									Light brownish gray, LIMESTONE, moderately to highly weathered, extremely weak to weak, extremely fractured		III-IV	R0-R2				
182																
183				055	RB-036	73	0			P4			20	1.0	2.0	183.73
184																
185								CL								
186									Becomes slightly weathered, weak		II	R2				
187				056	RB-037	45	0									
188								CL								
189									Gray, ARGILLACEOUS LIMESTONE, slightly to moderately weathered, very weak to weak, sound, with breccia clasts		II-III	R1-R2				
190																
191				057	RB-038	67	54						0	2.0	2.0	191.27
192																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 4 of 6
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
								CL		P3						
194									Light brownish gray, ARGILLACEOUS LIMESTONE, moderately weathered, very weak, moderately to extremely fractured, with breccia clasts [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R1				
195				058	RB-039	72	20		Becomes olive gray, with vugs							
196								CL								
197									Light grayish brown, DOLOMITIC LIMESTONE, slightly to highly weathered, extremely weak to weak, moderately to extremely fractured, breccia texture with clayey sand (calcareous) cementation		II-IV	R0-R2				
198																
199				059	RB-040	100	0									
200													70	2.0	4.0	200.13
201				060		100	0		Becomes slightly weathered, weak		II	R2				
202									Becomes extremely fractured, with 20° bedding from 202.8-203.4 ft.		II-IV	R0-R2				
203									202.8: γ = 167 pcf	P2						
204				061	RB-041	87	13		Becomes slightly to highly weathered, extremely weak to weak, with horizontal bedding							
205													o90$_o$	1.0	1.0	204.72
206								CL								
									Becomes slightly to highly weathered		II-IV	R0-				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 5 of 6
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
208									Light grayish brown, DOLOMITIC LIMESTONE, slightly to highly weathered, extremely weak to weak, moderately to extremely fractured, breccia texture with clayey sand cementation [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]			R2				
209				062	RB-042	97	9									
210													70	1.0	3.0	210.30
211								CL								
212									Gray, ARGILLACEOUS LIMESTONE, moderately to highly weathered, very weak, extremely fractured with sound zones		III-IV	R1				
213									Becomes highly weathered	P1						
214				063	RB-043	73	45						0	3.0	6.0	214.24
215																
216								CL								
217											II	R1				
218				064	RB-044	90	0									
219								CL								
220											III-IV	R0-R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-35
SHEET NUMBER: 6 of 6
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: T. Lawer, R. Smith
INSPECTOR: L. Avila, C. Fischer

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
222				065	RB-045	100	0		Gray, ARGILLACEOUS LIMESTONE, moderately to highly weathered, extremely weak to weak, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
223									NOTE: 4 in. mechanical break zone		III-IV	R0-R1				
224									Greenish gray and reddish brown, CLAYSTONE, moderately to highly weathered, very to extremely weak, slightly to moderately fractured [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]							
225				066	RB-046	100	0									
226													60	1.5	3.0	226.05
											III-IV	R0-R2	30	1.5	3.0	226.38
227																
228									Becomes weak, alternating bands of highly and moderately weathered Claystone							
229				067	RB-047	100	13									
230													30	3.0	4.0	229.98
231																
									End of Boring at 231.3' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
232																
233																
234																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 1 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.79716 N Long: 84.77391 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 502.4 feet
DATUM: IGLD 1985
START DATE: 9/13/19 TIME: 8:00 pm
FINISH DATE: 9/18/19 TIME: 12:00 am

	Casing	CPT	Shelby Tube	Geobore-S	NCD	HQ3 Barrel
Type/Symbol	L80	CPT	ST	G-S	NCD	HQ3
I.D.	"	1.375"	2.938"	4.00"	N/A	3.11"
O.D.	7.00"	2"	3"	5.75"	5.75"	4.00"
Length	VARIES	24"	24"	VARIES	VARIES	9.85'
Hammer Wt.	N/A	N/A	Drill Rod Size			
Hammer Fall	N/A	N/A	I.D. (O.D.)		" (")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
0																		Mudline is 79.3 ft. (24.2 m) below lake level. NCD down to 8.4 ft. No sample was obtained.
1																		
2																		
3																		
4			NCD				0.0 - 8.4	100.79										
5																		
6																		
7																		
8																		Brown, COBBLES, wet, (GP), limestone, broken
9		0.44	G-S	1	RB-001		8.4 - 9.7	15.75	15.75	100								Brown, fine, CLAYEY SAND, with Silt, wet, (SC), sand grains are angular 8.4-9.7: Field MC = 11.6% Brown, fine, SILTY SAND, wet, (SM)

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 2 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
																		NCD down to 29.4 ft. No sample obtained.
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19			NCD				9.7 - 29.4	236.22										
20																		
21																		
22																		
23																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 3 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
25																		
26																		
27																		
28																		
29																		
30		0.98	G-S	2			29.4 - 34.3						59.05	25.59	43			Brown with black, coarse, GRAVEL, wet, (GP), crushed cherty Limestone with pieces of mixed igneous and methamorphic rocks, angular to subrounded, loose in the core liner
31																		
32																		
33																		
34																		
35																		NCD down to 39.2 ft. No sample obtained.
36																		
37			NCD			RB-002	34.3 - 39.2						59.05					

WSP BORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 4 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
39																		
40		0.42	G-S	3			39.2 - 42.2						35.43	20.47	58			Fine to coarse grained, COBBLES, and Gravel, some Sand, wet, (GP), varying rocks present (sedimentary and igneous), angular to subrounded, with residual matrix of light brown Silty Clay. Rest of matrix likely washed out.
41																		
42																		
43		0.16	G-S	4			42.2 - 44.2						23.62	18.90	80			
44																		
45		0.14	G-S	5			44.2 - 45.1						11.81	11.81	100			NCD down to 64.0 ft. No sample obtained.
46																		
47																		
48																		
49																		
50																		
51																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 5 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
53			NCD				45.1 - 64.0	225.78										
54																		
55																		
56																		
57																		
58																		
59																		
60																		
61						RB-003												
62																		
63																		
64		0.30	G-S	6			64.0 - 65.2	14.17	14.17	100								Medium to coarse grained, GRAVEL, with Cobble, wet, (GP), predominantly limestone and chert with other igneous rocks, subangular to subrounded, no matrix present (washed out)
65																		NCD down to 73.8 ft. No sample obtained.

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 6 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
67			NCD				65.2 - 73.8						103.94					
68																		
69																		
70																		
71																		
72																		
73																		
74																		Coarse, GRAVEL, and Cobble, wet, (GP), predominantly limestone and dolomite with other igneous rocks (basalt), angular to subrounded, no matrix present (washed out)
75		0.29	G-S	7			73.8 - 77.9						49.21	0	0			
76																		
77																		
78																		NCD down to 98.4 ft. No sample obtained.
79																		

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 7 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
81																		
82																		
83																		
84																		
85																		
86																		
87																		
88			NCD				77.9 - 98.4					246.06						
89																		
90																		
91																		
92																		
93																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 8 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	SAMPLE CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
95																		
96																		
97																		
98																		
99		0.38	G-S	8		RB-004	98.4 - 103.3					59.05	48.42	82				Coarse, GRAVEL, wet, (GP), boulder
100																		
101																		Graygreen, BOULDER, wet, (GP), DIORITE boulder
102																		Fine to coarse grained, COBBLES, wet, (GP), predominantly limestone and chert with other varying lithologies, subangular to subrounded, no matrix
103																		
104																		Fine to coarse grained, GRAVEL, wet, (GP), predominantly limestone and chert with other varying lithologies, angular to rounded, no matrix
105																		
106			G-S	9			103.3 - 108.3					59.05	19.68	33				
107																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 9 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
109																		NCD down to 118.1 ft. No sample obtained.
110																		
111						RB-005												
112																		
113			NCD				108.3 - 118.1						118.11					
114																		
115																		
116																		
117																		
118		0.44	G-S	10			118.1 - 119.4						15.75	11.81	75			Fine to coarse grained, GRAVEL, wet, (GP)
119																		NCD down to 123.0 ft. No sample obtained.
120																		
121			NCD				119.4 - 123.0						43.31					

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 10 of 10
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	GRAPHIC LOG	Coring Rate (ft/min)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	CORE BOX NO.	SAMPLE DEPTH (feet)	SOIL (Blows/6 in.) 0/6	6/12	12/18	18/24	REC. (in.)	CORING RUN (in.)	CORING REC. (in.)	CORING REC. %	CORING L>4" (in.)	CORING RQD %	FIELD CLASSIFICATION AND REMARKS
123																		Light gray, LEAN CLAY with SILT, some Gravel, little Sand, wet, (CL), low plasticity See Core Log.
124																		
125																		
126																		
127																		
128																		
129																		
130																		
131																		
132																		
133																		
134																		
135																		

WSP BORING LOG_DEEPWATER L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Geobor-S
RIG TYPE: Fugro R30
HAMMER TYPE: None

LOCATION: Deepwater - Middle of Strait
COORD. Lat: 45.79716 N Long: 84.77391 W
STN. NO.: OFFSET:
MUDLINE ELEV.: 502.4 feet
DATUM: IGLD 1985
START DATE: 9/13/19 TIME: 8:00 pm
FINISH DATE: 9/18/19 TIME: 12:00 am

CORE BARREL DATA:
TYPE:
CORE SIZE: Geobor-S
O.D.: Geobor-S
I.D.: Geobor-S
CASING SIZE: " (")

NOTES:
Mudline is 79.3 ft. (24.2 m) below lake level.

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
124																
									Light gray and brown, LIMESTONE, slightly weathered, weak to medium strong, close to moderate fracture spacing, argillaceous, moderately fractured to sound, brecciated clasts, possible debris flow [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R2-	0	1.0	2.0	123.75
												R3	0	1.0	6.0	123.78
													20	3.0	3.0	124.24
125																
	0.19			11	RB-006	91	85						0	4.0	4.0	125.23
126													20	3.0	3.0	125.88
127									Extremely weathered, extremely weak, clay seam 126.8-128.0 ft. with LIMESTONE corestones and subhorizontal bedding		V	R0	35	3.0	3.0	126.87
								CL								
128									Light grayish brown, DOLOMITE, slightly to moderately weathered, very weak, extremely close fracture spacing, extremely fractured, retrieved as subangular, coarse gravel 128.0-128.3 ft.		II-III	R1	5	3.0	4.0	127.95
													14	4.0	3.0	128.28
													0	1.0	6.0	128.44
129													90	3.0	3.0	128.64
													0	1.5	2.0	128.71
													0	1.5	2.0	128.80
													0	1.5	2.0	128.84
130													0	1.0	2.0	128.87
	0.27			12	RB-007	91	7		Extremely weathered, extremely weak, clay seam 129.9-130.0 ft.		V	R0	90	1.5	2.0	129.03
													90	1.5	2.0	129.07
													90	3.0	4.0	129.76
131													30	3.0	4.0	129.92
													65	3.0	4.0	130.05
													85	3.0	4.0	130.15
													10	1.5	2.0	130.25
													35	3.0	2.0	130.31
132													75	3.0	2.0	130.48
													5	3.0	2.0	130.81
								CL	132.38: PLL = 4,090 psi				10	3.0	2.0	131.00
													10	1.5	2.0	131.13

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, LIMESTONE, slightly to moderately weathered, medium strong, very close to close fracture spacing, moderately fractured, with pits, clay-filled fractures, 0° bedding		II-III	R3	85	1.5	2.0	131.23
													20	1.0	2.0	131.36
													70	3.0	2.0	131.63
134											II-III	R3	5	3.0	2.0	131.72
									Light grayish brown, LIMESTONE, slightly to moderately weathered, medium strong, very close to close fracture spacing, moderately fractured, with pits, clay-filled fractures, 0° bedding				30	3.0	2.0	131.89
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				10	3.0	2.0	131.92
													45	3.0	2.0	132.05
135													25	1.5	3.0	132.12
													80	3.0	3.0	132.31
	0.29			13	RB-008	69	16						20	1.5	3.0	132.45
													10	1.0	6.0	132.87
136													80	1.0	6.0	133.36
													20	1.0	6.0	133.66
													50	1.0	6.0	134.02
													30	1.0	6.0	134.45
													0	1.0	6.0	134.81
137								CL					40	1.0	6.0	134.87
													75	3.0	3.0	134.97
													45	1.0	6.0	135.27136.07
													80	1.0	6.0	135.33
138									Becomes highly weathered, extremely weak, extremely fractured, moderately strong corestones up to 2.5-inches in a sandy clay matrix		IV	R0	60	4.0	4.0	135.69
													15	1.0	6.0	135.89
													30	1.0	6.0	135.96
139	0.17			14	RB-009	47	0						40	1.0	6.0	136.28
140								CL								
141																
									Becomes slightly weathered, medium strong		II	R3	20	1.0	6.0	141.27
													45	1.5	2.0	141.34
													70	1.5	2.0	141.60
142	0.14			15	RB-009	59	0						30	1.0	6.0	141.73
								CL					70	1.0	2.0	141.80
													20	1.0	6.0	142.00
													70	1.0	2.0	142.06
143													0	1.0	6.0	142.12
													70	1.0	6.0	142.94
													85	1.0	2.0	142.98
144									Becomes gray, thinnly bedded, moderately weathered, very weak, close to moderate fracture spacing, argillaceous, sound, with clay on fracture surfaces	P7	III	R1	20	1.0	6.0	143.50
													20	1.0	6.0	143.67
													30	3.0	4.0	143.76
													10	1.5	4.0	144.39
145	0.12			16	RB-010	65	45									
													10	3.0	4.0	145.37
													0	3.0	4.0	145.63
146								CL					0	1.5	4.0	145.93

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
148									Brown, LIMESTONE, thinnly bedded, highly weathered, very weak, very to extremely close fracture spacing, argillaceous, extremely fractured to coarse gravel and cobbles		IV	R1				
									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				0	1.0	6.0	148.26
													0	3.0	4.0	148.43
149													0	1.0	6.0	148.72
150	0.41			17	RB-011	22	0									
								CL								
151																
152																
									Becomes grayish brown, moderately weathered		III					
153									Becomes light grayish brown and brown, extremely weathered, extremely weak, cobbles and gravel with some silt and clay		V	R0				
154										P6						
155	0.29			18	RB-011	73	0		Becomes light grayish brown, moderately weathered, weak, extremely close fracture spacing, with silt and clay on fracture surfaces		III	R2	10	1.0	6.0	154.85
													0	3.0	4.0	155.08
													0	1.5	3.0	155.31
													40	1.0	6.0	155.41
156													0	1.0	6.0	155.77
													85	3.0	3.0	156.00
													0	1.0	6.0	156.17
157								CL								
									157.48: PLL = 2,400 psi			R2-	0	1.0	6.0	157.48
									Becomes weak to medium strong			R3	90	1.0	2.0	157.68
158													0	1.5	2.0	157.77
									Extremely weathered, very weak, clay seam 158.2-158.5 ft.		V	R0	0	1.5	2.0	158.00
													85	1.5	3.0	158.13
159	0.16			19	RB-012	66	10						0	1.0	6.0	158.23
													0	1.0	6.0	158.53
													85	1.5	2.0	158.66
													5	1.0	6.0	158.86
160								CL								
									Becomes moderately weathered, very weak, only gravel-		II-III	R2				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									and cobble-sized LIMESTONE fragments recovered		II-III	R2				
	0.16			20	RB-012	67	0									
162								CL								
									Becomes dark gray and light gray, ARGILLACEOUS DOLOMITE, moderately weathered, very weak, calcareous, slightly fractured to sound, appears to have a dessicant feature			R3	0	1.0	6.0	162.40
163													10	3.0	3.0	162.66
										P5			10	1.0	6.0	163.65
164									Light grayish brown, DOLOMITE, slightly weathered, medium strong, and dolomite cobbles, flat bedding with thin dark laminae visible, cobbles are generally subrounded, breccia clasts visible, possible debris flow		III	R2	5	1.0	3.0	163.71
	0.31			21	RB-013	35	20						5	1.0	2.0	163.88
165													30	1.0	6.0	163.97
								CL								
166																
167																
									Becomes moderately weathered, weak, extremely close fracture spacing, extremely fractured, with silt and clay along fracture surfaces and completely weathered, clayey zones				0	1.0	6.0	167.52
168													0	1.0	6.0	167.75
													0	1.0	6.0	167.85
													90	1.5	2.0	167.98
													40	1.5	2.0	168.08
169													0	1.0	6.0	168.24
													0	1.0	6.0	168.31
													0	1.0	6.0	168.47
													50	1.0	4.0	168.63
	0.25			22	RB-013	53	0						30	1.0	6.0	169.19
170													30	1.0	6.0	169.29
													70	1.5	2.0	169.35
													90	3.0	3.0	169.49
													10	3.0	3.0	169.62
171								CL					90	3.0	4.0	169.72
172																
									Becomes gray							
													45	1.0	6.0	172.57
173									Olive gray, DOLOMITIC LIMESTONE, highly weathered, very weak, calcareous		IV	R1	30	3.0	4.0	172.80
									173.22: PLA = 609 psi	P4			10	3.0	4.0	173.26
									Gray, LIMESTONE, slightly to moderately weathered, medium strong, moderate fracture spacing, argillaceous, sound, with 30° bedding, possible debris flow		II-III	R3				
174																
	0.12			23	RB-014	55	41		Becomes light gray, highly weathered, very weak,		IV	R1				

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									extremely close fracture spacing, extremely fractured				10	3.0	4.0	174.87
													10	1.0	6.0	174.93
176								CL								
177									Olive gray, highly weathered, very weak, extremely close fracture spacing, extremely fractured, fragments are subrounded [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		IV	R1				
178																
179																
180	0.62			24	RB-014	9	0	CL								
181																
182									Light gray and brown, DOLOMITE, moderately weathered, weak, subangular to subrounded		III	R2-R3				
183									Light grayish brown, DOLOMITE, slightly weathered, medium strong, with clay and gravel, dolomite is vuggy/pitted/porous, parallel to bedding at about 30°	P3			30	1.0	6.0	182.87
													35	1.0	6.0	183.50
184									Grayish brown, CLAYSTONE, moderately weathered, weak		III	R2	50	1.0	6.0	183.72
	0.49			25	RB-015	55	22		Light grayish brown, DOLOMITE, moderately weathered, weak to medium strong, extremely close fracture spacing, extremely fractured		III	R2-R3	30	1.0	6.0	184.38
185																
186								CL								
187									Becomes slightly weathered, medium strong, close to moderate fracture spacing, with pits and 10° bedding		II	R3	0	1.0	6.0	187.01
													50	1.5	2.0	187.73
188									Olive brown, LIMESTONE, moderately weathered, weak, extremely fractured		III	R2	50	1.5	2.0	188.06
													20	1.0	6.0	188.15
									Becomes brecciated and cemented with clay				10	1.0	6.0	188.65

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
190	0.20			26	RB-016	48	33	CL					30	1.0	6.0	189.37
191																
192									Olive brown, LIMESTONE, moderately weathered, weak, extremely fractured, brecciated and cemented with clay, with DOLOMITE and pitted LIMESTONE fragments, subangular	P2	III	R2				
193	0.20			27	RB-016	22	0	CL	[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]							
194																
195	0.39			28	RB-016	0	0	CL								
196																
197									Light grayish brown, DOLOMITE, highly weathered, very weak, extremely fractured, brecciated and cemented in a clay matrix		IV	R1				
198																
199	0.27			29	RB-017	77	33		Greenish gray and, CLAYSTONE, highly weathered, very weak, slightly fractured to sound, with trace limestone fragments [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA]		IV	R1				
200																
201								CL								
202									202.43: γ = 139 pcf, PLL = 160 psi	P1			5	1.0	6.0	202.43

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
204	0.18			30	RB-018	100	100		Light brown, CLAYSTONE, highly weathered, weak, slightly fractured, with trace limestone fragments [POINTE AUX CHENES FORMATION - MACKINAC BRECCIA, coninued]		IV	R2	0	1.0	6.0	203.87
205													0	4.0	3.0	205.05
											II		5	4.0	3.0	205.38
206													0	4.0	3.0	205.87
													0	4.0	3.0	206.36
207	0.04			31	RB-019	100	20		Becomes greenish gray and reddish brown, slightly weathered, moderately to extremely fractured 206.7-208.3 ft.							
208																
209	0.10			32	RB-019	77	77		Becomes close to moderate fracture spacing, faint red mottling in places, slightly fractured to sound				0	1.5	3.0	208.66
210																
211								CL								
212	0.12			33	RB-020	100	79		211.61: γ = 144 pcf							
213																
214																
215									Becomes moderately fractured, crushed zone 214.6-215.1 ft. Becomes highly weathered, extremely weak		IV	R0				
216													0	1.0	3.0	216.27

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-36
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Fugro
DRILLER: M. Blight, T. Lawer
INSPECTOR: A. Hesse, D. Mein

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
218									Greenish gray and reddish brown, CLAYSTONE, slightly weathered, very weak, moderate fracture spacing, sound		II	R1				
219	0.11			34	RB-021	87	77				II	R1				
220													0	1.5	3.0	219.75
221								CL					5	1.5	3.0	220.54
222									End of Boring at 221.45' The borehole was backfilled with cement-bentonite grout composed of Type I with 2% powdered bentonite and no more than 6 gallons water for each 94 lb sack (0.53 water cement ratio). The borehole was backfilled from the bottom of the boring to mudline.							
223																
224																
225																
226																
227																
228																
229																
230																

WSP CORING LOG_DEEPWATER_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 1 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - South side of Strait
COORD. Lat: 45.79428 N Long: 84.77377 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 600.7 feet
DATUM: IGLD 1985
START DATE: 7/14/19 TIME: 1:25 pm
FINISH DATE: 7/15/19 TIME: 12:50 am

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol	PQ	SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1																	AIR
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	WATER
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 2 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												
54												
55												
56												
57												
58												
59												

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 3 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61																	
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69																	
70																	
71																	
72		SB-001 72.0-80.0 ft.															Brown, POORLY GRADED SAND, trace Silt, trace Gravel, (SP), [ALLUVIUM]
73																	
74																	
75																	75 - 80': PSA = 97.7% SAND, 2.3% FINES; SG = 2.73
76																	
77																	Brown, SILTY SAND, little Silt, trace Gravel, (SM), trace cobble, sand is fine to medium grained
78																	
79																	
80		SB-002 80.0-90.0 ft.															Brown, SILTY SAND, little Silt, trace Gravel, trace Cobbles, (SM), sand is fine to medium grained
81																	
82																	
83																	
84																	
85																	
86																	
87																	
88																	
89																	
90			SPT	SS-001		90.0 - 92.0	8	8	9	7	0						Becomes medium dense, sand is fine grained, gravel is fine to coarse
91																	
92																	
93																	
94																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 4 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96		SB-003 90.0-100.0 ft.															Brown, SILTY SAND, little Silt, trace Gravel, trace Cobbles, medium dense, (SM), sand is fine grained, gravel is fine to coarse [ALLUVIUM, continued]
97																	
98																	
99																	
100																	Brown, SILTY SAND, little Silt, trace Gravel, trace Cobbles, medium dense, (SM), sand is fine grained, gravel is fine to coarse [ALLUVIUM, continued]
101		SB-004 100.0-110.0 ft.															
102																	
103																	
104																	
105																	100-110': PSA = 90.9% SAND, 9.1% FINES
106																	
107																	
108																	
109																	
110		SB-006 110.0-120.0 ft.	SPT	SS-005		110.0 - 112.0	1	1	1	2	8						Brown, SILTY SAND, little Silt, trace Gravel, very loose, (SM)
111																	
112																	
113																	
114																	
115																	
116																	Brown, POORLY GRADED GRAVEL with SAND, trace Gravel, trace Cobble, (GP), gravel is fine grained
117																	
118																	
119																	
120		SB-007 120.0-130.0 ft.															Brown, SILTY SAND with GRAVEL, trace Gravel, (SM), sand is fine grained, gravel is of LIMESTONE lithology
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 5 of 5
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
131		SB-008 130.0-140.0 ft.															Brown, SILTY GRAVEL with SAND, some Sand, little Silt, (GM), [ALLUVIUM, continued]
132																	
133																	
134																	
135																	130-135': PSA = 46.4% GRAVEL, 31.6% SAND, 22.0% FINES; SG = 2.66
136																	
137																	ROCK, (GP), weathered bedrock with some corestones
138																	
139																	
140																	
141		SB-009 140.0-150.0 ft.															FAT CLAY, little Gravel, little Sand, soft, (CH)
142																	
143																	Becomes hard
144																	
145																	
146																	
147																	
148																	DOLOMITE, completely weathered [ST. IGNACE FORMATION - MACKINAC BRECCIA]
149																	
150																	Start Rock Coring at 150.0'
151																	
152																	
153																	
154																	
155																	
156																	
157																	
158																	
159																	
160																	
161																	
162																	
163																	
164																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 1 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - South side of Strait
COORD. Lat: 45.79428 N Long: 84.77377 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 600.7 feet
DATUM: IGLD 1985
START DATE: 7/14/19 TIME: 1:25 pm
FINISH DATE: 7/15/19 TIME: 12:50 am

CORE BARREL DATA:
TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: PQ

NOTES:
HQ3 (150-163', 173-248')
NQ3 (163-173')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
151	0.67			1		100	32		Light brownish gray, DOLOMITE, laminated, slightly weathered, medium strong, extremely fractured, locally crushed, occasionally calcareous. Becomes strong to very strong, moderately fractured at 150.5 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA]		II	R3	0-90	1.0	6.0	150.0-150.5
													30-50	2.0-3.0	1.0	150.6-151.0
													10	1.0	1.0	151.5
152													5	1.0	1.0	151.7
													50	2.0	1.0	152.2
													40	2.0	1.0	152.3
										P8			70	2.0	1.0	152.4
153									Becomes moderately to extremely fractured				60	3.0	1.0	152.9
													5-20	2.0	1.0	153.0-153.5
154																
													20	3.0	1.0	154.1-154.4
											II	R3				
													10	2.0	1.0	154.7
155	0.20			2		84	9		Becomes light gray, moderately weathered, extremely fractured, fracturing 154.4-154.7 ft. may be mechanical due to issues with drill head.				10-80	3.0	1.0	154.9-155.0
156					RB-001											
									Becomes moderately weathered, weak		III	R2	0-90	2.0	2.0	156.3-157.2
													90	1.5	6.0	156.7-157.2
157								CL								
158													10	1.0	1.0	158.1
													10-30	1.0	1.0	158.4-159.0
159									Becomes unweathered, very strong, moderately fractured		I	R5				
													50	2.0	1.0	159.3
													5	1.0	1.0	159.5
													80	1.0	1.0	

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 2 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.83			3		90	14		Light gray, DOLOMITIC LIMESTONE, unweathered, medium strong, moderately fractured, with CALCITE precipitation on fracture surfaces and small frosted QUARTZ grains. Becomes extremely fractured and crushed at 160.3 ft. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]	P7	I	R3	5	1.0	1.0	159.5-159.7
													5	1.0	1.0	159.7
													50	1.0	1.0	160.0
													10-40	2.0	1.0	160.3
161													20	2.0	1.0	160.4-160.6
													0-30	1.5	1.0	160.7-161.6
											II	R3				161.1-161.5
													15	1.0	1.0	161.7-162.0
162													85	2.0	1.0	162.0-162.9
								CL								
163									NOTE: Switch from HQ to NQ at 163.0 ft. for pressuremeter test. No test performed due to rock quality.				90	1.0	1.0	163.0-163.3
													10-80	2.0	1.0	163.3-164.7
164																
													60-70	3.0	2.0	164.7-165.1
165	0.28			4		68	6		Becomes weak, locally crushed to a coarse gravel, with vugs up to 0.04 in.		II	R2	5	1.0	1.0	165.2
													40	1.0	1.0	165.3
													85	1.0	1.0	165.5-165.8
166													80	1.0	1.0	166.0
													80	1.0	1.0	166.2
													5	2.0	1.0	166.3
167								CL								
168									168.6-169.1: PLL = 430 psi				10-50	1.5	1.0	168.0-168.5
									Gray, DOLOMITE, slightly weathered, very weak, slightly to moderately fractured, argillaceous		II	R1	5	2.0	1.0	168.5
													10	2.0	1.0	168.7
169									Becomes light olive gray, weak		II	R2	15	3.0	1.0	169.2
													5	0.5	1.0	169.5
170	0.63			5		34	26			P6						
171								CL								
172					RB-002											
173									Becomes medium strong, with abundant CALCITE dissolution cavities		II	R3	0-90	2.0	1.0	173.0-174.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 3 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, DOLOMITE, slightly weathered, medium strong, moderately fractured		II	R3	60	1.0	1.0	174.0-174.2
													70	1.0	1.0	174.2-174.5
	0.20			6		100	0		[ST. IGNACE FORMATION - MACKIANC BRECCIA, continued]		III	R1	0	2.0	6.0	174.5
175									Gray, LIMESTONE, moderately weathered, very weak, extremely fractured, locally clayey							
176									Becomes slightly weathered, weak, with dissolution cavities up to 0.16 in. partially filled with CALCITE		II	R2	10-30	2.0	1.0	176.0-176.6
	0.50			7		90	15						25	1.0	1.0	176.7
177													10	2.0	1.0	176.8
													10	1.0	1.0	177.2
													10	1.0	1.0	177.5
								CL					10	2.0	1.0	177.8
178									Becomes mottled olive gray and gray, laminated, moderately weathered, weak, argillaceous		III	R2	10-80	3.0	4.0	178.0-180.0
													20	1.5	1.0	178.5
179																
180									Becomes gray, moderately fractured		III	R1				
	0.50			8		84	16						15	3.0	2.0	180.4
181									Becomes olive gray		II	R3	30	2.0	1.0	181.1
									Pale brown, DOLOMITE, slightly weathered, medium strong, extremely fractured. Clay filled joint 181.3-181.5 ft.				20	1.5	3.0	181.3
													30	1.5	3.0	181.6
182													20	1.0	1.0	181.8
													80	1.0	1.0	181.8-182.1
								CL								
183													10-80	2.0	1.0	183.0-183.5
									Becomes medium strong to strong, moderately fractured, faint laminations		II	R3-R4	5	2.0	1.0	183.6
184										P5			85	3.0	2.0	183.7
													10	2.0	1.0	183.8
													30	1.0	1.0	184.0
													15	1.0	1.0	184.2
185													15	3.0	1.0	184.4
									Becomes medium strong		II	R3	90	2.0	2.0	184.5-185.8
	0.50			9		56	12						10	1.0	1.0	185.0
													10	1.0	1.0	185.3
													10	1.0	1.0	185.5
186													10	1.0	1.0	185.7
								CL								
187																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 4 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
189								CL								
190	0.83			10	RB-003	58	14		Gray and olive gray, LIMESTONE, slightly to moderately weathered, medium strong, moderately fractured, brecciated and healed [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II-III	R3	10-30	1.0	1.0	190.1-190.9
191													60	3.0	4.0	190.8
													30	1.5	4.0	190.9
													30	2.0	4.0	191.1
192													80	3.0	4.0	191.4-192.0
													75	3.0	1.0	192.4-192.7
193													30	3.0	2.0	192.8
	0.63			11		66	0		Light brownish gray, DOLOMITE, moderately weathered, weak, extremely fractured		III	R2	15	0.5	1.0	193.0-193.8
194													90	2.0	1.0	193.5-194.3
													10	3.0	2.0	193.6
													10	0.5	1.0	193.8
									Becomes laminated, with fracturing along bedding planes and CALCITE dissolution along fracture surfaces				20	2.0	1.0	193.8
195													5	0.5	0.75	194.4-195.1
196																
197								CL								
198									NOTE: only gravel-sized DOLOMITE clasts recovered from Core Run 12				0-90	1.0	1.0	198.0-198.8
199													0-10	1.5	1.0	198.9-200.1
									200.7-201.1: PLA = 4,480 psi							
200	0.83			12		80	24		Becomes greenish gray, CLAYSTONE, laminated, moderately weathered, extremely weak, extremely fractured, argillaceous, with CALCITE veins, locally clayey from 200.3 to 200.6 ft.		III	R0				
201									Becomes dark gray, medium strong	P4		R3	10	1.5	1.0	200.9
									Becomes weak, extremely fractured, crushed			R2	0-90	1.0	1.0	201.4-203.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 5 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
203					RB-004			CL								
204								CL	NOTE: driller reported very soft, void-like drilling 203.0-206.0 ft.							
205	0.71			13		60	0		Dark gray, DOLOMITE, slightly weathered, weak, extremely fractured, only gravel-sized DOLOMITE corestones with abundant CALCITE dissolution recovered 205.0-206.0 ft., brecciated		II	R2				
206									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				0-30	2.0	2.0	206.0-206.4
									Becomes moderately weathered, moderately fractured		III	R2	0-10	2.0	1.0	206.4-209.0
207													80	1.0	1.0	207.3-207.7
208									Crushed from drilling 207.8-208.0 ft. Becomes slightly fractured, with QUARTZ fragments and calcite veins				0-40	1.5	1.0	208.0-210.9
209																
210									209.7-210.2: γ = 154 pcf							
211	0.71			14		100	30		Becomes greenish gray, laminated, medium strong, moderately fractured along clay laminations	P3	III	R3	0-20	1.0	1.0	210.9-213.0
212													90	1.5	1.0	212.1-212.5
213					RB-005				Becomes weak			R2	0-20	1.5	1.0	213.0-218.0
214									Becomes dark greenish gray, very weak, slightly to moderately fractured, argillaceous, with 10° bedding			R1				
215	0.63			15		100	30									

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 6 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA: ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark greenish gray, DOLOMITE, laminated, slightly weathered, very weak, slightly fractured, argillaceous, with fractures along 10° bedding		II	R1	90	1.0	2.0	216.3-217.1
217									[ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]				20	1.0	1.0	217.1
218									Becomes dark gray, weak, sound with calcite veins		II	R2	50	1.5	1.0	218.0-218.8
219													0-10	1.5	1.0	219.0-220.0
220	0.67			16		76	34		Becomes light gray, medium strong, extremely fractured, not argillaceous, with CALCITE-filled vugs up to 1-inch		II	R3	15-40	3.0	2.0	220.0-220.5
221													10	1.0	1.0	220.7
													90	1.0	1.0	220.8-220.9
222									Dark gray, LIMESTONE, moderately weathered, weak, extremely fractured, locally crushed, with thin, black clay laminations	P2	III	R2				
								CL								
223					RB-006								0-90	4.0	1.0	223.0-223.7
224									Light gray, DOLOMITIC LIMESTONE, slightly weathered, weak, moderately fractured		II	R2	0-10	1.5	1.0	223.7-224.2
									Becomes extremely fractured				0-90	1.5	1.0	224.2-224.9
225									Dark gray, DOLOMITE, slightly weathered, weak, moderately fractured		II	R2	0-20	1.5	1.0	224.9-225.0
	0.71			17		94	24						80	1.0	1.0	225.0
226									Becomes light gray, laminated, moderately weathered, sound, argillaceous, with 30° bedding		III					
									Becomes light brown, slightly weathered, medium strong, extremely fractured		II	R3				
227									225.8-226.9: ω = 2.47%; γ_d = 151 lb/ft^3; SG = 2.41; n = 0.084; PLA = 5,200 psi				0-90	1.0	1.0	227.0-227.7
								CL								
228									Becomes light brown, moderately fractured, with Fe staining on fracture surfaces		II	R3	10	1.0	1.0	228.2
													10	1.0	1.0	228.7
229													80	1.5	1.0	229.2-230.5
									Becomes highly weathered, weak, with increasing calcareous zones at 229.8 ft.		IV	R2	80	1.5	1.0	229.3

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 7 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	0.71			18	RB-007	84	22		Light brown, DOLOMITE, highly weathered, weak, moderately fractured, with calcareous zones, Fe staining on fracture surfaces, and thin laminations [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		IV	R2	80	2.0	1.0	230.0-230.7
231									Becomes extremely fractured		III	R1	0-30	3.0	1.0	231.1-232.2
232									Dark gray, LIMESTONE, laminated, moderately weathered, very weak, slightly to moderately fractured, argillaceous, locally clayey							
								CL		P1						
233													15	3.0	1.0	233.3
234									Light brownish gray, DOLOMITE, slightly weathered, medium strong, moderately fractured		II	R3				
									Gray, LIMESTONE, slightly weathered, medium strong, extremely fractured, with CALCITE precipitation on fractures and in vugs up to 1/2-inch		II	R3	30-50	2.0	1.0	234.4-236.2
235	0.63			19		72	10		Light brownish gray, DOLOMITE, slightly weathered, medium strong, extremely fractured, with CALCITE precipitation on fracture surfaces		II	R3				
236									With trace CLAY on fracture surfaces				0	1.5	3.0	236.2-236.6
237								CL								
238									Gray, LIMESTONE, weakly laminated, slightly weathered, weak, sound		II	R2				
239									Becomes moderately fractured				10-20	1.0	1.0	239.0-239.6
									Becomes medium strong, extremely fractured		II	R3	0-90	1.5	1.0	239.6-240.6
240									Becomes thinly bedded, with Fe staining on fracture surfaces				15-45	1.5	1.0	240.0-240.6
	0.63			20		64	20						0-90	2.0	6.0	240.6-241.1
241									Becomes moderately weathered, weak		III	R2				
242								CL								
243					RB-008								30	1.0	1.0	243.0
									[See next page]		II	R3	0-10	1.5	1.0	243.0-245.8

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-37
SHEET NUMBER: 8 of 8
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Williams, X. You, K. Zeiger

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
244									Light gray, DOLOMITE, laminated, slightly weathered, medium strong, moderately fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3	90	1.0	1.0	244.0-245.2
245	0.71			21		94	0						15	1.0	1.0	245.0
													90	1.0	1.0	245.0-245.6
246									Becomes moderately to extremely fractured				0-10	1.5	1.0	245.8-247.7
247																
248								CL	NOTE: blind drilled to 248.4 ft. for weather standby							
									End of Boring at 248.4' The boring was backfilled with neat cement grout to the mudline at 4:30 AM on 7/17/2019.							
249																
250																
251																
252																
253																
254																
255																
256																
257																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - South side of Strait
COORD. Lat: 45.79162 N Long: 84.77478 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 598.2 feet
DATUM: IGLD 1985
START DATE: 7/18/19 TIME: 1:30 pm
FINISH DATE: 7/19/19 TIME: 6:15 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol	PQ	SPT ■	ST □	SB ▨	G ☒	C □
I.D.		1.375"	2.938"	4.00"		HQ3, NQ3"
O.D.		2"	3"	4.75"		HQ3, NQ3"
Length		24"	24"	10.00'		
Hammer Wt.	140 lbs		Drill Rod Size			
Hammer Fall	30"		I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1																	AIR
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	WATER
18																	
19																	
20																	
21																	
22																	
23																	
24																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
26																	
27																	
28																	
29																	
30																	
31																	
32																	
33																	
34																	
35																	
36																	
37																	
38																	
39																	
40																	
41																	
42																	
43																	
44																	
45																	
46																	
47																	
48																	
49																	
50																	
51																	
52																	
53																	Grayish brown, POORLY GRADED SAND, few Gravel, wet, (SP), sand is medium grained, gravel is subrounded and coarse, with trace shell fragments [ALLUVIUM]
54																	
55																	
56																	
57		SB-001 52.5-61.0 ft.															Grayish brown, POORLY GRADED SAND with GRAVEL, some Gravel, wet, (SP), gravel is subrounded and coarse
58																	
59																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
61		SB-002 61.0-69.0 ft.															Grayish brown, POORLY GRADED SAND with GRAVEL, some Gravel, wet, (SP), gravel is subrounded and coarse [ALLUVIUM, continued]
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69			G	SS-004		69.0 - 70.0											Grayish brown, medium grained, POORLY GRADED SAND, trace Silt, wet, (SP), 69': PSA = 97.3% SAND, 2.7% FINES; SG = 2.74
70			SPT	G-003		70.0 - 72.0	36	48	36	42	12						
71																	Grayish brown, POORLY GRADED SAND with GRAVEL, some Gravel, very dense, wet, (SP), sand is medium to fine grained, gravel is coarse and rounded, up to 3/4-inch of mixed lithologies (LIMESTONE, DOLOMITE, GRANITE) 70.0-72.0: ω = 13.4%
72																	
73																	
74																	
75		SB-005 72.0-80.0 ft.															
76																	
77																	
78																	
79			G	G-006		79.0 - 80.0											Brown, SILTY CLAYEY SAND, some Gravel, very dense, wet, (SC-SM), sand is medium grained, gravel is subrounded to rounded up to 1 1/4-inches of mixed lithologies, fines are medium plastic [GLACIAL TILL]
80																	
81																	With little Gravel, moist, some low plastic cohesive fines, gravel is fine to coarse with trace cobbles
82																	
83																	With trace Cobbles, dry
84																	
85		SB-007 80.0-90.0 ft.															
86																	
87																	
88																	
89																	
90			SPT	SS-008		90.0 - 92.0	5	16	20	44	24						Brown, medium grained, POORLY GRADED SAND, very dense, moist, (SP), with narrow clayey zones
91																	
92																	Brown, POORLY GRADED SAND, wet, (SP), sand is fine to medium grained, fines are nonplastic, gravel is angular to subrounded, up to 1-inch
93																	
94																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

BORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96		SB-009 92.0-99.0 ft.															Brown, POORLY GRADED SAND, wet, (SP), sand is fine to medium grained, fines are nonplastic, gravel is subangular to rounded, up to 1-inch [GLACIAL TILL, continued]
97																	
98																	
99			G	G-010		99.0 - 100.0											
100																	
101		SB-011 100.0-110.0 ft.															
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110			SPT	SS-012		110.0 - 110.5	113										
111																	POORLY GRADED SAND with GRAVEL, (SP)
112																	
113																	
114																	
115		SB-013 110.0-120.0 ft.															
116																	
117																	
118																	DOLOMITE, completely weathered to a hard CLAY with SAND and GRAVEL [BOIS BLANC FORMATION - MACKINAC BRECCIA]
119																	
120																	Start Rock Coring at 120.0'
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP BORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 1 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa
BORING INCLINATION FROM HORIZONTAL: 90°
DRILLING METHOD: Sonic/Rotary Core
RIG TYPE: Boart Longyear 600C
HAMMER TYPE: Auto

LOCATION: Nearshore - South side of Strait
COORD. Lat: 45.79162 N Long: 84.77478 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 598.2 feet
DATUM: IGLD 1985
START DATE: 7/18/19 TIME: 1:30 pm
FINISH DATE: 7/19/19 TIME: 6:15 pm

CORE BARREL DATA:

TYPE: Triple barrel
CORE SIZE: HQ3, NQ3
O.D.: HQ3, NQ3
I.D.: HQ3, NQ3
CASING SIZE: PQ

NOTES:

HQ3 (120-128', 138-203')
NQ3 (128-138')

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
121	1.00			1		100	11		Grayish brown, DOLOMITE, slightly weathered, medium strong, extremely fractured, only gravel-sized corestones recovered [BOIS BLANC FORMATION - MACKINAC BRECCIA]		II	R3	0-90	2.0	1.0	120.0-121.7
									Becomes moderately fractured, with dark gray CHERT							
122													0-90	3.0	2.0	120.0-123.0
													50	1.5	1.0	122.5
													70	1.0	1.0	122.7
123									Becomes extremely fractured				0-90	1.0	3.0	123.0-125.0
									Becomes moderately weathered, extremely weak, increasingly calcareous, with CALCITE filled vugs	P5	III	R0				
124													90	1.5	1.0	124.0
125	1.00			2		100	7		Becomes locally crushed				0-90	1.5	3.0	125.0-125.7
									Becomes very weak, brecciated and healed			R1	10-30	2.0	6.0	125.3-125.5
126					RB-001				Becomes slightly weathered, not crushed		II					
													90	2.0	1.0	126.5-127.2
127									Extremely weathered, extremely weak, moderately fractured, clayey zone 127.3-127.8'				0-90	1.5	3.0	127.0-128.0
									NOTE: Switch from HQ to NQ at 128.0' for pressuremeter test.		V	R0				
128									Light grayish brown, LIMESTONE, slightly weathered, medium strong, moderately fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA]	P4	II	R3	60	1.5	1.0	128.1
									128.0 - 128.8': ω = 2.26%; γ_{d1} = 152 lb/ft^3; γ_{d2} = 148 lb/ft^{3}SG = 2.43; n = 0.143; PLA = 4,090 psi							
129													50	1.0	1.0	128.9
									Becomes yellowish brown, moderately weathered, medium strong, extremely fractured		III	R3	15-45	2.0	2.0	123.3-130.0
													0-90	2.0	1.0	129.5-130.0

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 2 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
	1.00			3		75	40		Light grayish brown, LIMESTONE, slightly weathered, strong, moderately fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	60	1.0	1.0	130.1-130.4
131									Becomes medium strong to strong			R3-R4	0	2.0	2.0	130.9
													0	2.0	2.0	131.5
132								CL								
133									Becomes moderately weathered, medium strong, extremely fractured (Run 4 retrieved as gravel) Note: Changes back to HQ3 core barrel		III	R3	0-90	1.0	1.0-2.0	133.0-135.5
134																
135	0.83			4		100	7		Becomes very weak, locally crushed to a sand		III	R1				
136									Becomes weak, moderately to extremely fractured, with clay and sand fracture infillings			R2	45	1.0	1.0	135.8
													90	1.0	1.0	135.8-136.1
													30	1.0	6.0	136.3-135.5
137													30	1.0	1.0	136.7
													50	1.5	1.0	136.8
													55	1.5	6.0	137.0
													60	1.5	1.0	137.2
138					RB-002								60	1.5	1.0	137.7
									Light gray and white, DOLOMITE, slightly weathered, medium strong, moderately fractured, locally calcareous		II	R3				
													80	1.0	1.0	138.3
139										P3			90	1.0	1.0	138.5
													0	1.5	1.0	138.8
140									Becomes highly weathered, weak to medium strong, extremely fractured, crushed, increasingly calcareous		IV	R2-R3				
	1.00			5		70	0						0-90	1.5	1.0	140.0
141													0-90	1.0	4.0	140.0-141.5
142								CL								
143									Becomes slightly weathered, strong		II	R4	0-90	1.0	1.0-2.0	143.0-144.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 3 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
145	1.00			6	RB-003	100	45		Light gray and white, DOLOMITE, slightly weathered, medium strong, moderately fractured with small vugs and abundant CALCITE veins. Becomes slightly fractured at 144.5'. [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R4	20	1.5	1.0	144.0
													0	1.0	1.0	144.4
													40	1.0	1.0	145.1
146									144.5 - 144.7': ω = 0.77%; γ_{d1} = 157 lb/ft^3; γ_{d2} = 160 lb/ft^3 SG = 2.58; n = 0.082; UCS = 12,209 psi				30	1.5	1.0	145.2
									Becomes extremely fractured, with vugs up to 1/4-inch				30	1.5	1.0	146.3
147													0-90	1.5	1.0	146.8-147.3
									Light brownish gray, LIMESTONE, moderately weathered, strong, moderately fractured, with vugs up to 1/2-inches		III	R4				
148													45	2.0	1.0	147.7
									Becomes weak to medium strong, extremely fractured			R2-R3	0-90	2.0	1.0	148.0-148.5
													60	2.0	1.0	148.6
149										P2			55	1.5	1.0	149.0
								CL								
150	1.00			7		90	17		Becomes slightly weathered, strong, slightly fractured		II	R4				
													30	1.0	1.0	150.3
									PLA = 5,940 psi			R3				
151									Becomes moderately weathered, medium strong, extremely fractured		III	R3	0	1.5	1.0	151.0
													80	1.5	1.0	151.2-152.2
													0	1.5	1.0	151.3
152																
									Becomes highly weathered, weak		IV	R2				
								CL					30	1.5	2.0-3.0	152.5
153									Becomes medium strong, with dissolution along fracture surfaces			R3				
154																
									Becomes moderately weathered, strong, moderately fractured		III	R4	40	1.5	2.0-3.0	154.2
													60	1.5	1.0	154.5
155																
	1.00			8		86	7						90	1.5	1.0	155.1-155.5
													0-90	1.5	2.0-3.0	155.5-156.5
156													30	1.5	1.0	155.7
157									Becomes highly weathered, weak to medium strong, moderately fractured, locally crushed to a gravel Void space along edge/bottom of last core segment		IV	R2-R3	80	1.5	1.0	157.0
								CL								

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 4 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
					RB-004				Light gray, LIMESTONE, slightly weathered, medium strong, extremely fractured [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R3	60	1.5	1.0	158.5
159									Light gray, LIMESTONE, slightly weathered, medium strong, moderately fractured				0-90	1.5	3.0	159.0
										P1			30	1.5	1.0	159.5
160	1.00			9		96	8						30	1.5	1.0	159.7
													50	1.5	1.0	160.0
													20	1.5	1.0	160.2
161													40	1.5	1.0	161.0
													40	1.5	1.0	161.1
													0	1.5	0.75	161.5
162									Becomes highly weathered, very weak, locally clayey		IV	R1	40	1.5	3.0	162.0
								CL								
163									Gray and white, DOLOMITE, slightly weathered, medium strong, extremely fractured, locally crushed		II	R3	0-90	1.5	4.0-6.0	163.0-166.9
164													10-80	1.0	1.0	164.0-168.0
165	1.00			10		78	0									
166																
167								CL					20	1.0	4.0	166.8
168					RB-005				Becomes light grayish brown, strong		II	R4	0-90	1.0-1.5	0.75-1.0	168.0-171.0
								CL								
169																
170	0.50			11		80	0						10	1.0	2.0	170.1
								CL								
171									Becomes weak, locally crushed, with CALCITE precipitation and sand infilling on fracture surfaces		II	R2	0-90	1.0-1.5	1.0-3.0	171.0-172.0

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 5 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Light grayish brown, DOLOMITE, slightly weathered, weak, extremely fractured, locally crushed, with trace dark brown mineral precipitation up to 1-inch and CALCITE precipitation and sand infilling on fracture surfaces [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II	R2	60	2.0	6.0	171.9
173													0-90	1.0	1.0	173.0-174.0
174									Becomes medium strong			R3	0-90	1.0	2.0-3.0	173.0-176.0
									Becomes highly weathered, weak, extremely fractured and crushed to a sand and gravel, locally moderately fractured		IV	R2				
175	1.25			12		100	0									
176													0-90	1.0	4.0	176.0-178.0
													0	3.0	6.0	176.3-176.4
													0	3.0	8.0	176.6-176.9
177									Extremely weathered, extremely weak, clay-filled fracture 177.2 - 177.8'		V	R0				
													10	3.0	8.0	177.6-177.9
178					RB-006				Becomes dark brown, highly weathered, weak, moderately to extremely fractured		IV	R2	0-90	1.0	2.0	178.2
													0-10	1.0	6.0	178.2-179.0
179									Becomes gray, slightly weathered, sound, laminated		II					
180	1.00			13		86	38						5	1.5	1.0	180.0
													0	1.5	1.0	180.5
181									Brown, LIMESTONE, slightly weathered, weak, extremely fractured		II		0-10	1.5	1.0	180.5-181.4
									Becomes moderately weathered		III					
182													0-90	1.5	1.0-3.0	181.7-182.2
								CL								
183									Light grayish brown, DOLOMITE, weakly laminated, slightly weathered, medium strong, calcite precipitation on fractures		II	R3	0-90	1.0	1.0	183.0-184.0
													0-90	1.0-1.5	1.0	183.0-184.7
184													60	1.0	1.0	184.2-184.3
									Becomes moderately fractured				70	1.0	2.0	184.7
185	1.00			14		100	37		Becomes laminated, moderately weathered, very weak, calcareous		III	R1	0-5	1.0-1.5	1.0-3.0	185.0-186.7

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 6 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
									Dark gray, DOLOMITE, slightly weathered, very weak, sound, with local clay-filled fractures. Becomes highly weathered at 186.4' [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		II IV	R1				
187																
188					RB-007											
													0-10	1.0	3.0	188.5
189									Becomes olive gray, slightly weathered, brecciated and healed		II		30-50	1.5	3.0	189.0
									Light grayish brown, LIMESTONE, strong, moderately fractured			R4				
190	0.83			15		95	32		190.1 - 190.4': PLA = 5,000 psi				0-10 0-90 0-5	1.0 1.0 1.5	3.0 6.0 2.0	190.0 190.0-190.5 190.7
191									Light grayish brown, DOLOMITE, slightly weathered, medium strong, moderately to extremely fractured Becomes extremely fractured				0-10	1.5	3.0	191.0-192.0
192													0-90	1.0	3.0	192.0-192.5
									Becomes moderately weathered, medium strong		III	R3				
193								CL								
									Becomes slightly weathered		II		0-90	1.0	6.0	193.2-194.7
194									Becomes light gray, highly weathered, very weak, locally crushed to small gravel, locally chalky. Becomes moderately fractured at 194.9'.		IV	R1				
195													0	1.0	3.0	195.0
	1.00			16		60	10		Becomes extremely weak, 6" clay layer			R0	0	1.0	3.0	195.5
196																
197								CL								
198					RB-008				Becomes dark gray, moderately weathered, weak, moderately to extremely fractured		III	R2	0-90	1.5	1.0-3.0	198.0-198.7
									Becomes very dark gray, slightly weathered, very weak, extremely fractured		II	R1				
199																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

CORING LOG

BORING NUMBER: BH19-38
SHEET NUMBER: 7 of 7
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Bond and S. Parks
INSPECTOR: K. Zeiger, X. You, O. El-Quqa

DEPTH (feet)	CORING RATE (ft/min)	GRAPHIC LOG	CORE RUN TYPE	CORE RUN NO.	ROCK BOX NO.	RECOVERY (%)	RQD (%)	ESTIMATED CORE LOSS	DESCRIPTION AND REMARKS (Lithology, Structure, Weathering, Continuity, Strength, Color, Grain Size)	PACKER TEST ZONE	WEATHERING	STRENGTH	DISCONTINUITY DATA ANGLE (deg)	Jr	Ja	DEPTH (feet)
200	1.00			17		88	28		Light gray, DOLOMITE, moderately weathered, medium strong, extremely fractured, locally crushed [ST. IGNACE FORMATION - MACKINAC BRECCIA, continued]		III	R3				
											II	R3	0-90	1.0	1.0	200.6-201.2
201									Becomes gray, slightly weathered, moderately fractured				0-90	1.5	1.0	201.2-202.4
202																
								CL								
203									End of Boring at 203' The boring was backfilled with neat cement grout to the mudline at 9:30 AM on 7/21/2019.							
204																
205																
206																
207																
208																
209																
210																
211																
212																
213																

WSP CORING LOG_NEARSHORE_L5RTPROJECT_20200219.GPJ WSP USA_20200219.GLB 2/19/20

APPENDIX

B-3 *OBSERVATION WELL CONSTRUCTION LOGS*

OBSERVATION WELL INSTALLATION LOG

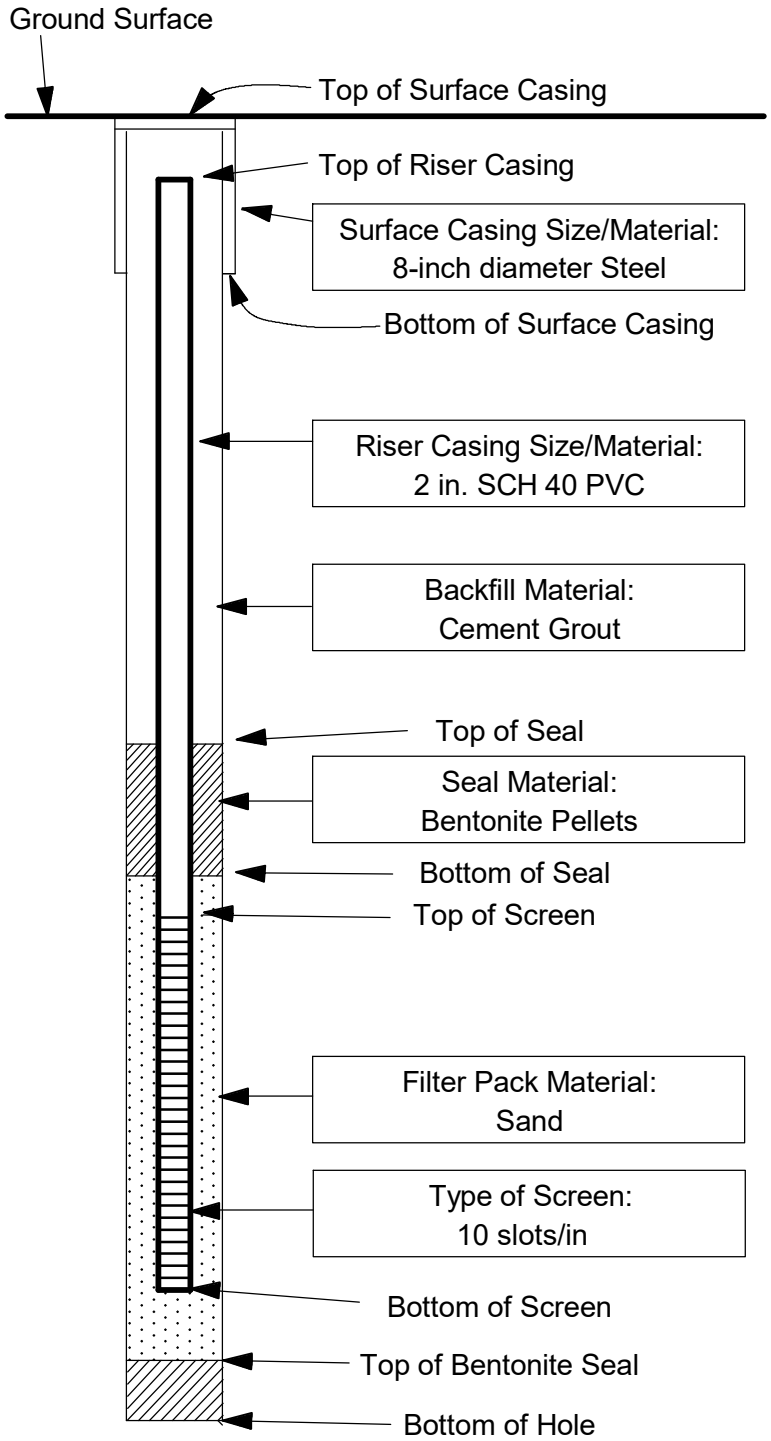
WELL NUMBER: PZ19-08

Contractor: Cascade Drilling

Driller: M. Osterberg

Inspector: K. Hanson

LOCATION: South side of Strait



	Depth (ft)	Elev. (ft)	Water Level Elevations (ft)
Top of Surface Casing	0	584.3	
	0	584.3	
Top of Riser Casing	0	584.3	
Bottom of Surface Casing	1	583.4	
			10/8/19, 582.5
			11/19/19, 581.6
Top of Seal	2	582.4	
Bottom of Seal	10	574.9	
Top of Screen	70	518.5	
Bottom of Screen	80	509.1	
Top of Bentonite Seal	108	482.8	
Bottom of Hole	113	478.1	

Note: With 8-inch diameter, locking, water tight well protector and a expandable compression cap. The well was developed on 6/23/2019 with a bailing water pump.

WSP OBSERVATION WELL LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

OBSERVATION WELL INSTALLATION LOG

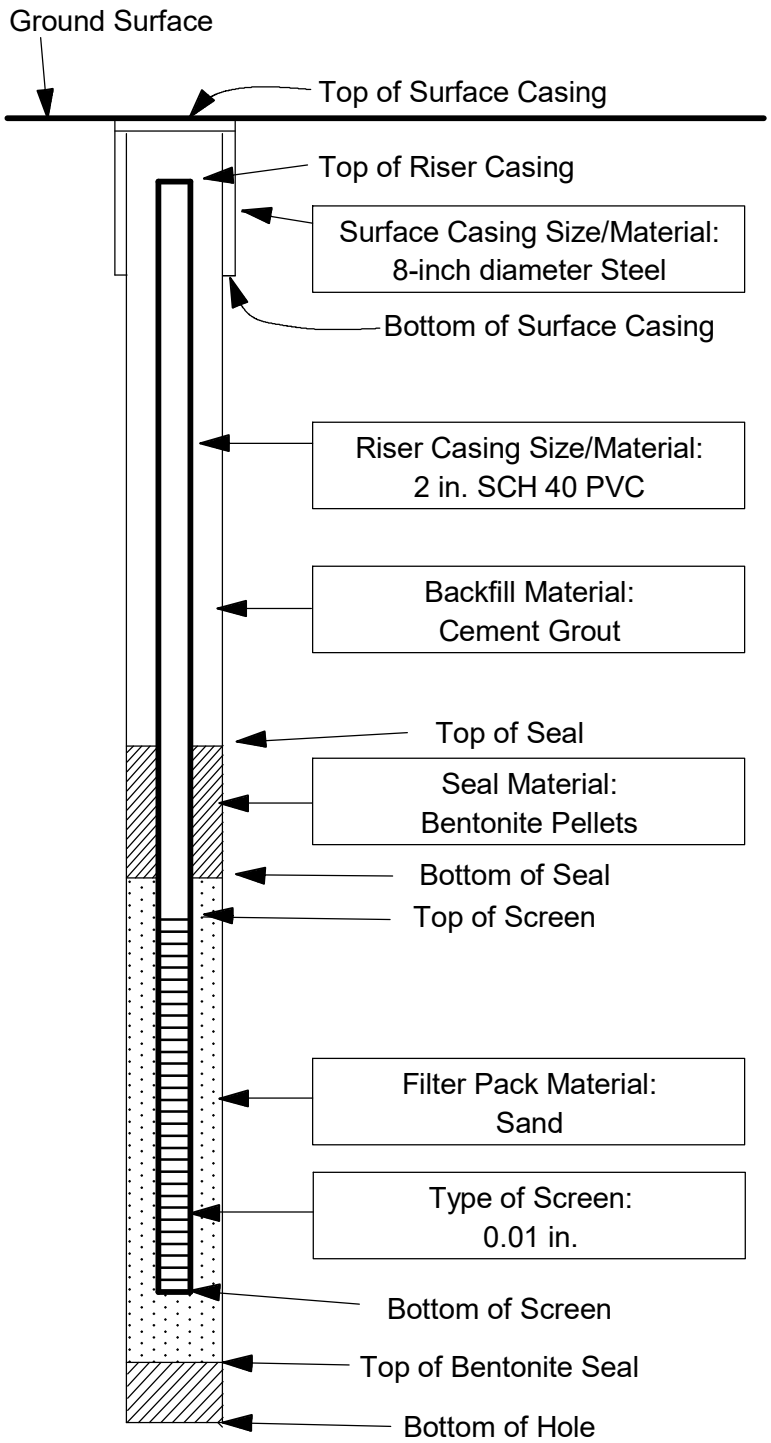
WELL NUMBER: PZ19-09

Contractor: Cascade Drilling

Driller: M. Osterberg

Inspector: C. Fisher

LOCATION: South side of Strait



	Depth (ft)	Elev. (ft)	Water Level Elevations (ft)
Top of Surface Casing	0	619.2	
	0	619.2	
Top of Riser Casing	0	619.2	
Bottom of Surface Casing	1	618.2	
Top of Seal	31	588.2	
Bottom of Seal	33	586.2	
Top of Screen	85	534.2	
Bottom of Screen	95	524.2	
Top of Bentonite Seal			
Bottom of Hole	104	515.2	

Note: With 8-inch diameter, unlocked, water tight well protector and a flat, flush-threaded cap.

WSP OBSERVATION WELL LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

OBSERVATION WELL INSTALLATION LOG

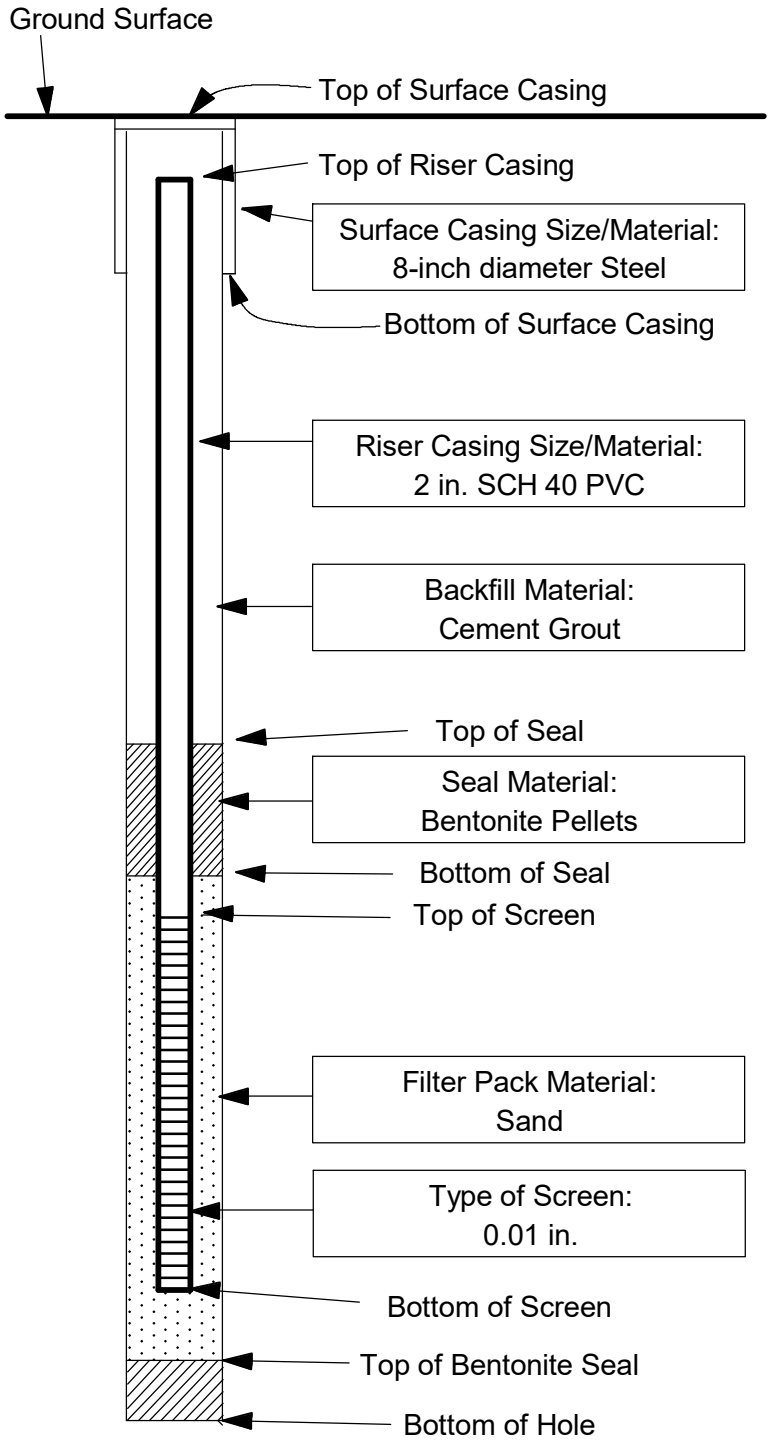
WELL NUMBER: PW19-12

Contractor: Cascade Drilling

Driller: M. Osterberg

Inspector: A. Heft

LOCATION: South side of Strait



	Depth (ft)	Elev. (ft)	Water Level Elevations (ft)
Top of Surface Casing	0	652.1	7/24/19 - 580.9'
			10/8/19, 563.1
Top of Riser Casing	0	652.1	11/19/19, 584.9
Bottom of Surface Casing	1	651.1	
Top of Seal			
Bottom of Seal	50	602.1	
Top of Screen	130	522.1	
Bottom of Screen	140	512.1	
Top of Bentonite Seal			
Bottom of Hole	150	502.1	

Note: With 8-inch diameter, unlocked, water tight well protector and a flat, flush-threaded cap.

WSP OBSERVATION WELL LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

OBSERVATION WELL INSTALLATION LOG

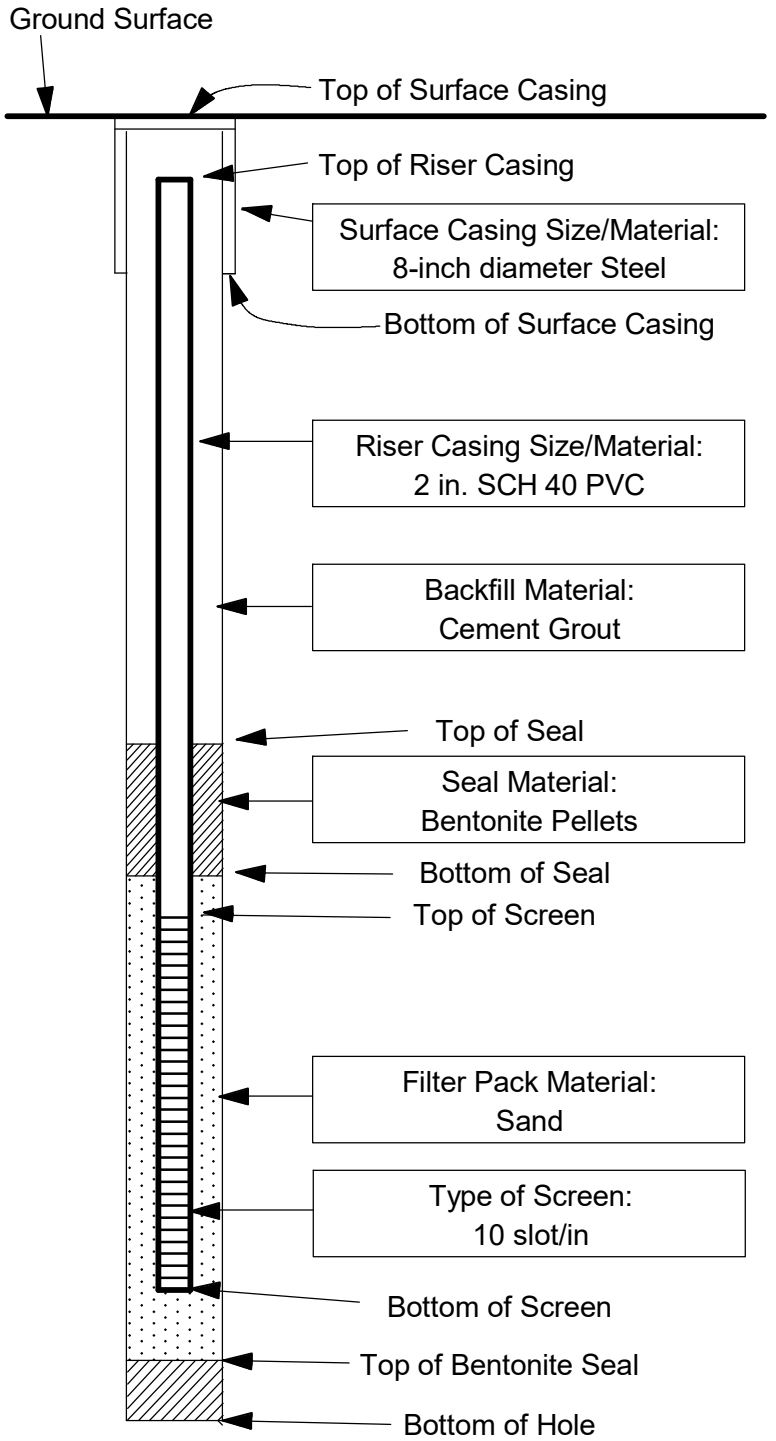
WELL NUMBER: PZ19-40

Contractor: Cascade Drilling

Driller: M. Osterberg

Inspector: K. Hanson

LOCATION: South side of Strait



	Depth (ft)	Elev. (ft)	Water Level Elevations (ft)
Top of Surface Casing	0	652.2	
	0	652.2	
Top of Riser Casing	0	652.2	
Bottom of Surface Casing	1	651.2	10/8/19, 584.3
			11/19/19, 584.2
Top of Seal	47	605.2	
Bottom of Seal	50	602.2	
Top of Screen	85	567.2	
Bottom of Screen	95	557.2	
Top of Bentonite Seal	95	557.2	
Bottom of Hole	100	552.2	

Note: With 8-inch diameter, unlocked, water tight well protector and a flat, flush-threaded cap. The well was developed on 6/26/2019 with a bailing water pump.

WSP OBSERVATION WELL LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-40
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78667 N Long: 84.77627 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 652.2 feet
DATUM: IGLD 1985

START DATE: 6/25/19 TIME: 8:00 am
FINISH DATE: 6/25/19 TIME: 12:15 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.		1.375"	2.938"	4.00"		
O.D.		2"	3"	4.75"		
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
7/24/19	8:00 am	66.7	50.0	95.0

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1–24		SB-001 0.0-7.0 ft.															Dark brown, SILTY SAND AND CLAY, (SC-SM), [TOPSOIL] Light brown, SILTY SAND, some Gravel, (SM)
		SB-002 7.0-17.0 ft.															Tan, LIMESTONE, moderately to extremely weathered, with occasional CLAY zones
		SB-003 17.0-27.0 ft.															

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-40
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
26												
27												Becomes light gray, slightly weathered
28												
29												
30												
31												
32												
33												
34												
35												
36		SB-004 27.0-47.0 ft.										
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												
54												
55												
56		SB-005 47.0-67.0 ft.										
57												
58												
59												

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-40
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
61												
62												
63												
64												
65												
66												
67		SB-006 67.0-87.0 ft.										
68												
69												
70												
71												
72												
73												
74												
75												
76												
77												
78												
79												
80												
81												
82												
83												
84												
85												
86												
87												
88		SB-007 87.0-100.0 ft.										
89												
90												
91												
92												
93												
94												

WSP OW LOG L5RTPROJECT_20191219.GPJ WSP USA_20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-40
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96																	
97																	
98																	
99																	
100																	End of boring at 100 feet. An open-standpipe piezometer was constructed in PZ19-40 on 6/25/2019.
101																	
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	
119																	
120																	
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL INSTALLATION LOG

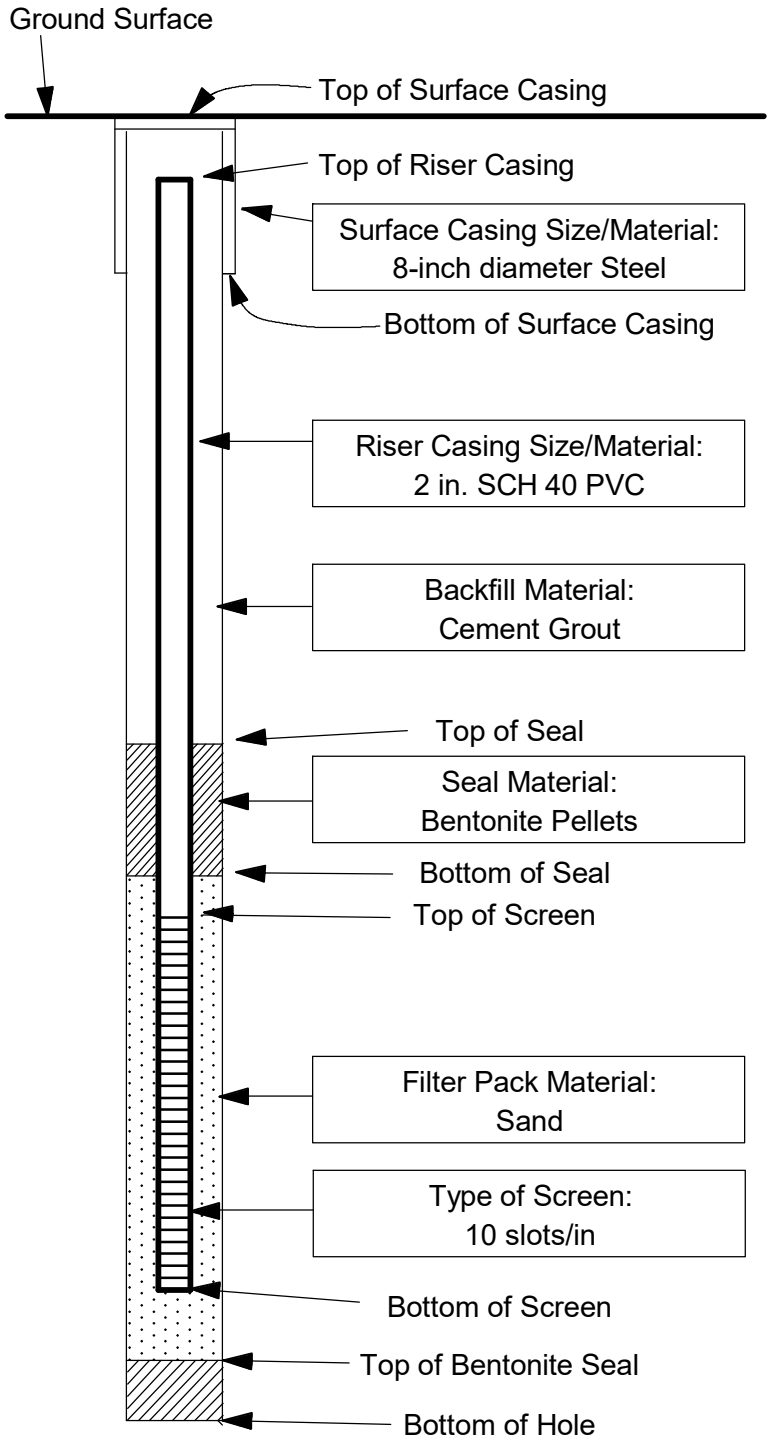
WELL NUMBER: PZ19-41

Contractor: Cascade Drilling

Driller: M. Osterberg

Inspector: K. Hanson

LOCATION: South side of Strait



	Depth (ft)	Elev. (ft)	Water Level Elevations (ft)
Top of Surface Casing	0	652.3	
	0	652.3	
Top of Riser Casing	0	652.3	
Bottom of Surface Casing	1	651.3	
			10/8/19, 584.5
			11/19/19, 584.4
Top of Seal	47	605.3	
Bottom of Seal	50	602.3	
Top of Screen	85	567.3	
Bottom of Screen	95	557.3	
Top of Bentonite Seal	95	557.3	
Bottom of Hole	100	552.3	

Note: With 8-inch diameter, unlocked, water tight well protector and a flat, flush-threaded cap. The well was developed on 6/26/2019 with a bailing water pump.

WSP OBSERVATION WELL LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-41
SHEET NUMBER: 1 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78671 N Long: 84.77650 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 652.3 feet
DATUM: IGLD 1985

START DATE: 6/24/19 TIME: 9:30 am
FINISH DATE: 6/24/19 TIME: 3:15 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.		1.375"	2.938"	4.00"		
O.D.		2"	3"	4.75"		
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
7/24/19	8:02 am	66.6	50.0	95.0

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1		SB-001 0.0-12.0 ft.															SANDY SILT, with Organics, little Gravel, (ML)
2																	SILTY SAND, with Gravel, (SM)
3																	
4																	
5																	
6																	
7																	
8																	Light gray, LIMESTONE, moderately weathered
9																	
10																	
11																	
12																	Becomes gray
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-41
SHEET NUMBER: 2 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
26		SB-002 12.0-47.0 ft.										
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												
54												
55												
56												
57												
58												
59		SB-003 47.0-70.0 ft.										

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-41
SHEET NUMBER: 3 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE					SOIL (Blows/6 in.)					FIELD CLASSIFICATION AND REMARKS
		SONIC BOX	TYPE	NUMBER	SYMBOL	DEPTH (feet)	0/6	6/12	12/18	18/24	REC. (in.)	
							CORING					
							RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	
61												
62												
63												
64												
65												
66												
67												
68												
69												
70												
71												
72												
73												
74												
75												
76												
77												
78												
79												
80												
81												
82												
83												
84												
85		SB-004 70.0-100.0 ft.										
86												
87												
88												
89												
90												
91												
92												
93												
94												

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-41
SHEET NUMBER: 4 of 4
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
96																	
97																	
98																	
99																	
100																	End of boring at 100 feet. An open-standpipe piezometer was constructed in PZ19-41 on 6/24/2019.
101																	
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	
119																	
120																	
121																	
122																	
123																	
124																	
125																	
126																	
127																	
128																	
129																	

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL INSTALLATION LOG

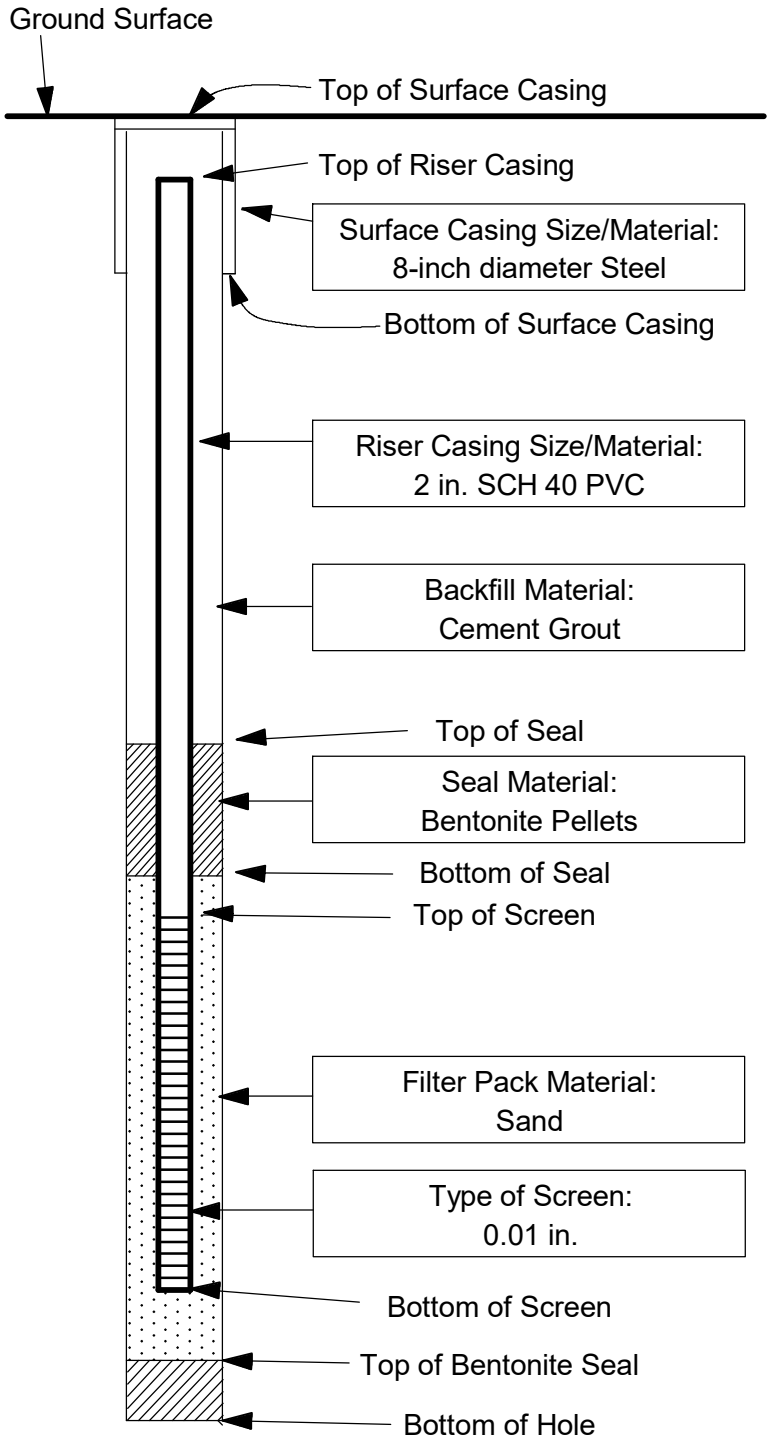
WELL NUMBER: PZ19-42

Contractor: Cascade Drilling

Driller: M. Osterberg

Inspector: C. Fisher

LOCATION: South side of Strait



	Depth (ft)	Elev. (ft)	Water Level Elevations (ft)
Top of Surface Casing	0	621.4	
	0	621.4	
Top of Riser Casing	0	621.4	
Bottom of Surface Casing	1	620.4	
			10/8/19, 584.5
			11/19/19, 584.4
Top of Seal	27	594.4	
Bottom of Seal	30	591.4	
Top of Screen	40	581.4	
Bottom of Screen	50	571.4	
Top of Bentonite Seal			
Bottom of Hole	50	571.4	

Note: With 8-inch diameter, unlocked, water tight well protector and a flat, flush-threaded cap. The well was developed on 6/23/2019 with a bailing water pump.

WSP OBSERVATION WELL LOG L5RTPROJECT_20191216.GPJ WSP USA_20191216.GLB 12/17/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-42
SHEET NUMBER: 1 of 2
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership
CONTRACTOR: Cascade Drilling

DRILLER: M. Osterberg
INSPECTOR: C. Fischer
BORING INCLINATION FROM HORIZONTAL: 90°

DRILLING METHOD: Sonic
RIG TYPE: Boart Longyear 600
HAMMER TYPE: None

LOCATION: Onshore - South of Strait
COORD. Lat: 45.78712 N Long: 84.77699 W
STN. NO.: OFFSET:
TOP OF CASING ELEV.: 621.4 feet
DATUM: IGLD 1985

START DATE: 6/23/19 TIME: 1:30 pm
FINISH DATE: 6/23/19 TIME: 6:00 pm

	Casing	Split Spoon	Shelby Tube	Sonic	Grab	Core Barrel
Type/Symbol		SPT ■	ST ☐	SB ▨	G ☒	C ☐
I.D.		1.375"	2.938"	4.00"		
O.D.		2"	3"	4.75"		
Length		24"	24"	10.00'		
Hammer Wt.			Drill Rod Size			
Hammer Fall			I.D. (O.D.)			

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Cave Depth (ft)	Hole Depth (ft)
7/24/19	8:02 am	35.8	30.0	50.0

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	REC. (in.)	REC. %	L>4" (in.)	RQD %	FIELD CLASSIFICATION AND REMARKS
1		SB-001 0.0-8.0 ft.															Light to dark brown, SILTY SAND, little Gravel, trace Cobbles, (SM), [TOPSOIL]
2																	Light brown, SILTY SAND, little Gravel, trace Cobbles, (SM)
3																	LIMESTONE, moderately weathered
4																	
5																	Becomes light gray to light brown, with slightly weathered zones
6																	
7																	
8																	Becomes tannish gray to light gray
9																	
10																	
11																	
12																	
13		SB-002 8.0-18.0 ft.															
14																	
15																	
16																	
17																	
18																	
19																	
20																	20': ω = 2.37%; γ_d = 152 lb/ft^3; SG = 2.42; n = 0.11; PLA = 4,050 psi; PP = 5,589 lbs
21																	
22																	
23																	
24																	

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

OBSERVATION WELL LOG

BORING NUMBER: PZ19-42
SHEET NUMBER: 2 of 2
PROJECT NUMBER: 31402024.00

PROJECT: Line 5 Replacement and Tunnel Project
LOCATION: Straits of Mackinac, Michigan
CLIENT: Enbridge Energy, Limited Partnership

CONTRACTOR: Cascade Drilling
DRILLER: M. Osterberg
INSPECTOR: C. Fischer

DEPTH (feet)	GRAPHIC LOG	SAMPLE: SONIC BOX	SAMPLE: TYPE	SAMPLE: NUMBER	SAMPLE: SYMBOL	SAMPLE: DEPTH (feet)	SOIL (Blows/6 in.): 0/6	6/12	12/18	18/24	REC. (in.)	CORING: RUN (in.)	CORING: REC. (in.)	CORING: REC. %	CORING: L>4" (in.)	CORING: RQD %	FIELD CLASSIFICATION AND REMARKS
26		SB-003 18.0-38.0 ft.															
27																	
28																	
29																	
30																	30': PP = 16,347 lbs; MOHS = 2.5
31																	
32																	
33																	
34																	
35																	
36																	
37																	
38																	38': ω = 1.49%; γ_d = 154 lb/ft^3; SG = 2.48; n = 0.09
39		SB-004 38.0-50.0 ft.															
40																	40': PLL = 2,250 psi
41																	
42																	
43																	
44																	
45																	45': PP = 45,937 lbs; MOHS = 2.5
46																	
47																	
48																	
49																	50': ω = 1.73%; γ_d = 151 lb/ft^3; SG = 2.42; n = 0.12; PLA = 5,940 psi; PP = 14,016 lbs
50																	End of boring at 50 feet.
51																	An open-standpipe piezometer was constructed in PZ19-42 on 6/23/2019.
52																	
53																	
54																	
55																	
56																	
57																	
58																	
59																	

WSP OW LOG L5RTPROJECT 20191219.GPJ WSP USA 20191219.GLB 12/20/19

APPENDIX

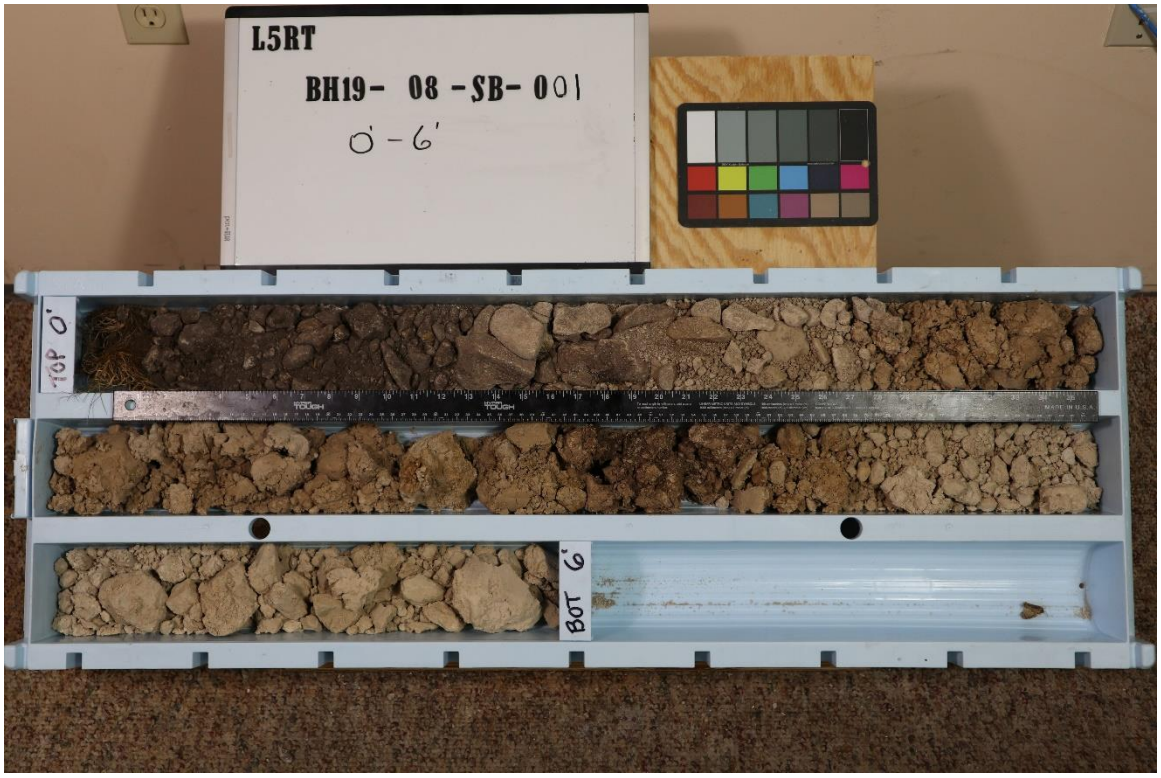
C SAMPLE PHOTOGRAPHS

APPENDIX

C-1 *SOIL SAMPLE PHOTOGRAPHS*

BH19-07-SB-001

BH19-07-SB-003



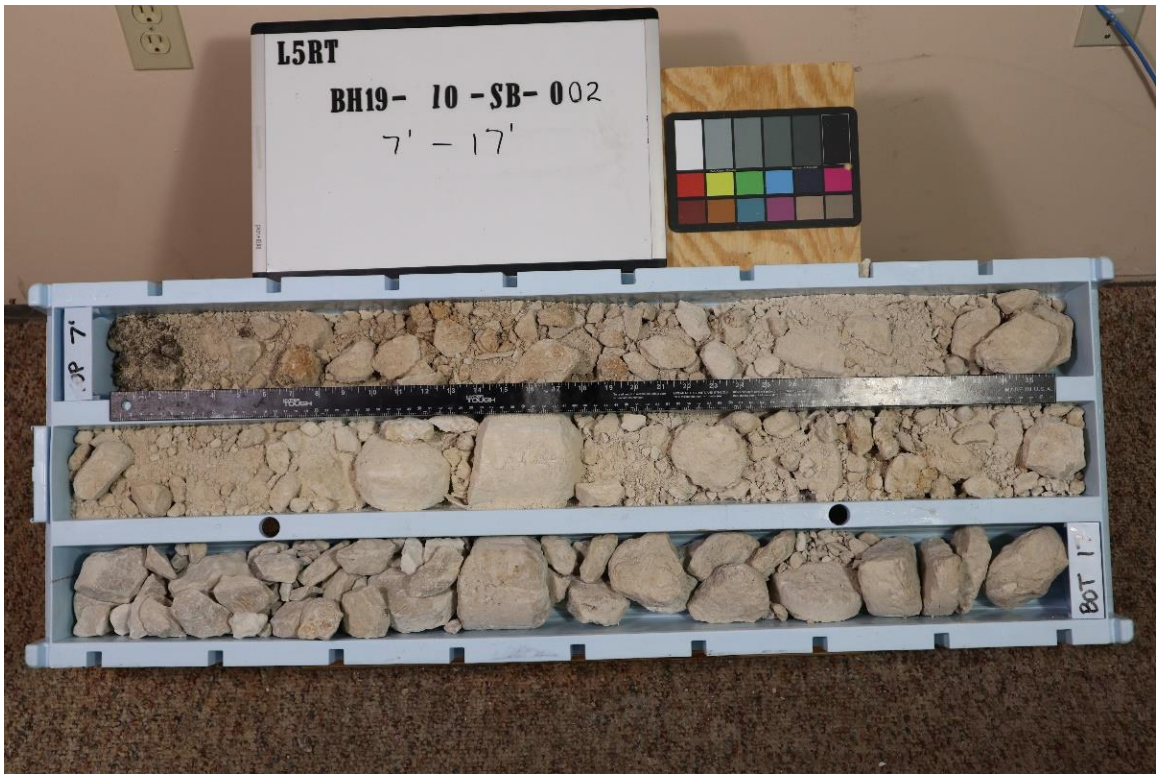
BH19-08-SB-001

BH19-08-SB-002

BH19-08-SB-003

[Intentionally Left Blank]

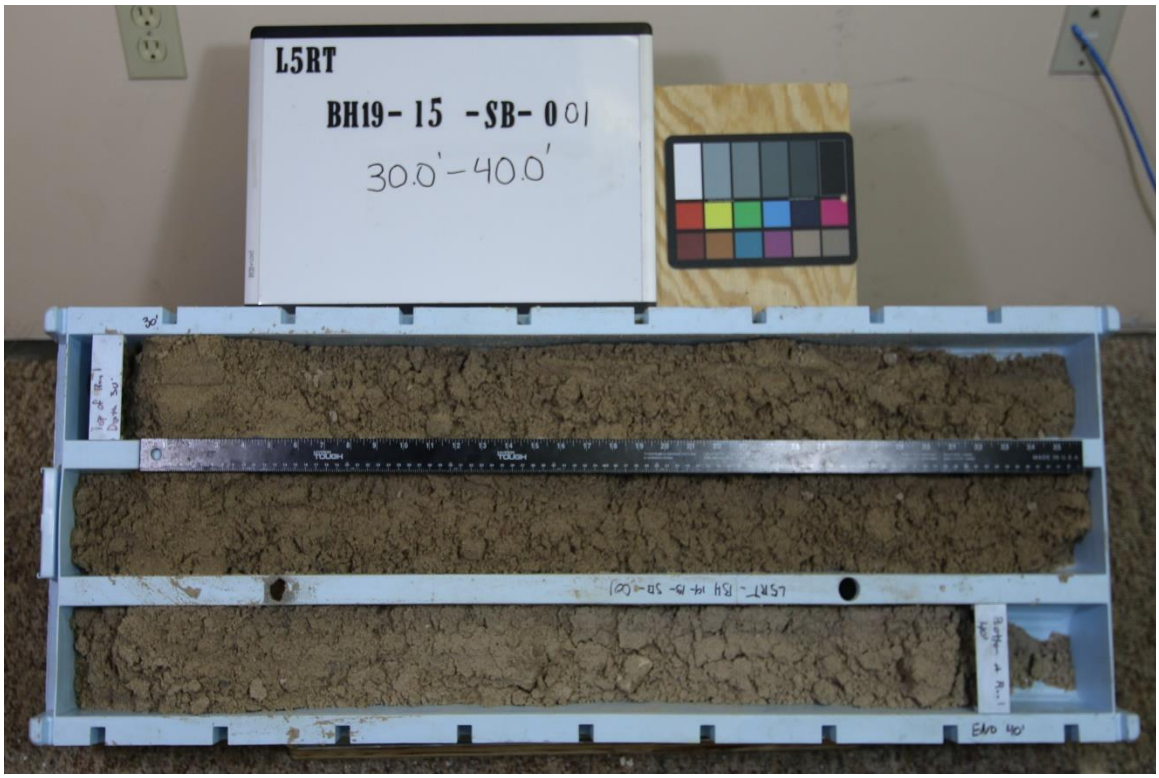
BH19-10 SB-001



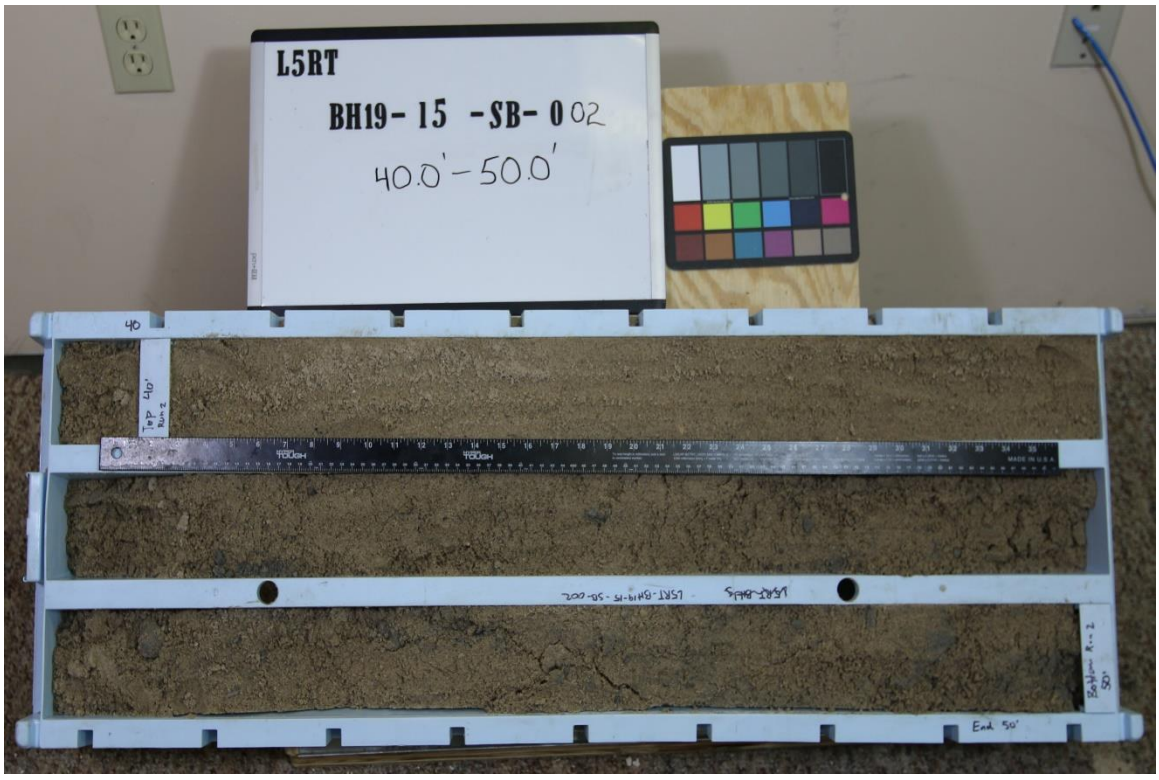
BH19-10 SB-002

BH19-14-SB-001

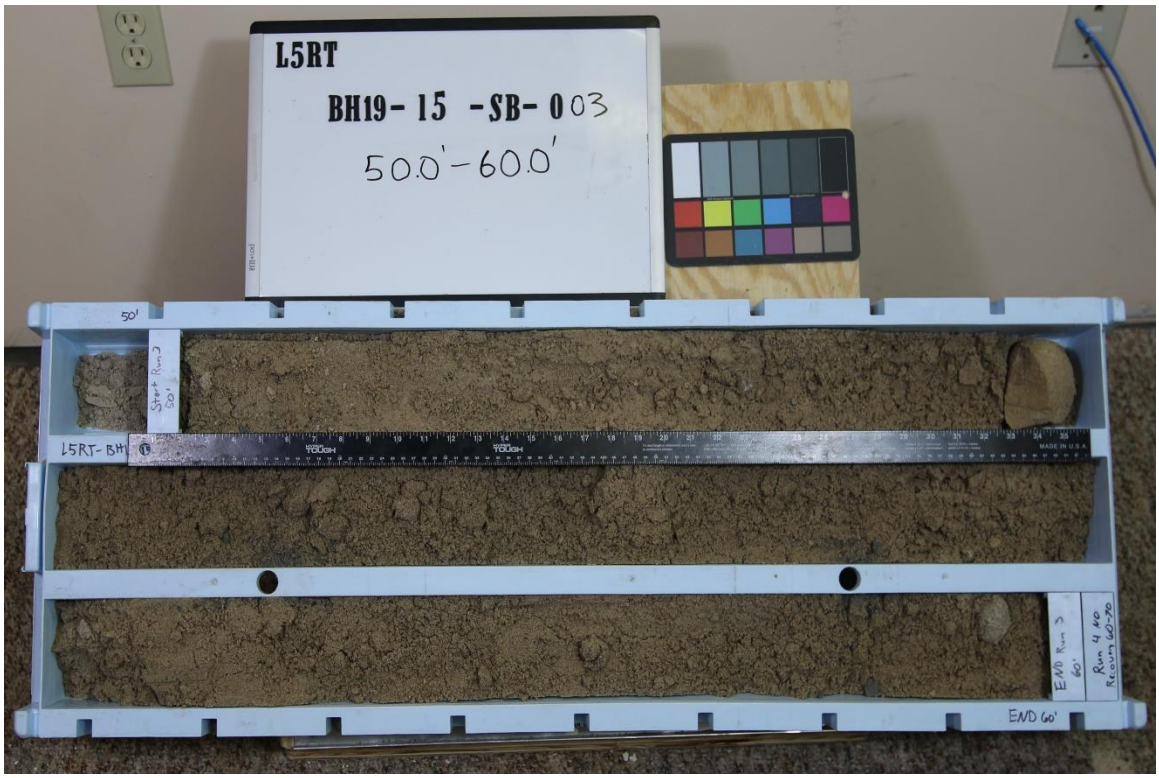
BH19-14-SB-002



BH19-15-SB-001

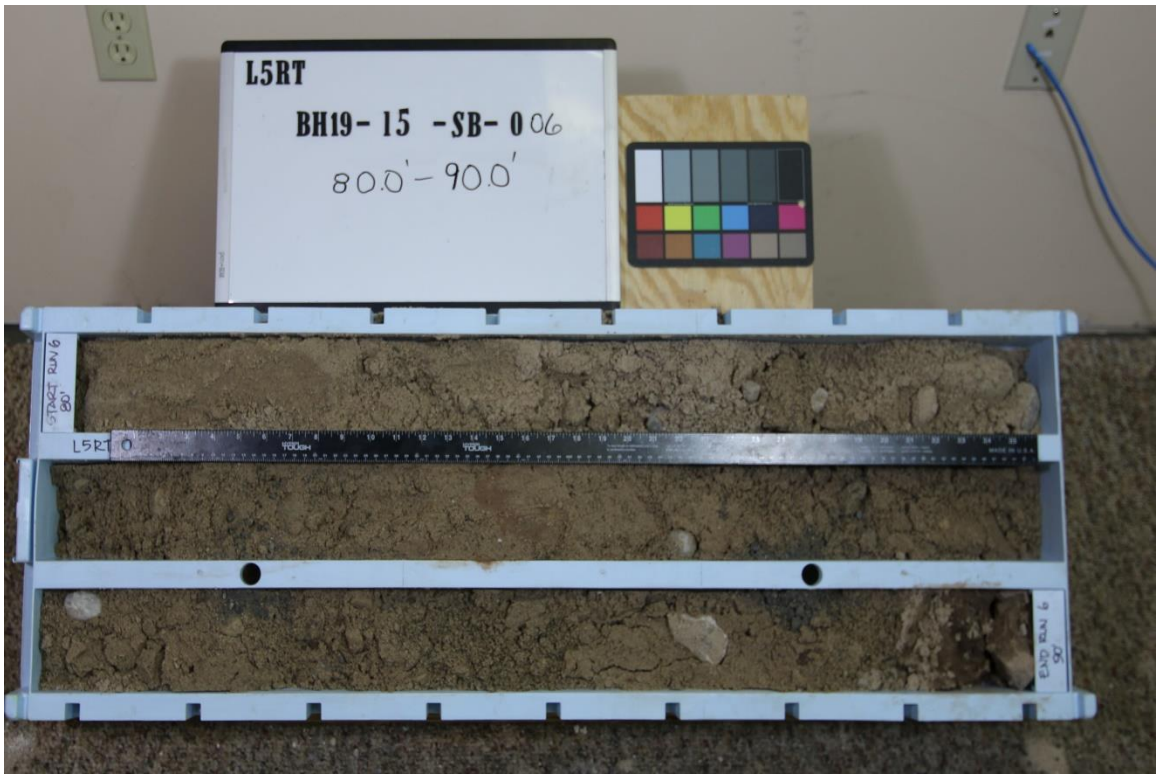


BH19-15-SB-002

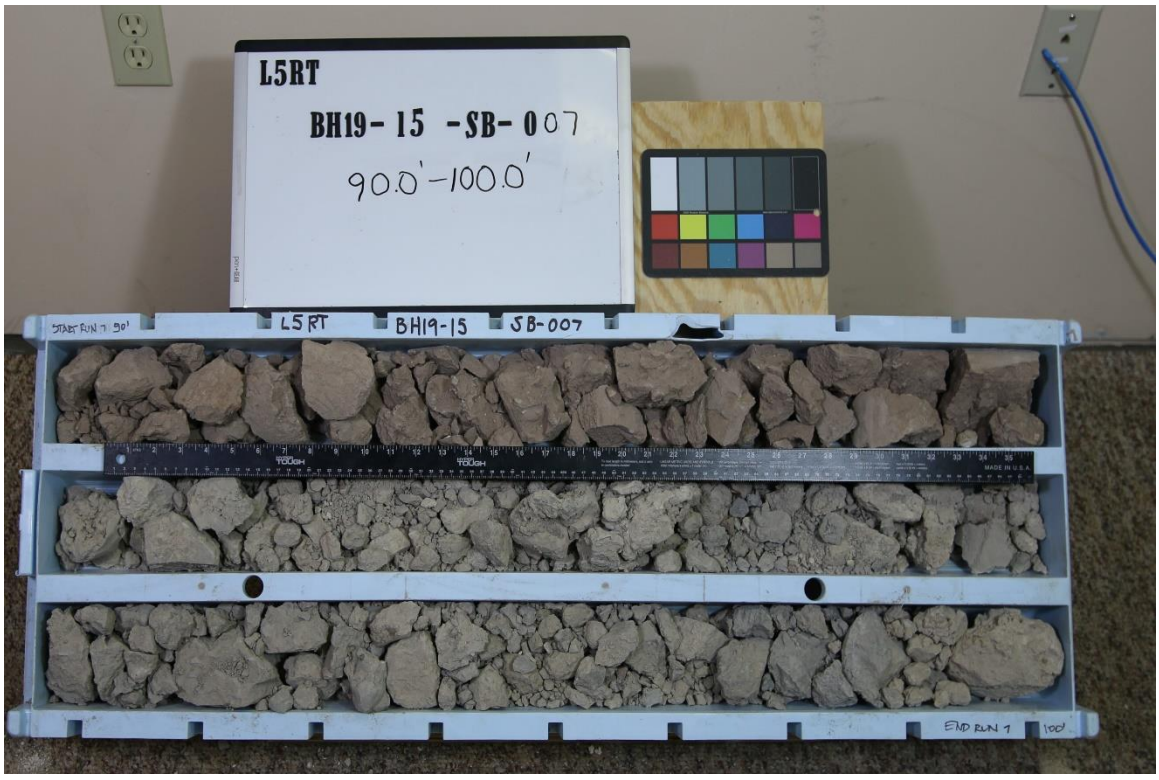


BH19-15-SB-003

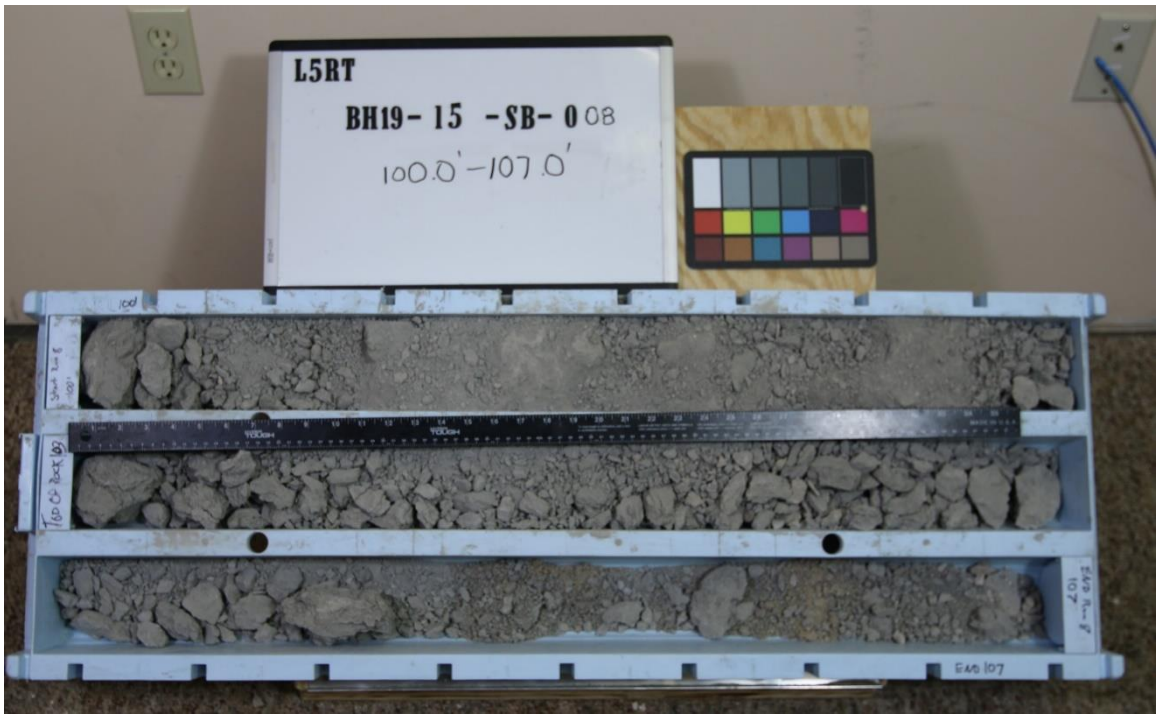
BH19-15-SB-005



BH19-15-SB-006



BH19-15-SB-007



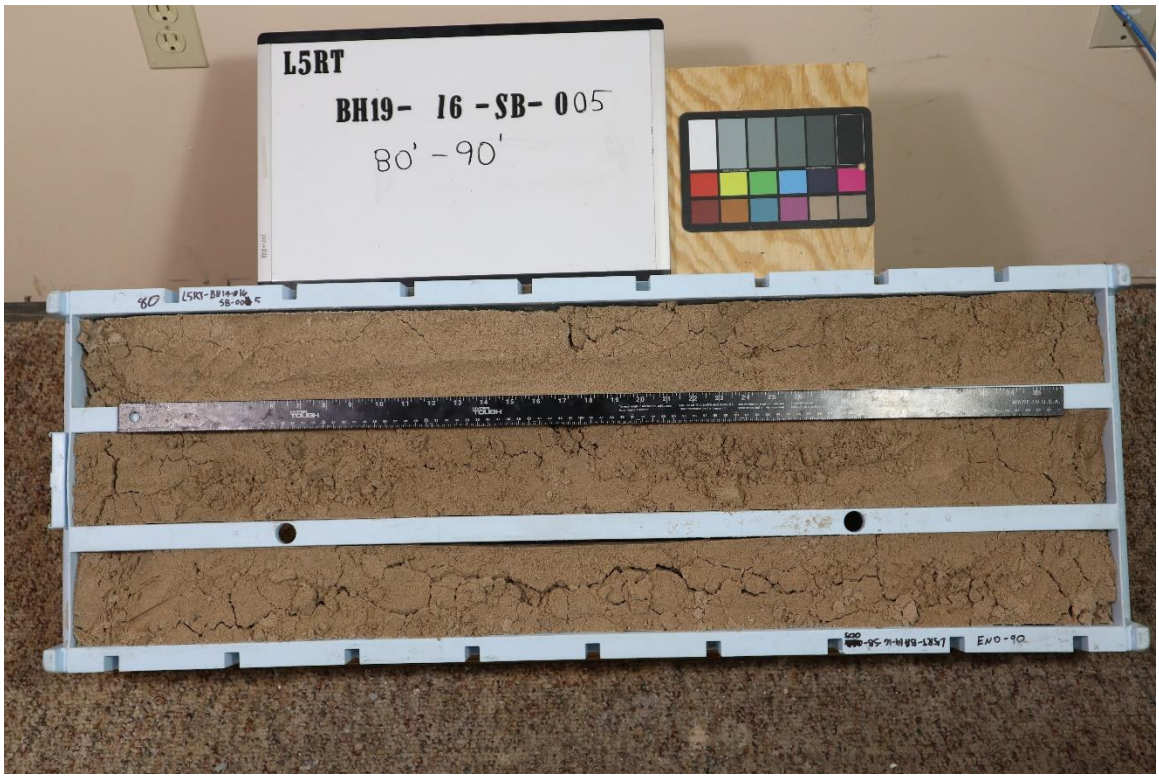
BH19-15-SB-008

[Intentionally Left Blank]

BH19-16-SB-001

BH19-16-SB-002

BH19-16-SB-004



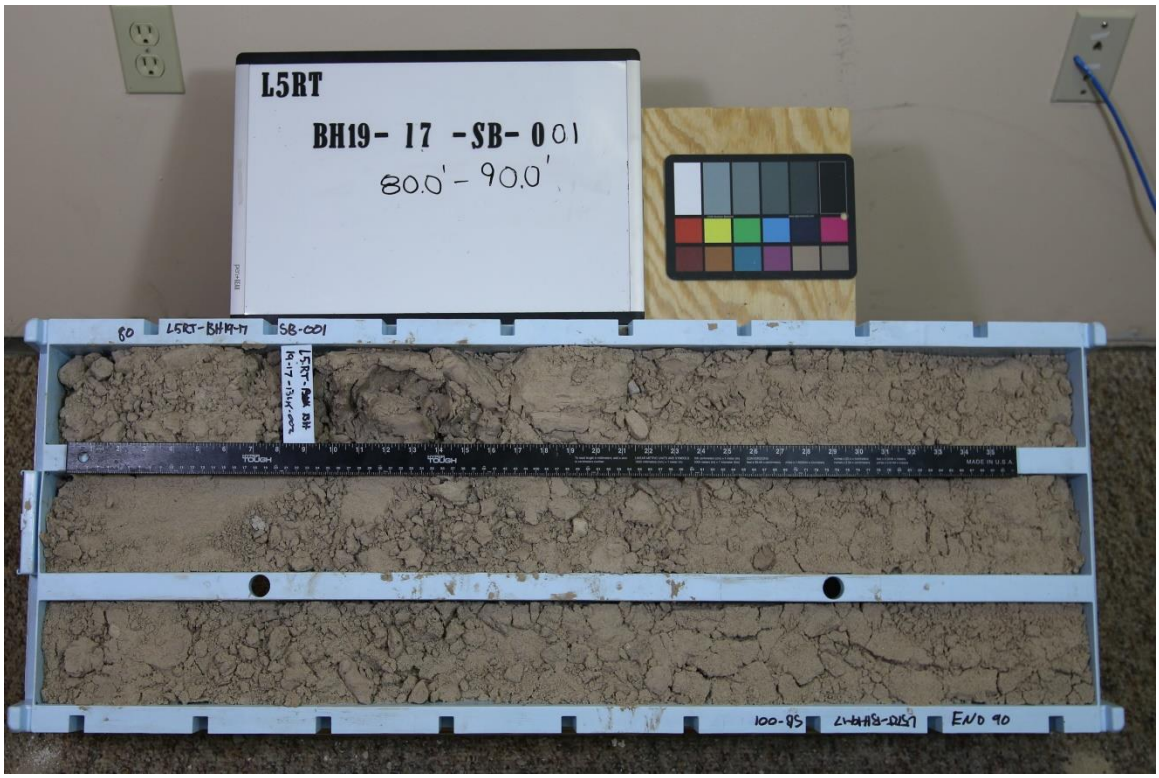
BH19-16-SB-005

BH19-16-SB-006

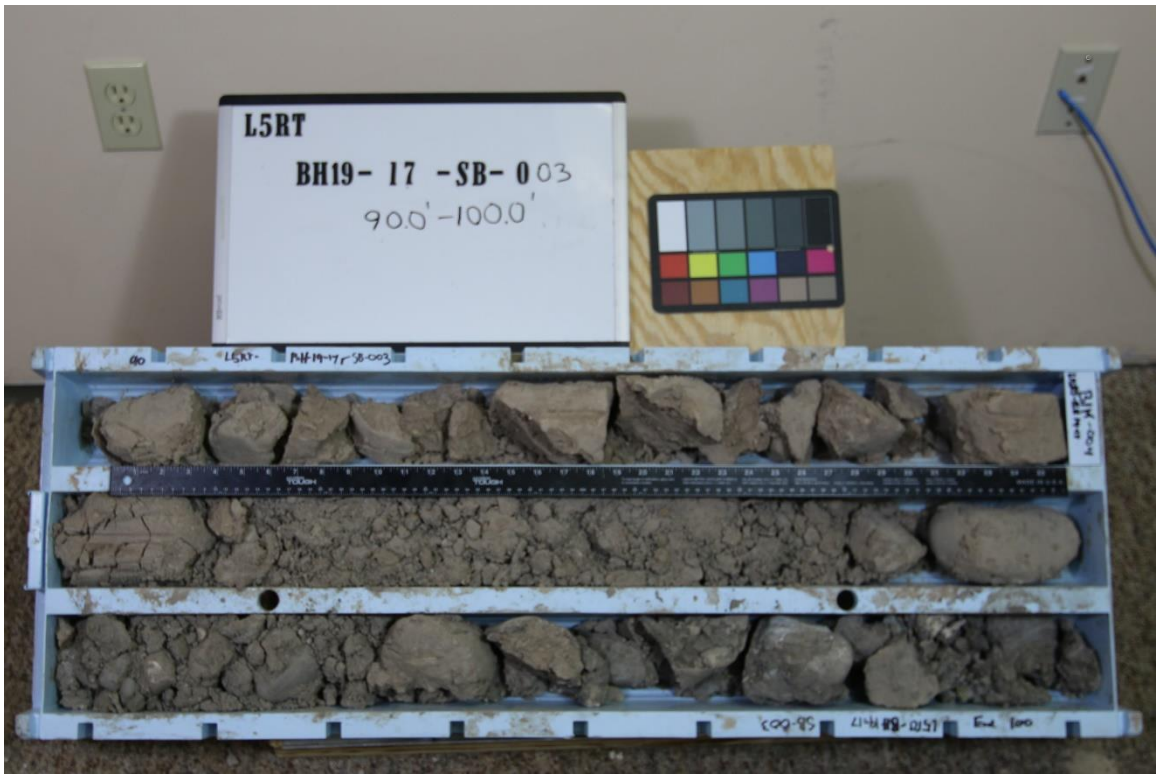
BH19-16-SB-008

BH19-16-SB-009

[Intentionally Left Blank]

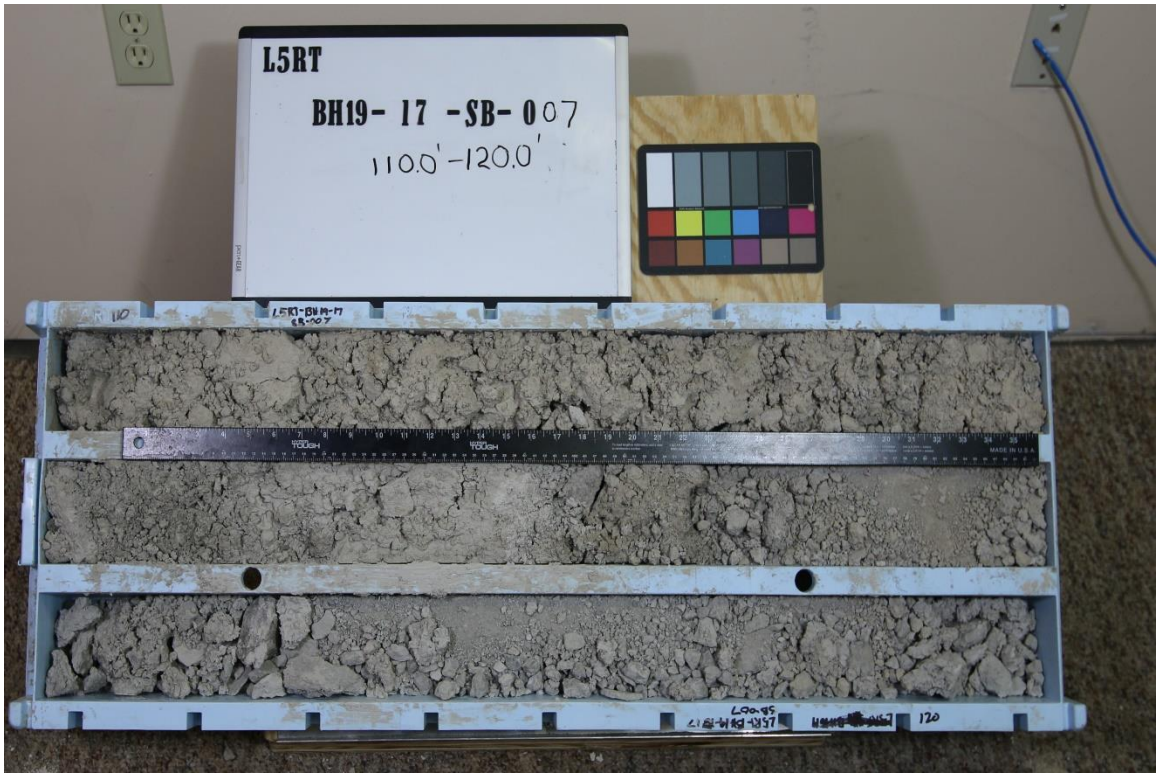


BH19-17-SB-001



BH19-17-SB-003

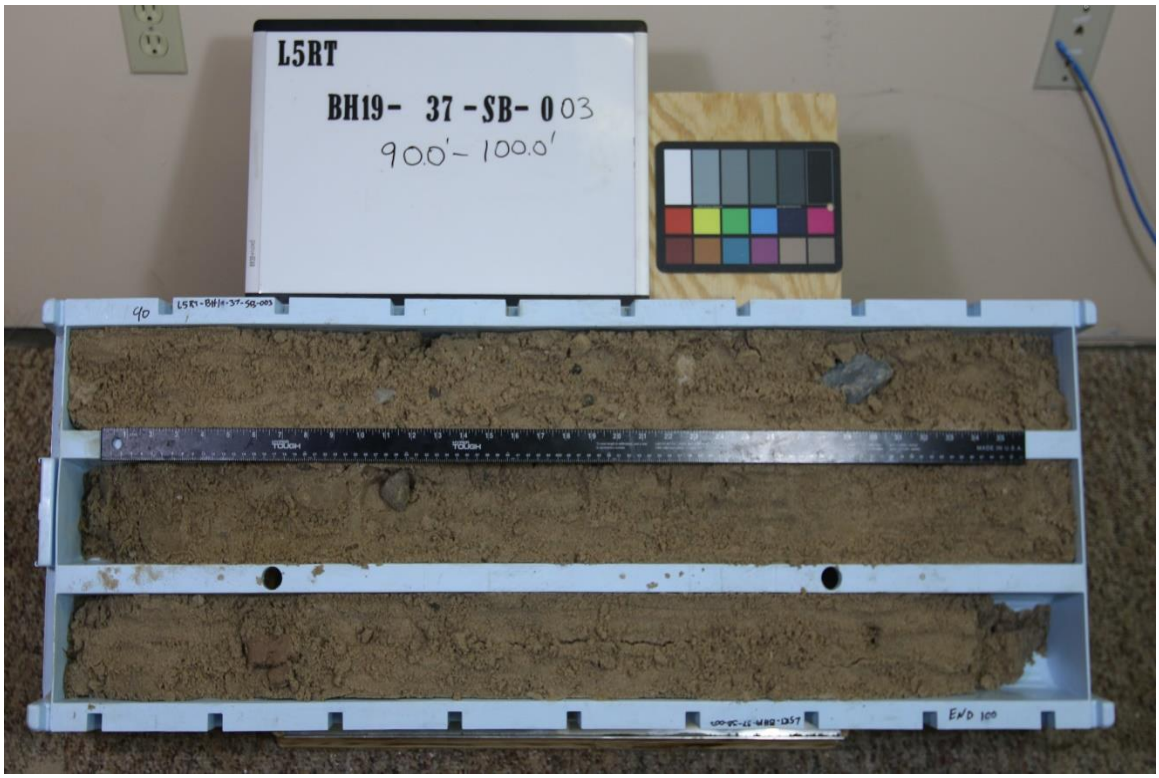
BH19-17-SB-006



BH19-17-SB-007

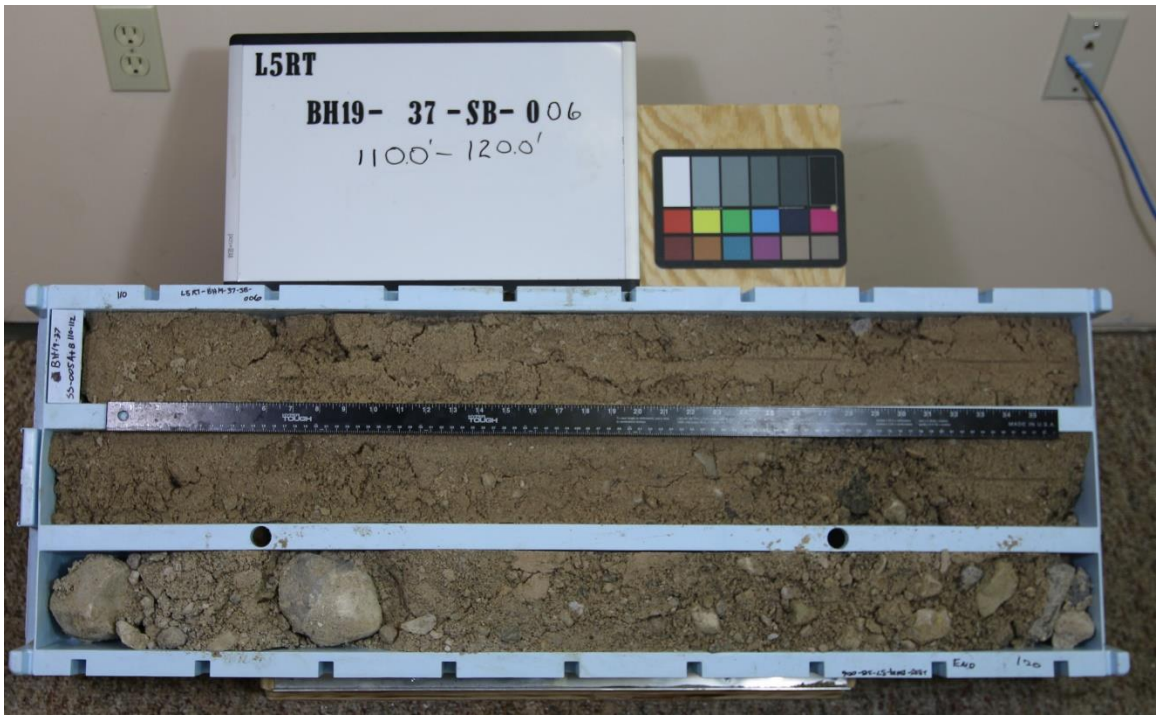
BH19-37-SB-001

BH19-37-SB-002

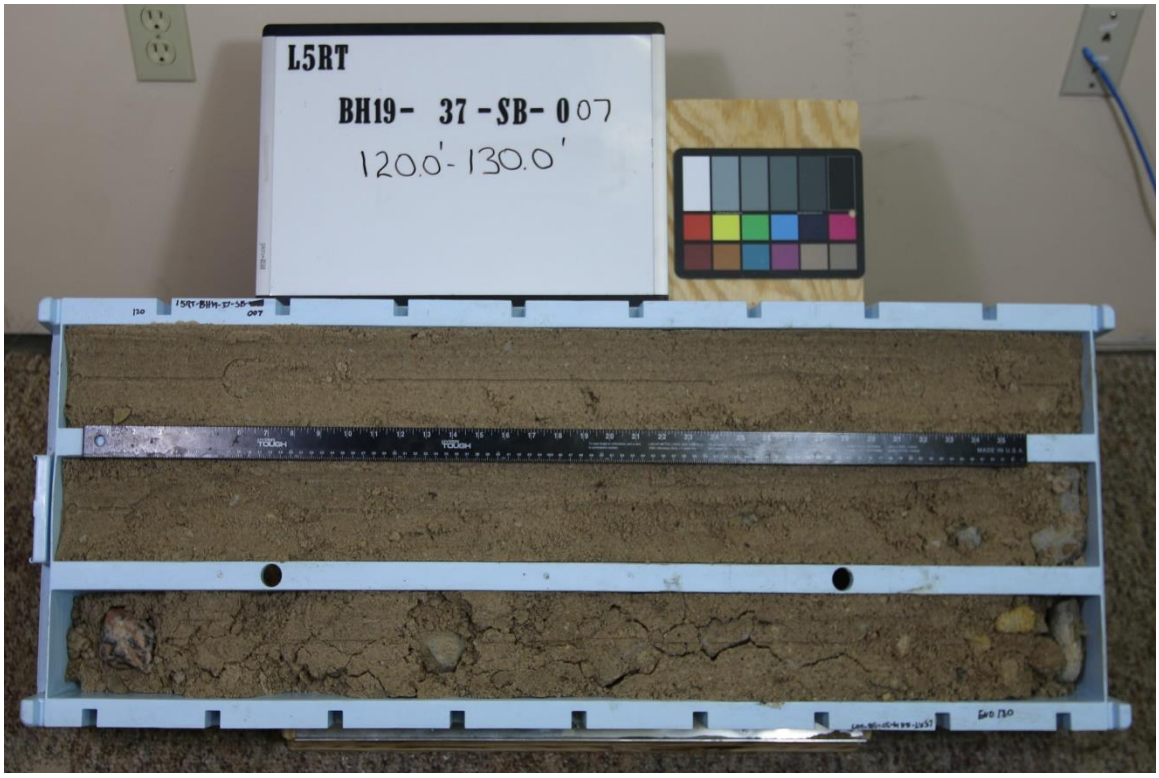


BH19-37-SB-003

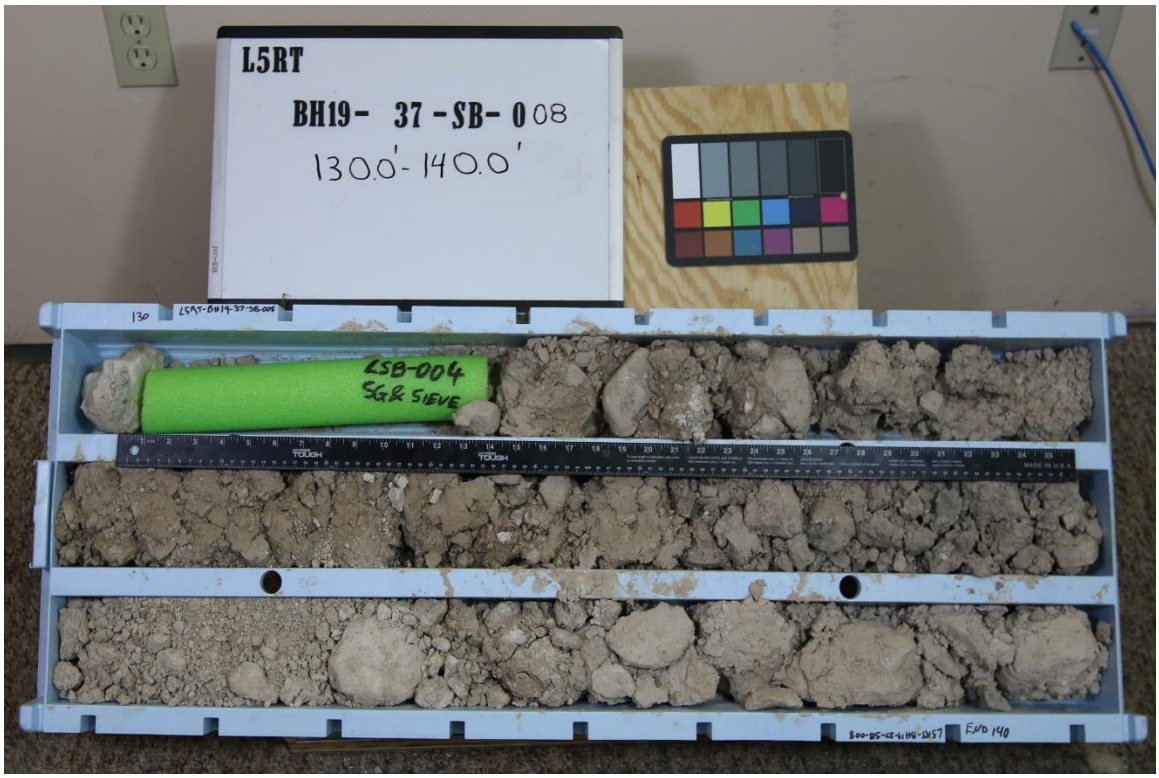
BH19-37-SB-004



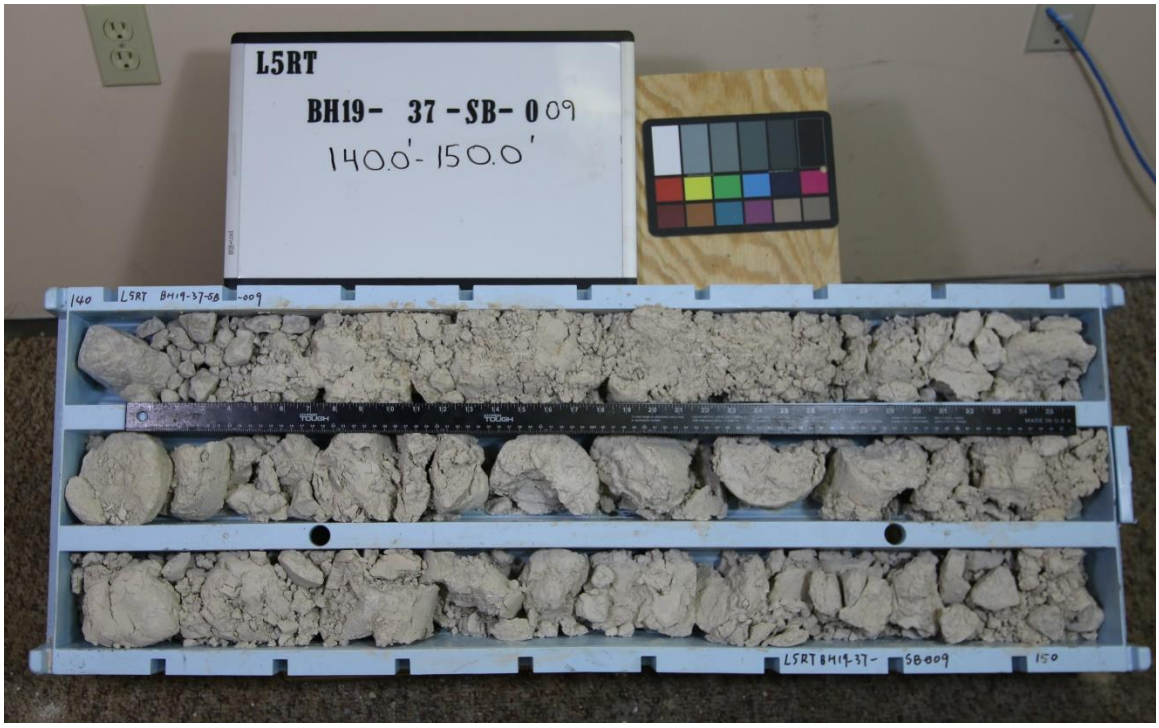
BH19-37-SB-006



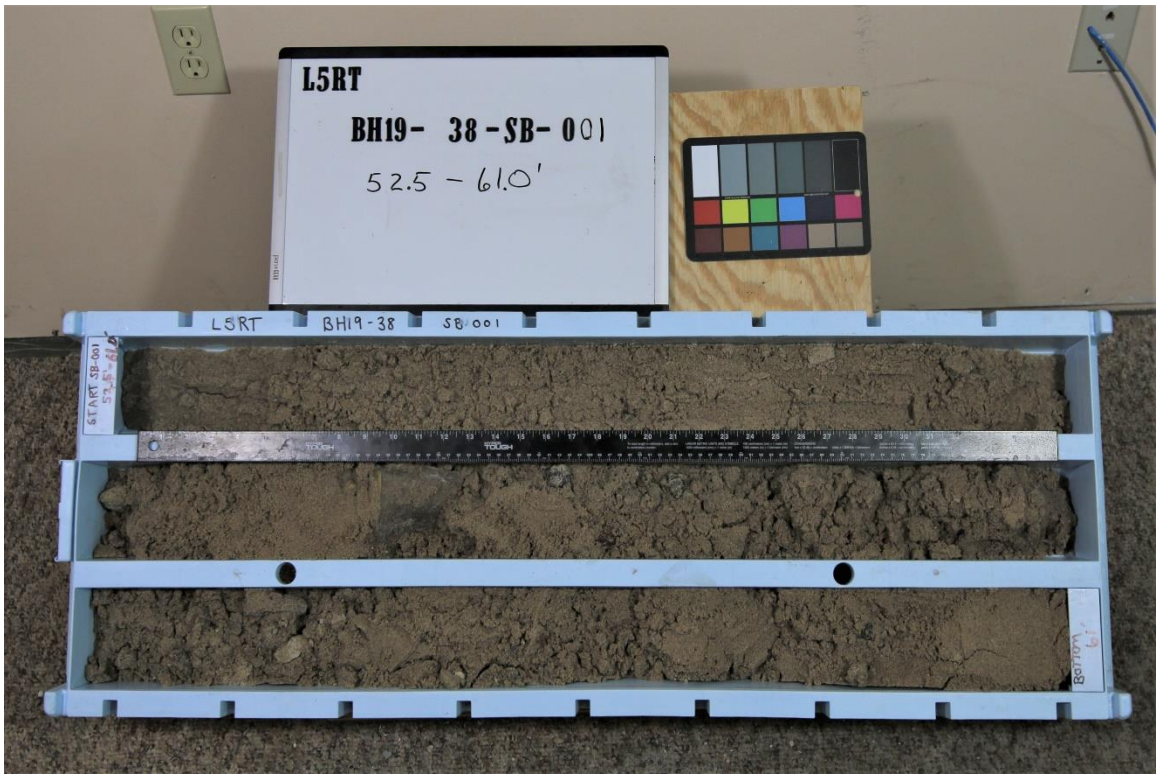
BH19-37-SB-007



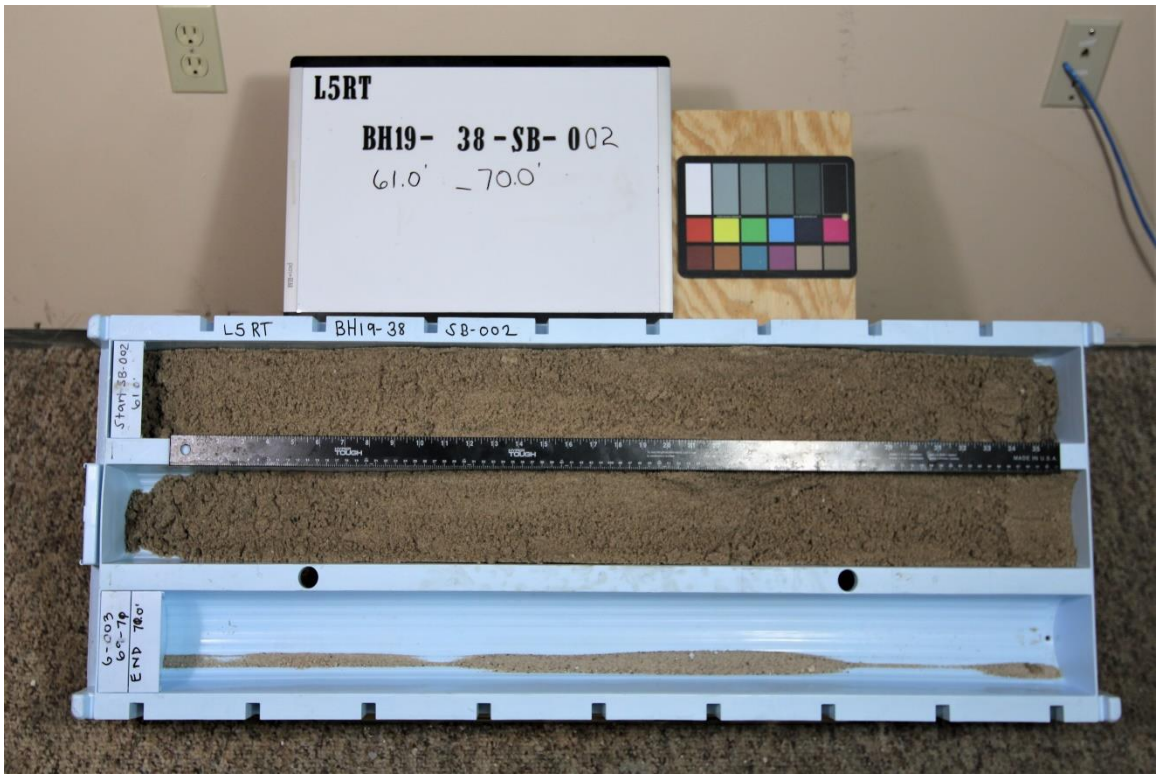
BH19-37-SB-008



BH19-37-SB-009

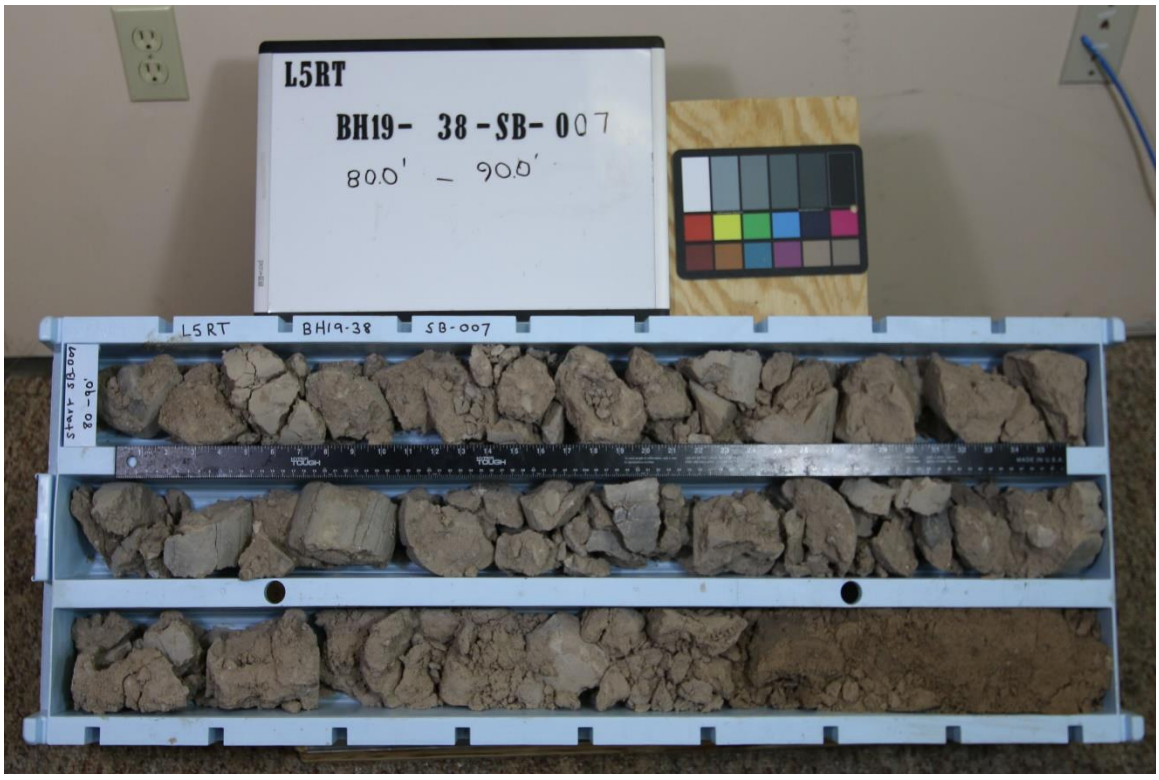


BH19-38-SB-001

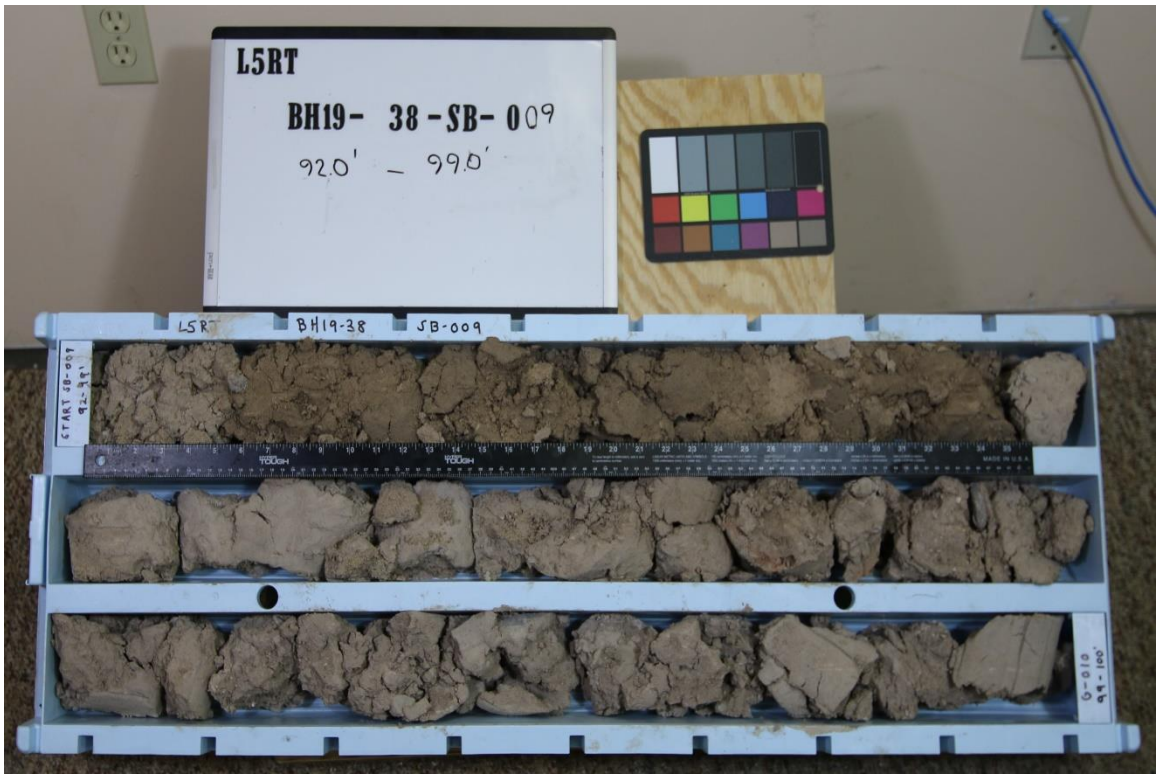


BH19-38-SB-002

BH19-38-SB-005



BH19-38-SB-007



BH19-38-SB-009

BH19-38-SB-011

BH19-38-SB-013

[Intentionally Left Blank]

APPENDIX

C-2 *ROCK CORE PHOTOGRAPHS*

BH19-07-RB-001 (Dry)

BH19-07-RB-001 (Wet)

BH19-07-RB-002 (Dry)

BH19-07-RB-002 (Wet)

BH19-07-RB-003 (Dry)

BH19-07-RB-003 (Wet)

BH19-07-RB-004 (Dry)

BH19-07-RB-004 (Wet)

BH19-07-RB-005 (Dry)

BH19-07-RB-005 (Wet)

BH19-07-RB-006 (Dry)

BH19-07-RB-006 (Wet)

BH19-07-RB-007 (Dry)

BH19-07-RB-007 (Wet)

BH19-07-RB-008 (Dry)

BH19-07-RB-008 (Wet)

BH19-07-RB-009 (Dry)

BH19-07-RB-009 (Wet)

BH19-07-RB-010 (Dry)

BH19-07-RB-010 (Wet)

BH19-07-RB-011 (Dry)

BH19-07-RB-011 (Wet)

BH19-08-RB-001 (Dry)

BH19-08-RB-001 (Wet)

BH19-08-RB-002 (Dry)

BH19-08-RB-002 (Wet)

BH19-08-RB-003 (Dry)

BH19-08-RB-003 (Wet)

BH19-08-RB-004 (Dry)

BH19-08-RB-004 (Wet)

BH19-08-RB-005 (Dry)

BH19-08-RB-005 (Wet)

BH19-08-RB-006 (Dry)

BH19-08-RB-006 (Wet)

BH19-08-RB-007 (Dry)

BH19-08-RB-007 (Wet)

BH19-08-RB-008 (Dry)

BH19-08-RB-008 (Wet)

BH19-09-RB-001 (Dry)

BH19-09-RB-001 (Wet)

BH19-09-RB-002 (Dry)

BH19-09-RB-002 (Wet)

BH19-09-RB-003 (Dry)

BH19-09-RB-003 (Wet)

BH19-09-RB-004 (Dry)

BH19-09-RB-004 (Wet)

BH19-09-RB-005 (Dry)

BH19-09-RB-005 (Wet)

BH19-09-RB-006 (Dry)

BH19-09-RB-006 (Wet)

BH19-09-RB-007 (Dry)

BH19-09-RB-007 (Wet)

BH19-09-RB-008 (Dry)

BH19-09-RB-008 (Wet)

BH19-09-RB-009 (Dry)

BH19-09-RB-009 (Wet)

BH19-10-RB-001 (Dry)

BH19-10-RB-001 (Wet)

BH19-10-RB-002 (Dry)

BH19-10-RB-002 (Wet)

BH19-10-RB-003 (Dry)

BH19-10-RB-003 (Wet)

BH19-10-RB-004 (Dry)

BH19-10-RB-004 (Wet)

BH19-10-RB-005 (Dry)

BH19-10-RB-005 (Wet)

BH19-10-RB-006 (Dry)

BH19-10-RB-006 (Wet)

BH19-10-RB-007 (Dry)

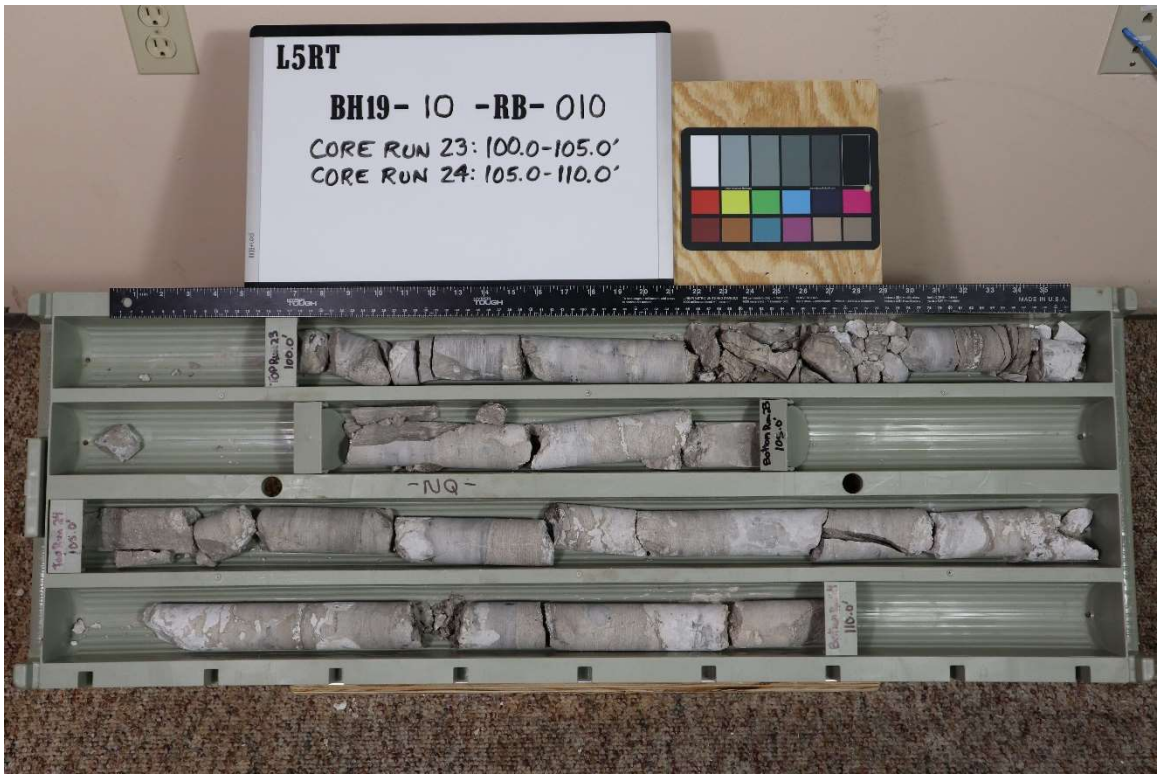
BH19-10-RB-007 (Wet)

BH19-10-RB-008 (Dry)

BH19-10-RB-008 (Wet)

BH19-10-RB-009 (Dry)

BH19-10-RB-009 (Wet)



BH19-10-RB-010 (Dry)

BH19-10-RB-010 (Wet)

BH19-15-RB-001 (Dry)

BH19-15-RB-001 (Wet)

BH19-15-RB-002 (Dry)

BH19-15-RB-002 (Wet)

BH19-15-RB-003 (Dry)

BH19-15-RB-003 (Wet)

BH19-15-RB-004 (Dry)

BH19-15-RB-004 (Wet)

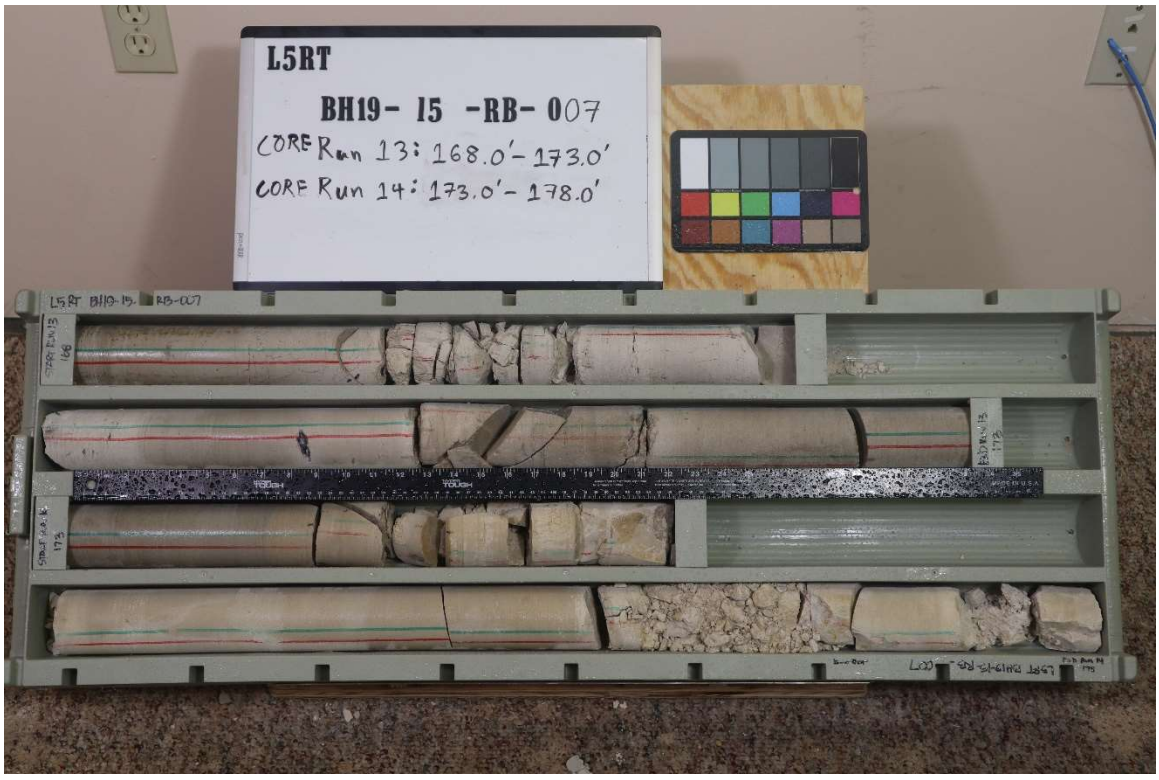
BH19-15-RB-005 (Dry)

BH19-15-RB-005 (Wet)

BH19-15-RB-006 (Dry)

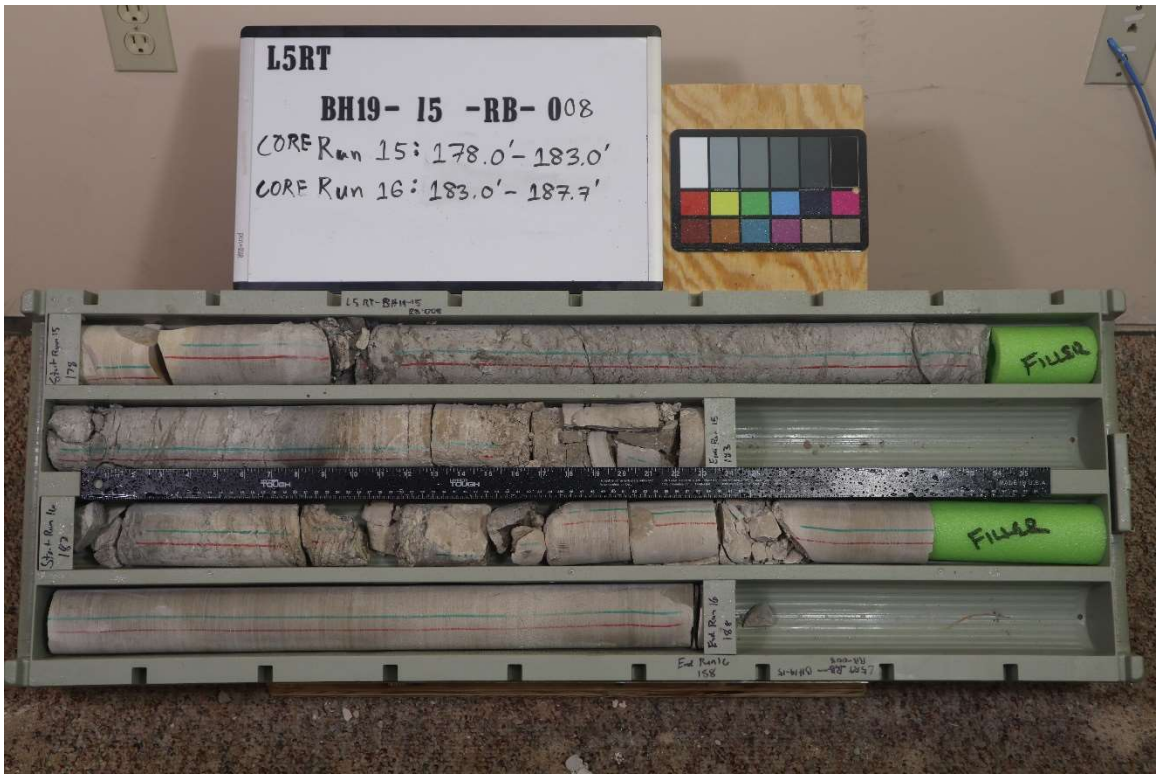
BH19-15-RB-006 (Wet)

BH19-15-RB-007 (Dry)



BH19-15-RB-007 (Wet)

BH19-15-RB-008 (Dry)



BH19-15-RB-008 (Wet)

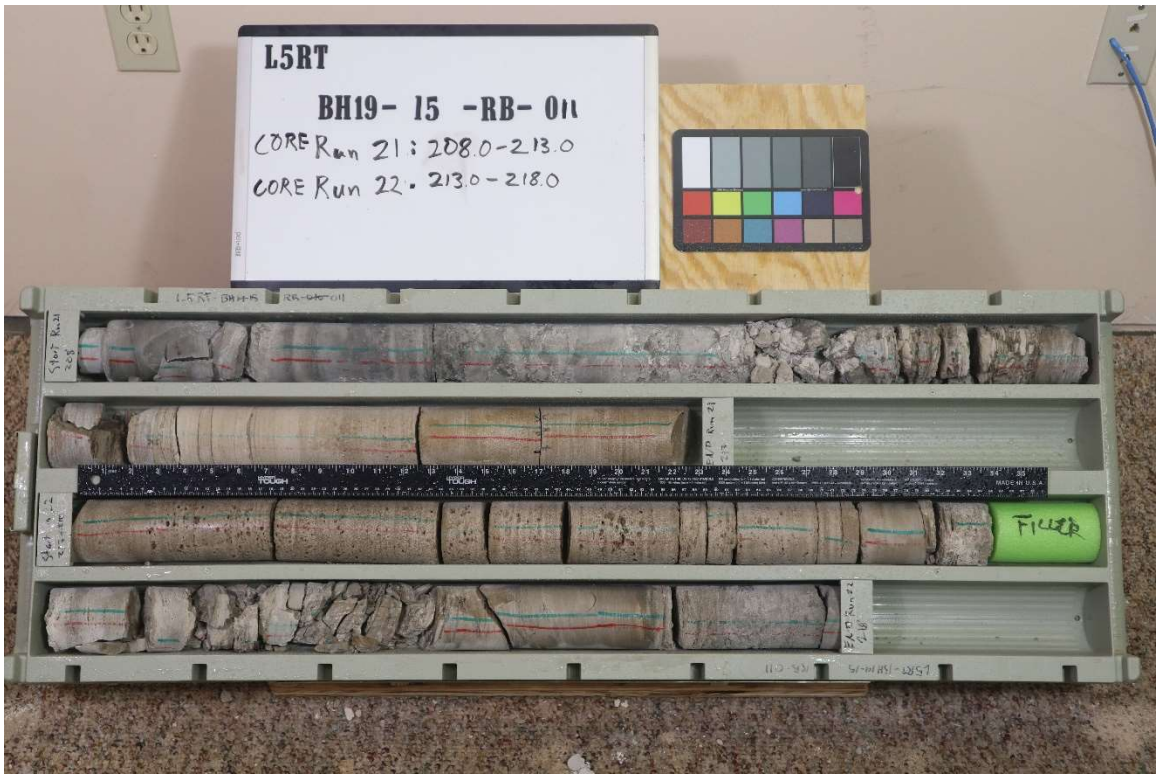
BH19-15-RB-009 (Dry)

BH19-15-RB-009 (Wet)

BH19-15-RB-010 (Dry)

BH19-15-RB-010 (Wet)

BH19-15-RB-011 (Dry)



BH19-15-RB-011 (Wet)

BH19-15-RB-012 (Dry)

BH19-15-RB-012 (Wet)

BH19-16-RB-001 (Dry)

BH19-16-RB-001 (Wet)

BH19-16-RB-002 (Dry)

BH19-16-RB-002 (Wet)

BH19-16-RB-003 (Dry)

BH19-16-RB-003 (Wet)

BH19-16-RB-004 (Dry)

BH19-16-RB-004 (Wet)

BH19-16-RB-005 (Dry)

BH19-16-RB-005 (Wet)

BH19-16-RB-006 (Dry)

BH19-16-RB-006 (Wet)

BH19-16-RB-007 (Dry)

BH19-16-RB-007 (Wet)

BH19-16-RB-008 (Dry)

BH19-16-RB-008 (Wet)

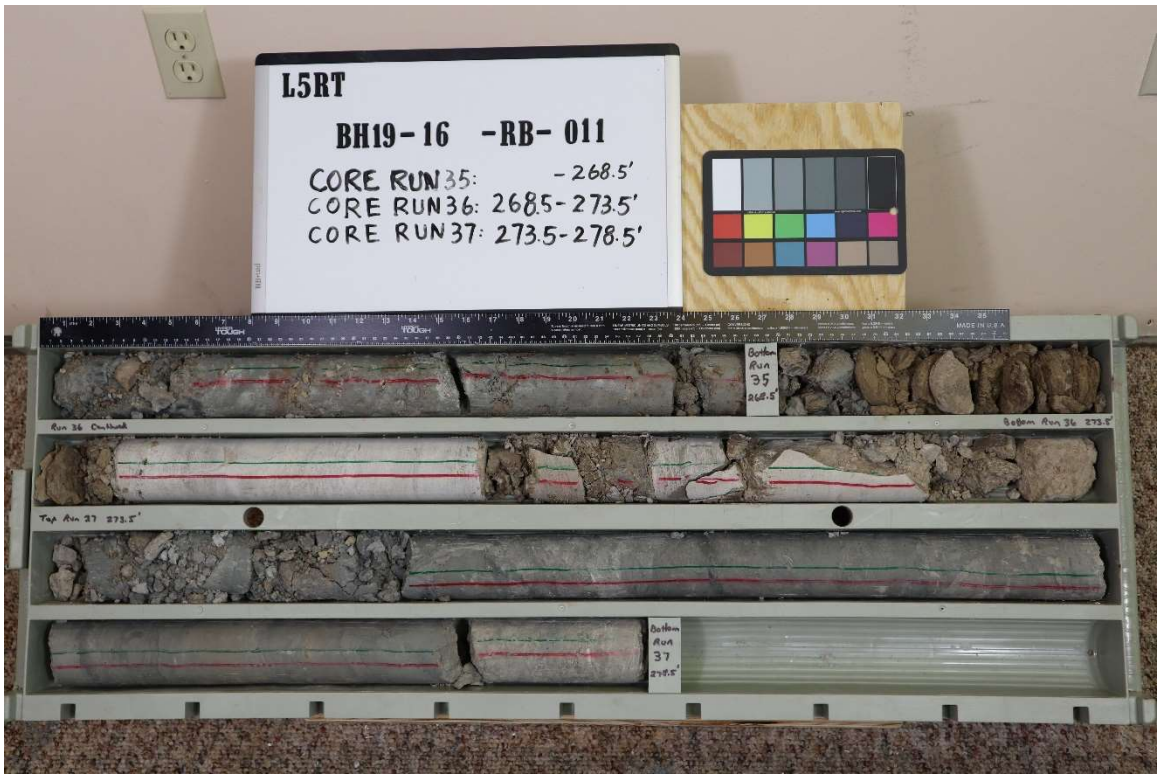
BH19-16-RB-009 (Dry)

BH19-16-RB-009 (Wet)

BH19-16-BAG-001 (Dry)

BH19-16-RB-010 (Dry)

BH19-16-RB-010 (Wet)



BH19-16-RB-011 (Dry)

BH19-16-RB-011 (Wet)

BH19-16-RB-012 (Dry)

BH19-16-RB-012 (Wet)

BH19-16-RB-013 (Dry)

BH19-16-RB-013 (Wet)

BH19-16-RB-014 (Dry)

BH19-16-RB-014 (Wet)

BH19-16-RB-015 (Dry)

BH19-16-RB-015 (Wet)

BH19-16-RB-016 (Dry)

BH19-16-RB-016 (Wet)

BH19-17-RB-001 (Dry)

BH19-17-RB-001 (Wet)

BH19-17-RB-002 (Dry)

BH19-17-RB-002 (Wet)

BH19-17-RB-003 (Dry)

BH19-17-RB-003 (Wet)

BH19-17-RB-004 (Dry)

BH19-17-RB-004 (Wet)

BH19-17-RB-005 (Dry)

BH19-17-RB-005 (Wet)

BH19-17-RB-006 (Dry)

BH19-17-RB-006 (Wet)

BH19-17-RB-007 (Dry)

BH19-17-RB-007 (Wet)

BH19-17-RB-008 (Dry)

BH19-17-RB-008 (Wet)

BH19-17-RB-009 (Dry)

BH19-17-RB-009 (Wet)

BH19-17-RB-010 (Dry)

BH19-17-RB-010 (Wet)

BH19-17-RB-011 (Dry)

BH19-17-RB-011 (Wet)

BH19-17-RB-012 (Dry)

BH19-17-RB-012 (Wet)

BH19-17-RB-013 (Dry)

BH19-17-RB-013 (Wet)

BH19-17-RB-014 (Dry)

BH19-17-RB-014 (Wet)

BH19-17-RB-015 (Dry)

BH19-17-RB-015 (Wet)

BH19-17-RB-016 (Dry)

BH19-17-RB-016 (Wet)

BH19-17-RB-017 (Dry)

BH19-17-RB-017 (Wet)

BH19-17-RB-018 (Dry)

BH19-17-RB-018 (Wet)

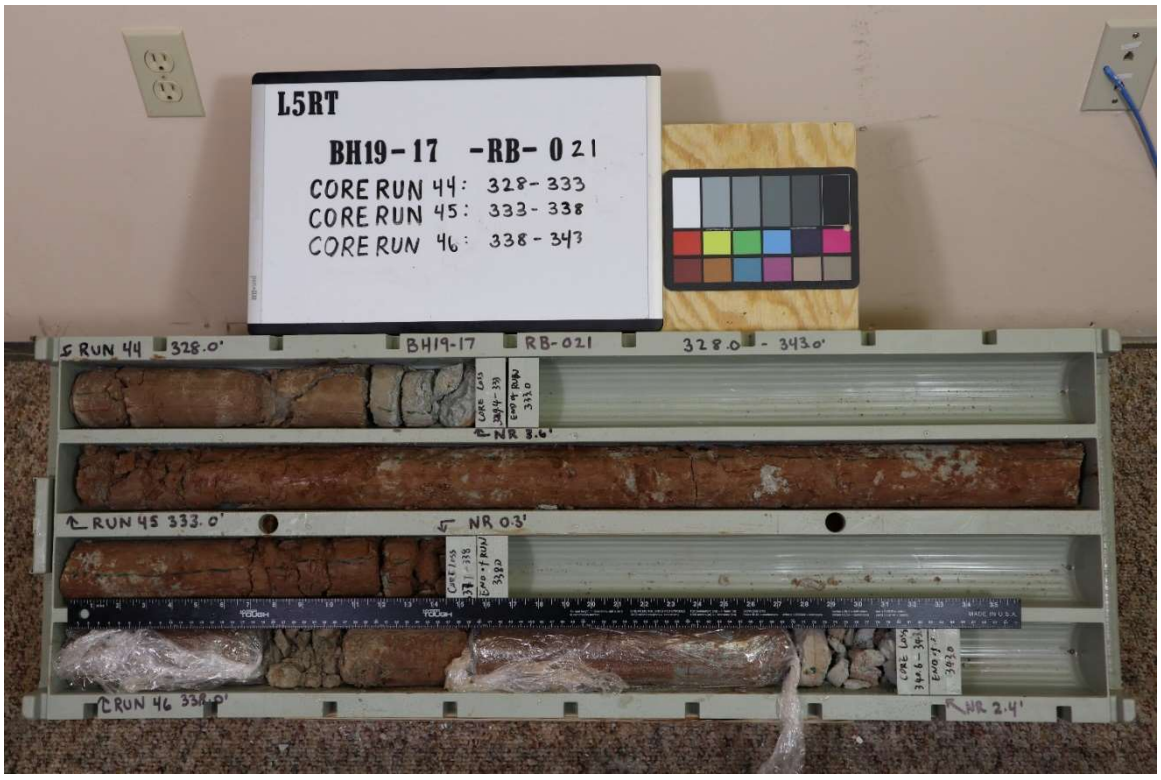
BH19-17-RB-019 (Dry)

BH19-17-RB-019 (Wet)

BH19-17-RB-020 (Dry)

BH19-17-RB-020 (Wet)

BH19-17-RB-021 (Dry)



BH19-17-RB-021 (Wet)

BH19-17-RB-022 (Dry)

BH19-17-RB-022 (Wet)

BH19-17-RB-023 (Dry)

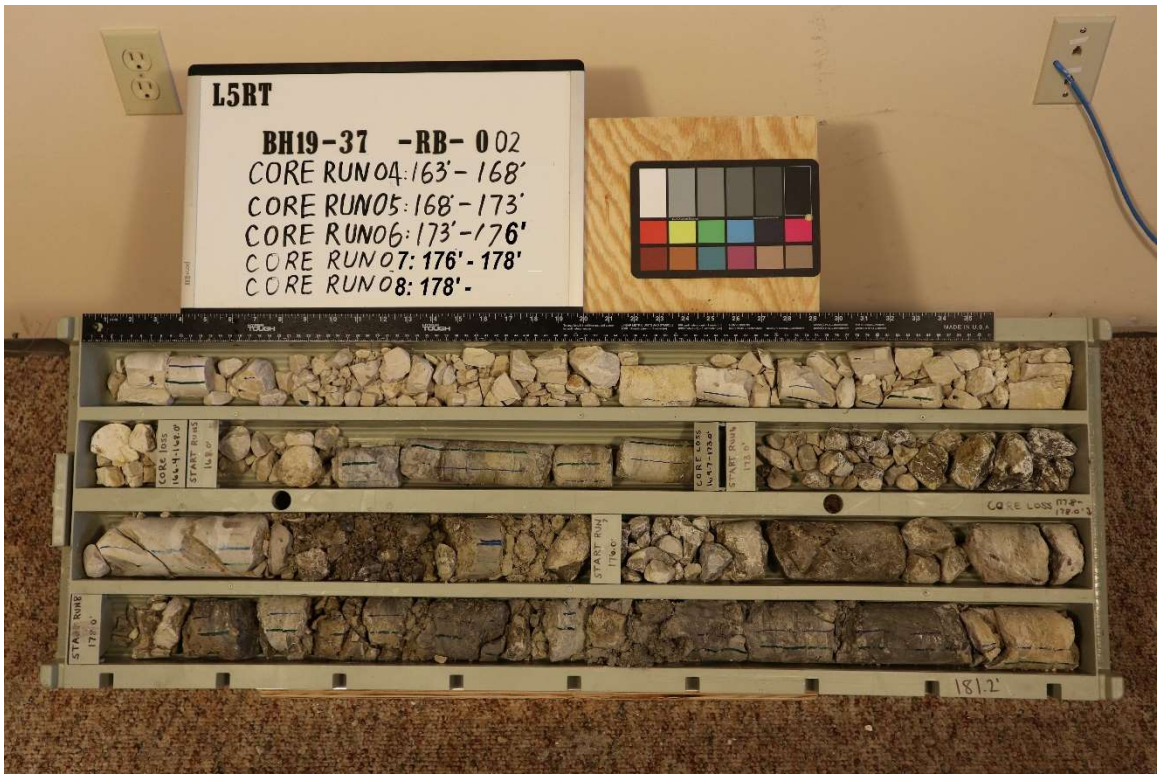
BH19-17-RB-023 (Wet)

BH19-17-RB-024 (Dry)

BH19-17-RB-024 (Wet)

BH19-37-RB-001 (Dry)

BH19-37-RB-001 (Wet)



BH19-37-RB-002 (Dry)

BH19-37-RB-002 (Wet)

BH19-37-RB-003 (Dry)

BH19-37-RB-003 (Wet)

BH19-37-RB-004 (Dry)

BH19-37-RB-004 (Wet)

BH19-37-RB-005 (Dry)

BH19-37-RB-005 (Wet)

BH19-37-RB-006 (Dry)

BH19-37-RB-006 (Wet)

BH19-37-RB-007 (Dry)

BH19-37-RB-007 (Wet)

BH19-37-RB-008 (Dry)

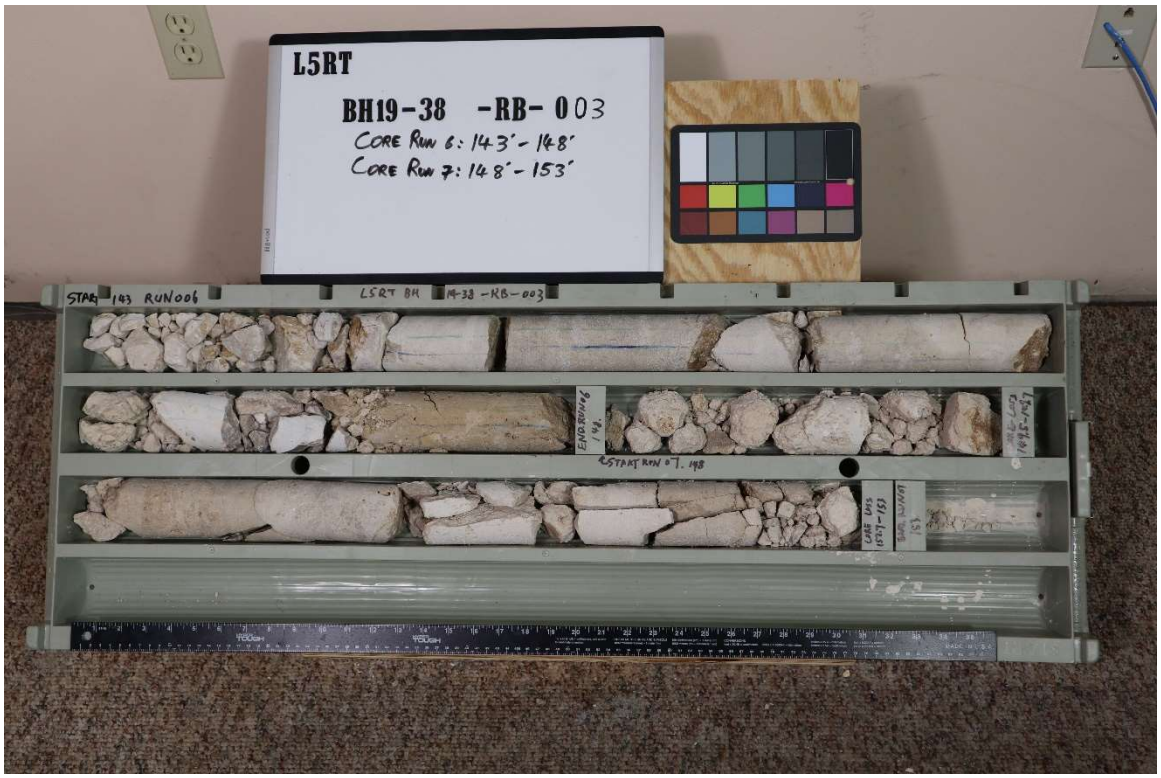
BH19-37-RB-008 (Wet)

BH19-38-RB-001 (Dry)

BH19-38-RB-001 (Wet)

BH19-38-RB-002 (Dry)

BH19-38-RB-002 (Wet)



BH19-38-RB-003 (Dry)

BH19-38-RB-003 (Wet)

BH19-38-RB-004 (Dry)

BH19-38-RB-004 (Wet)

BH19-38-RB-005 (Dry)

BH19-38-RB-005 (Wet)

BH19-38-RB-006 (Dry)

BH19-38-RB-006 (Wet)

BH19-38-RB-007 (Dry)

BH19-38-RB-007 (Wet)

BH19-38-RB-008 (Dry)

BH19-38-RB-008 (Wet)

APPENDIX

C-3 *DEEPWATER CORE PHOTOGRAPHS*

BH19-19-RB-001 (Dry)

BH19-19-RB-001 (Wet)

BH19-19-RB-002 (Dry)

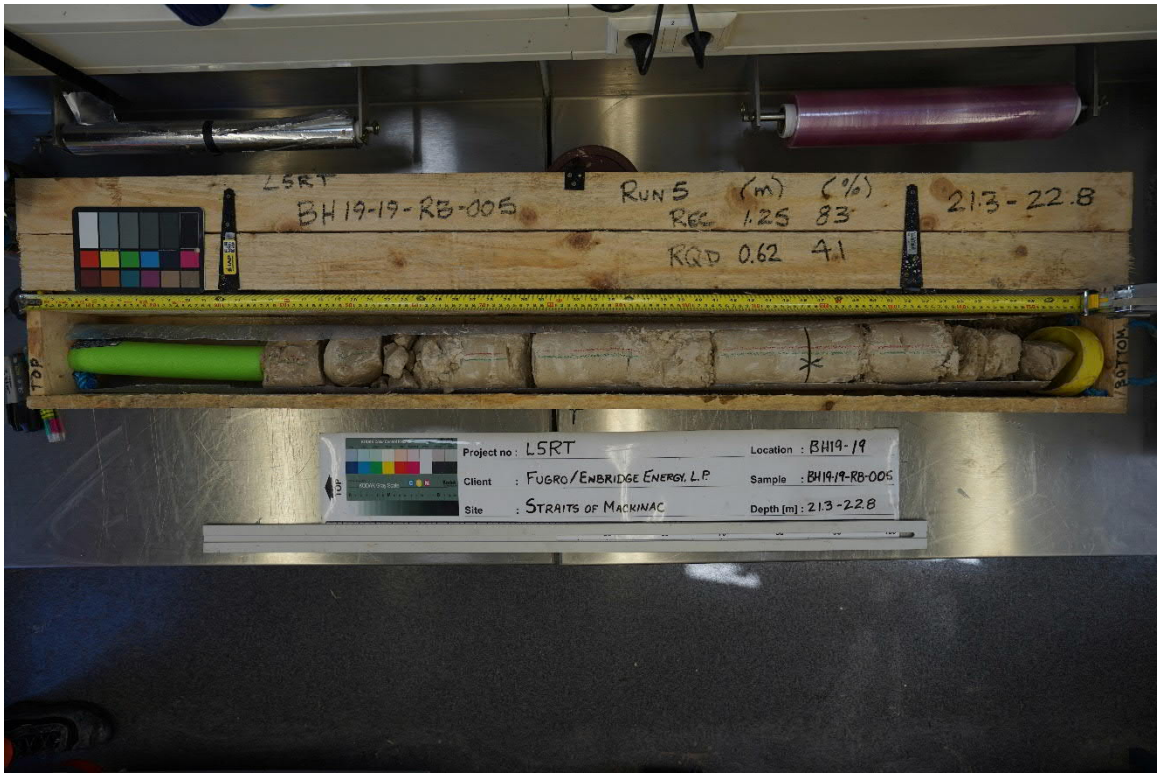
BH19-19-RB-002 (Wet)

BH19-19-RB-003 (Dry)

BH19-19-RB-003 (Wet)

BH19-19-RB-004 (Dry)

BH19-19-RB-004 (Wet)



BH19-19-RB-005 (Dry)

BH19-19-RB-005 (Wet)

BH19-19-RB-006 (Dry)

BH19-19-RB-006 (Wet)

BH19-19-RB-007 (Dry)

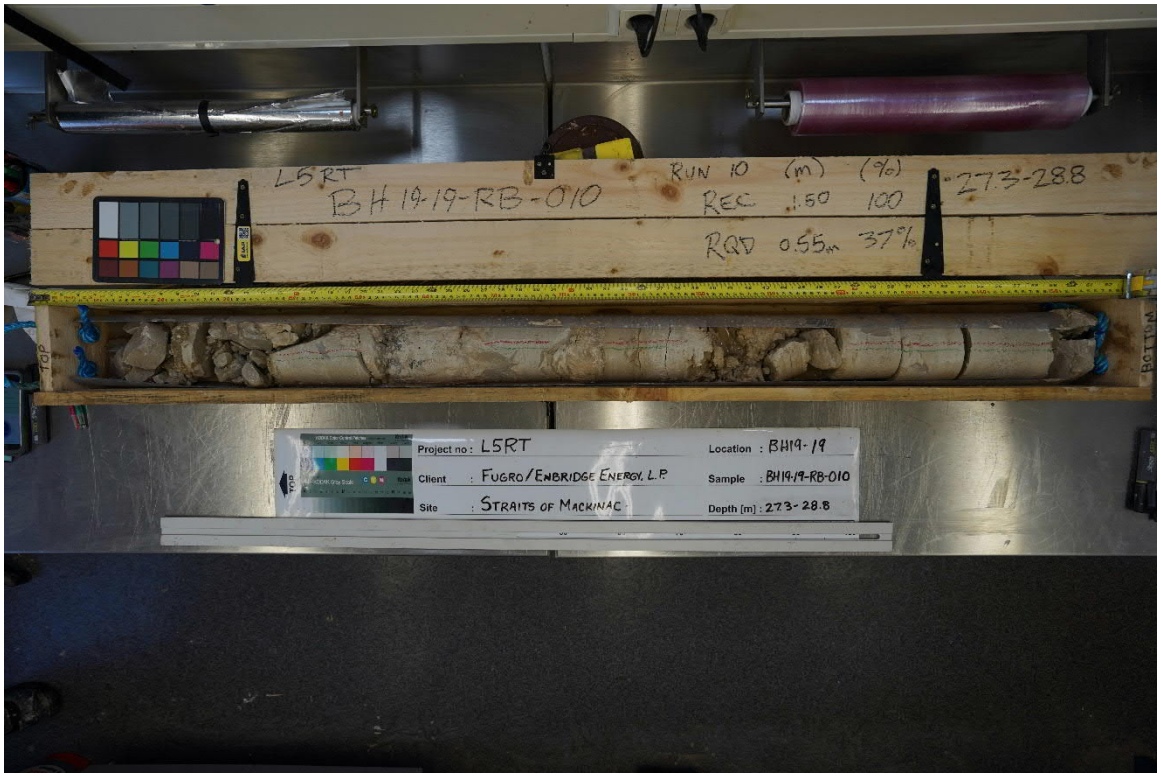
BH19-19-RB-007 (Wet)

BH19-19-RB-008 (Dry)

BH19-19-RB-008 (Wet)

BH19-19-RB-009 (Dry)

BH19-19-RB-009 (Wet)



BH19-19-RB-010 (Dry)

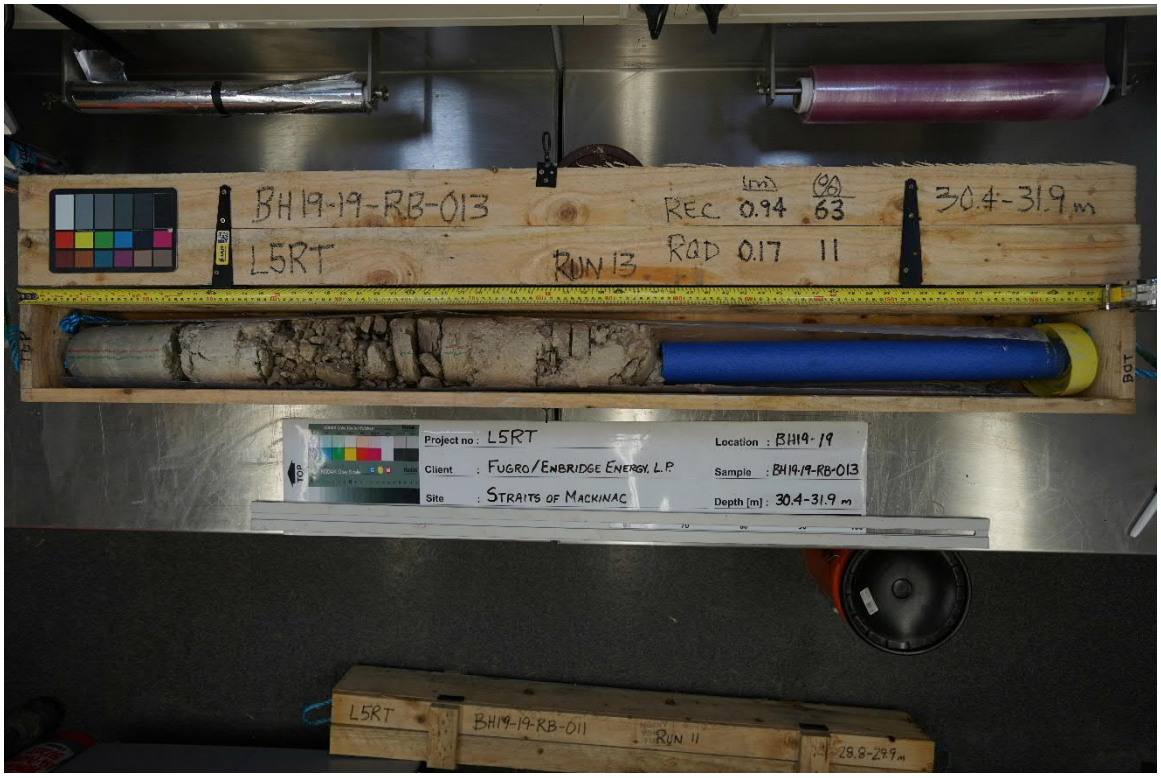
BH19-19-RB-010 (Wet)

BH19-19-RB-011 (Dry)

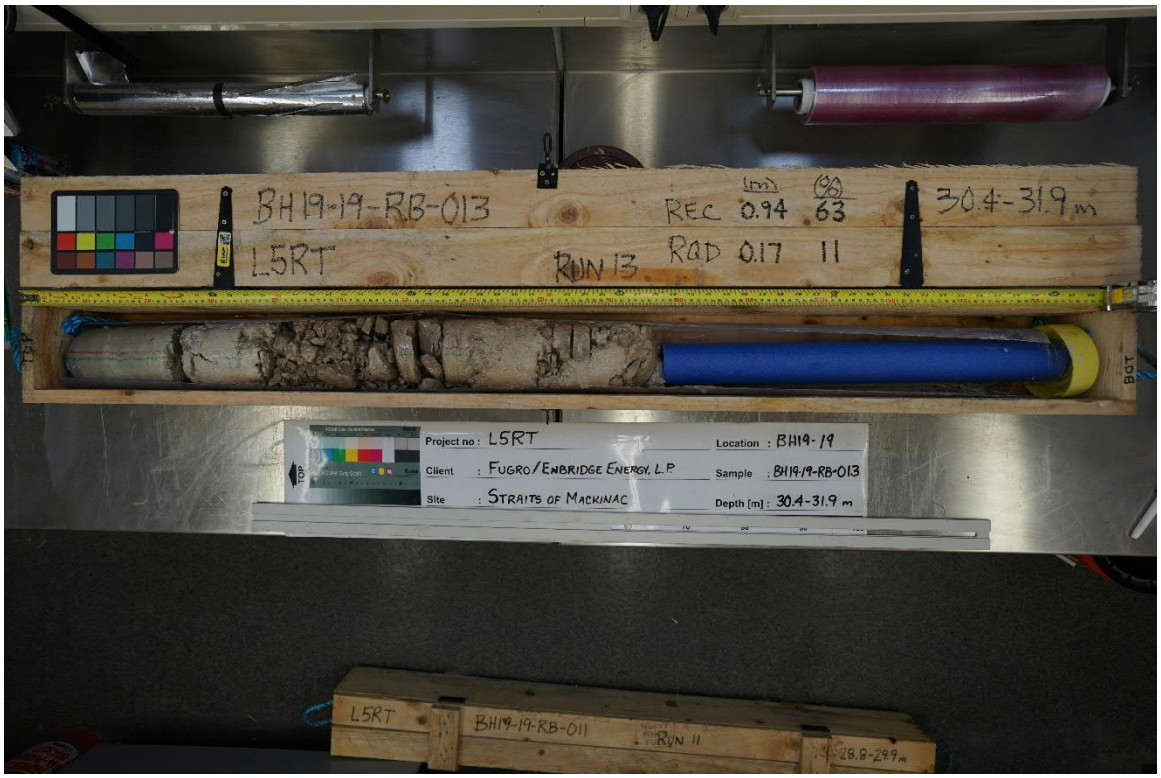
BH19-19-RB-011 (Wet)

BH19-19-RB-012 (Dry)

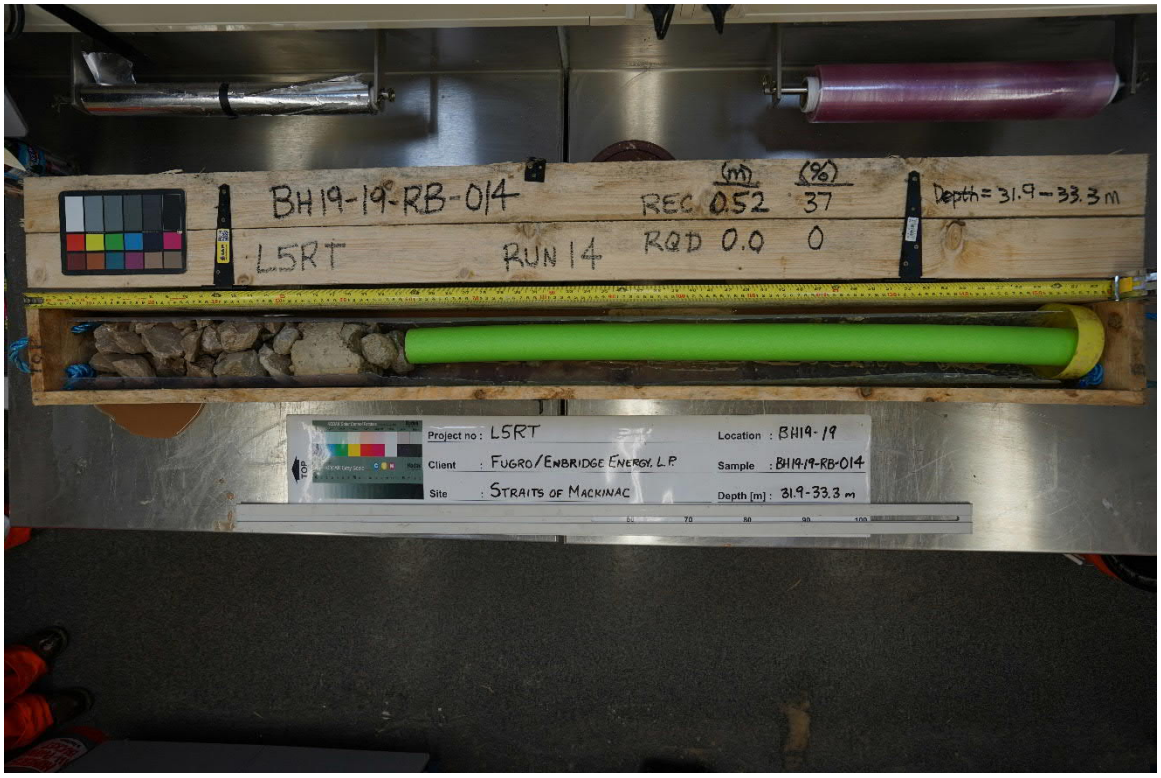
BH19-19-RB-012 (Wet)



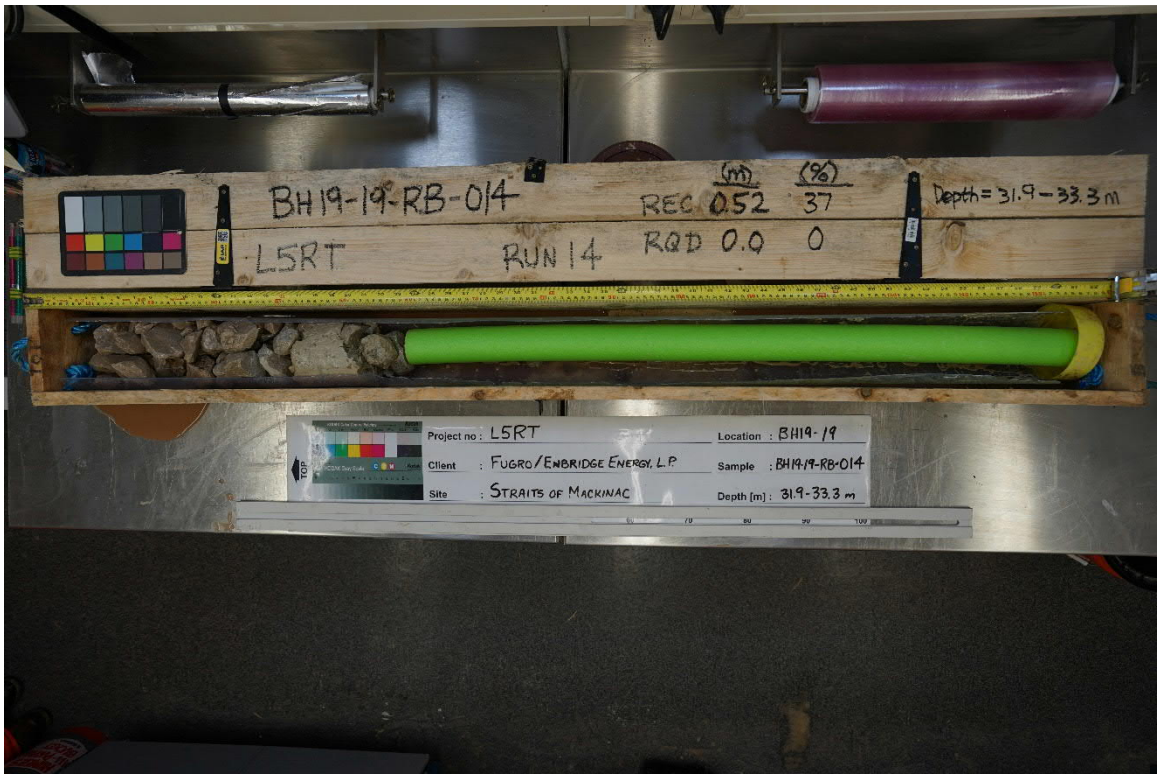
BH19-19-RB-013 (Dry)



BH19-19-RB-013 (Wet)



BH19-19-RB-014 (Dry)



BH19-19-RB-014 (Wet)

BH19-19-RB-015 (Dry)

BH19-19-RB-015 (Wet)

BH19-19-RB-016 (Dry)

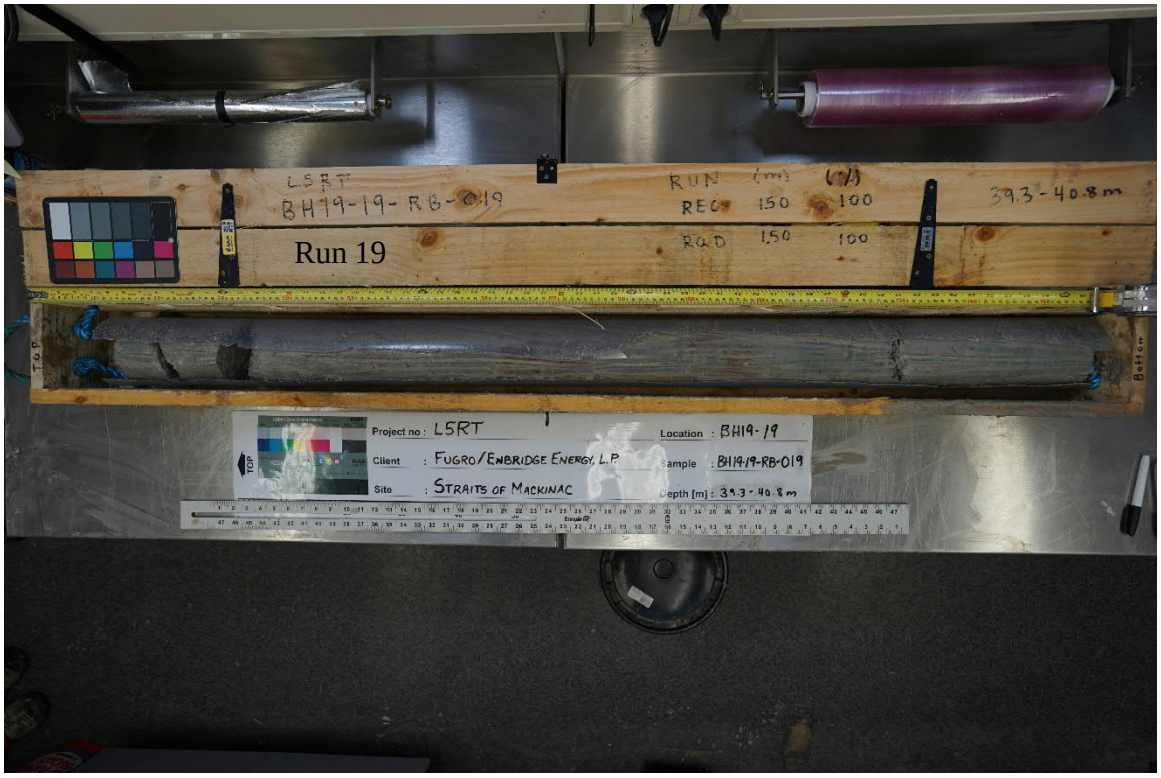
BH19-19-RB-016 (Wet)

BH19-19-RB-017 (Dry)

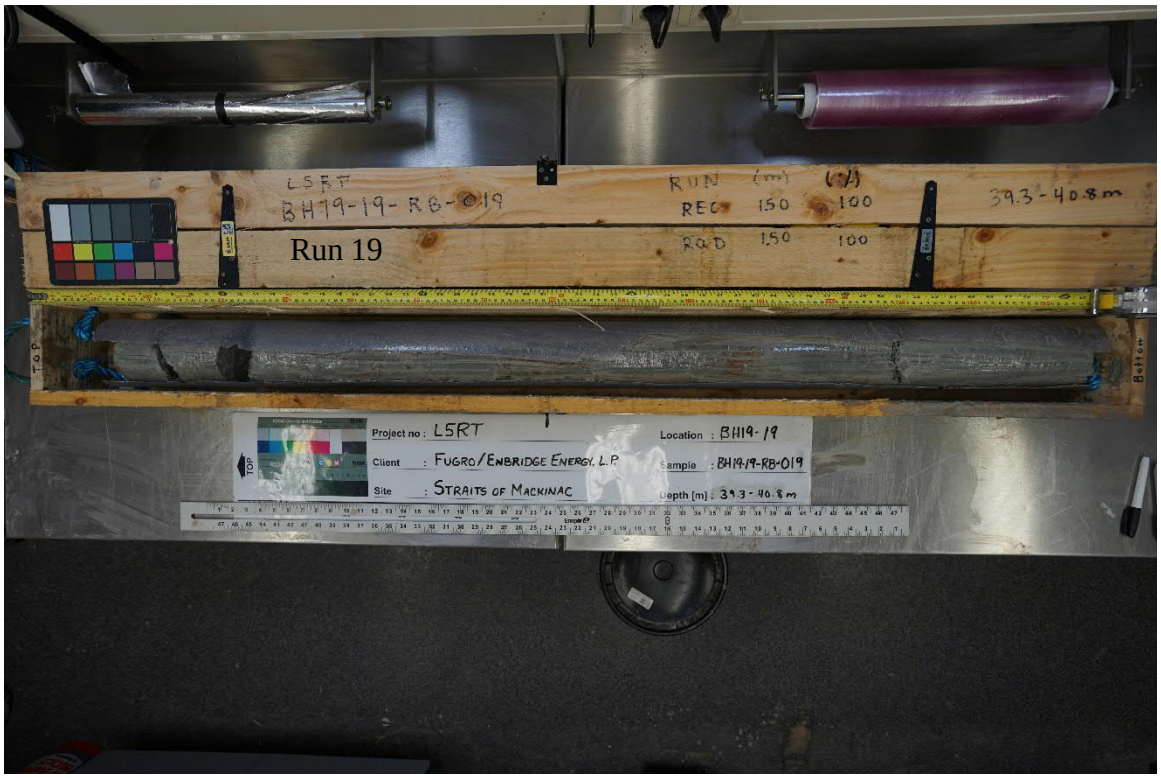
BH19-19-RB-017 (Wet)

BH19-19-RB-018 (Dry)

BH19-19-RB-018 (Wet)



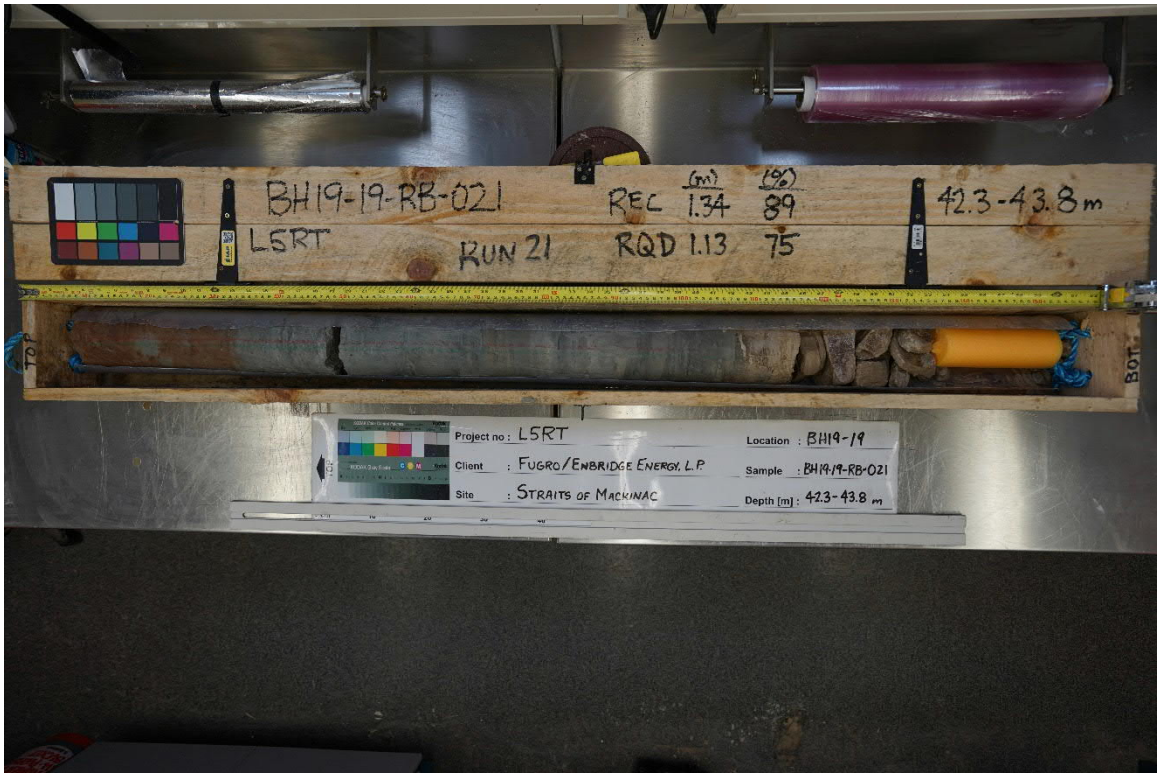
BH19-19-RB-019 (Dry)



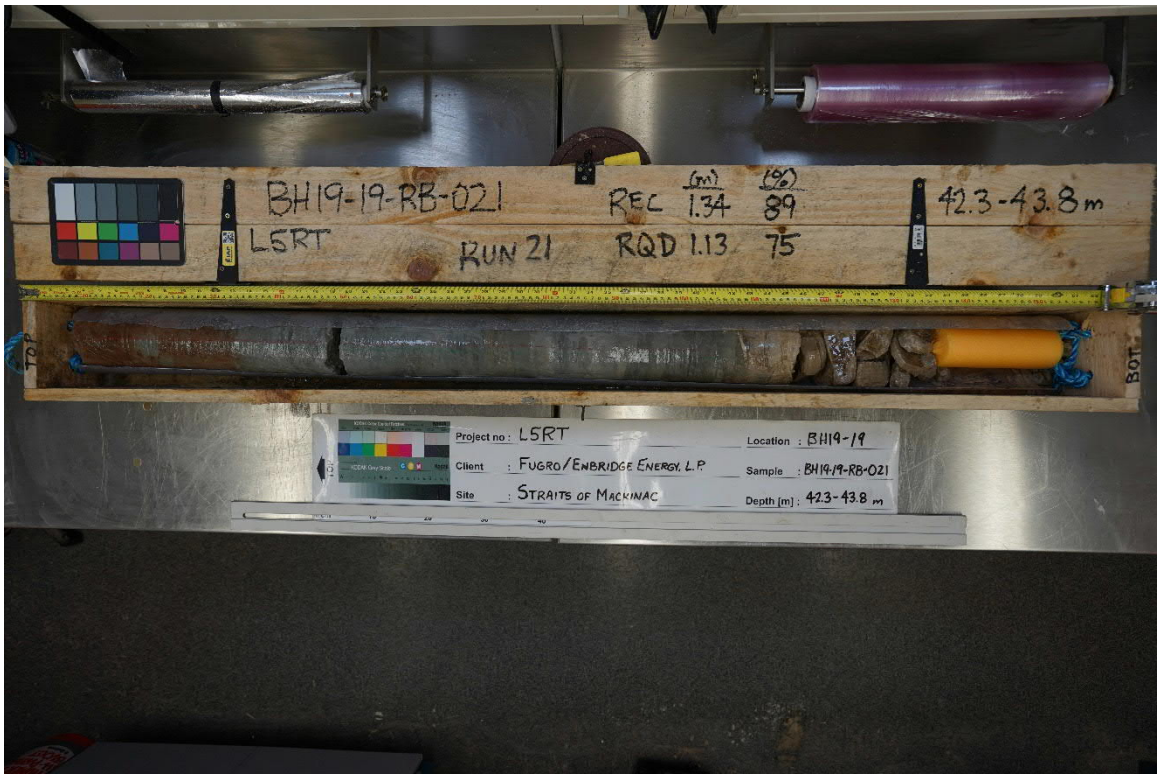
BH19-19-RB-019 (Wet)

BH19-19-RB-020 (Dry)

BH19-19-RB-020 (Wet)



BH19-19-RB-021 (Dry)



BH19-19-RB-021 (Wet)

BH19-19-RB-022 (Dry)

BH19-19-RB-022 (Wet)

BH19-19-RB-023 (Dry)

BH19-19-RB-023 (Wet)

BH19-19-RB-024 (Dry)

BH19-19-RB-024 (Wet)

BH19-19-RB-025 (Dry)

BH19-19-RB-025 (Wet)

BH19-19-RB-026 (Dry)

BH19-19-RB-026 (Wet)

BH19-19-RB-027 (Dry)

BH19-19-RB-027 (Wet)

BH19-19-RB-028 (Dry)

BH19-19-RB-028 (Wet)

BH19-19-RB-029 (Dry)

BH19-19-RB-029 (Wet)

BH19-19-RB-030 (Dry)

BH19-19-RB-030 (Wet)

BH19-19-RB-031 (Dry)

BH19-19-RB-031 (Wet)

BH19-21-RB-001

BH19-21-RB-002

BH19-21-RB-003

BH19-21-RB-004

BH19-21-RB-005

[Left Blank Intentionally]

BH19-21-RB-006 (Dry)

BH19-21-RB-006 (Wet)

BH19-21-RB-007 (Dry)

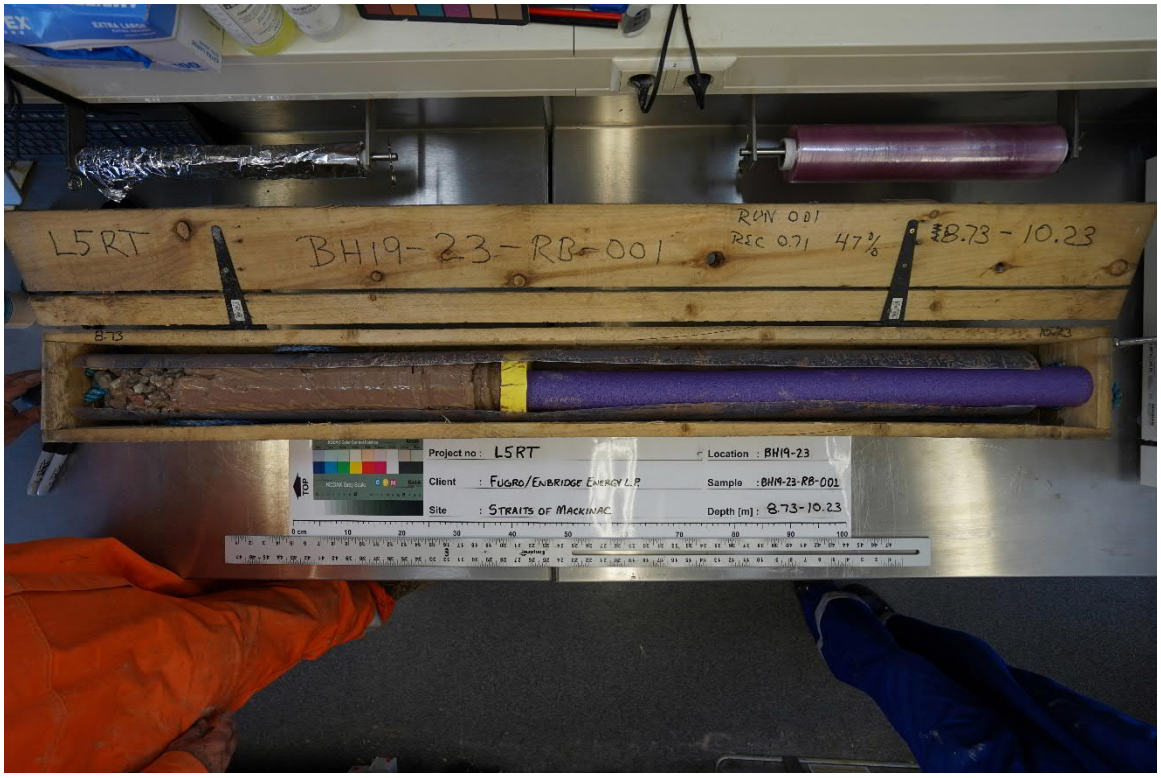
BH19-21-RB-007 (Wet)

BH19-21-RB-008 (Dry)

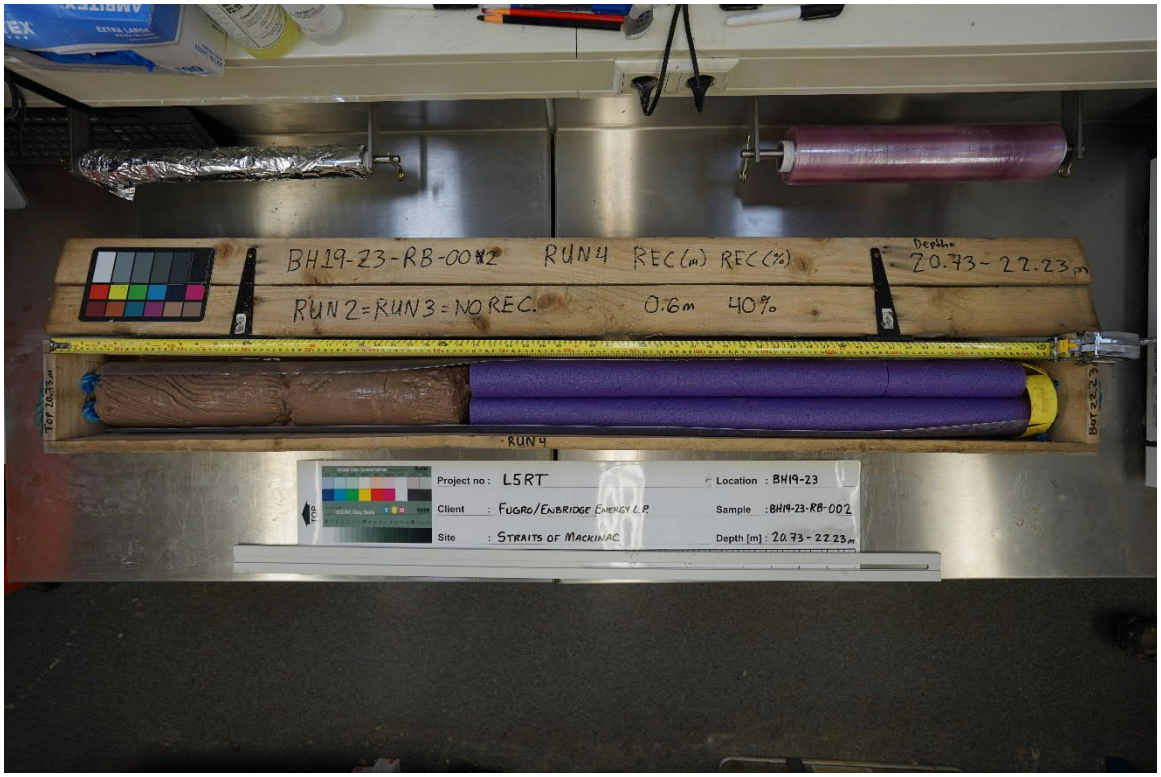
BH19-21-RB-008 (Wet)

BH19-21-RB-009 (Dry)

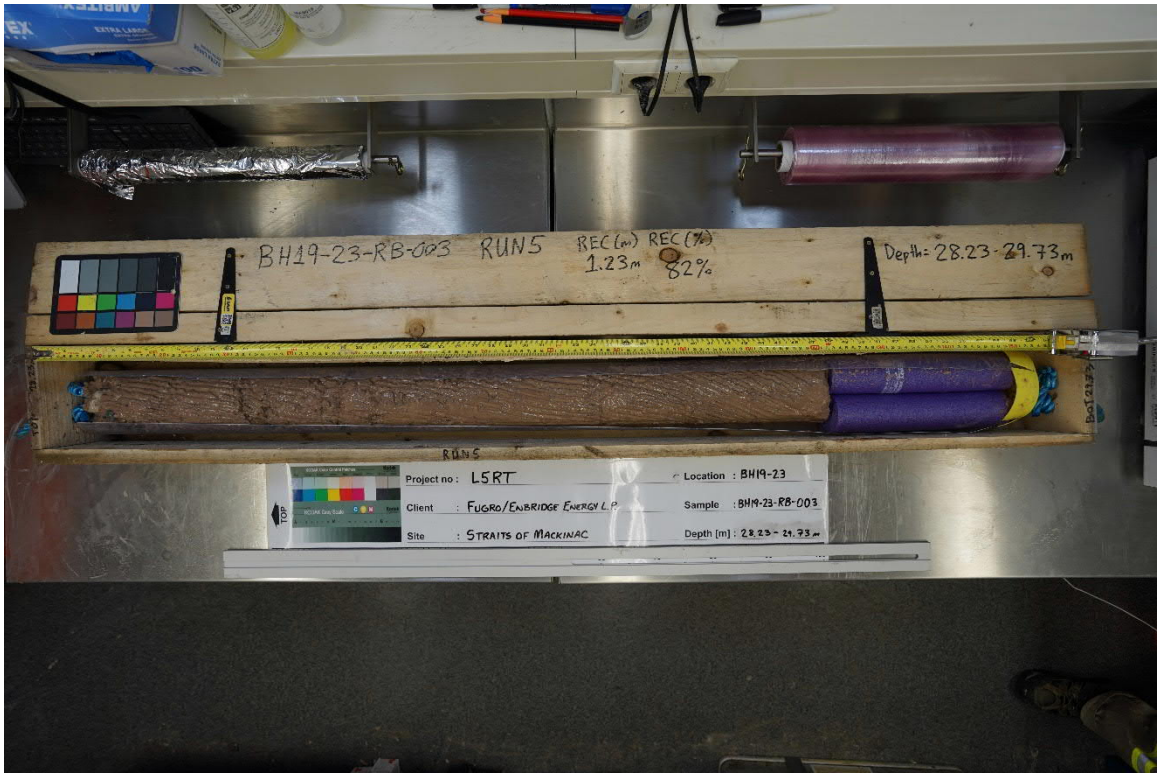
BH19-21-RB-009 (Wet)



BH19-23-RB-001



BH19-23-RB-002



BH19-23-RB-003

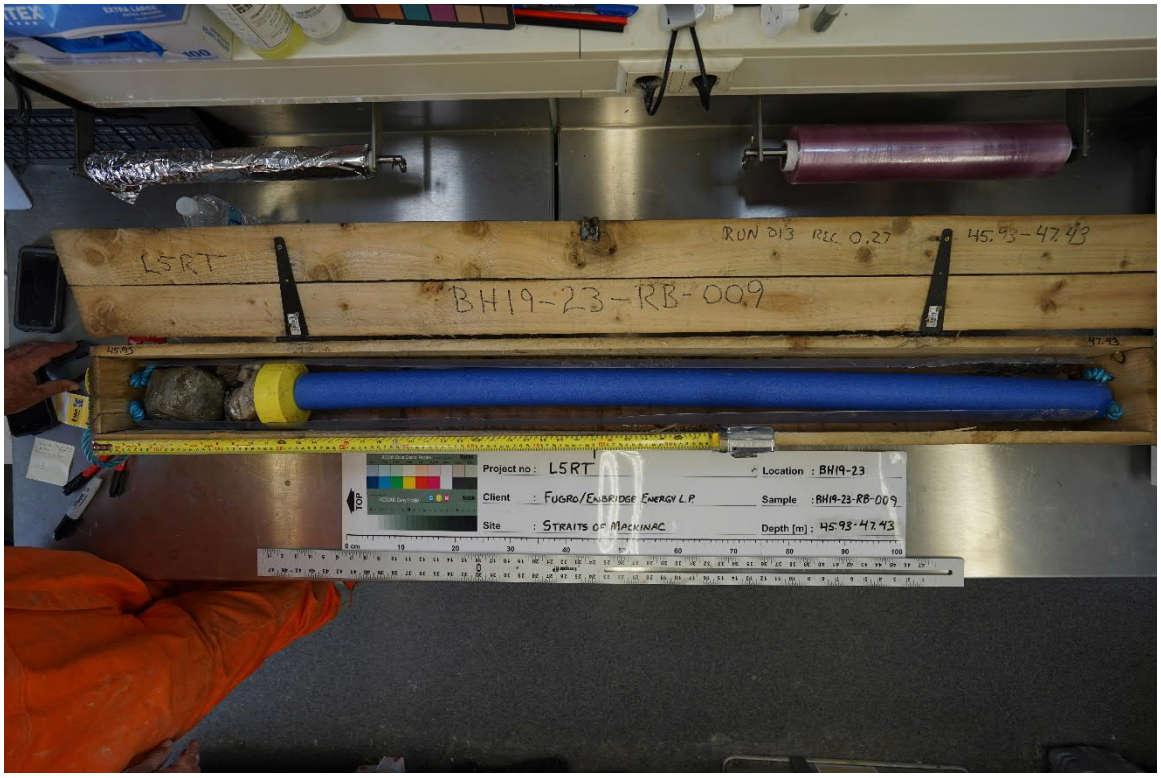
BH19-23-RB-004

BH19-23-RB-005

BH19-23-RB-006

BH19-23-RB-007

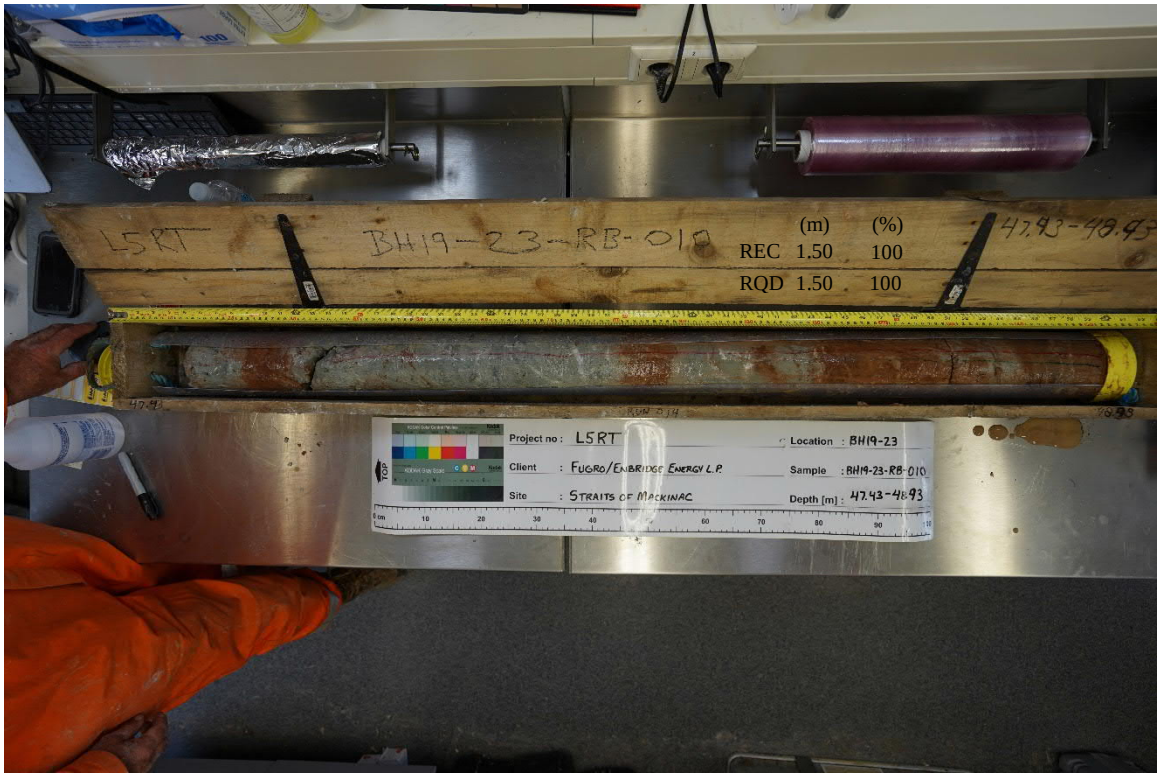
BH19-23-RB-008



BH19-23-RB-009

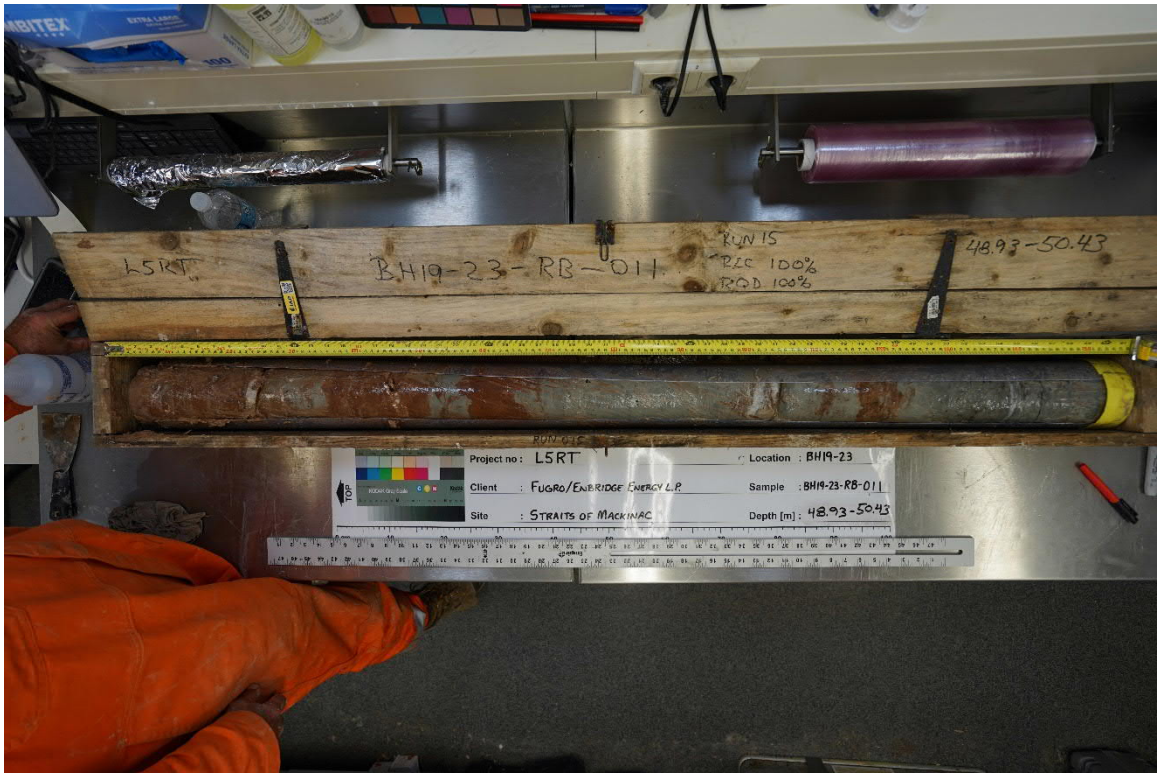
[Intentionally Left Blank]

BH19-23-RB-010 (Dry)



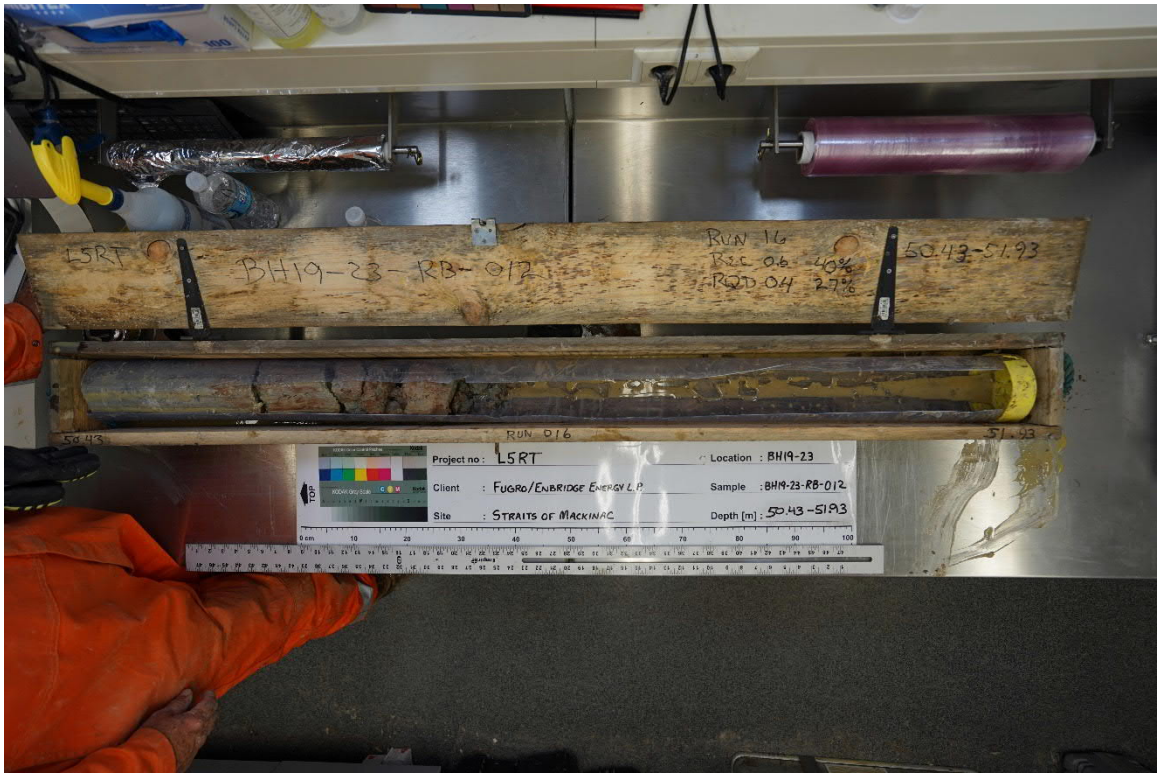
BH19-23-RB-010 (Wet)

BH19-23-RB-011 (Dry)

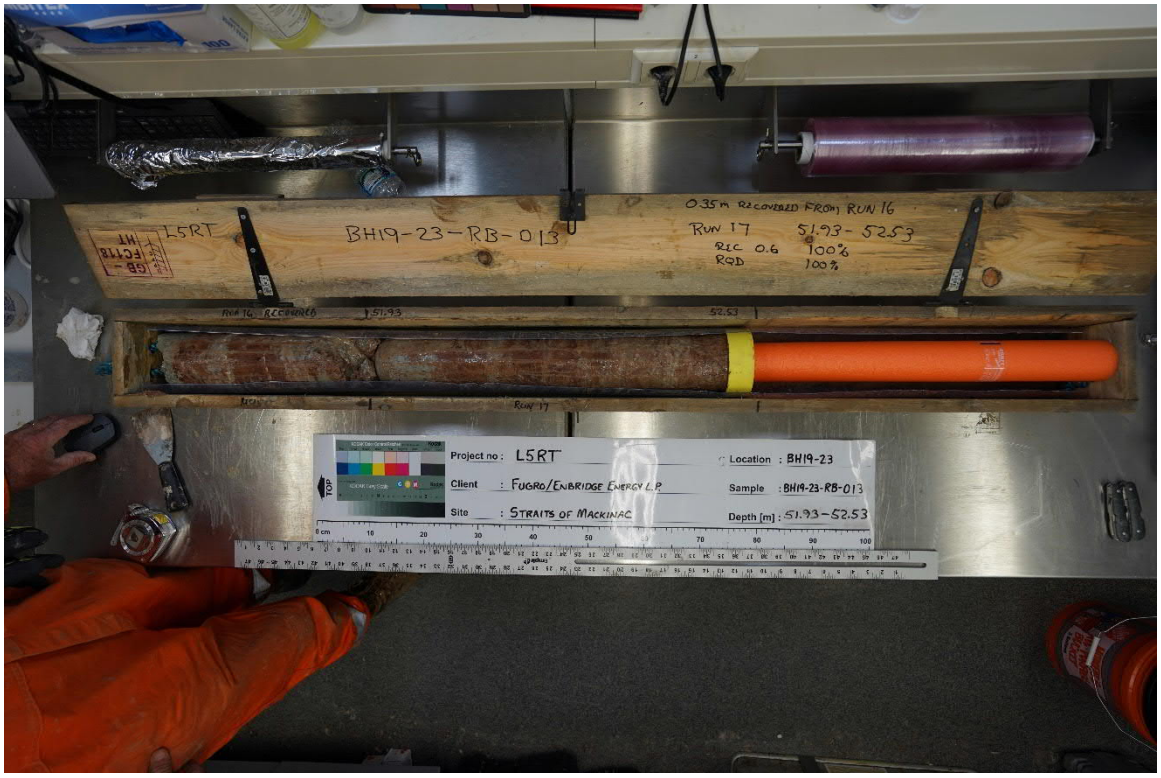


BH19-23-RB-011 (Wet)

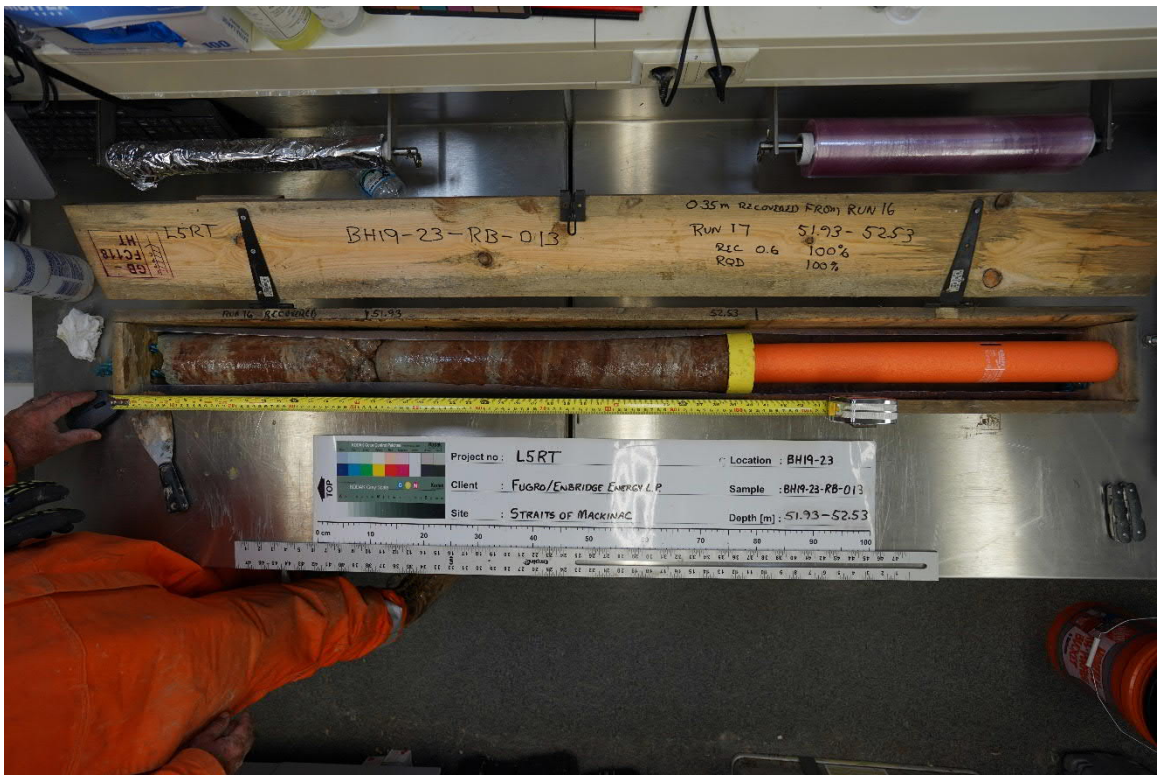
BH19-23-RB-012 (Dry)



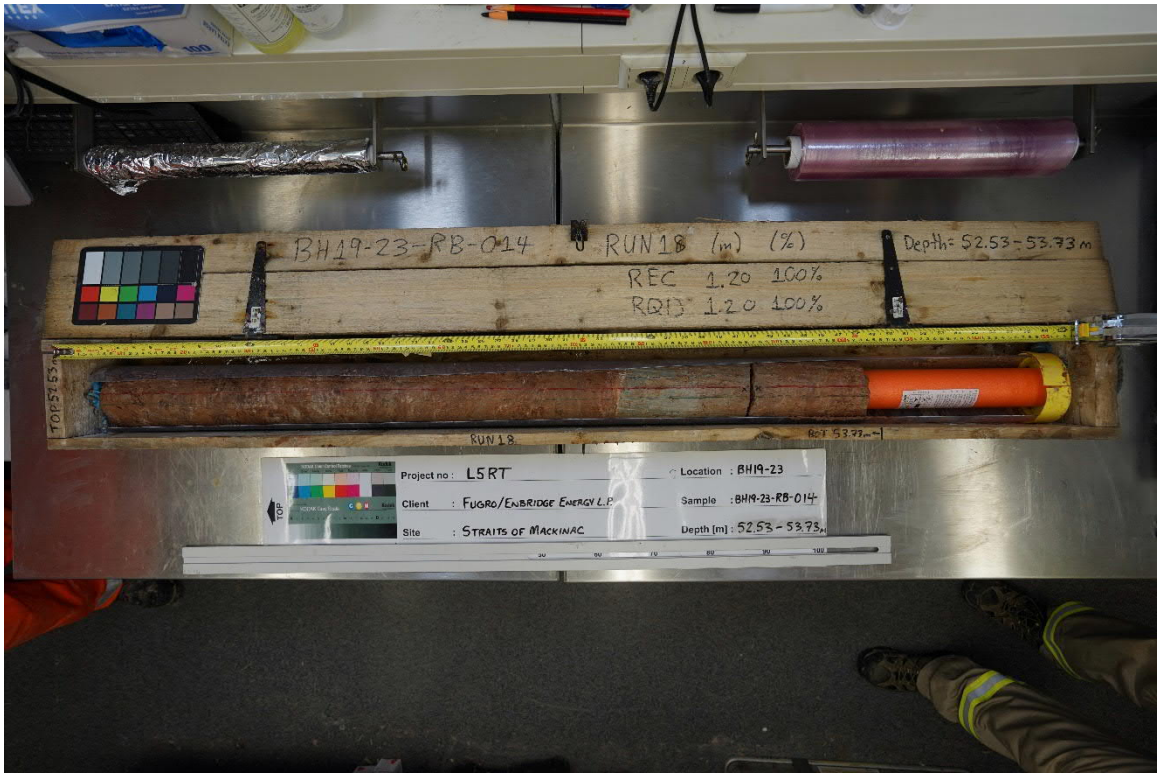
BH19-23-RB-012 (Wet)



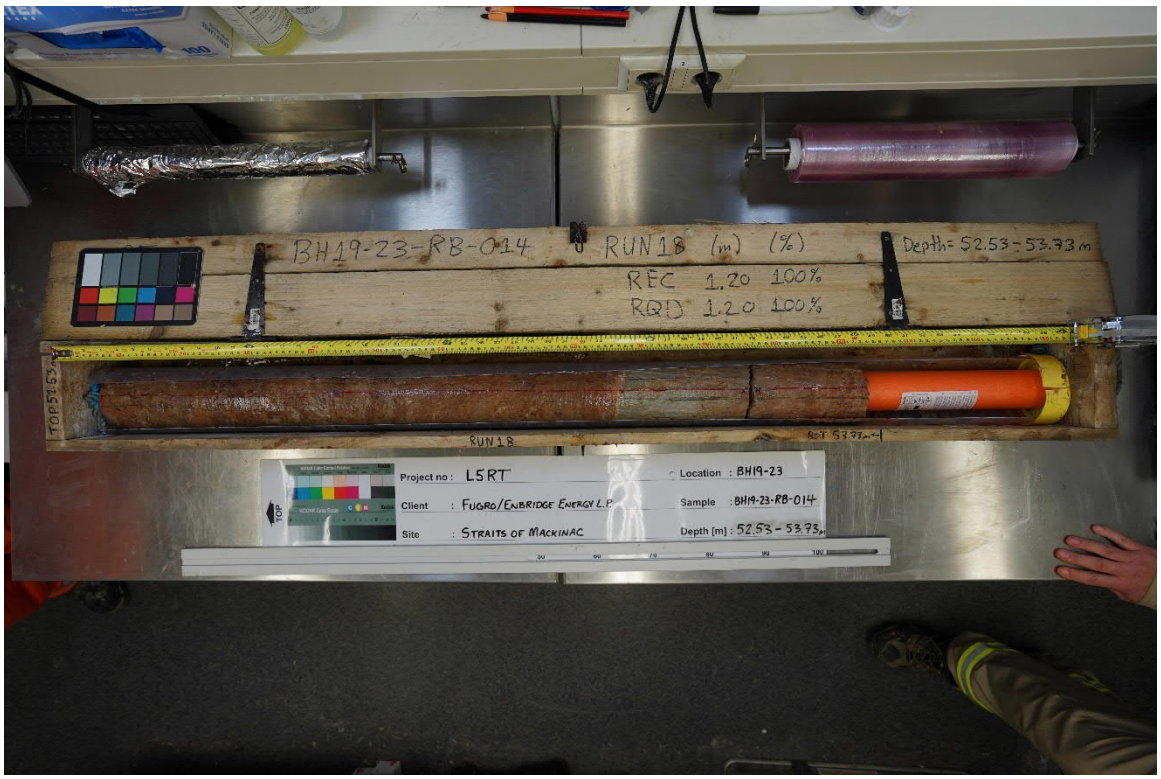
BH19-23-RB-013 (Dry)



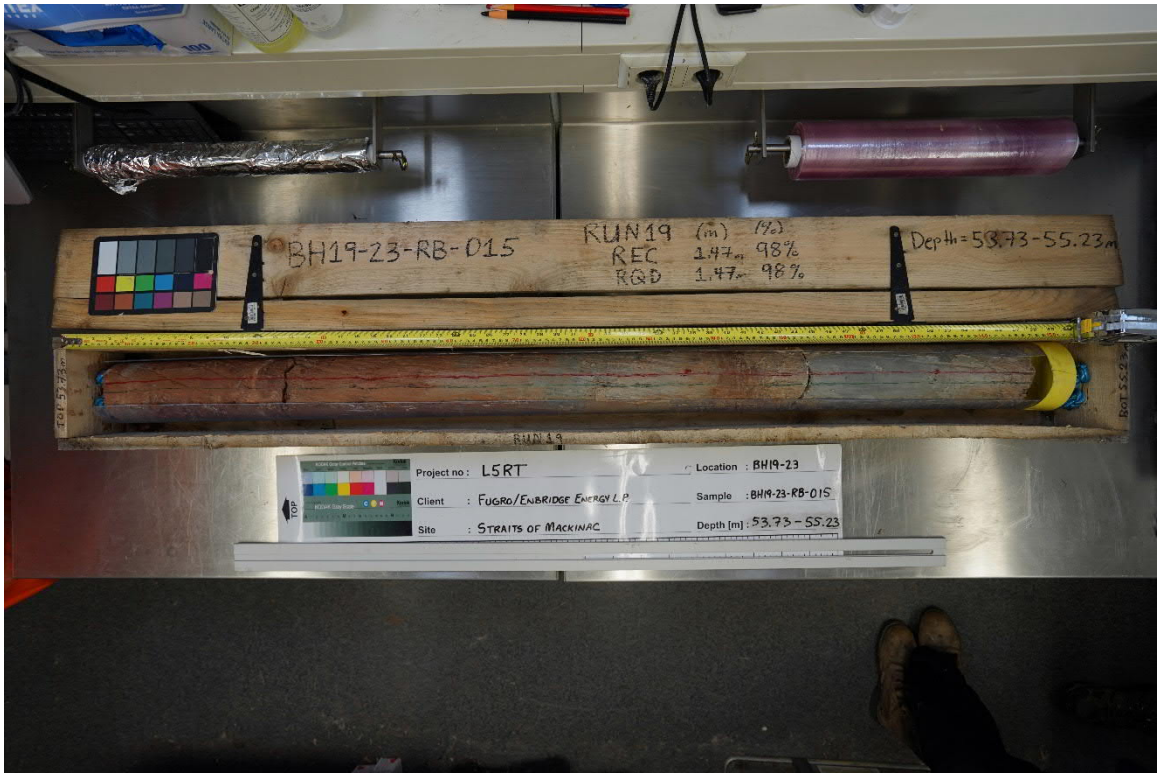
BH19-23-RB-013 (Wet)



BH19-23-RB-014 (Dry)

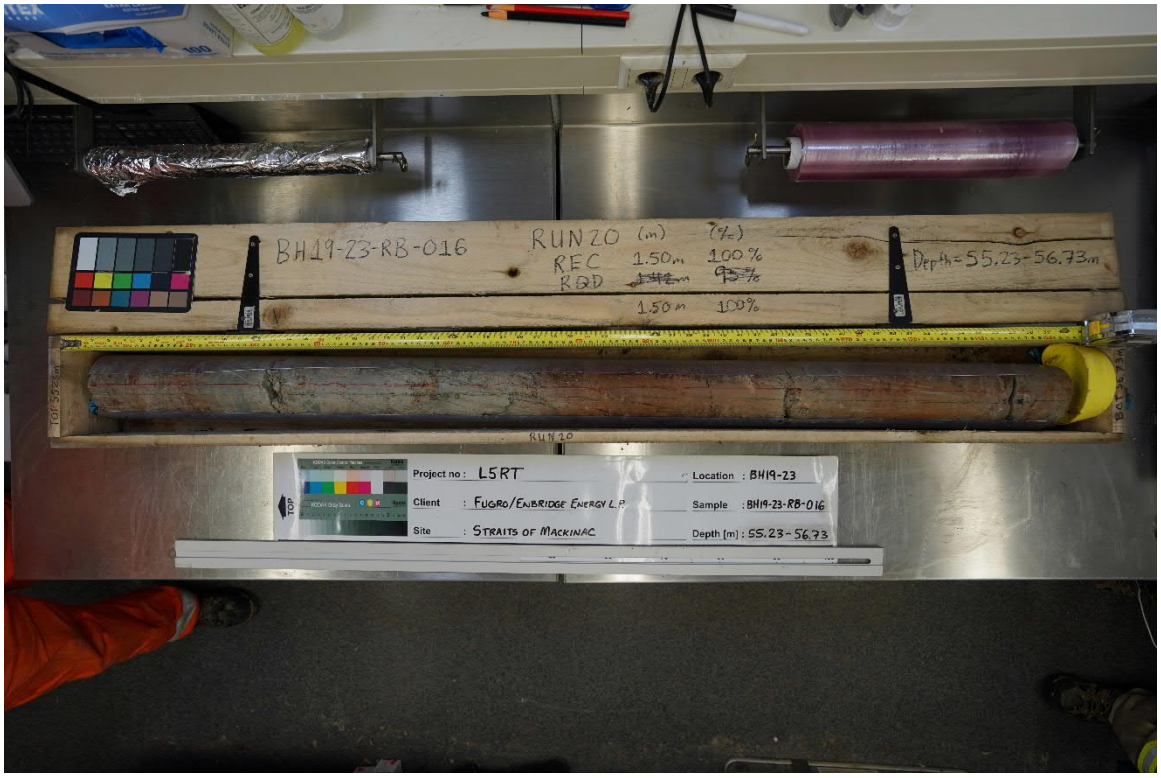


BH19-23-RB-014 (Wet)



BH19-23-RB-015 (Dry)

BH19-23-RB-015 (Wet)



BH19-23-RB-016 (Dry)

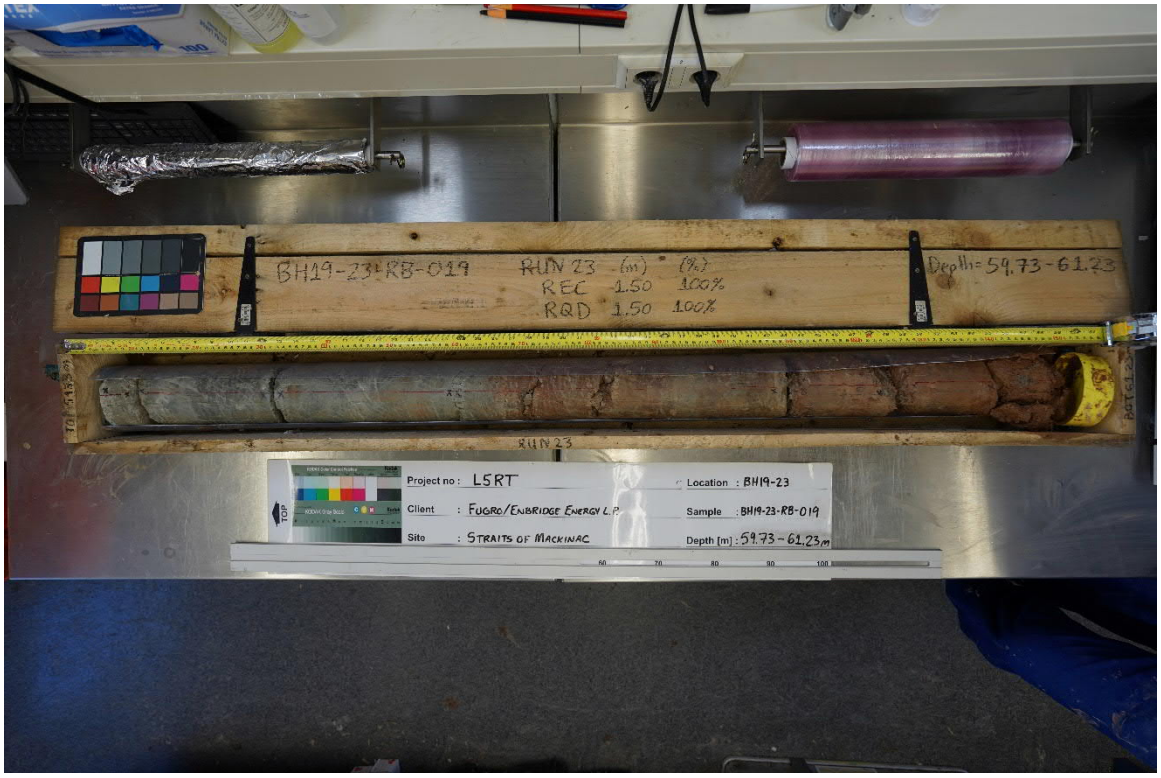
BH19-23-RB-016 (Wet)

BH19-23-RB-017 (Dry)

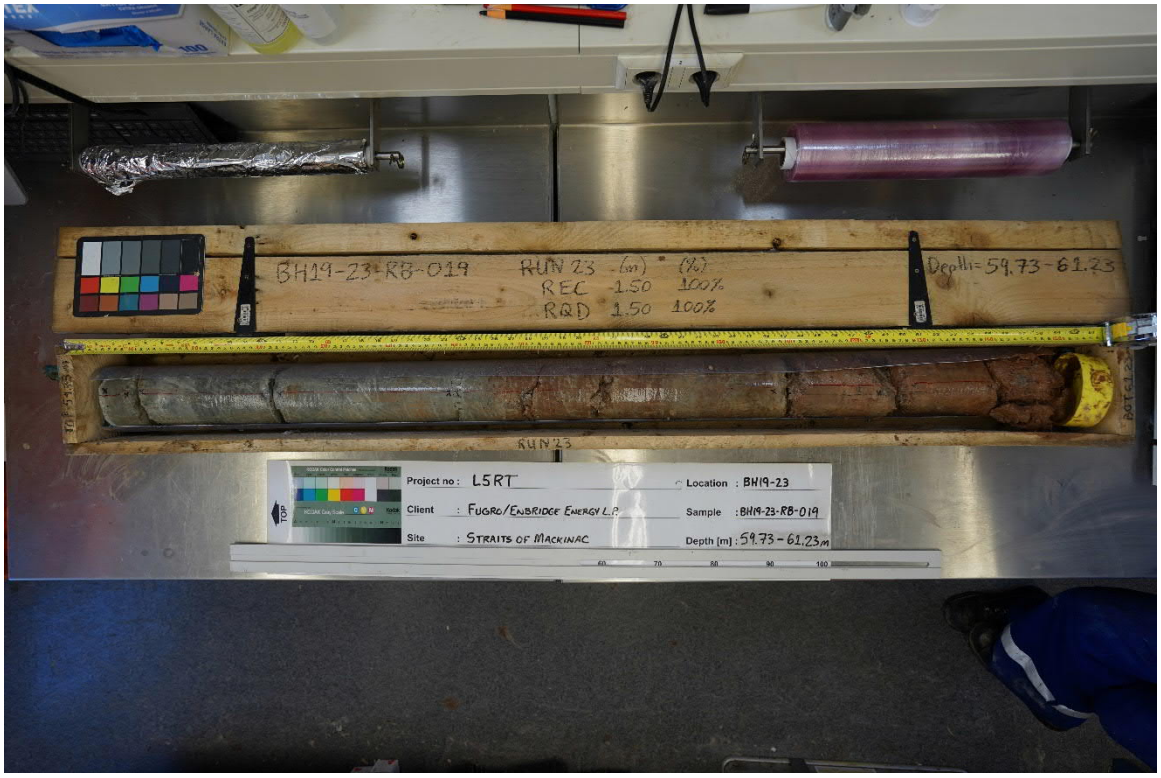
BH19-23-RB-017 (Wet)

BH19-23-RB-018 (Dry)

BH19-23-RB-018 (Wet)



BH19-23-RB-019 (Dry)



BH19-23-RB-019 (Wet)

BH19-23-RB-020 (Dry)

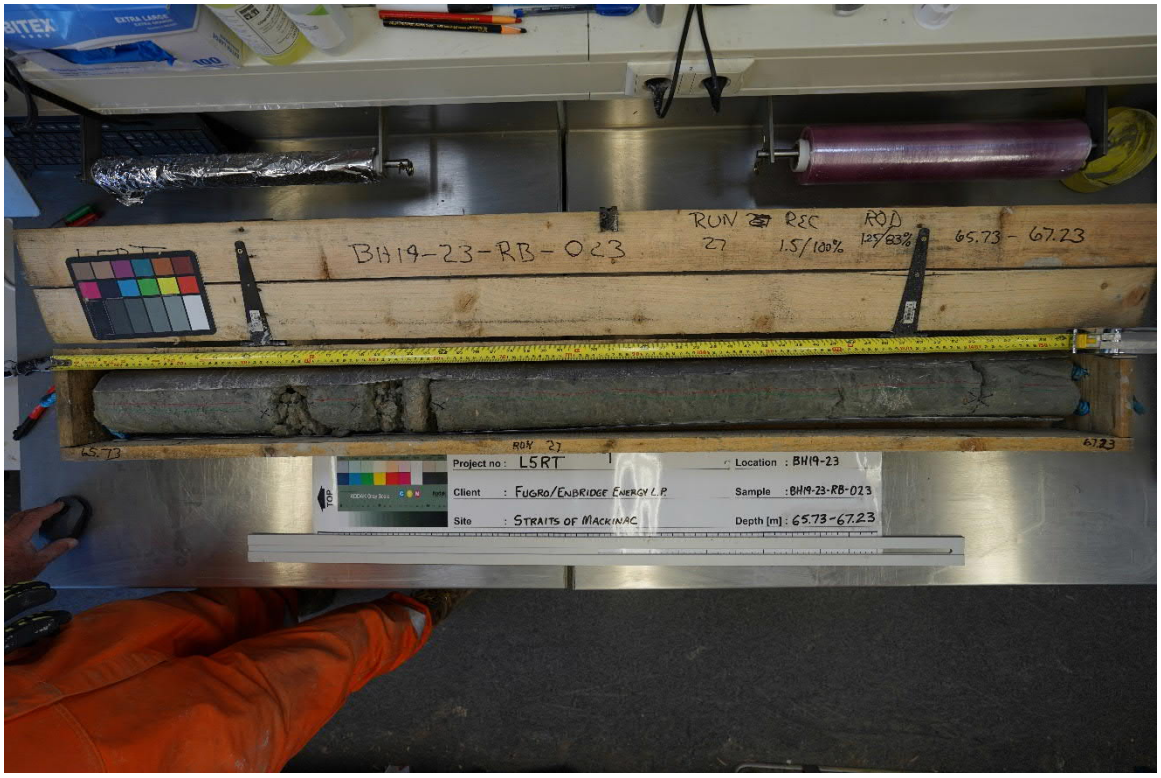
BH19-23-RB-020 (Wet)

BH19-23-RB-021 (Dry)

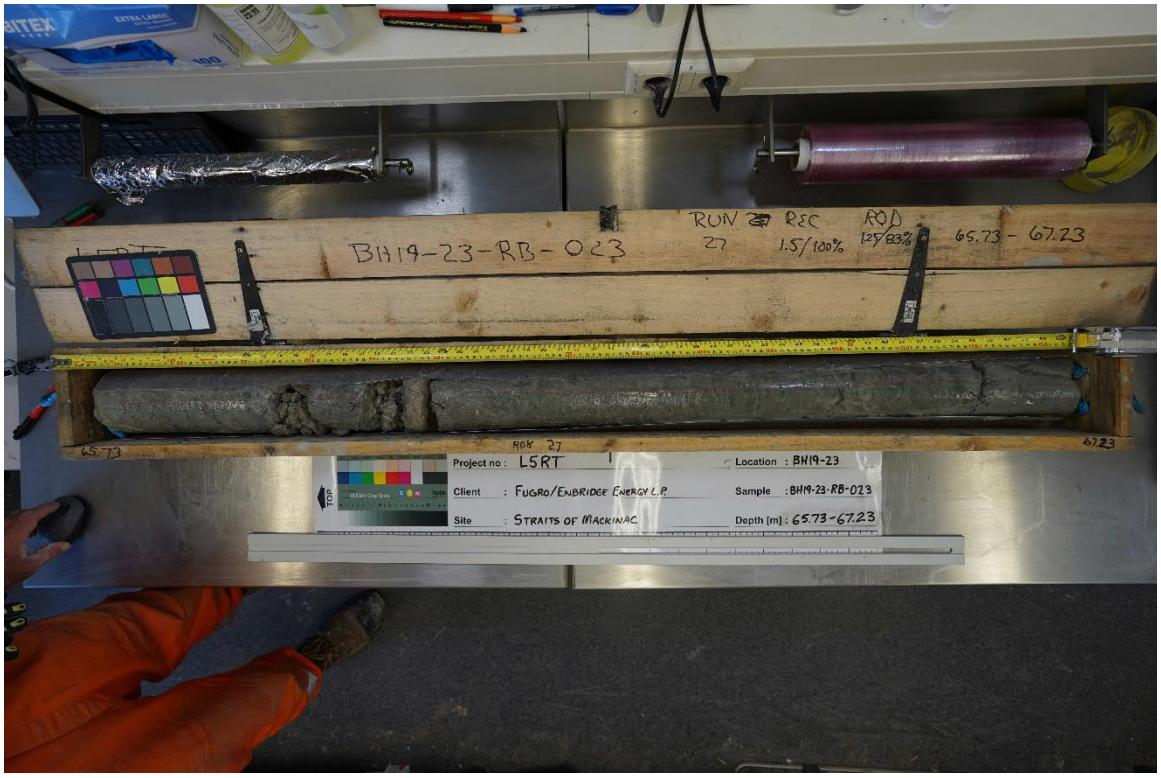
BH19-23-RB-021 (Wet)

BH19-23-RB-022 (Dry)

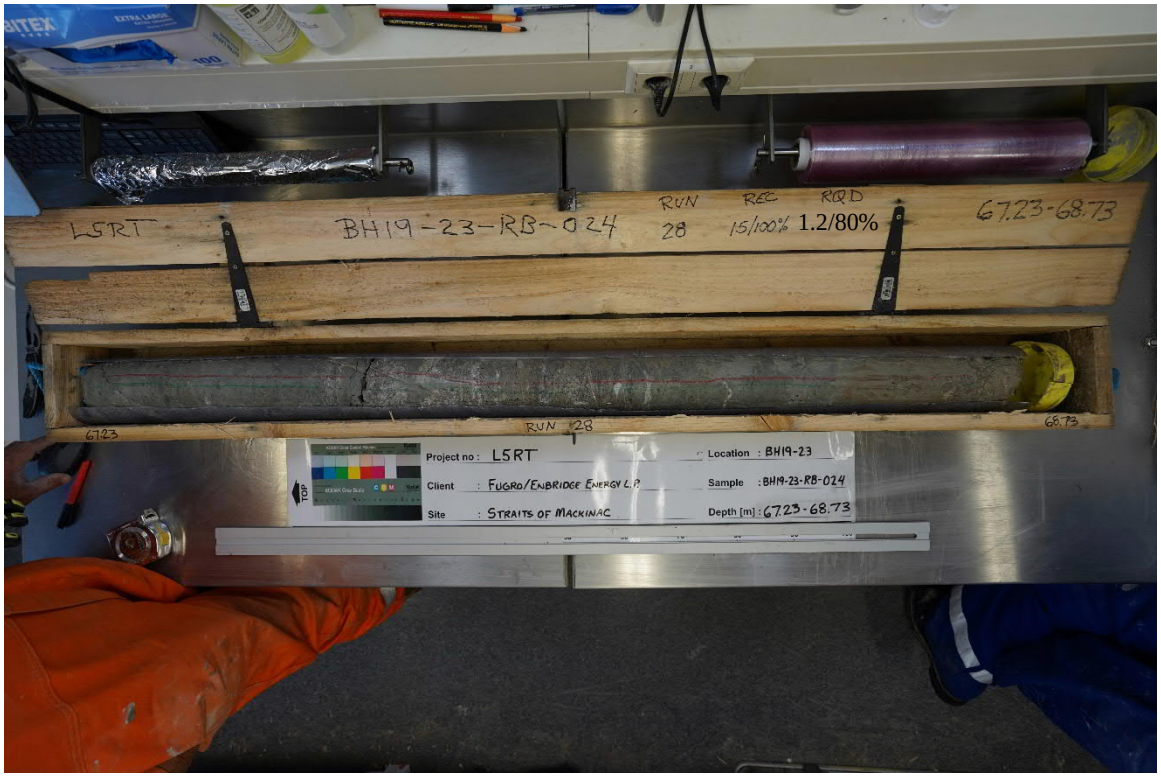
BH19-23-RB-022 (Wet)



BH19-23-RB-023 (Dry)

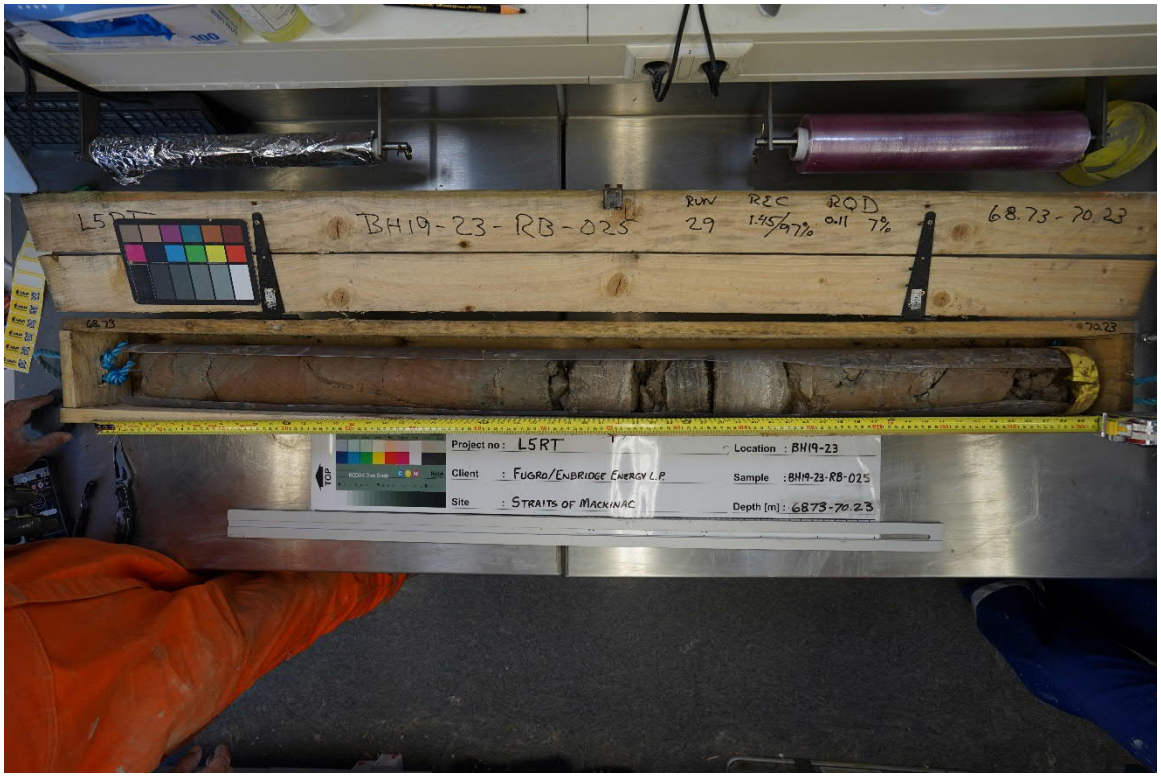


BH19-23-RB-023 (Wet)

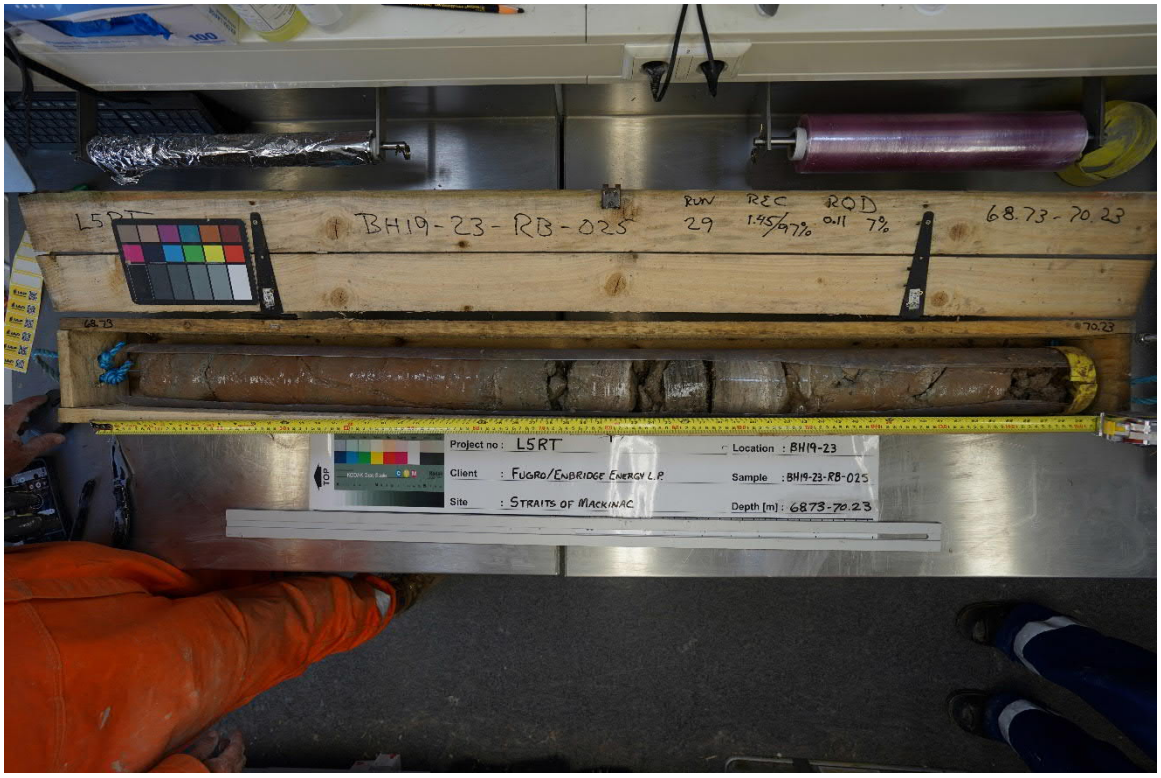


BH19-23-RB-024 (Dry)

BH19-23-RB-024 (Wet)



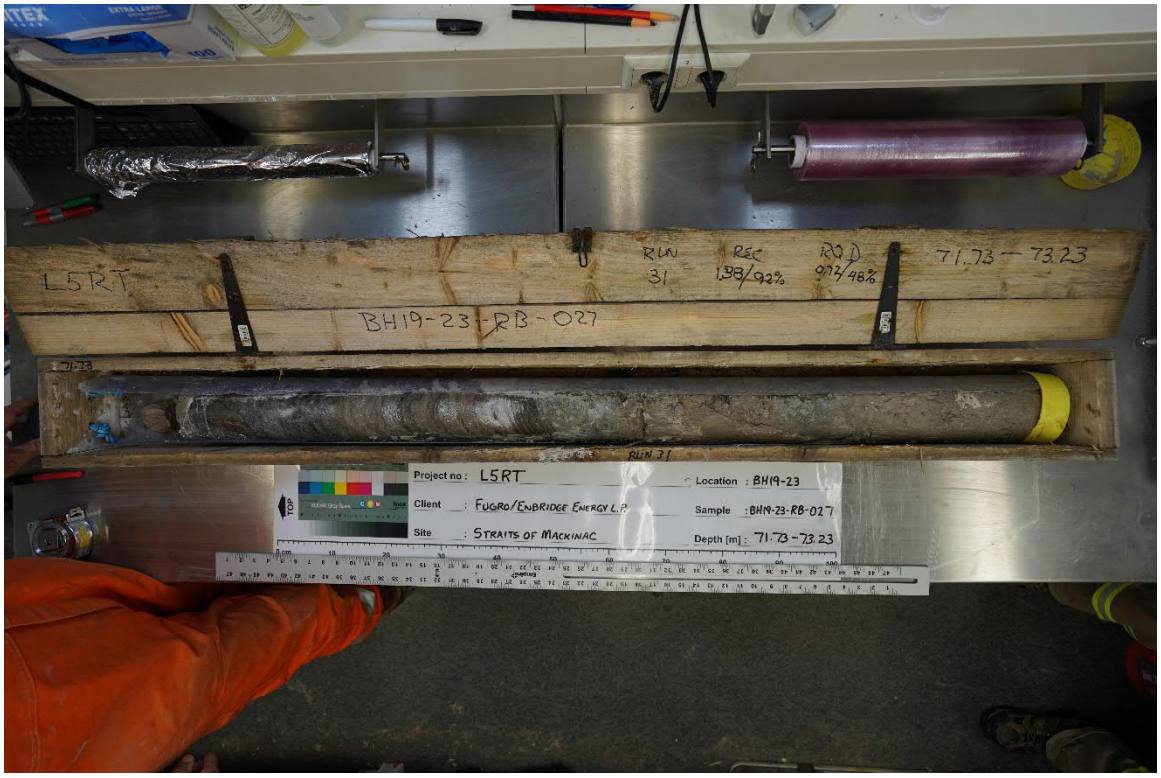
BH19-23-RB-025 (Dry)



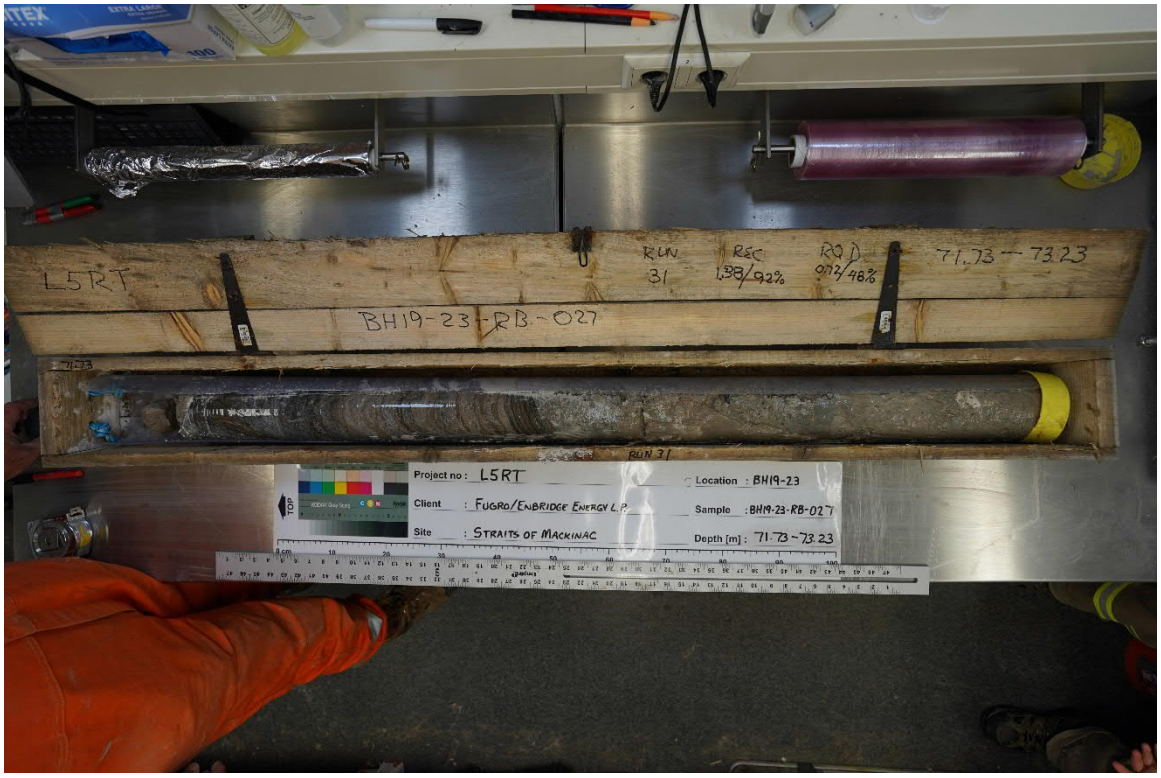
BH19-23-RB-025 (Wet)

BH19-23-RB-026 (Dry)

BH19-23-RB-026 (Wet)



BH19-23-RB-027 (Dry)



BH19-23-RB-027 (Wet)

BH19-23-RB-028 (Dry)

BH19-23-RB-028 (Wet)

BH19-24-RB-001

BH19-24-RB-002

BH19-24-RB-003

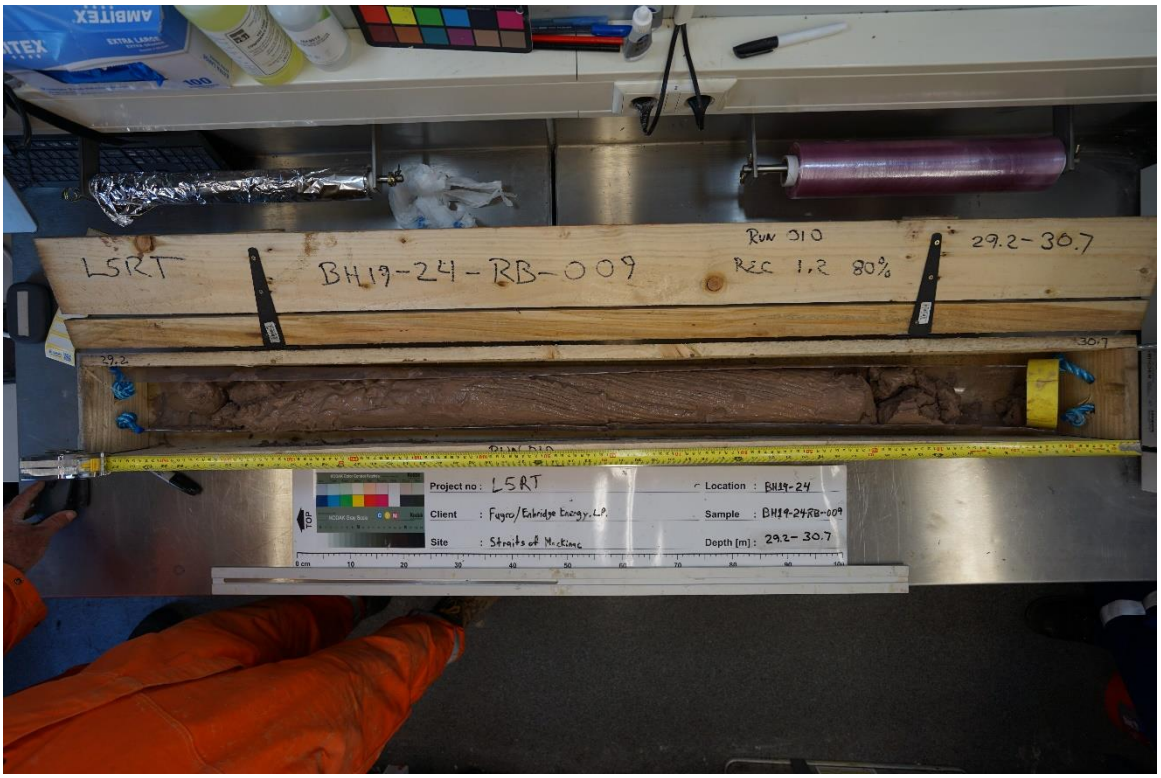
BH19-24-RB-004

BH19-24-RB-005

BH19-24-RB-006

BH19-24-RB-007

BH19-24-RB-008



BH19-24-RB-009

BH19-24-RB-010

BH19-24-RB-011

BH19-24-RB-012

BH19-24-RB-013

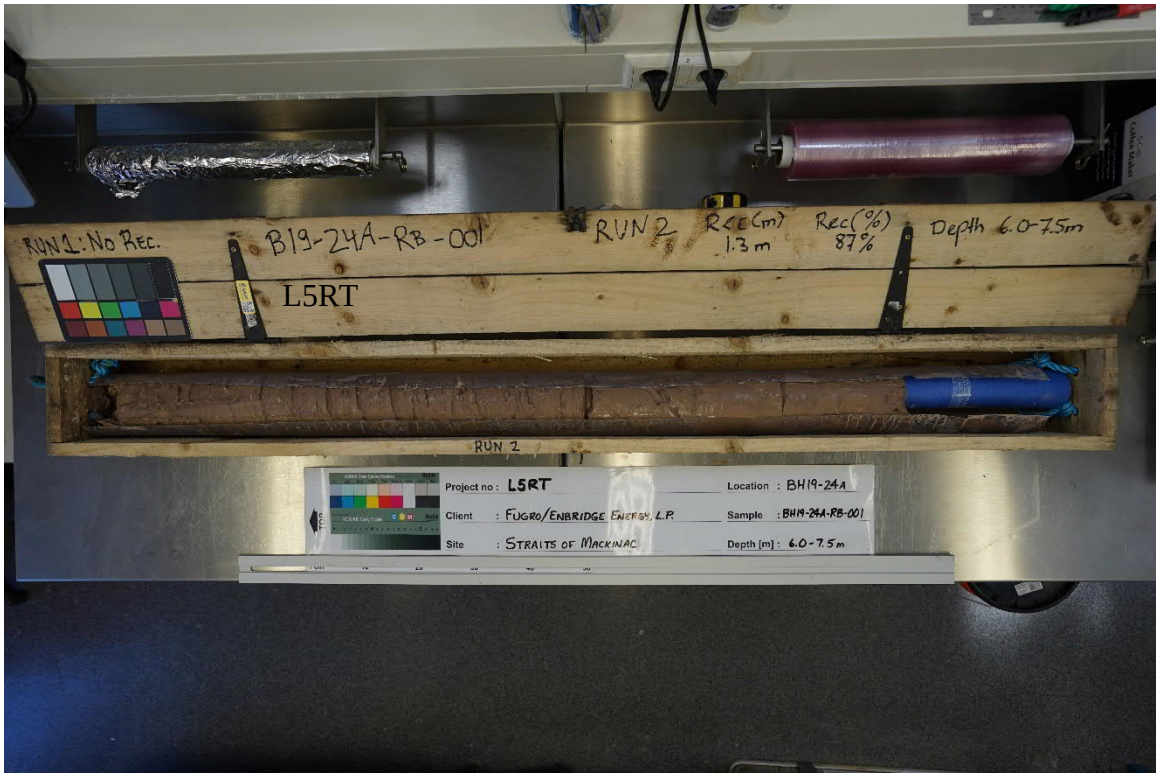
BH19-24-RB-014

BH19-24-RB-015

BH19-24-RB-016

BH19-24-RB-017

[INTENTIONALLY LEFT BLANK]



BH19-24A-RB-001

BH19-24A-RB-002

BH19-24A-RB-003

BH19-24A-RB-004

BH19-24A-RB-005

BH19-24A-RB-006

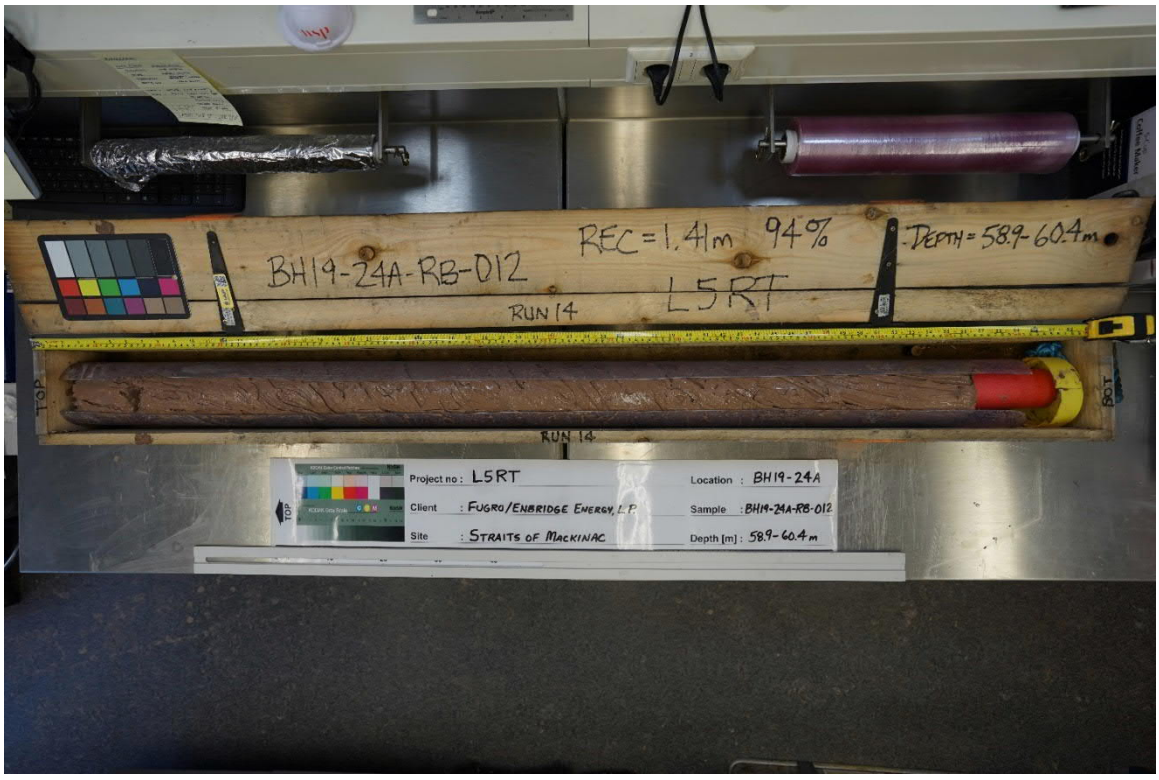
BH19-24A-RB-007

BH19-24A-RB-008

BH19-24A-RB-009

BH19-24A-RB-010

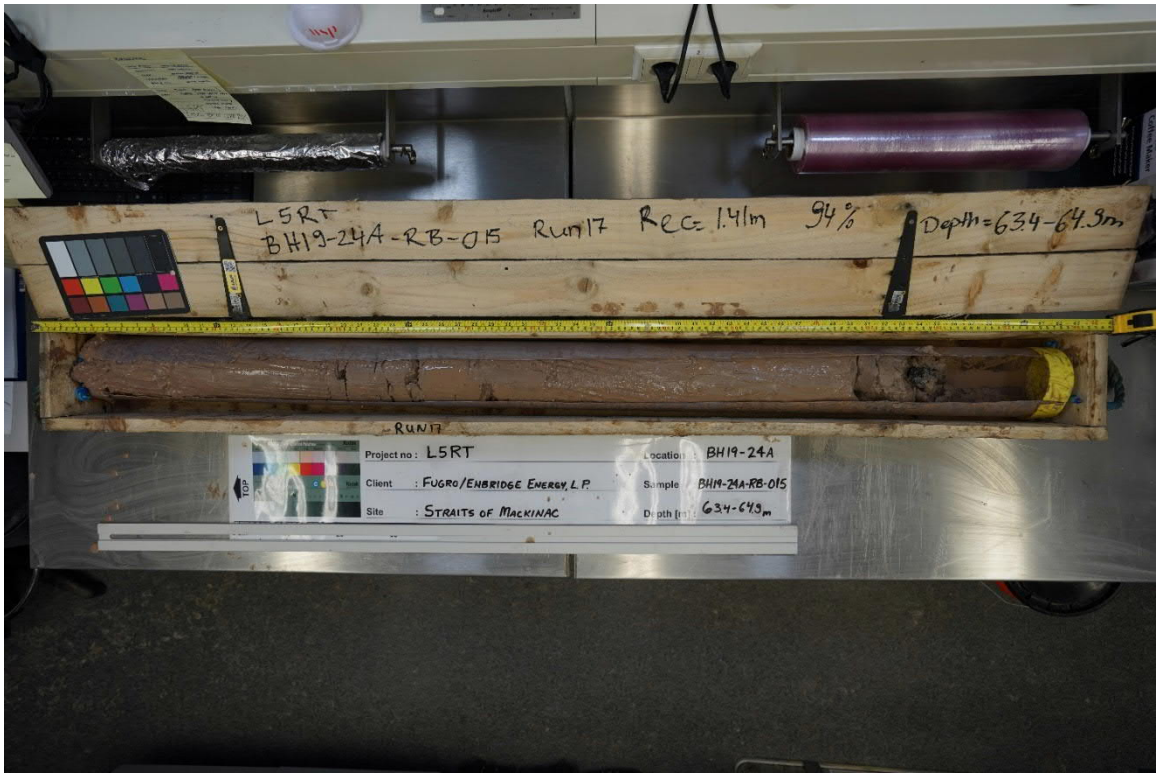
BH19-24A-RB-011



BH19-24A-RB-012

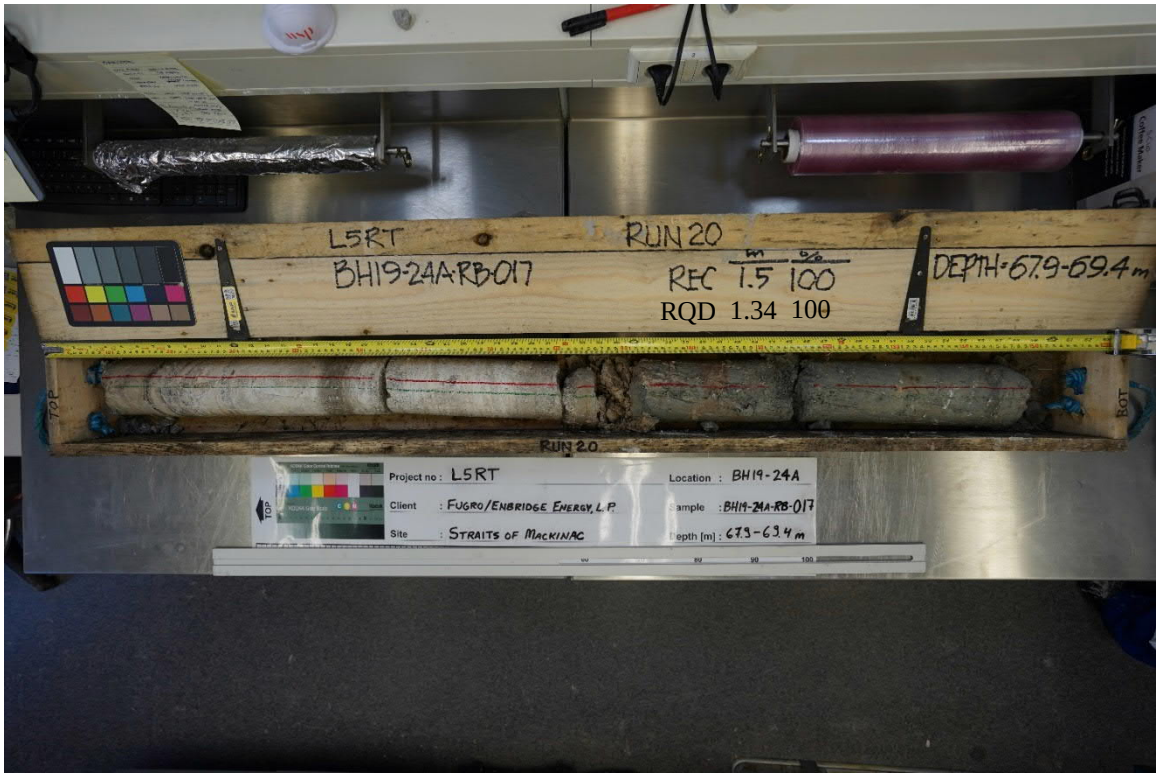
BH19-24A-RB-013

BH19-24A-RB-014



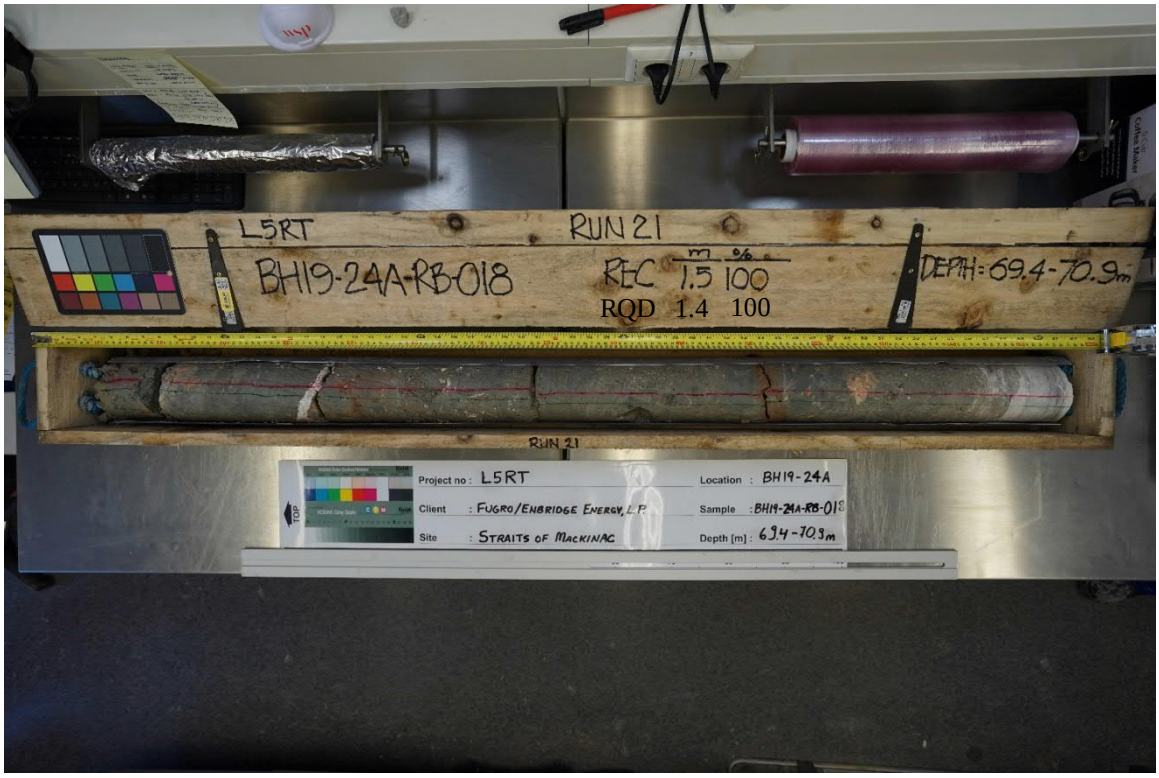
BH19-24A-RB-015

BH19-24A-RB-016



BH19-24A-RB-017 (Dry)

BH19-24A-RB-017 (Wet)



BH19-24A-RB-018 (Dry)

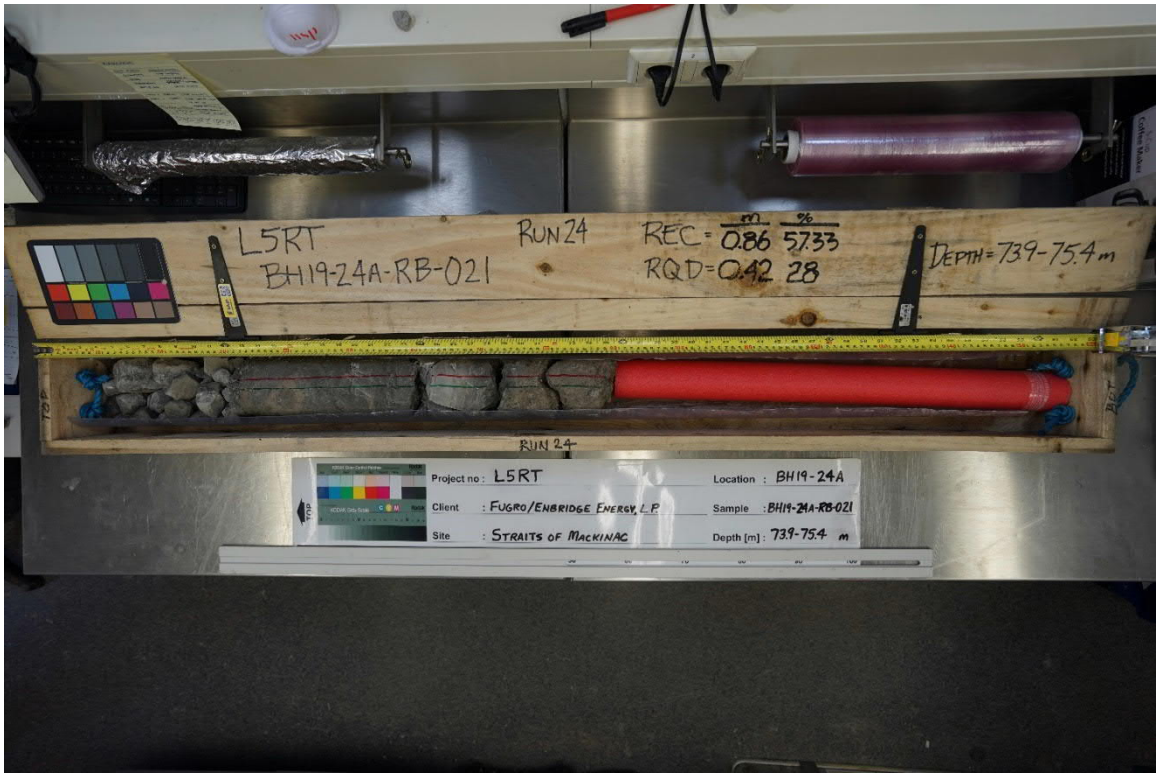
BH19-24A-RB-018 (Wet)

BH19-24A-RB-019 (Dry)

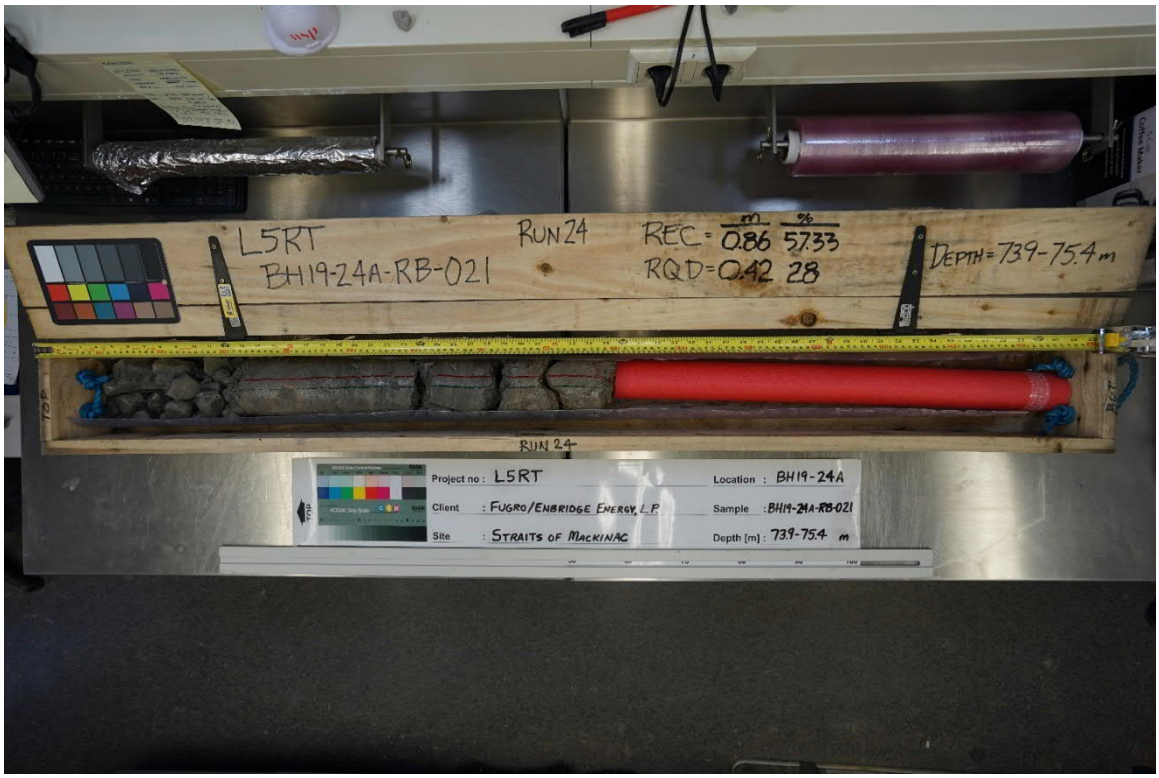
BH19-24A-RB-019 (Wet)

BH19-24A-RB-020 (Dry)

BH19-24A-RB-020 (Wet)



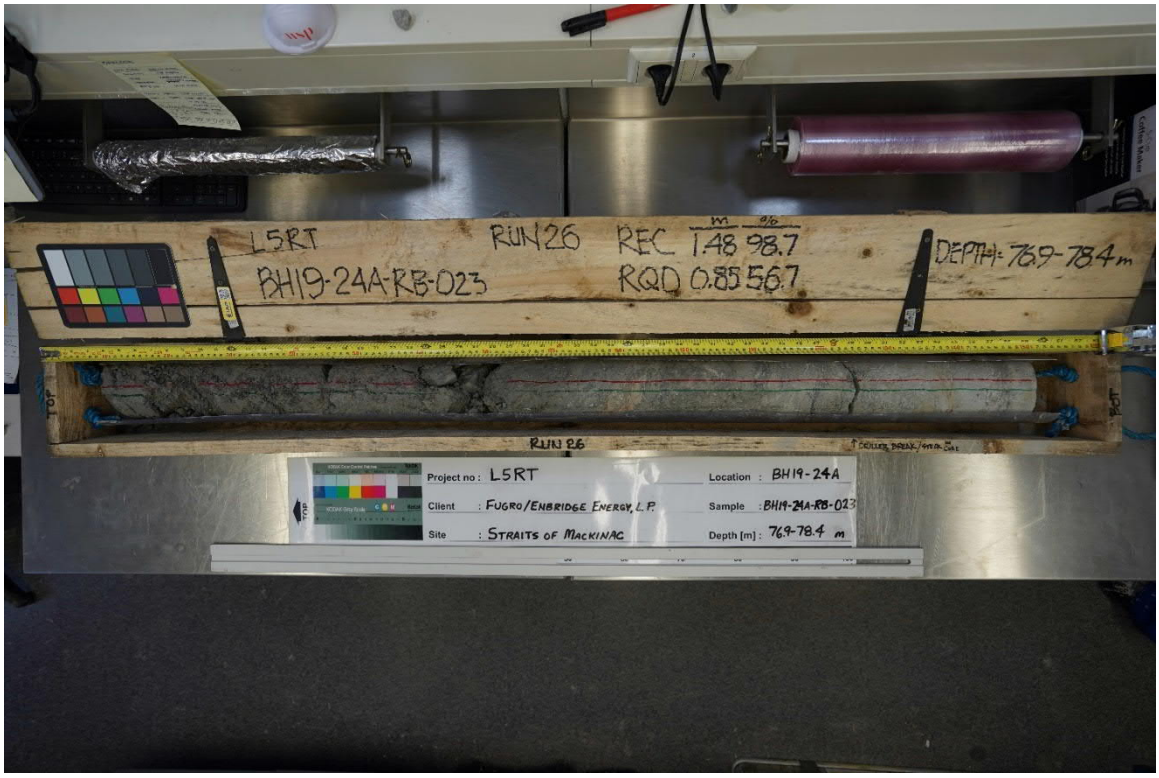
BH19-24A-RB-021 (Dry)



BH19-24A-RB-021 (Wet)

BH19-24A-RB-022 (Dry)

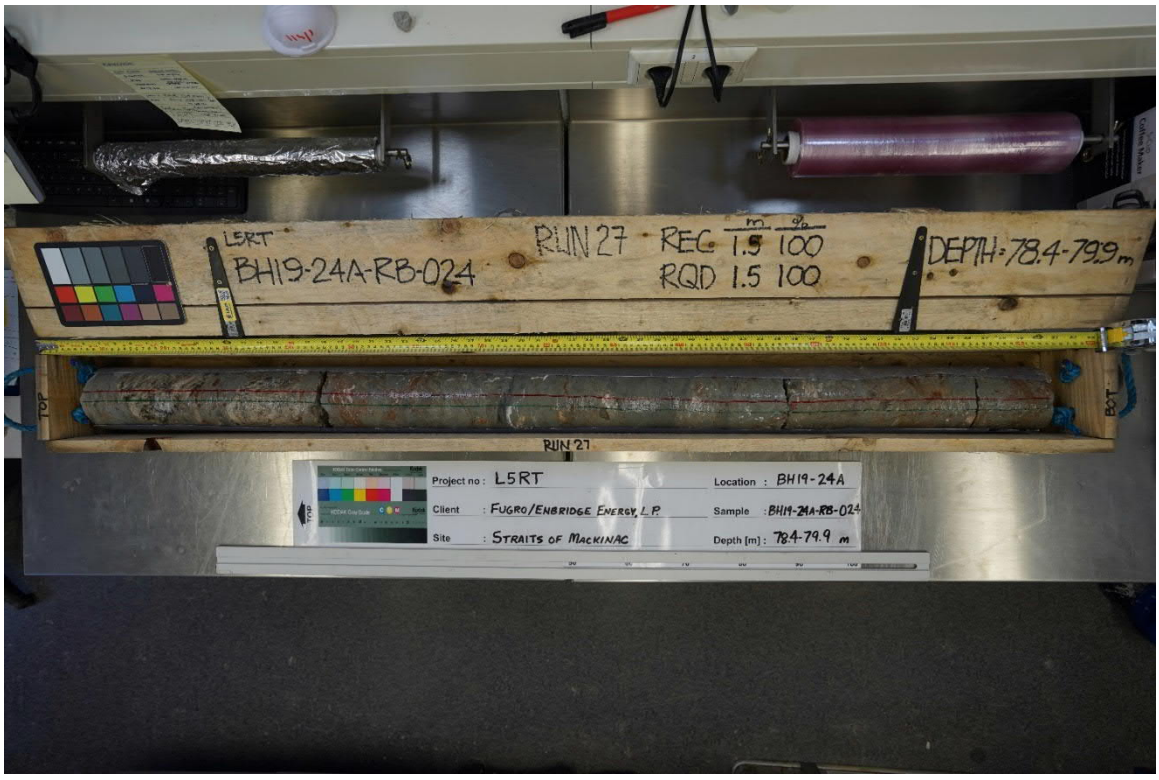
BH19-24A-RB-022 (Wet)



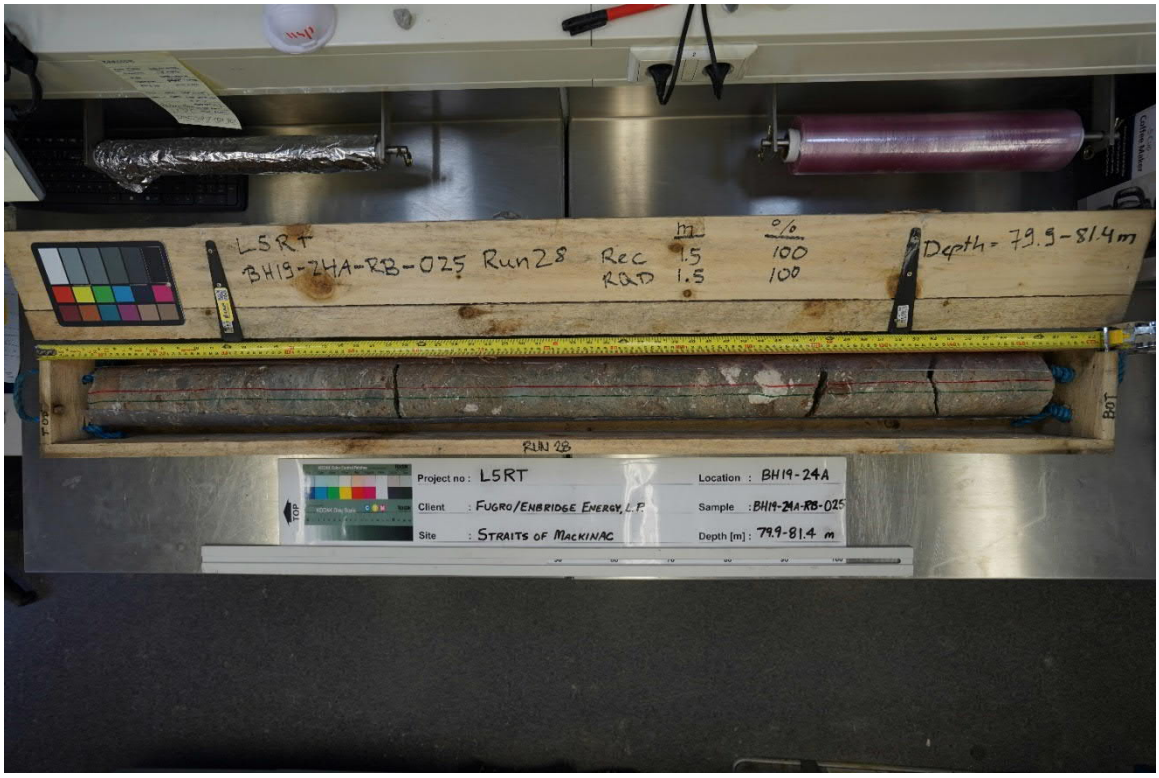
BH19-24A-RB-023 (Dry)

BH19-24A-RB-023 (Wet)

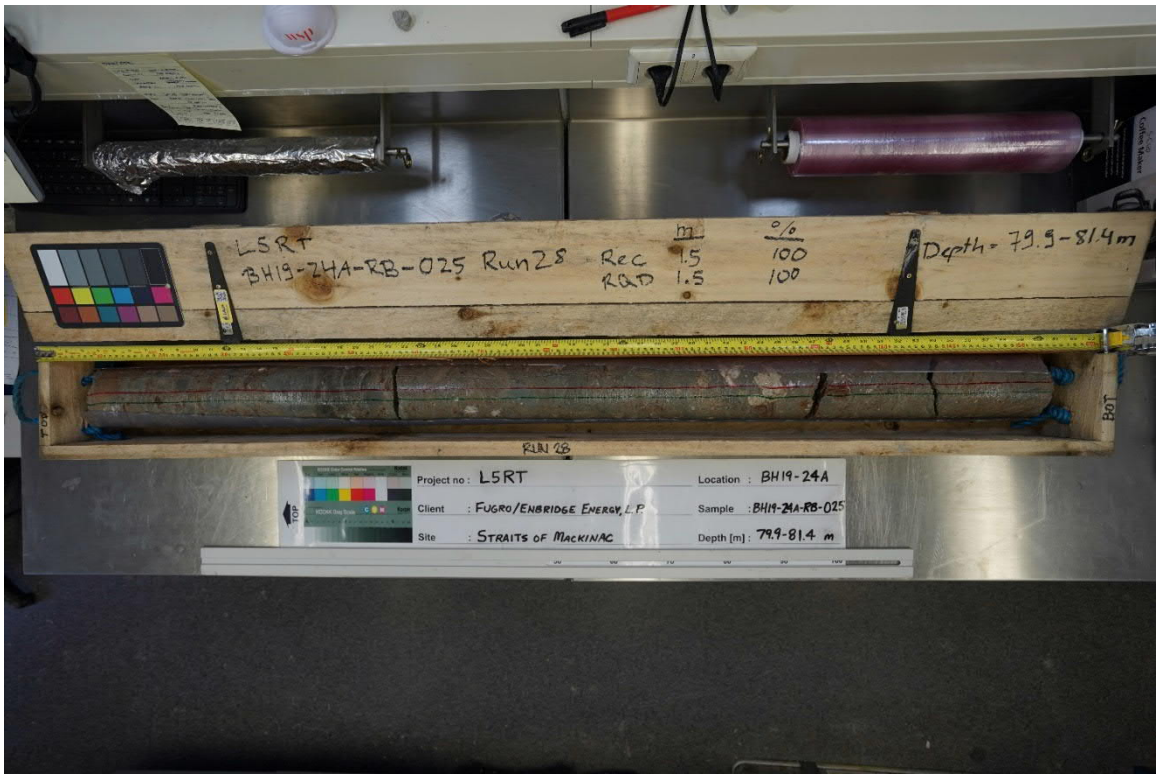
BH19-24A-RB-024 (Dry)



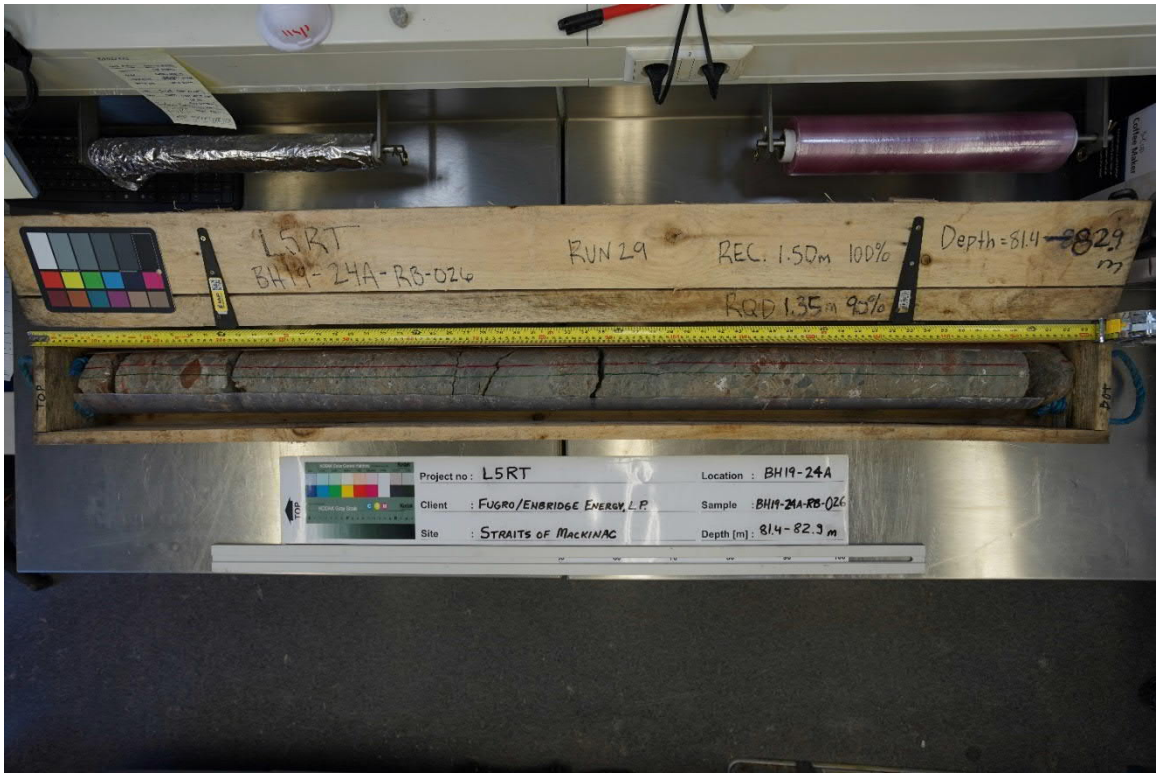
BH19-24A-RB-024 (Wet)



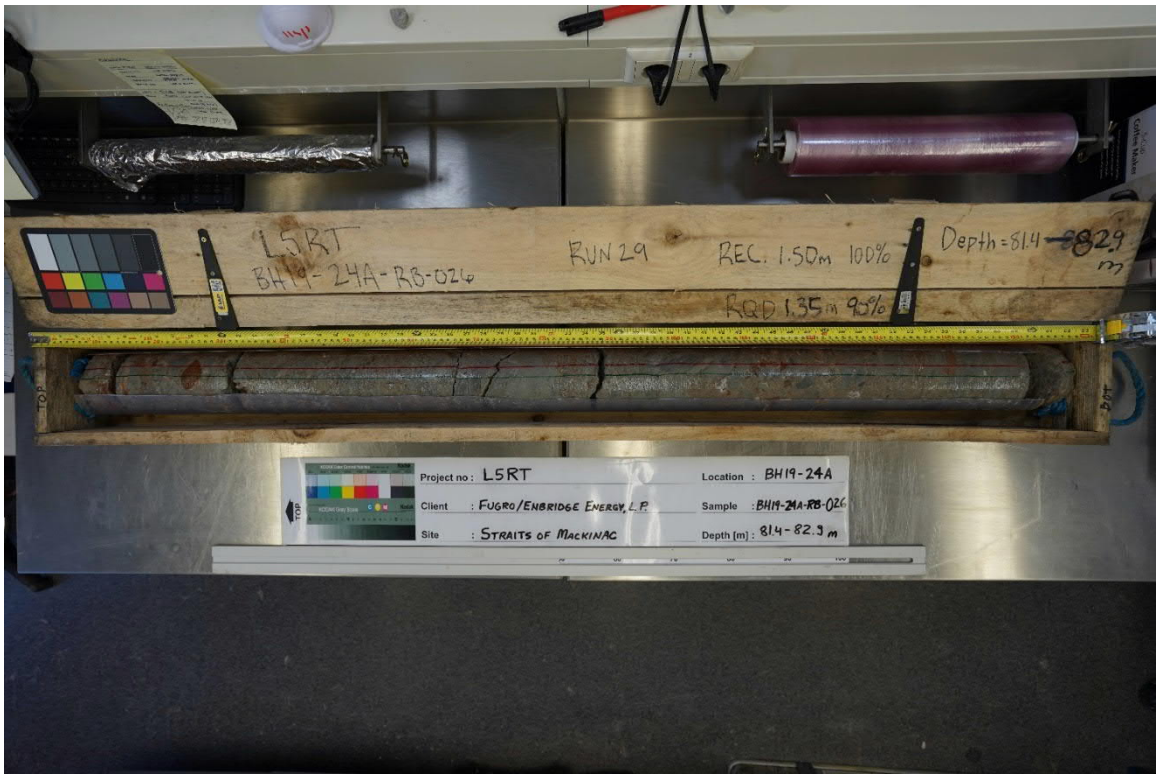
BH19-24A-RB-025 (Dry)



BH19-24A-RB-025 (Wet)



BH19-24A-RB-026 (Dry)



BH19-24A-RB-026 (Wet)

BH19-24A-RB-027 (Dry)

BH19-24A-RB-027 (Wet)

BH19-24A-RB-028 (Dry)

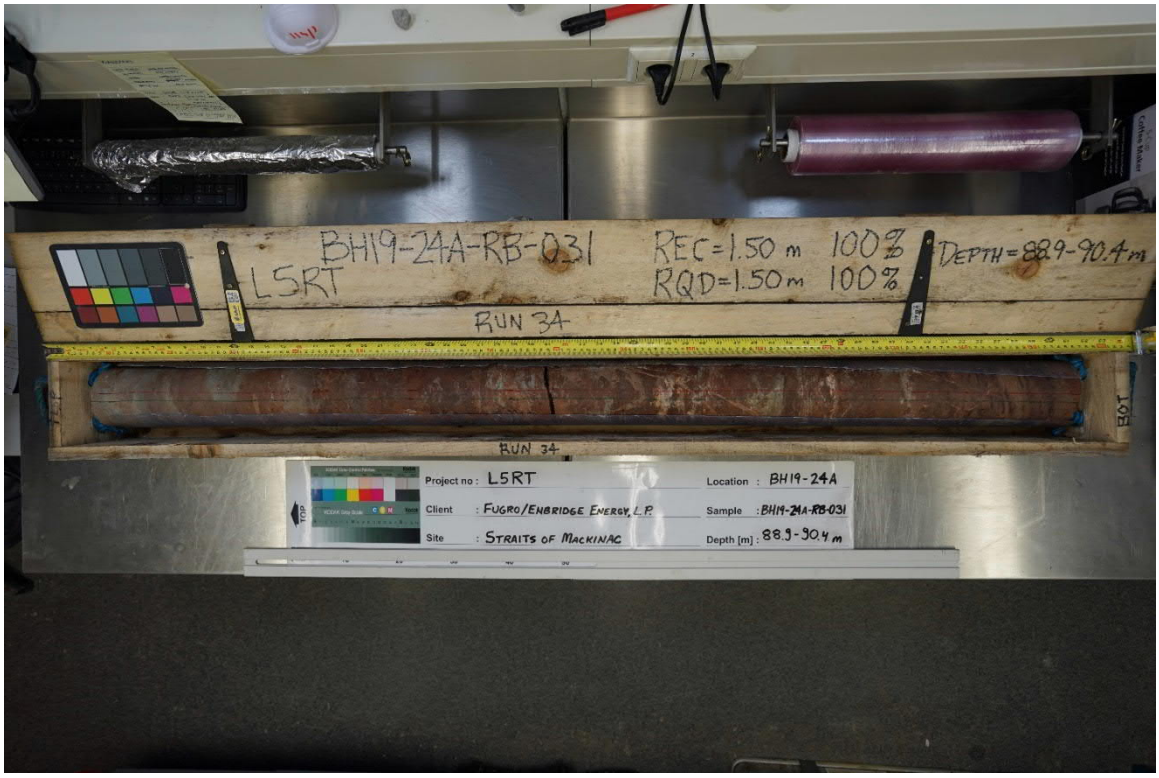
BH19-24A-RB-028 (Wet)

BH19-24A-RB-029 (Dry)

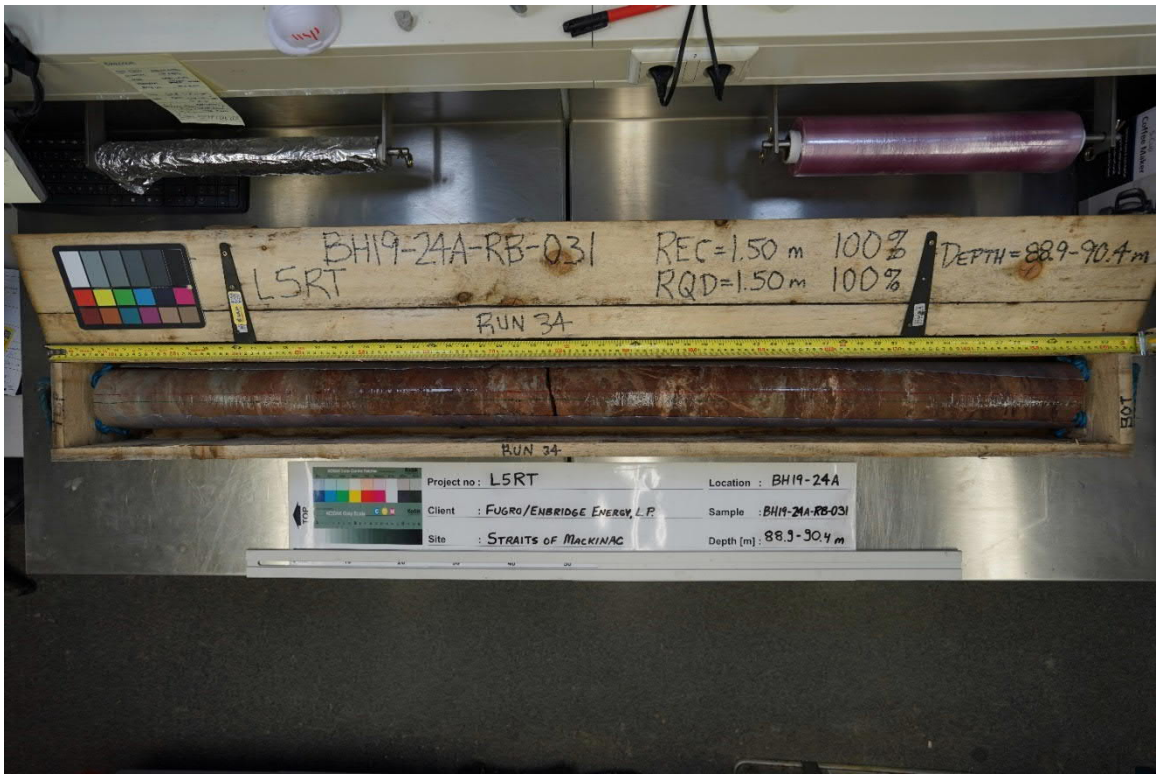
BH19-24A-RB-029 (Wet)

BH19-24A-RB-030 (Dry)

BH19-24A-RB-030 (Wet)

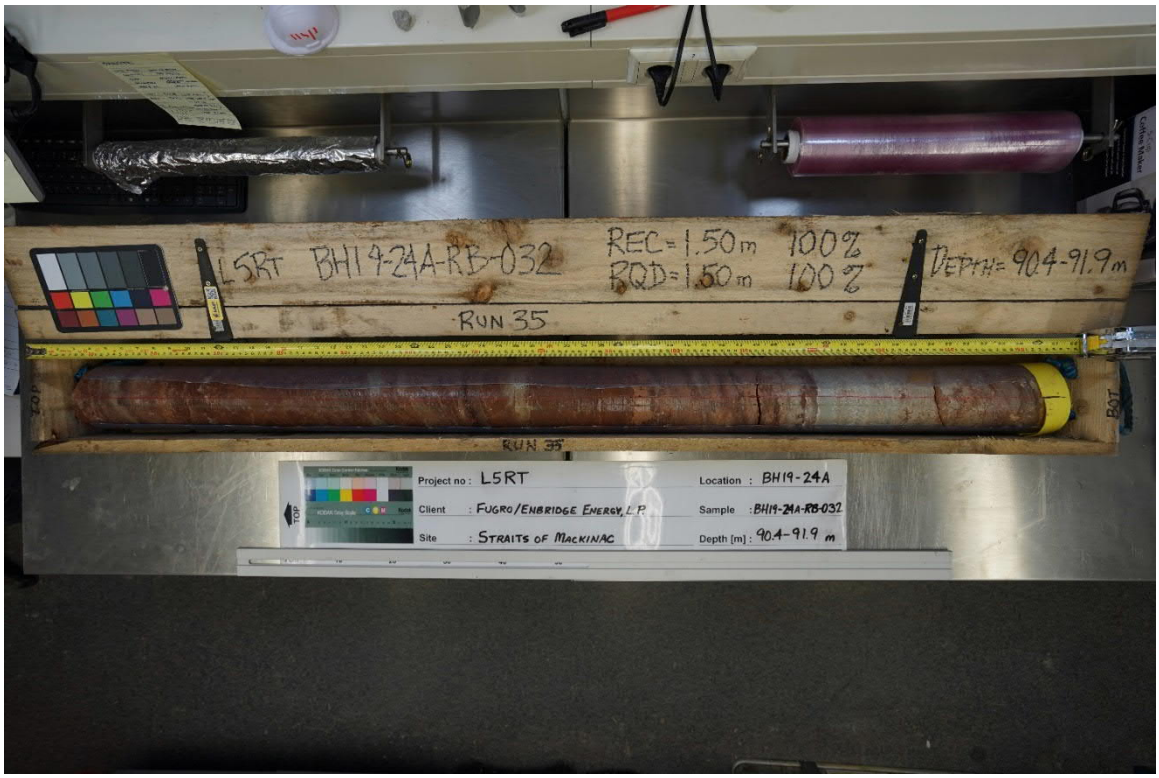


BH19-24A-RB-031 (Dry)



BH19-24A-RB-031 (Wet)

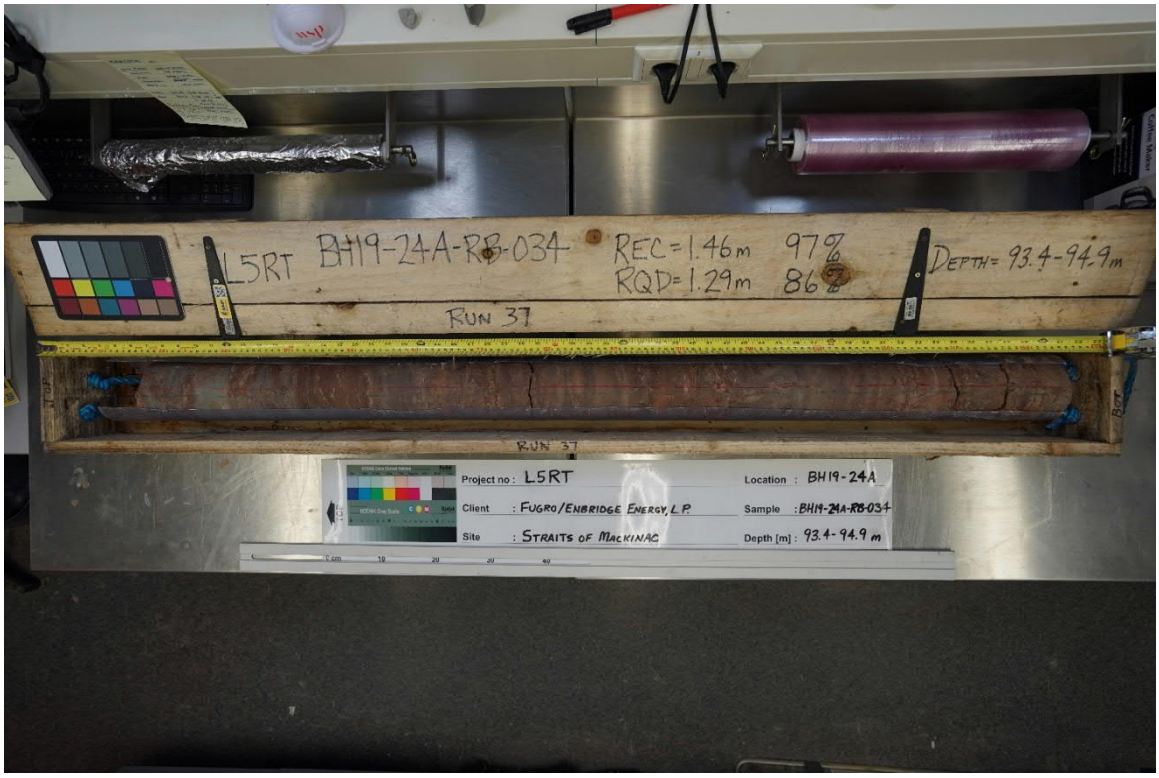
BH19-24A-RB-032 (Dry)



BH19-24A-RB-032 (Wet)

BH19-24A-RB-033 (Dry)

BH19-24A-RB-033 (Wet)



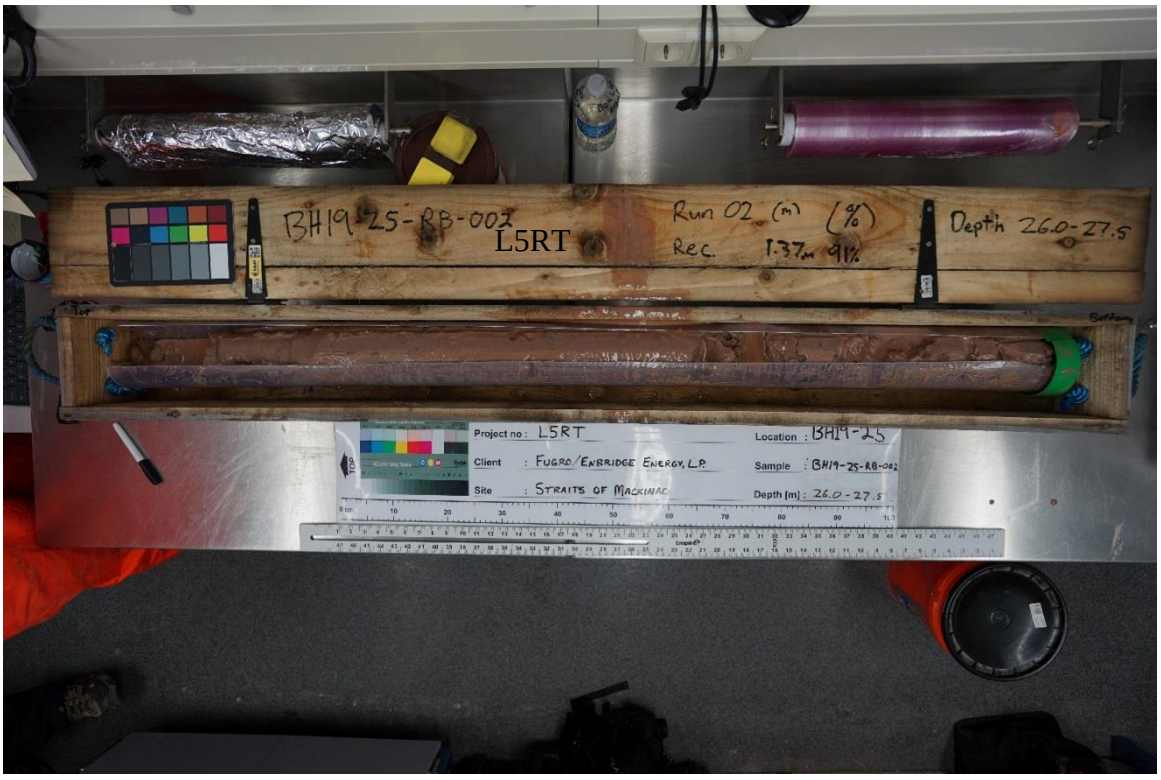
BH19-24A-RB-034 (Dry)

BH19-24A-RB-034 (Wet)

BH19-24A-RB-035 (Dry)

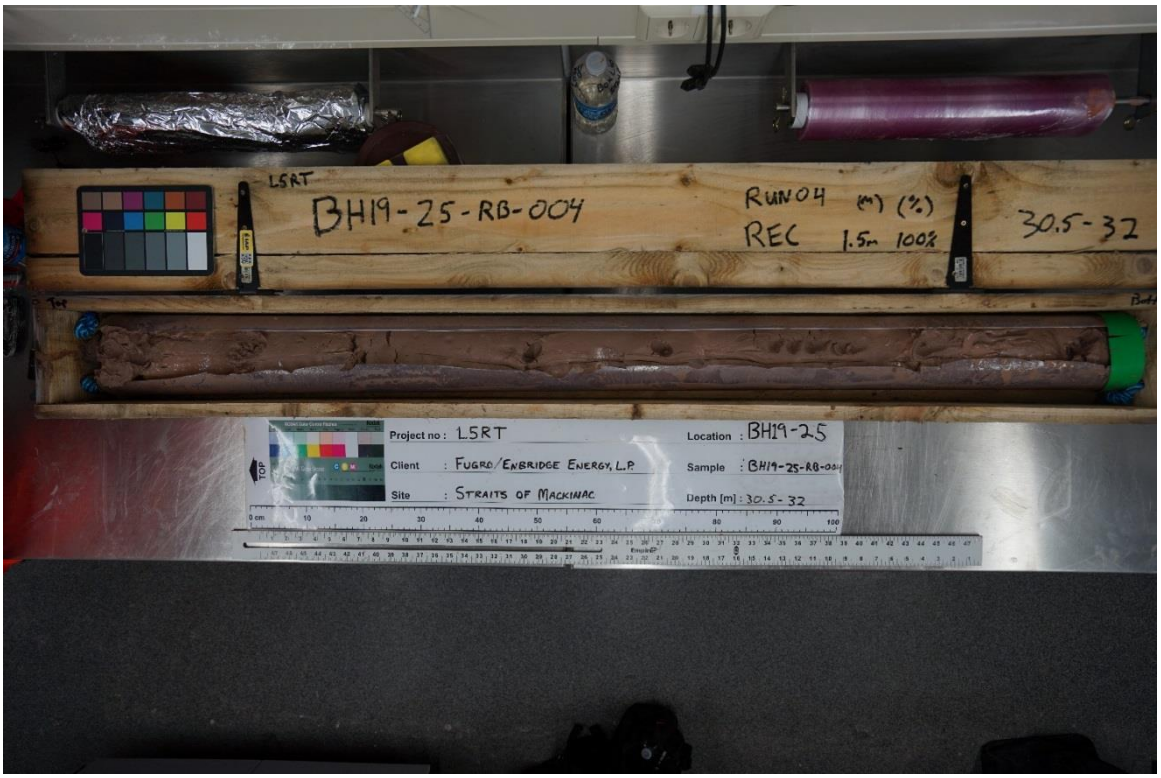
BH19-24A-RB-035 (Wet)

BH19-25-RB-001



BH19-25-RB-002

BH19-25-RB-003



BH19-25-RB-004

BH19-25-RB-005

BH19-25-RB-006

BH19-25-RB-007

BH19-25-RB-008

BH19-25-RB-009

BH19-25-RB-010

BH19-25-RB-011

BH19-25-RB-012

BH19-25-RB-013

BH19-25-RB-014

BH19-25-RB-015

BH19-25-RB-016

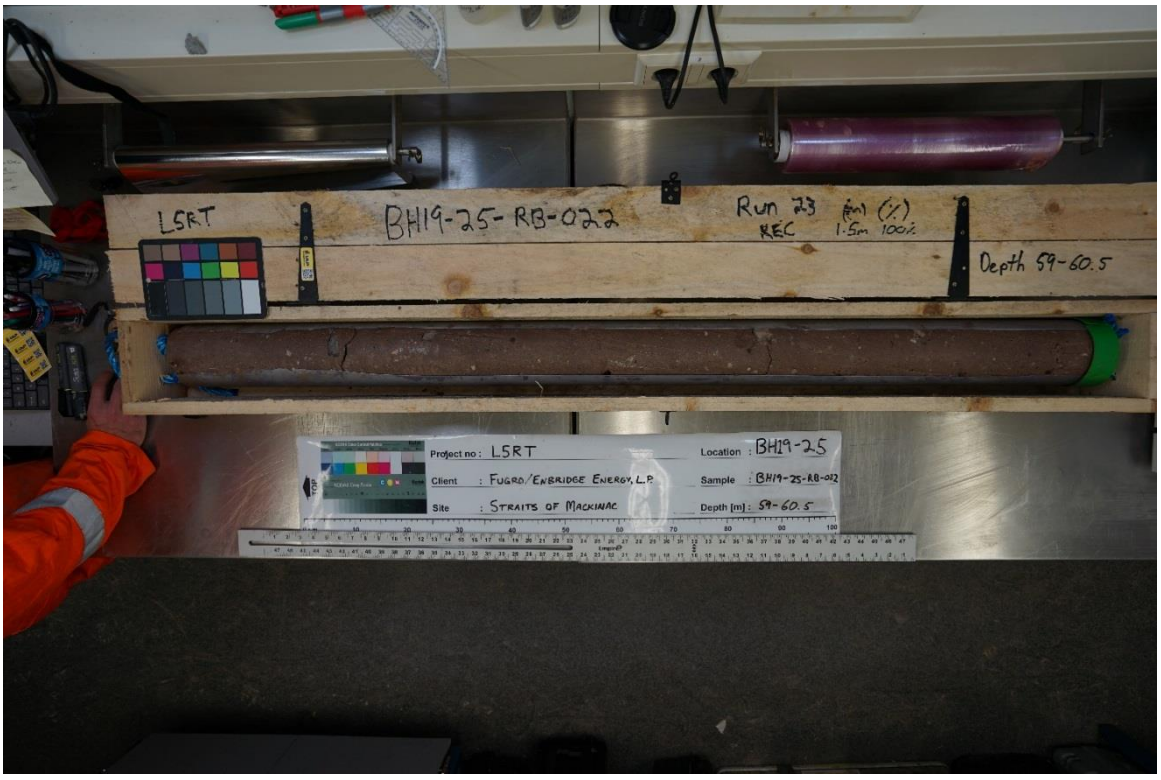
BH19-25-RB-017

BH19-25-RB-018

BH19-25-RB-019

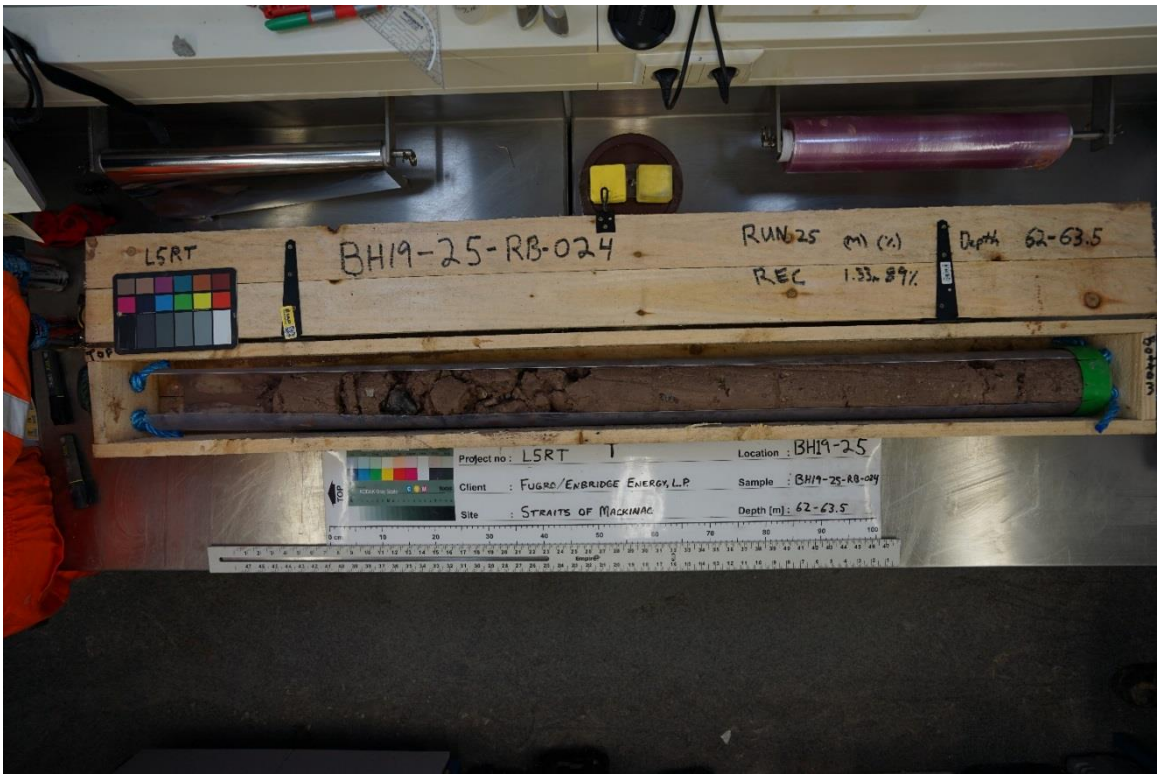
BH19-25-RB-020

BH19-25-RB-021



BH19-25-RB-022

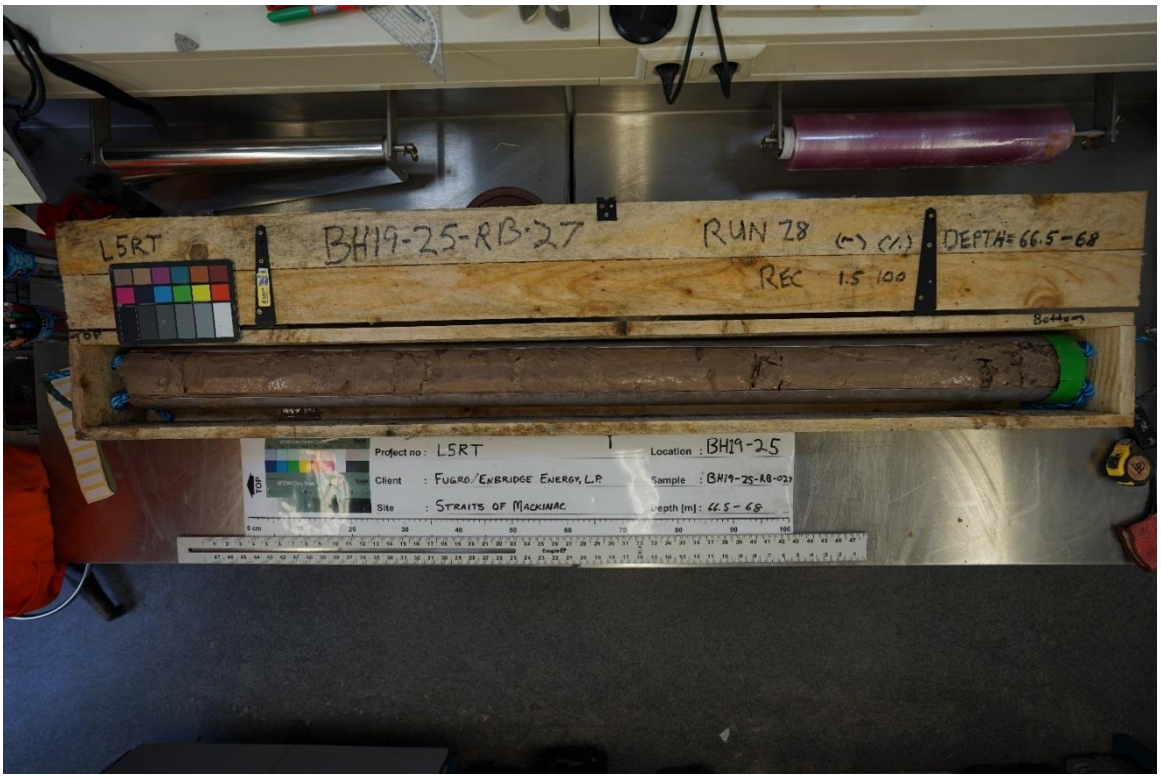
BH19-25-RB-023



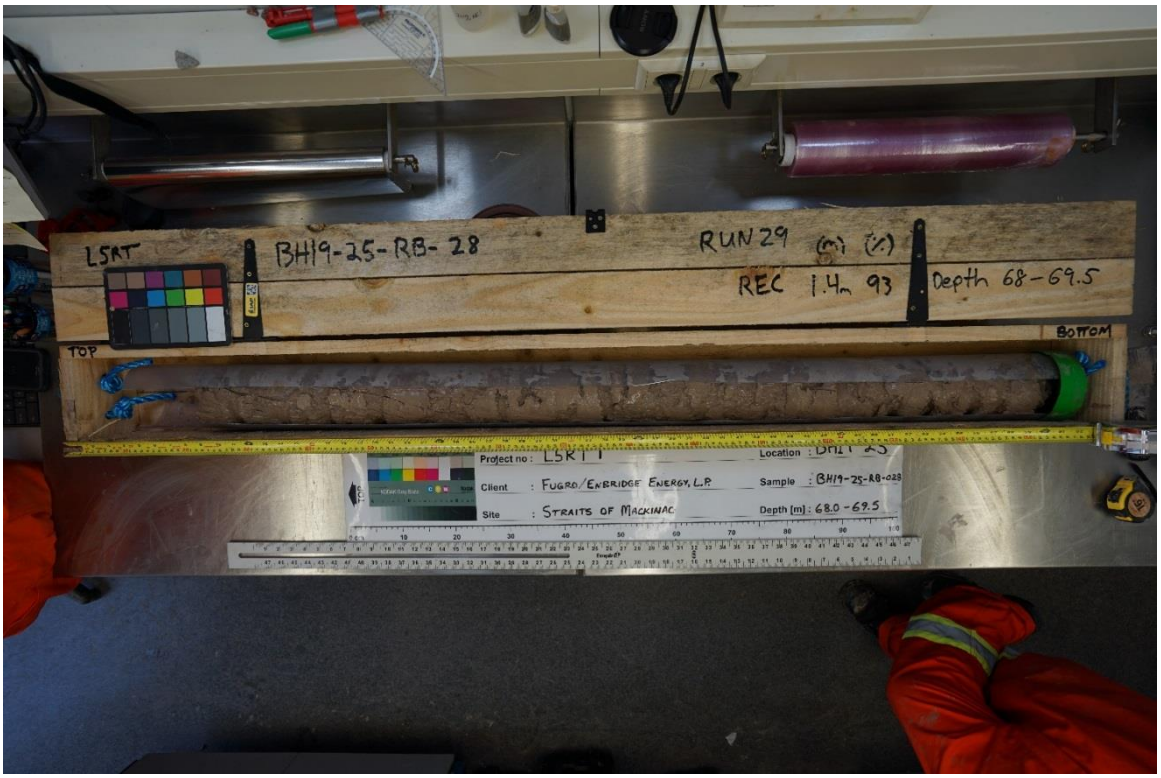
BH19-25-RB-024

BH19-25-RB-025

BH19-25-RB-026



BH19-25-RB-027

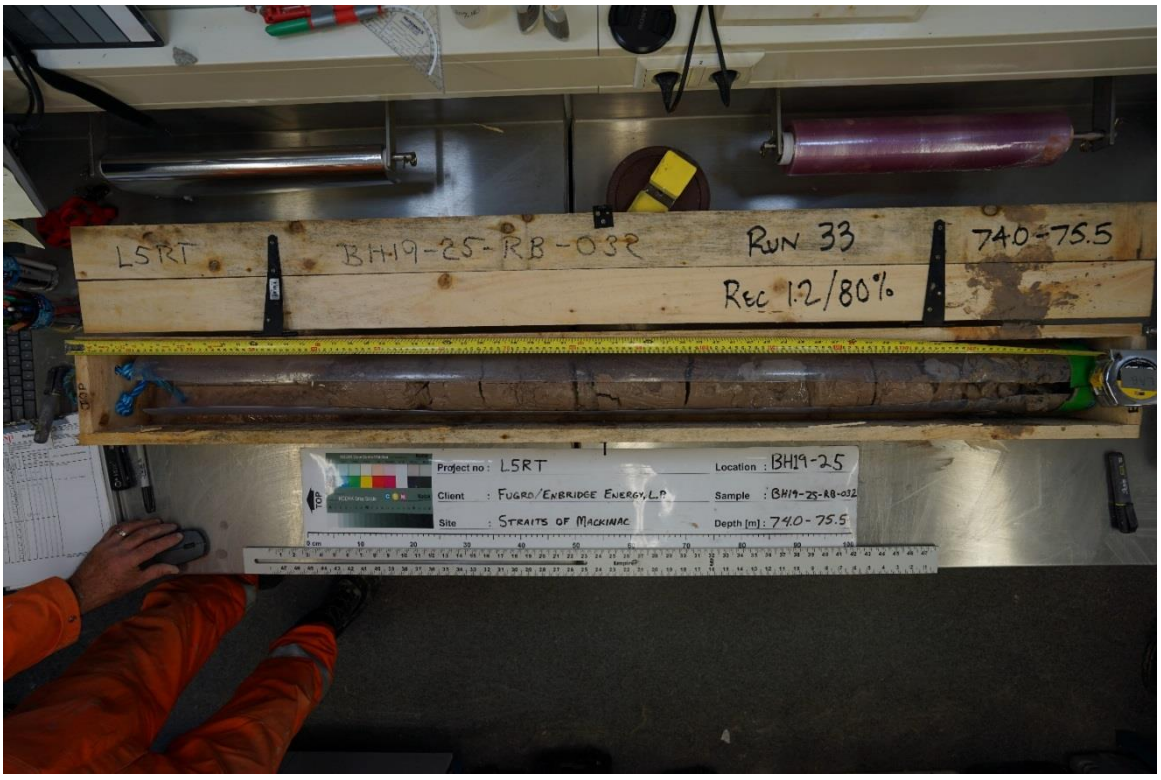


BH19-25-RB-028

BH19-25-RB-029

BH19-25-RB-030

BH19-25-RB-031



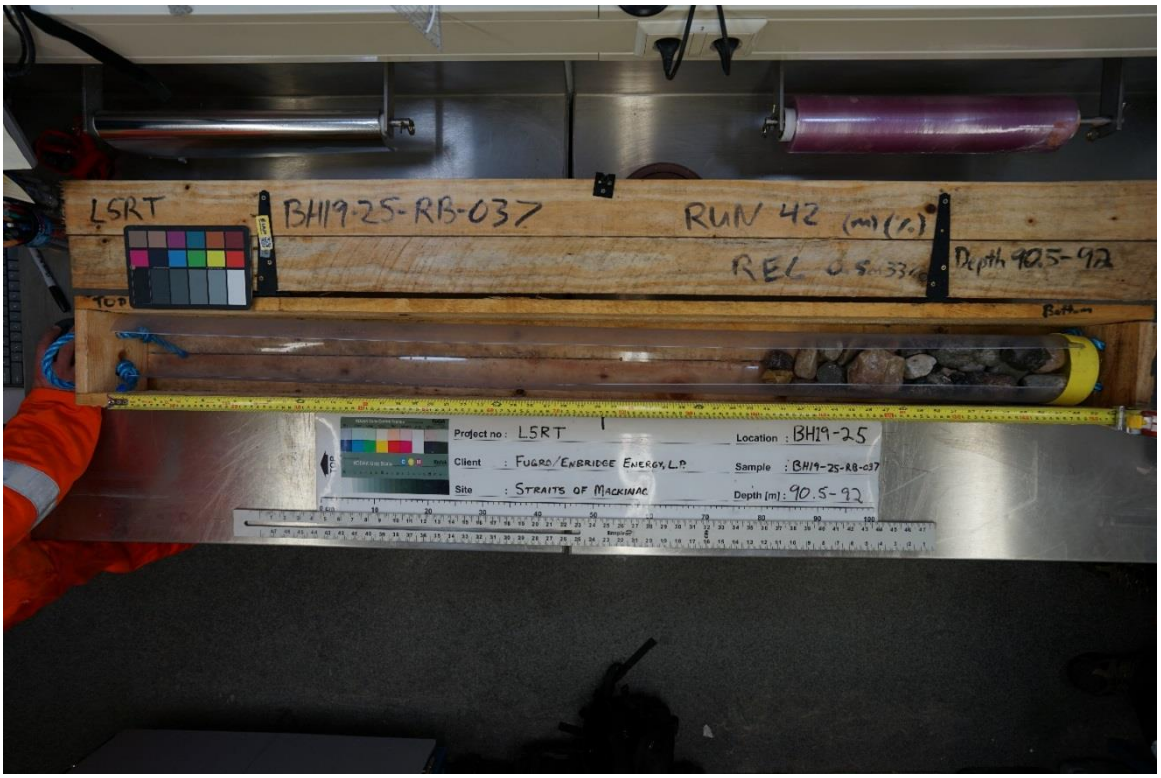
BH19-25-RB-032

BH19-25-RB-033

BH19-25-RB-034

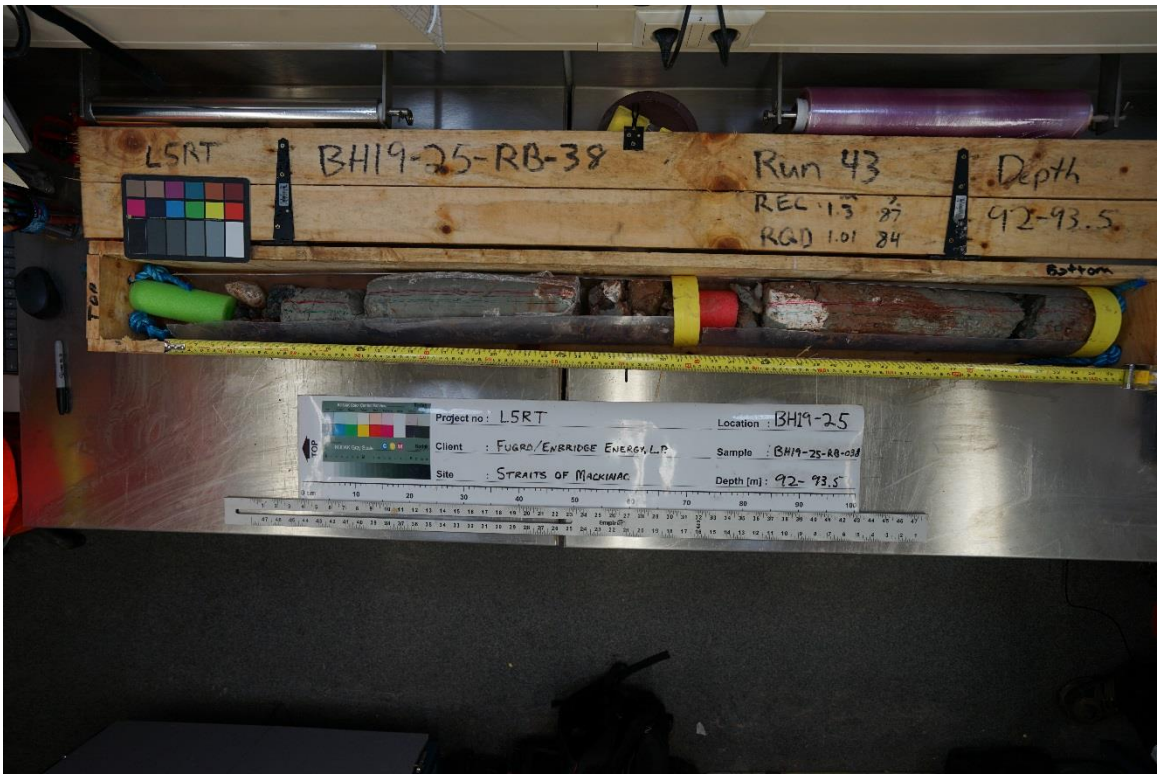
BH19-25-RB-035

BH19-25-RB-036



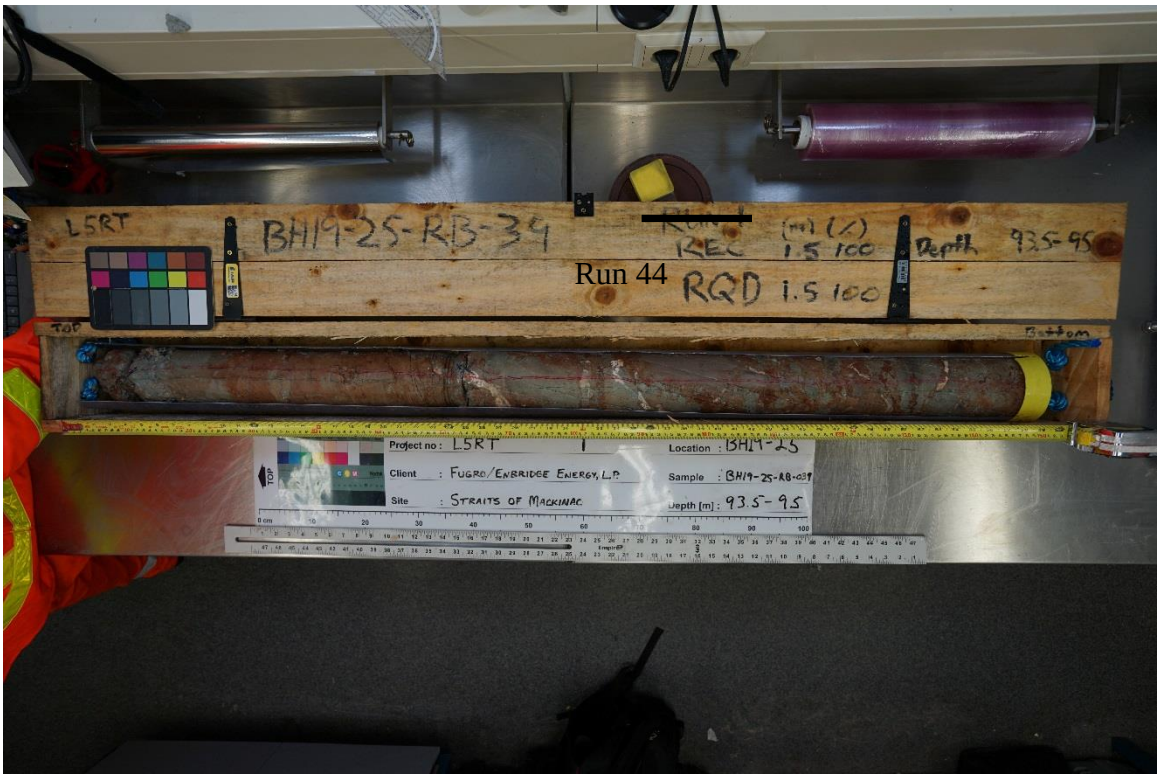
BH19-25-RB-037

[Intentionally Left Blank]

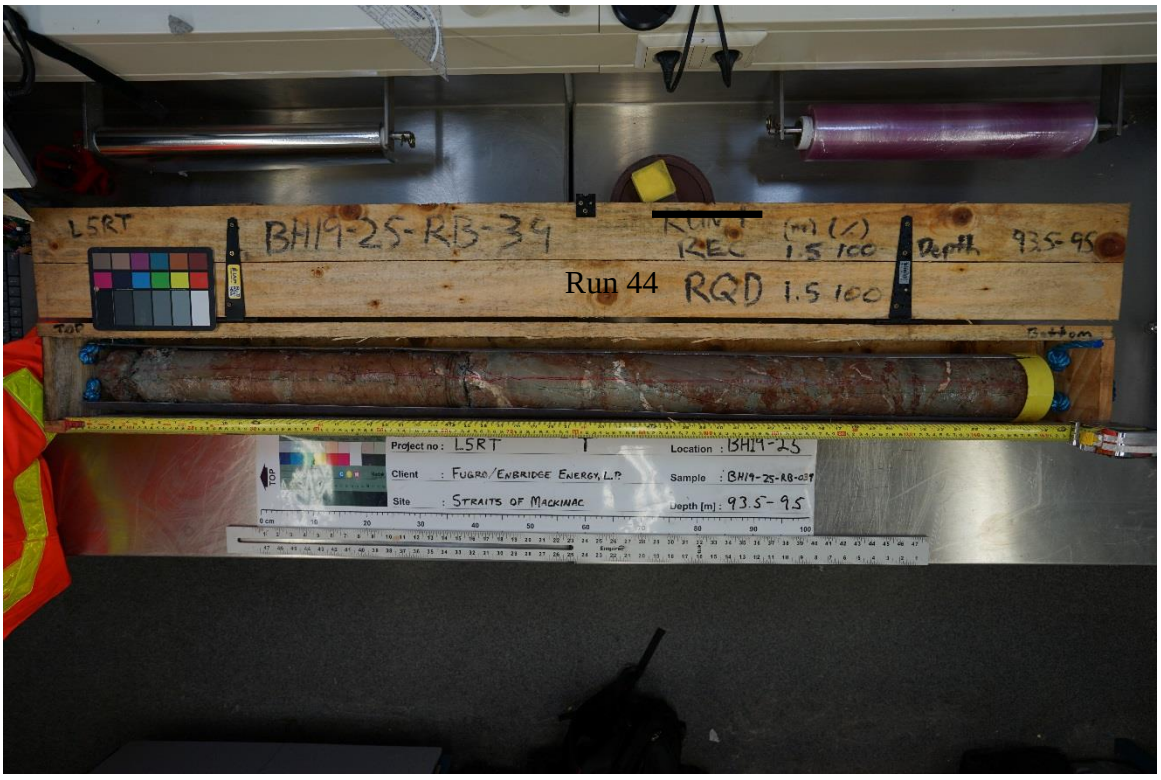


BH19-25-RB-038 (Dry)

BH19-25-RB-038 (Wet)



BH19-25-RB-039 (Dry)



BH19-25-RB-039 (Wet)

BH19-25-RB-040 (Dry)

BH19-25-RB-040 (Wet)

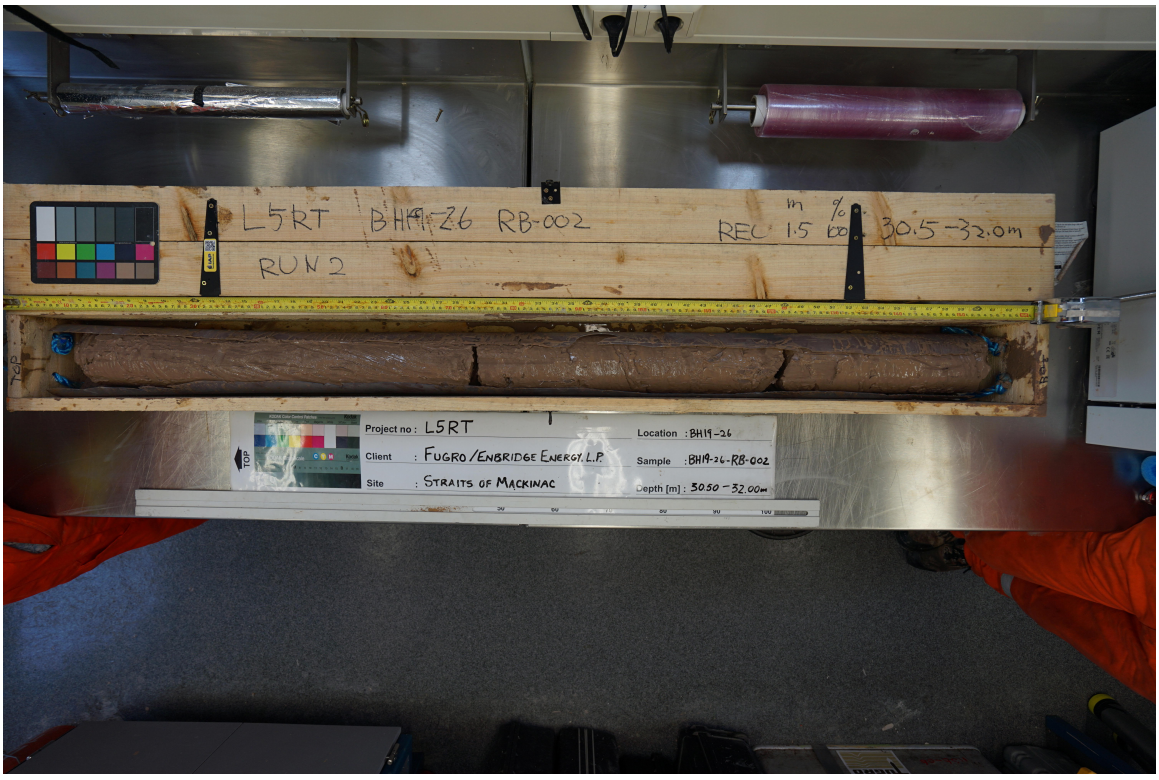
BH19-25-RB-041 (Dry)

BH19-25-RB-041 (Wet)

BH19-25-RB-042 (Dry)

BH19-25-RB-042 (Wet)

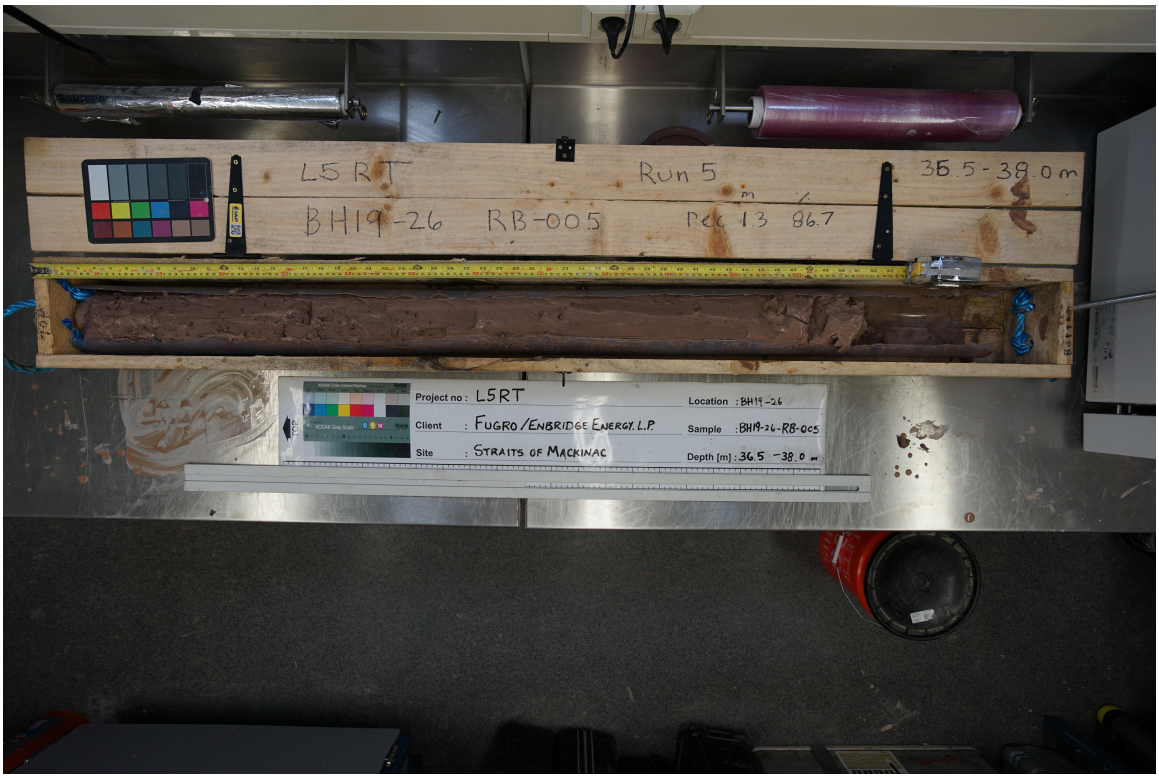
BH19-26-RB-001



BH19-26-RB-002

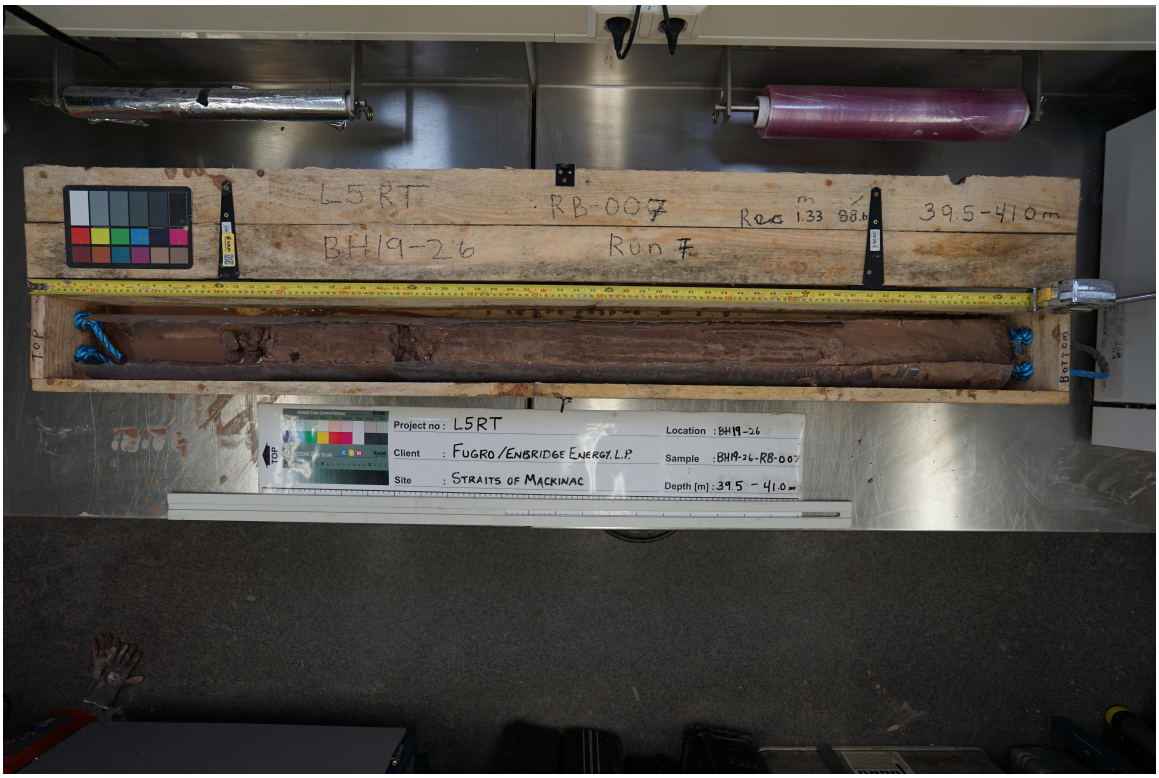
BH19-26-RB-003

BH19-26-RB-004



BH19-26-RB-005

BH19-26-RB-006

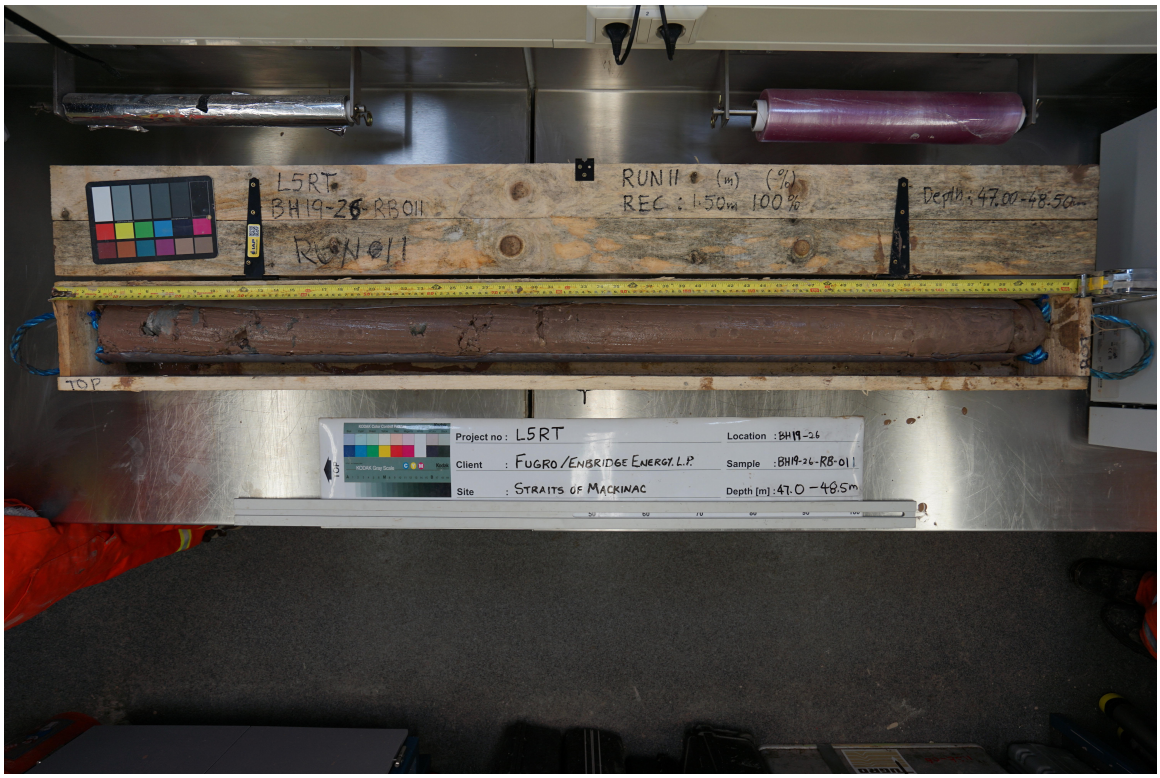


BH19-26-RB-007

BH19-26-RB-008

BH19-26-RB-009

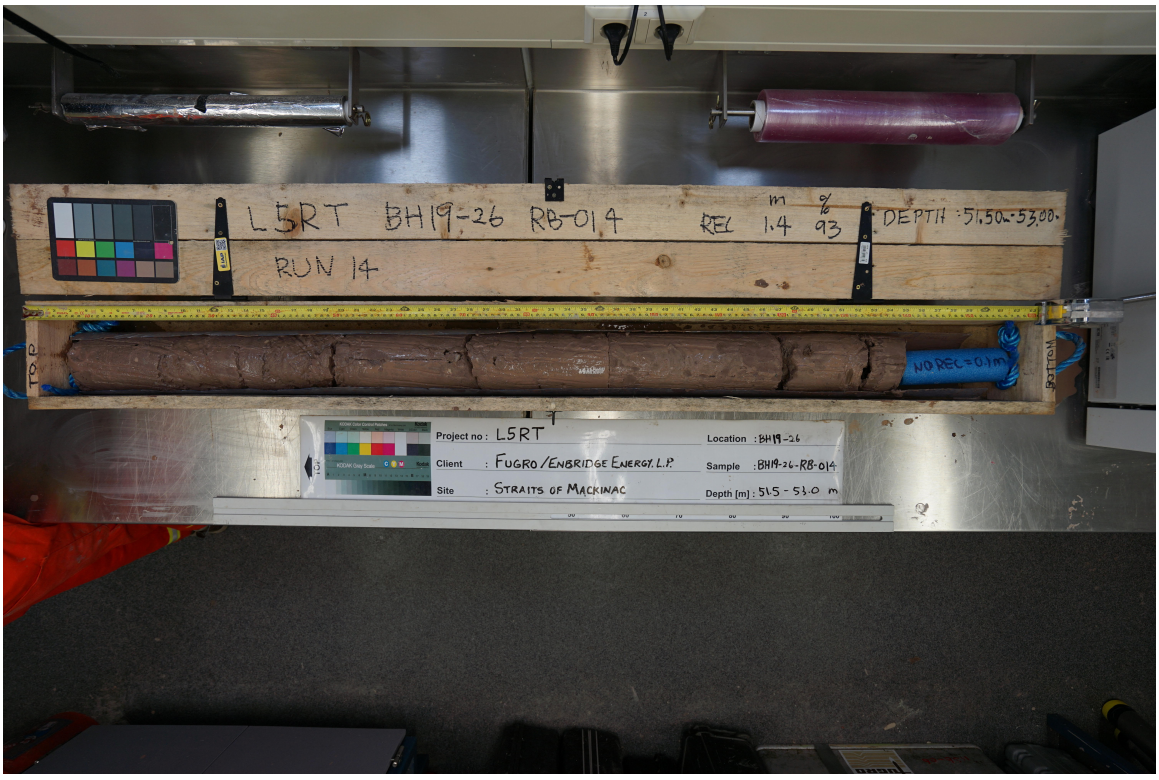
BH19-26-RB-010



BH19-26-RB-011

BH19-26-RB-012

BH19-26-RB-013



BH19-26-RB-014

BH19-26-RB-015

BH19-26-RB-016

BH19-26-RB-017

BH19-26-RB-018

BH19-26-RB-019

BH19-26-RB-020

BH19-26-RB-021

BH19-26-RB-022

BH19-26-RB-023

BH19-26-RB-024

BH19-26-RB-025

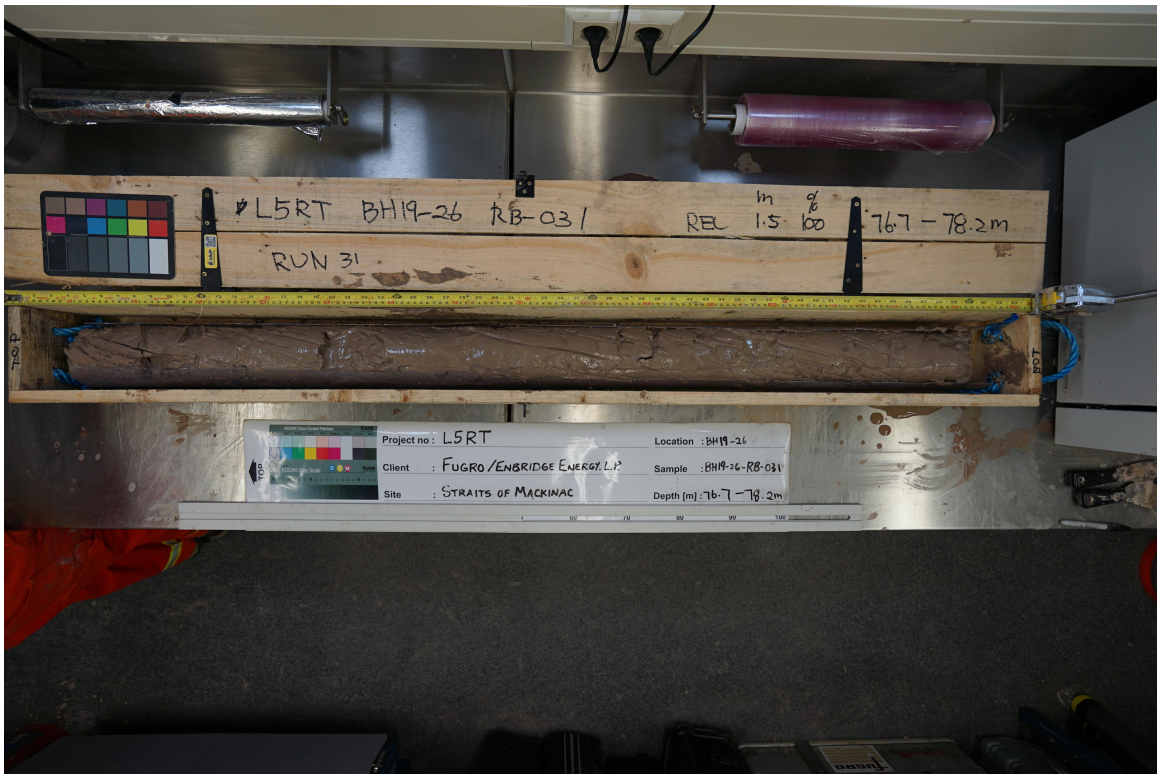
BH19-26-RB-026

BH19-26-RB-027

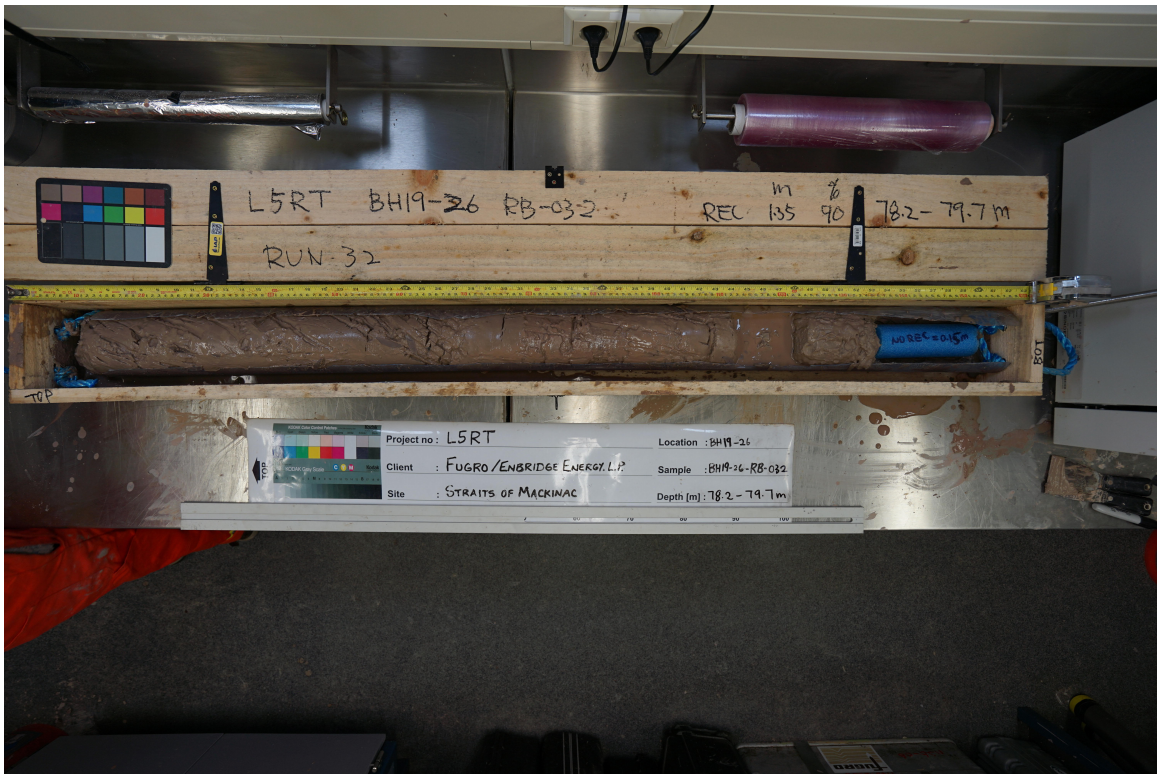
BH19-26-RB-028

BH19-26-RB-029

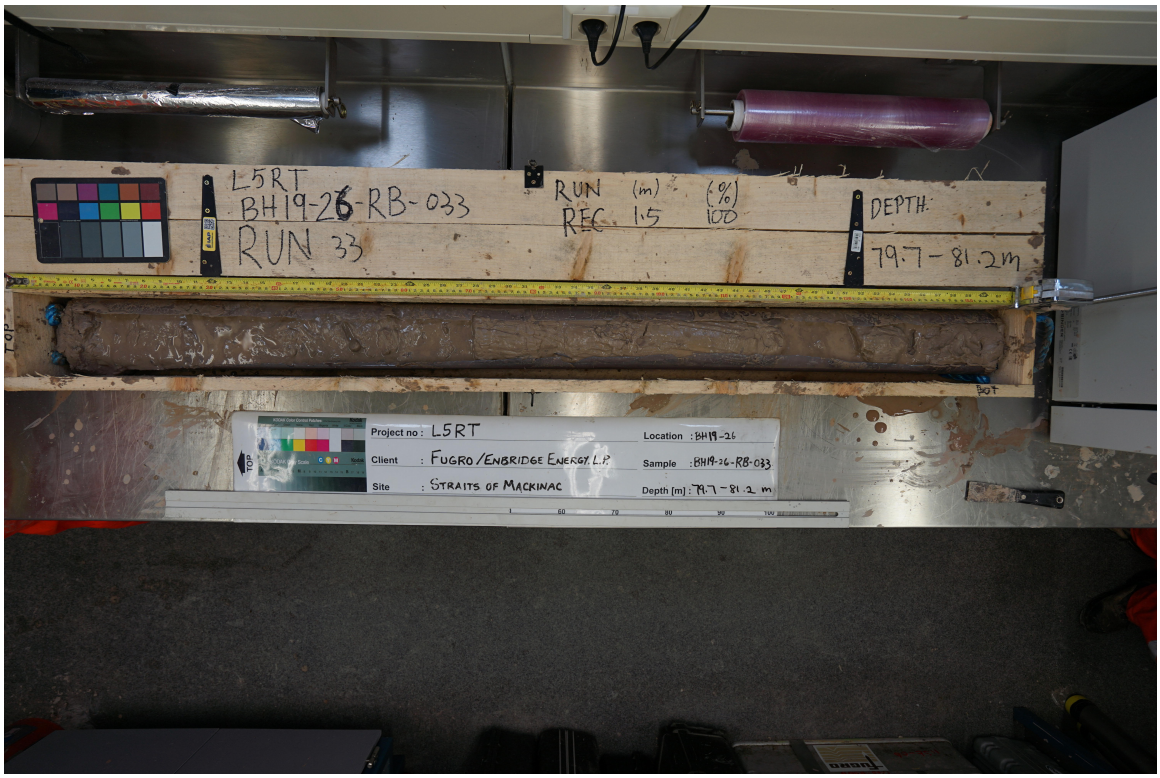
BH19-26-RB-030



BH19-26-RB-031



BH19-26-RB-032



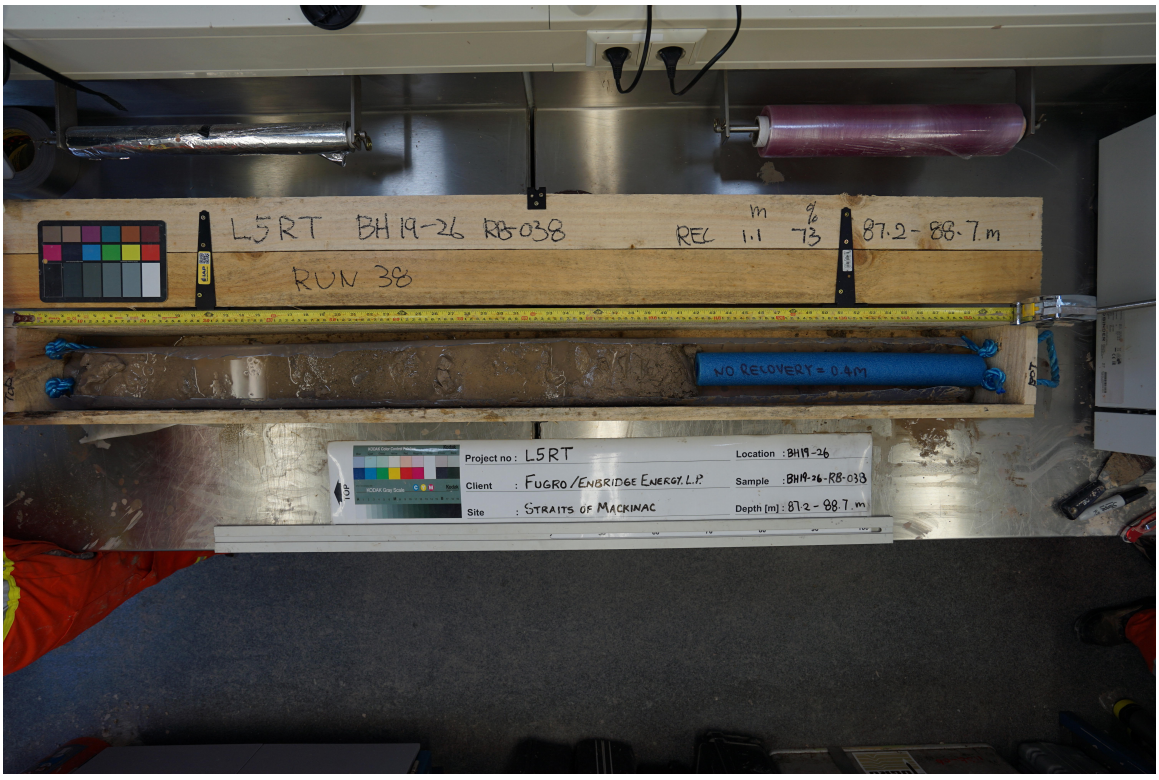
BH19-26-RB-033

BH19-26-RB-034

BH19-26-RB-035

BH19-26-RB-036

BH19-26-RB-037



BH19-26-RB-038

BH19-26-RB-039

BH19-26-RB-040

BH19-26-RB-041

BH19-26-RB-042

BH19-26-RB-043

BH19-26-RB-044

BH19-26-RB-045

[Intentionally Left Blank]

BH19-26-RB-046 (Dry)

BH19-26-RB-046 (Wet)

BH19-26-RB-047 (Dry)

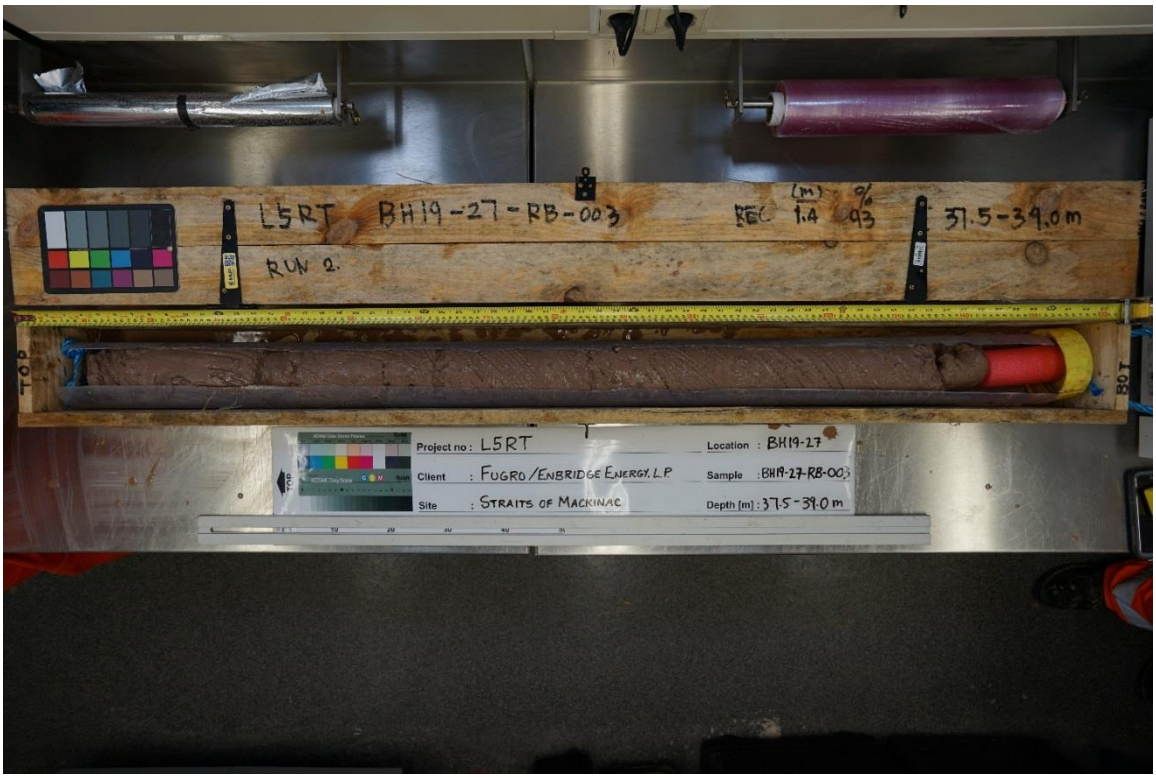
BH19-26-RB-047 (Wet)

BH19-26-RB-048 (Dry)

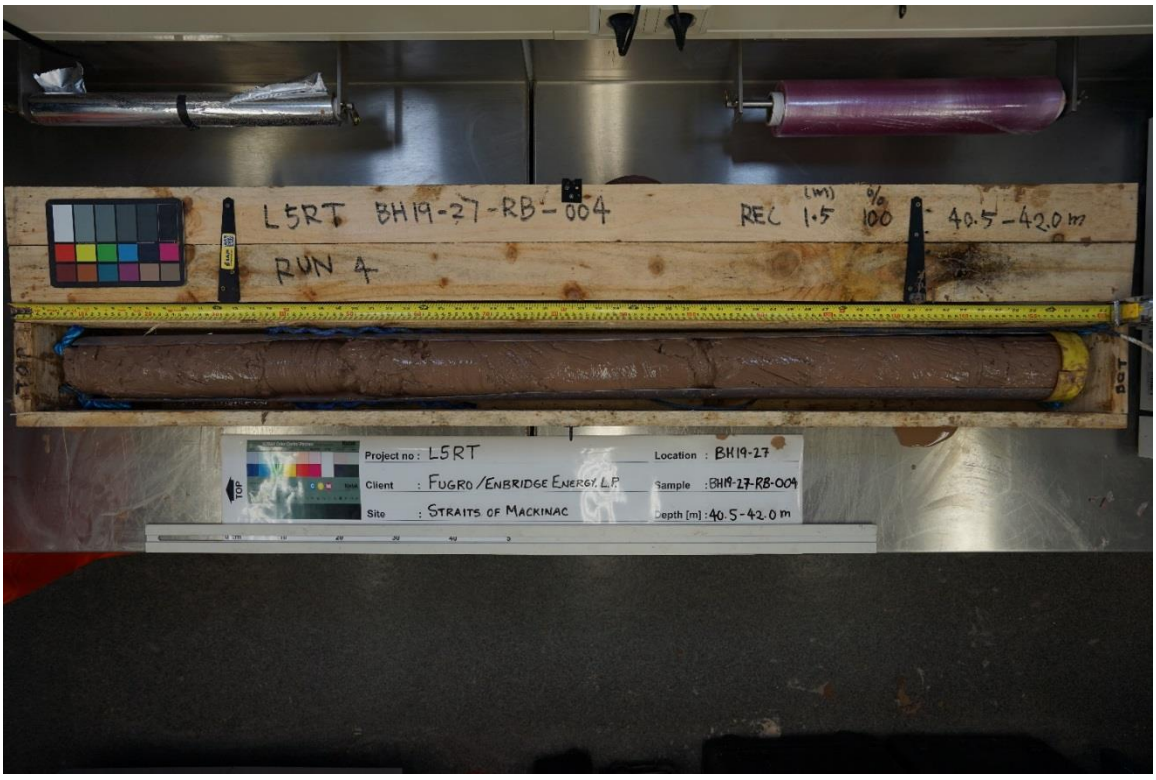
BH19-26-RB-048 (Wet)

BH19-27-RB-001

BH19-27-RB-002



BH19-27-RB-003



BH19-27-RB-004

BH19-27-RB-005

BH19-27-RB-006

BH19-27-RB-007

BH19-27-RB-008

BH19-27-RB-009

BH19-27-RB-010

BH19-27-RB-011

BH19-27-RB-012

BH19-27-RB-013

BH19-27-RB-014

BH19-27-RB-015

BH19-27-RB-016

BH19-27-RB-017

BH19-27-RB-018

BH19-27-RB-019

BH19-27-RB-020

BH19-27-RB-021

BH19-27-RB-022

BH19-27-RB-023

BH19-27-RB-024

BH19-27-RB-025

BH19-27-RB-026

BH19-27-RB-027

BH19-27-RB-028

BH19-27-RB-029

BH19-27-RB-030

BH19-27-RB-031

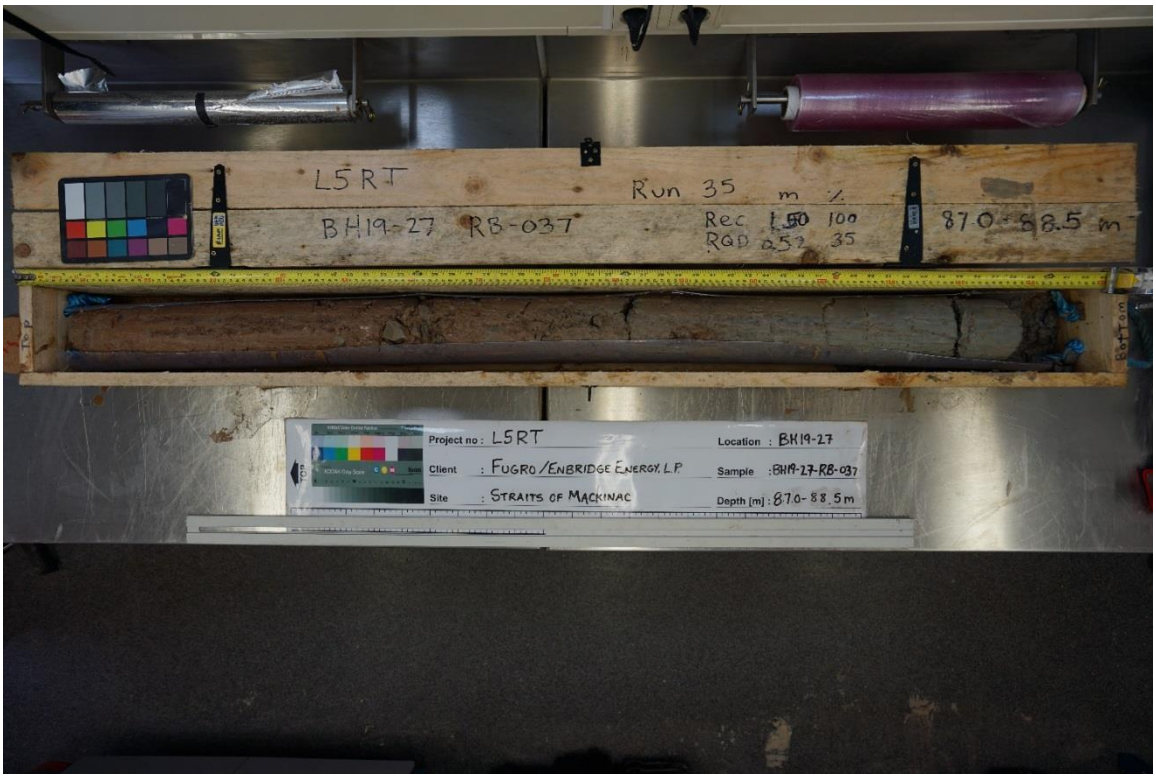
BH19-27-RB-032

BH19-27-RB-033

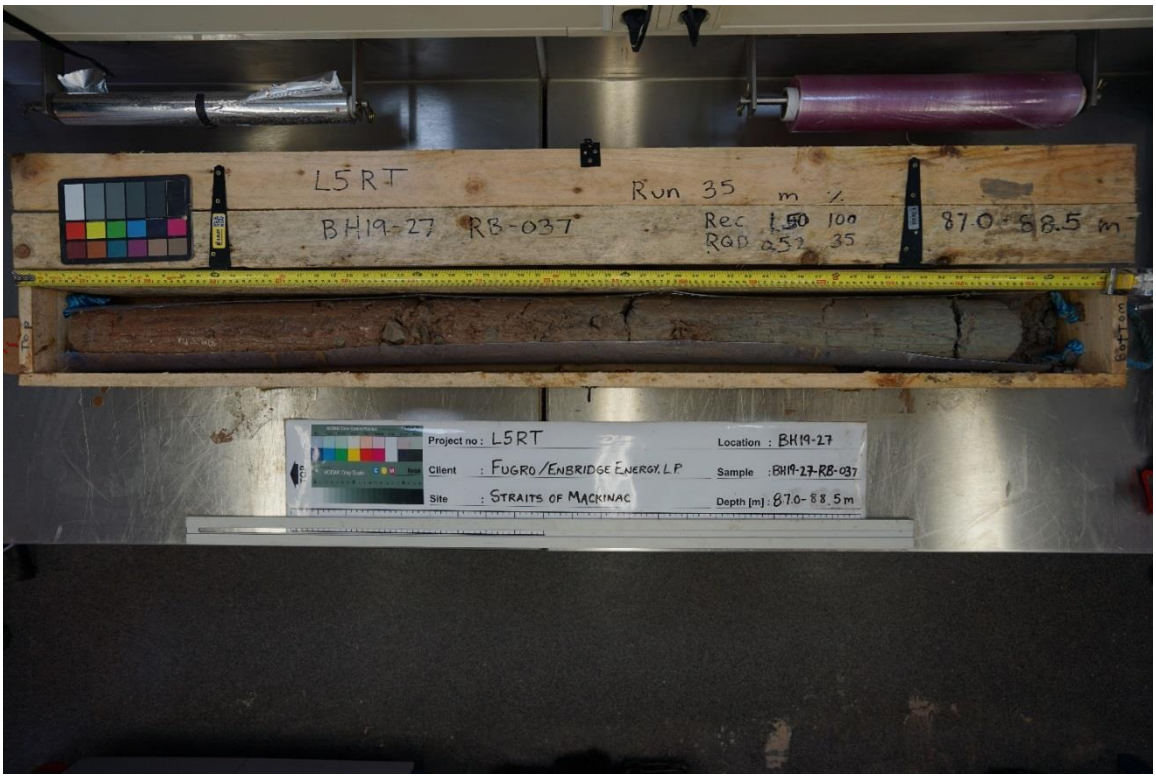
BH19-27-RB-034

BH19-27-RB-035

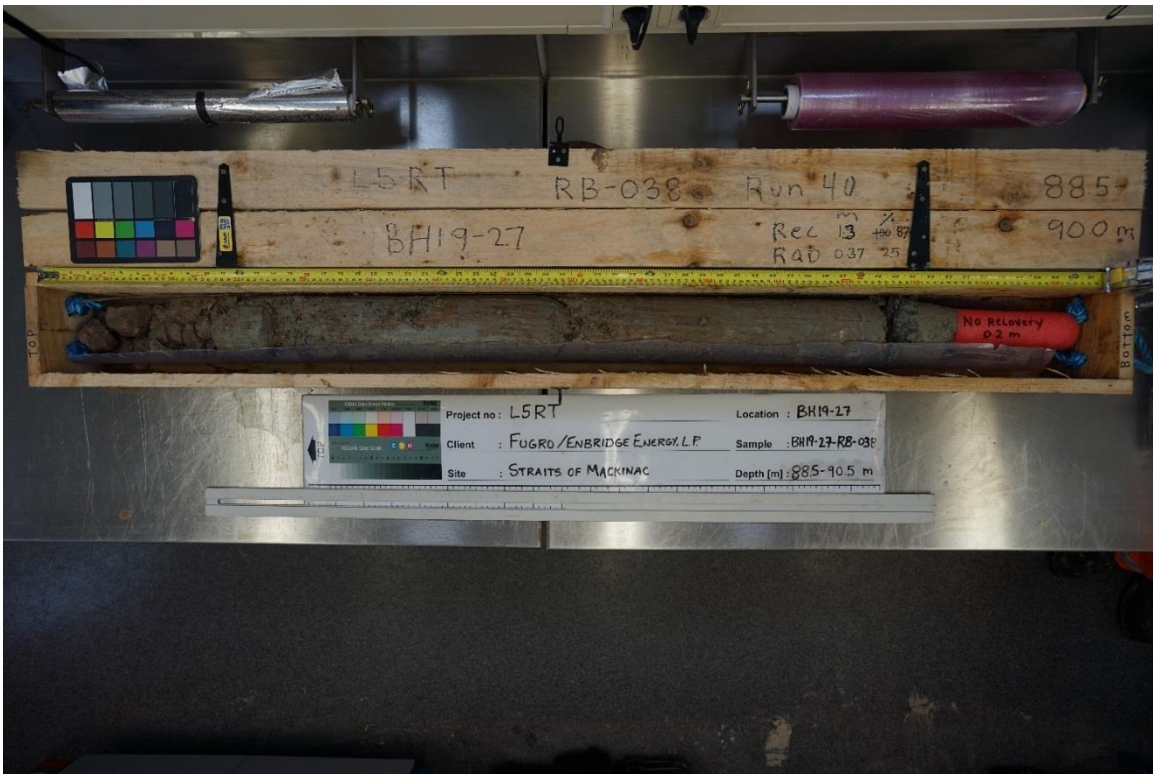
BH19-27-RB-036



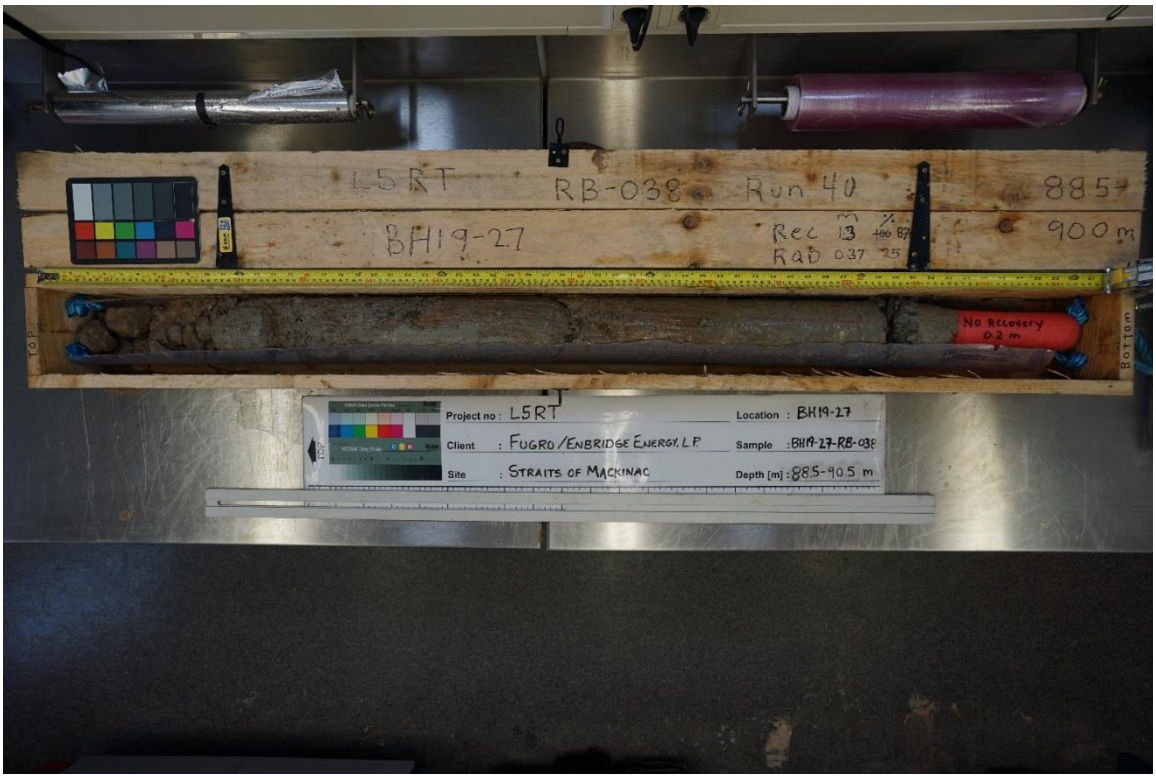
BH19-27-RB-037 (Dry)



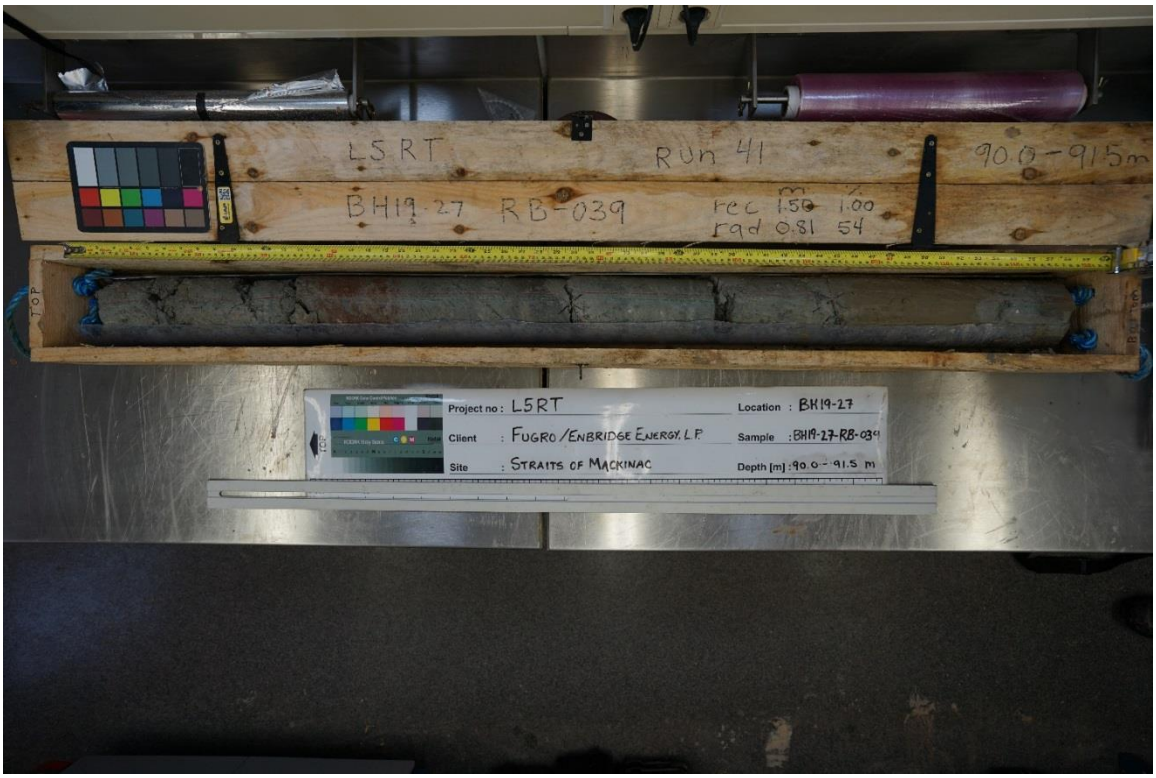
BH19-27-RB-037 (Wet)



BH19-27-RB-038 (Dry)



BH19-27-RB-038 (Wet)

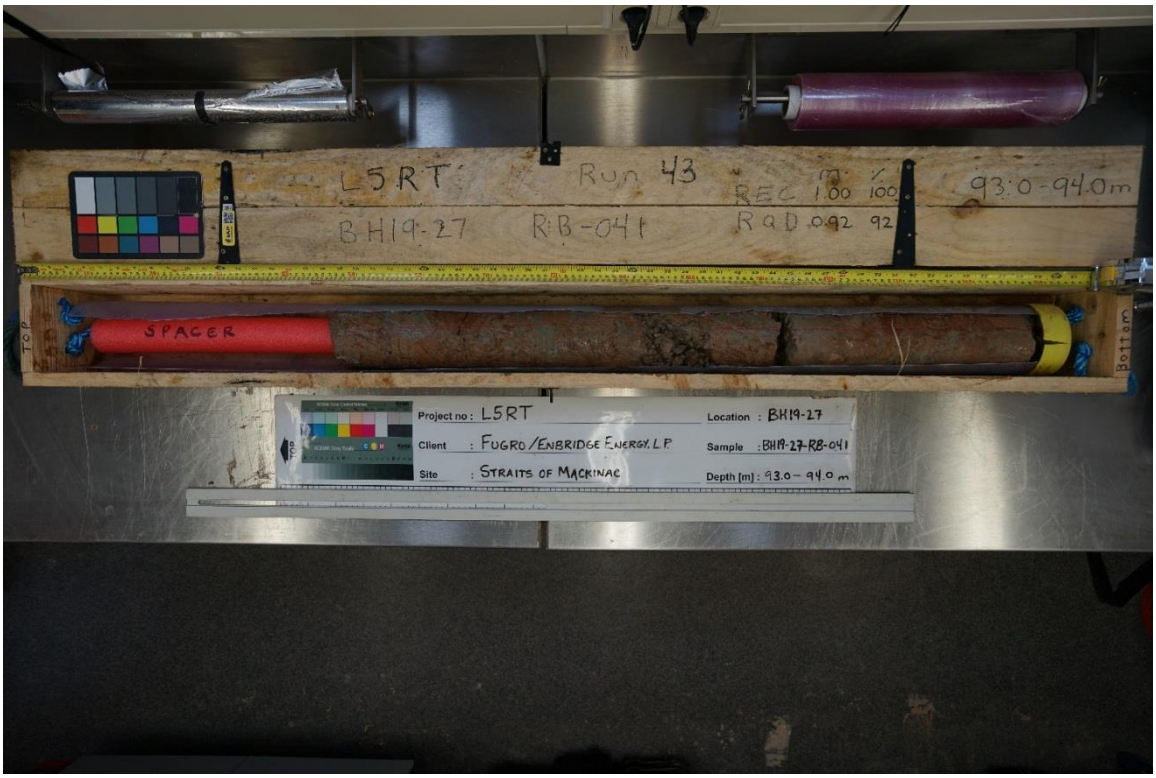


BH19-27-RB-039 (Dry)

BH19-27-RB-039 (Wet)

BH19-27-RB-040 (Dry)

BH19-27-RB-040 (Wet)



BH19-27-RB-041 (Dry)

BH19-27-RB-041 (Wet)

BH19-27-RB-042 (Dry)

BH19-27-RB-042 (Wet)

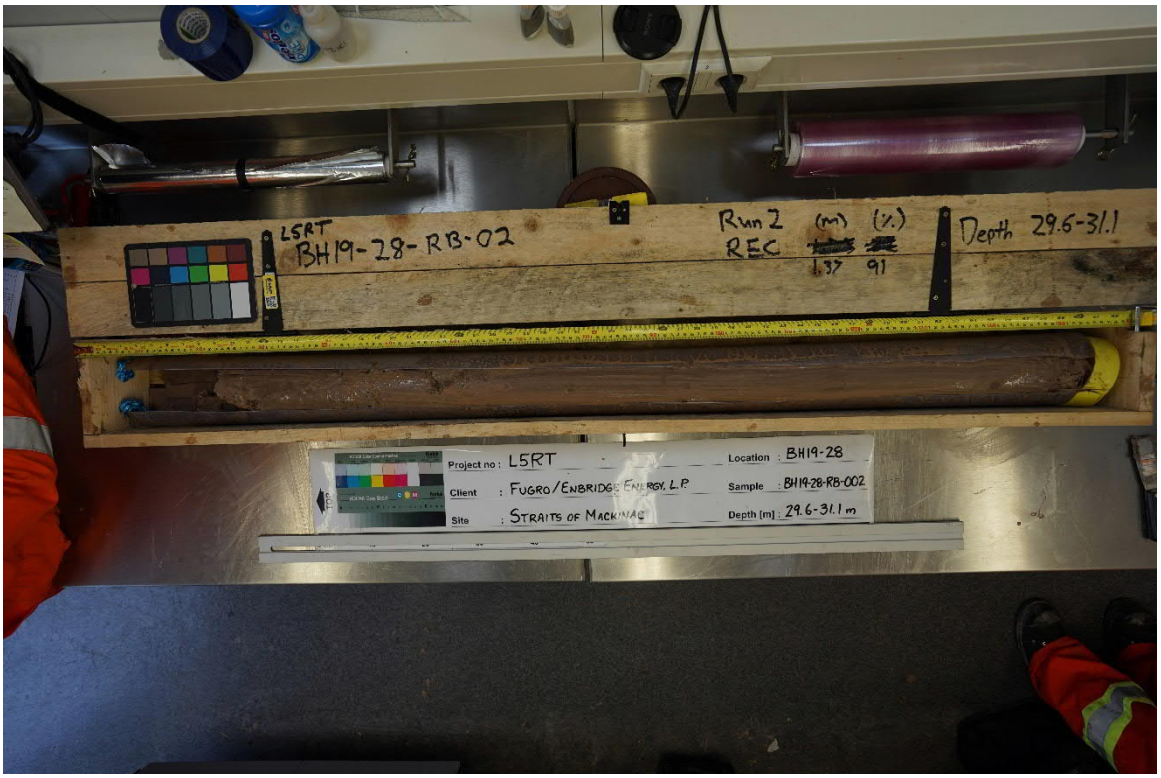
BH19-27-RB-043 (Dry)

BH19-27-RB-043 (Wet)

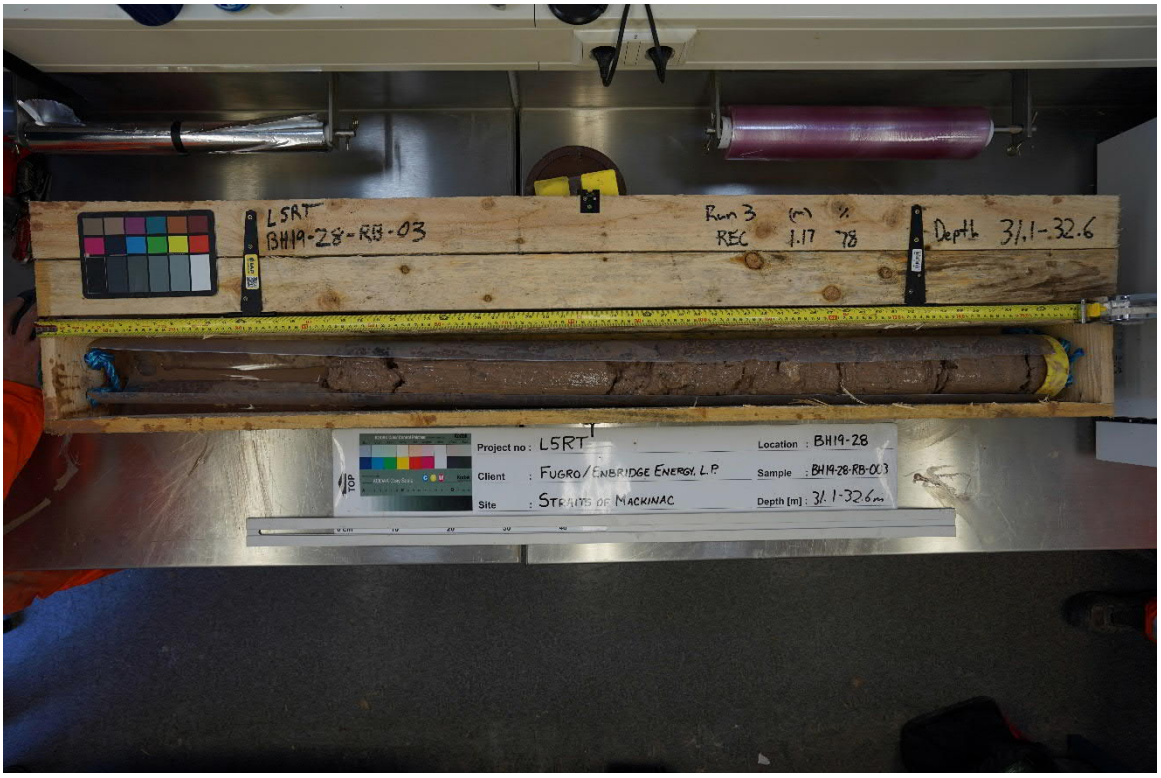
BH19-27-RB-044 (Dry)

BH19-27-RB-044 (Wet)

BH19-28-RB-001



BH19-28-RB-002



BH19-28-RB-003

BH19-28-RB-004

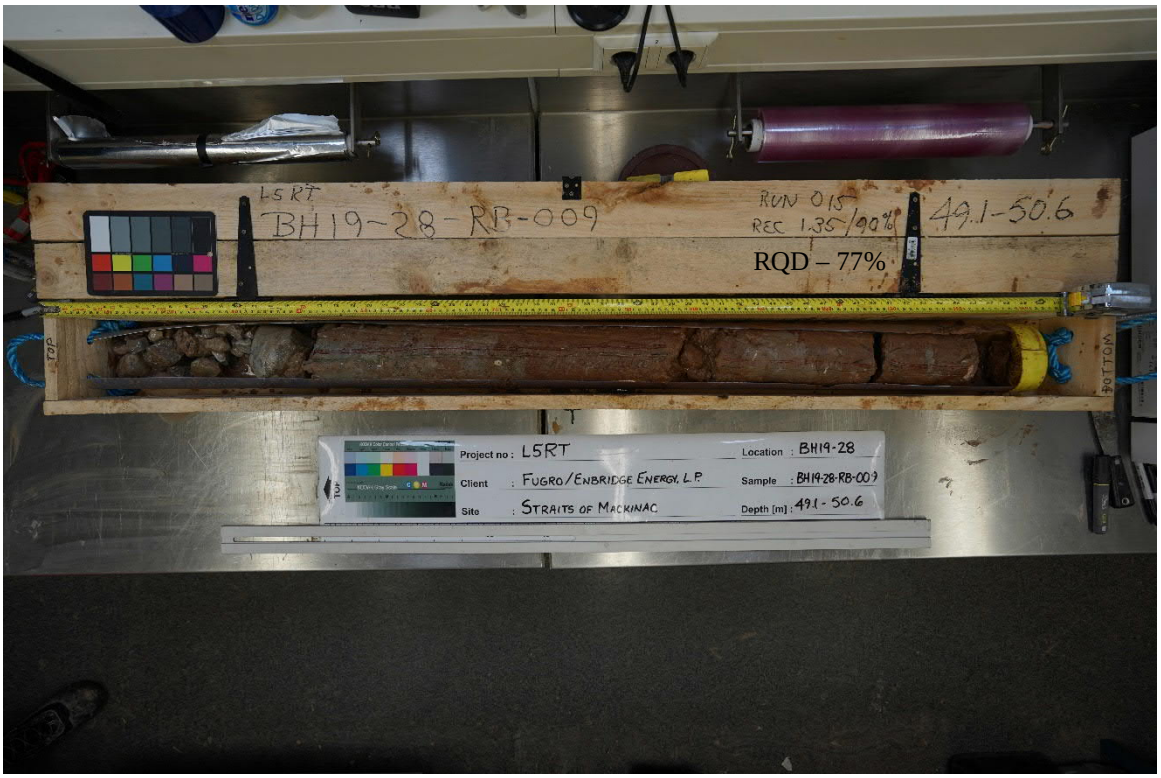
BH19-28-RB-005

BH19-28-RB-006

BH19-28-RB-007

BH19-28-RB-008

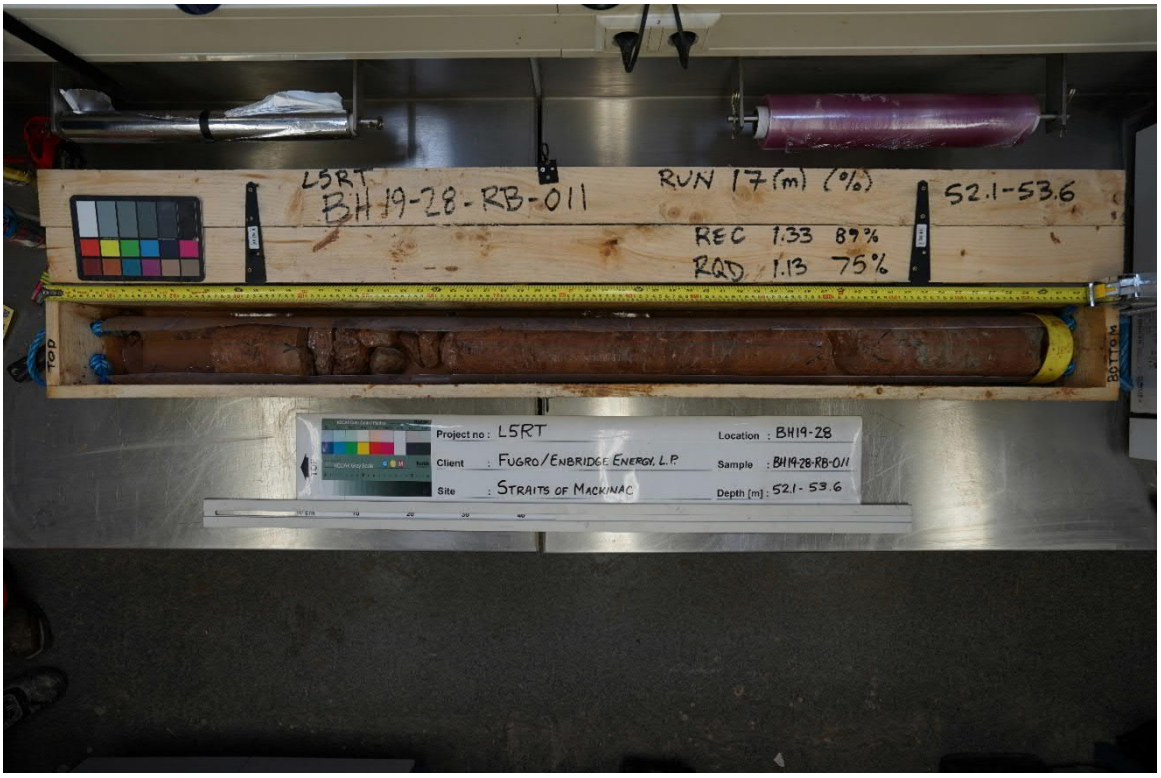
BH19-28-RB-009 (Dry)



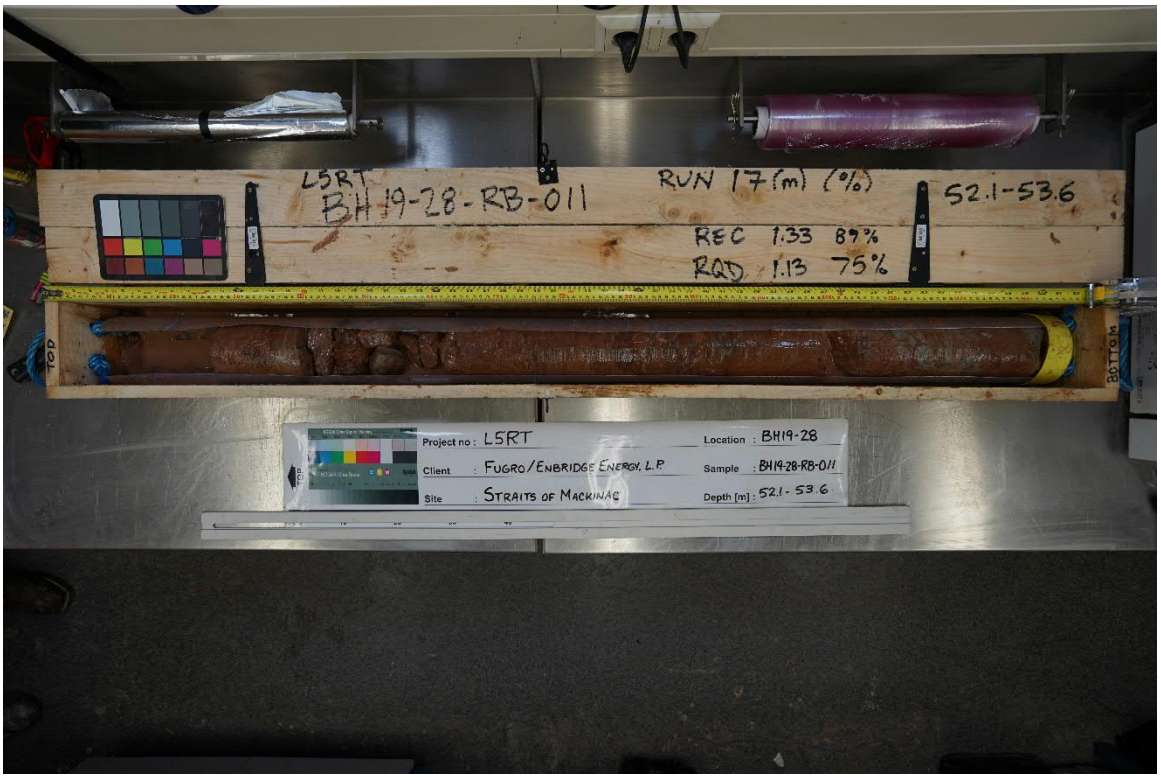
BH19-28-RB-009 (Wet)

BH19-28-RB-010 (Dry)

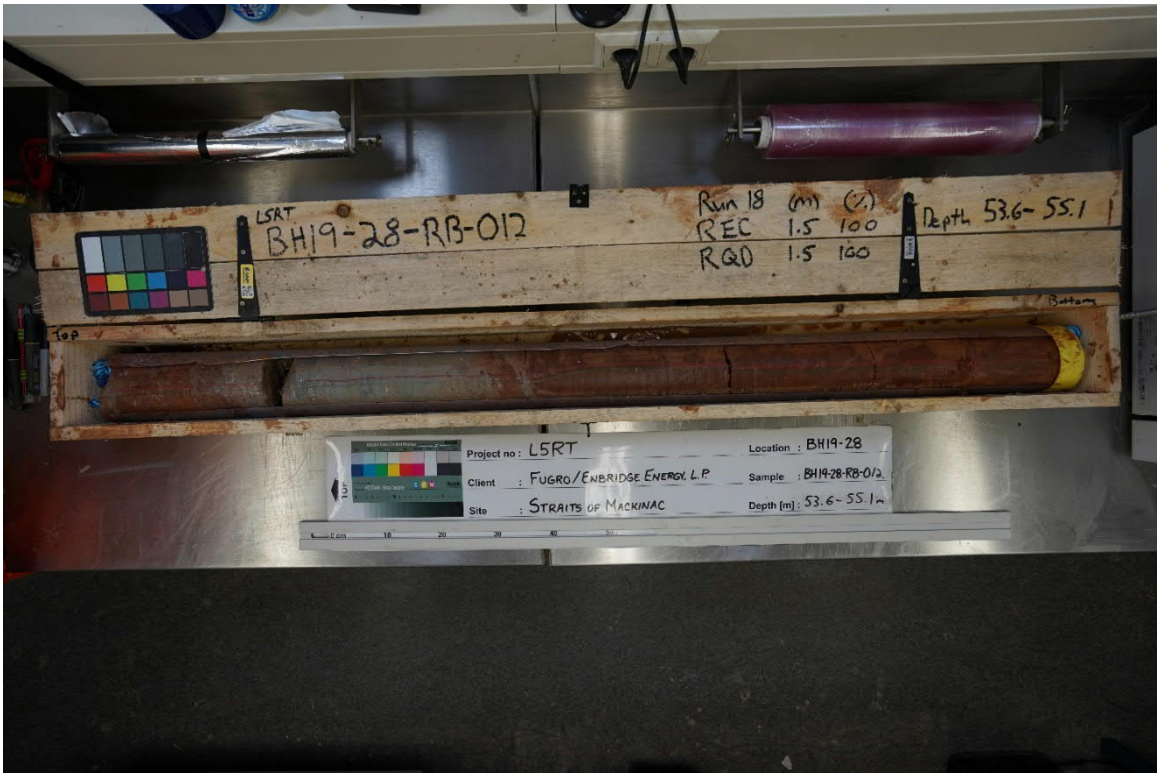
BH19-28-RB-010 (Wet)



BH19-28-RB-011 (Dry)



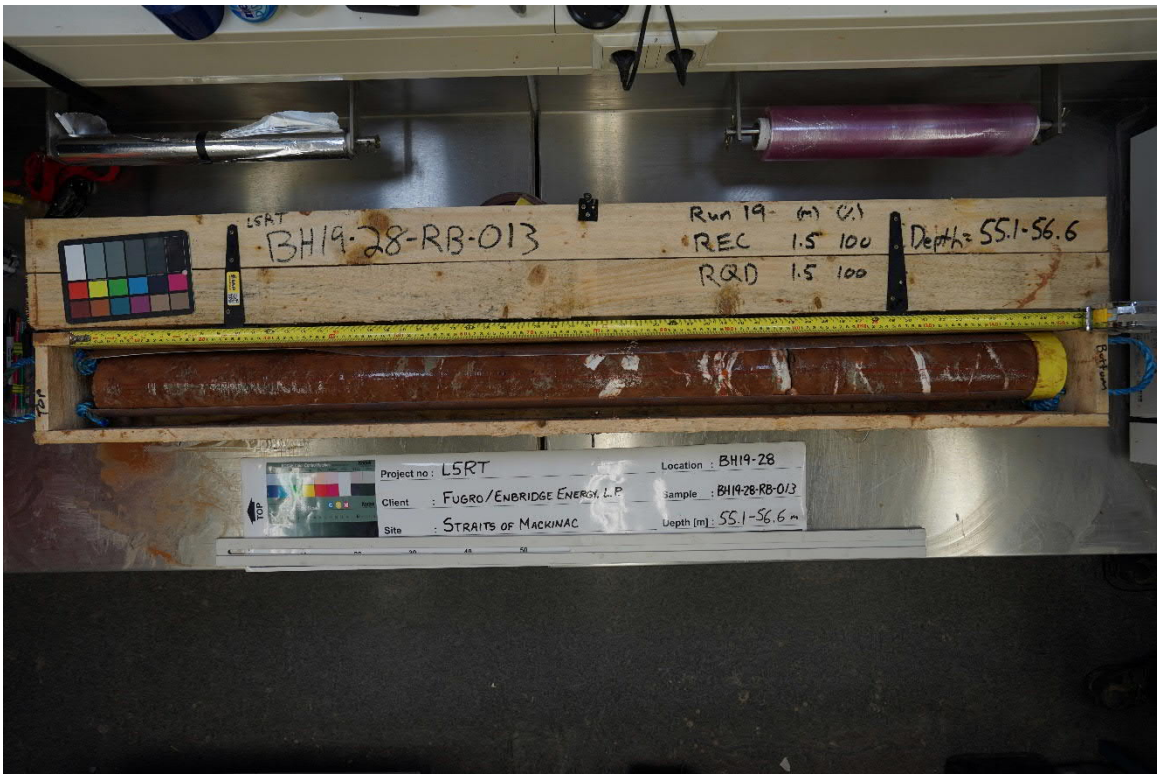
BH19-28-RB-011 (Wet)



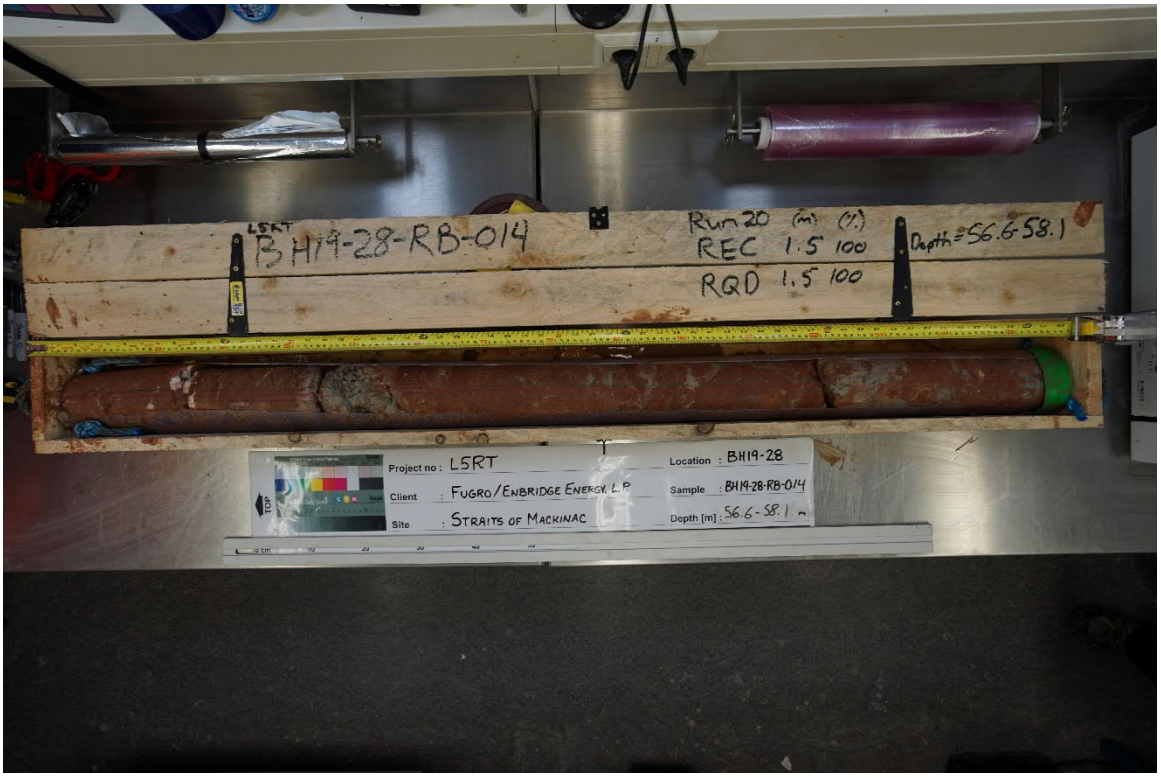
BH19-28-RB-012 (Dry)

BH19-28-RB-012 (Wet)

BH19-28-RB-013 (Dry)

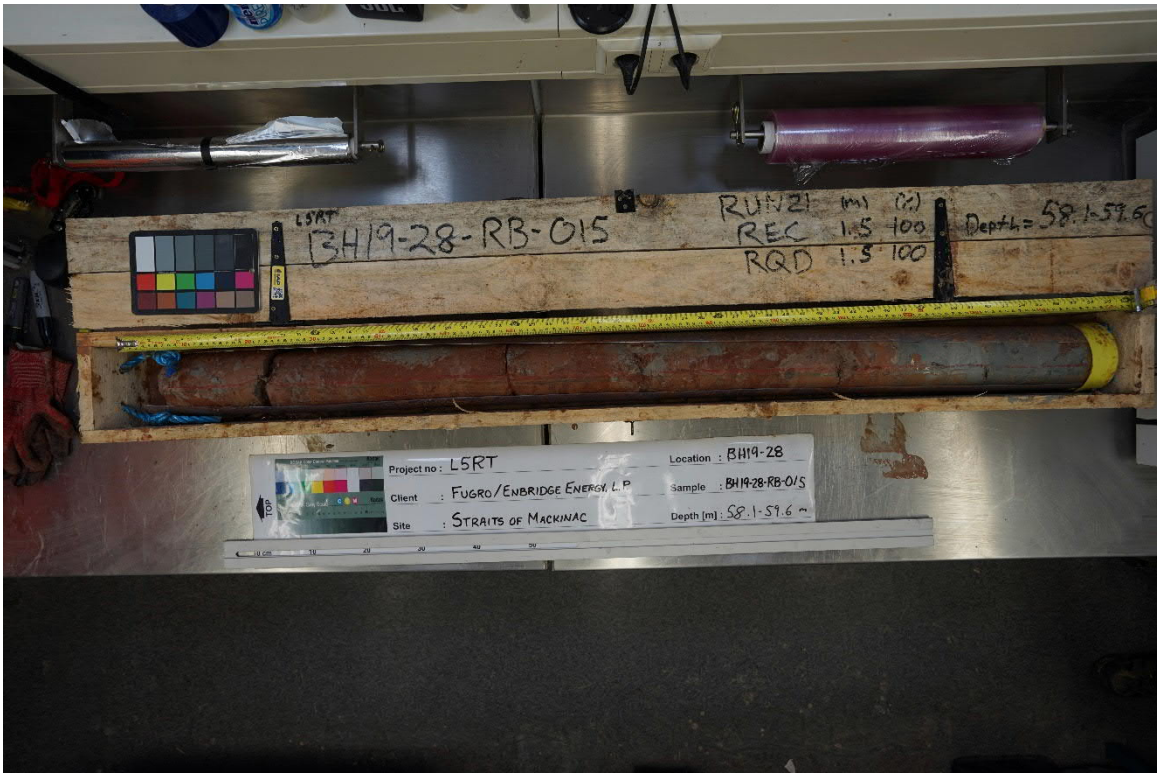


BH19-28-RB-013 (Wet)



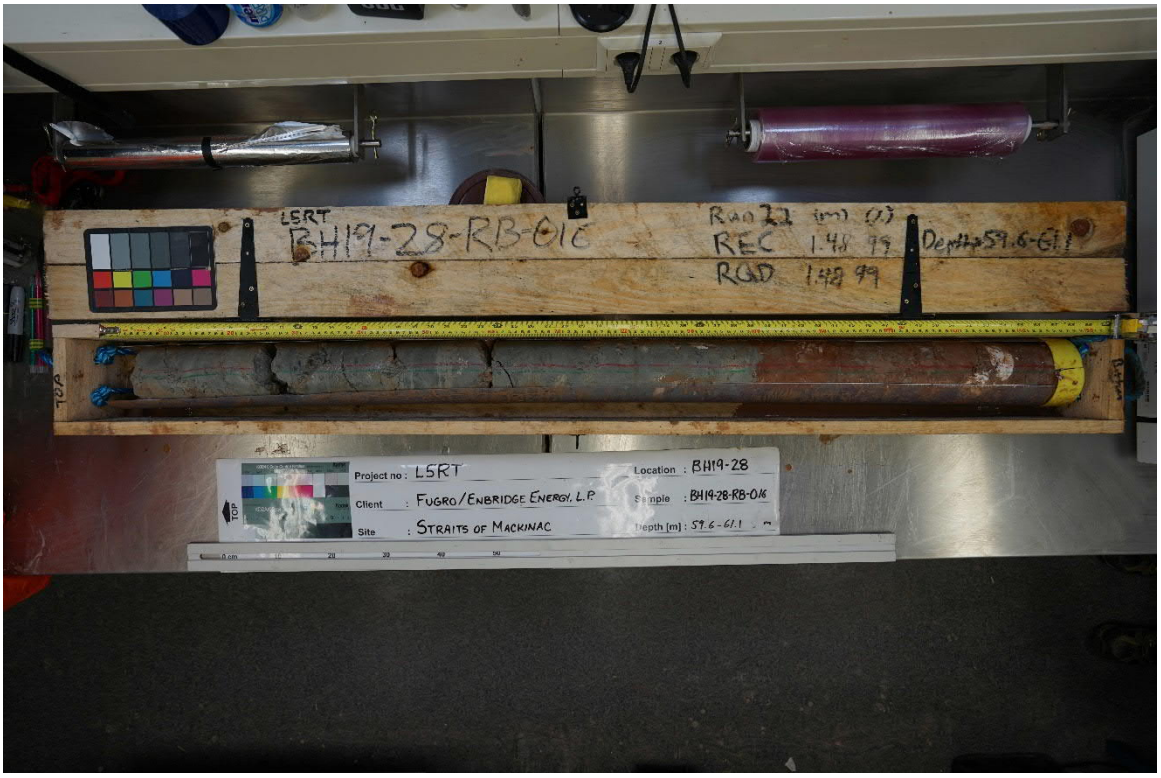
BH19-28-RB-014 (Dry)

BH19-28-RB-014 (Wet)



BH19-28-RB-015(Dry)

BH19-28-RB-015 (Wet)



BH19-28-RB-016 (Dry)

BH19-28-RB-016 (Wet)

BH19-28-RB-017 (Dry)

BH19-28-RB-017 (Wet)

BH19-28-RB-018 (Dry)

BH19-28-RB-018 (Wet)

BH19-28-RB-019 (Dry)

BH19-28-RB-019 (Wet)

BH19-28-RB-020 (Dry)

BH19-28-RB-020 (Wet)

BH19-28-RB-021 (Dry)

BH19-28-RB-021 (Wet)

BH19-28-RB-022 (Dry)

BH19-28-RB-022 (Wet)

BH19-28-RB-023 (Dry)

BH19-28-RB-023 (Wet)

BH19-28-RB-024 (Dry)

BH19-28-RB-024 (Wet)

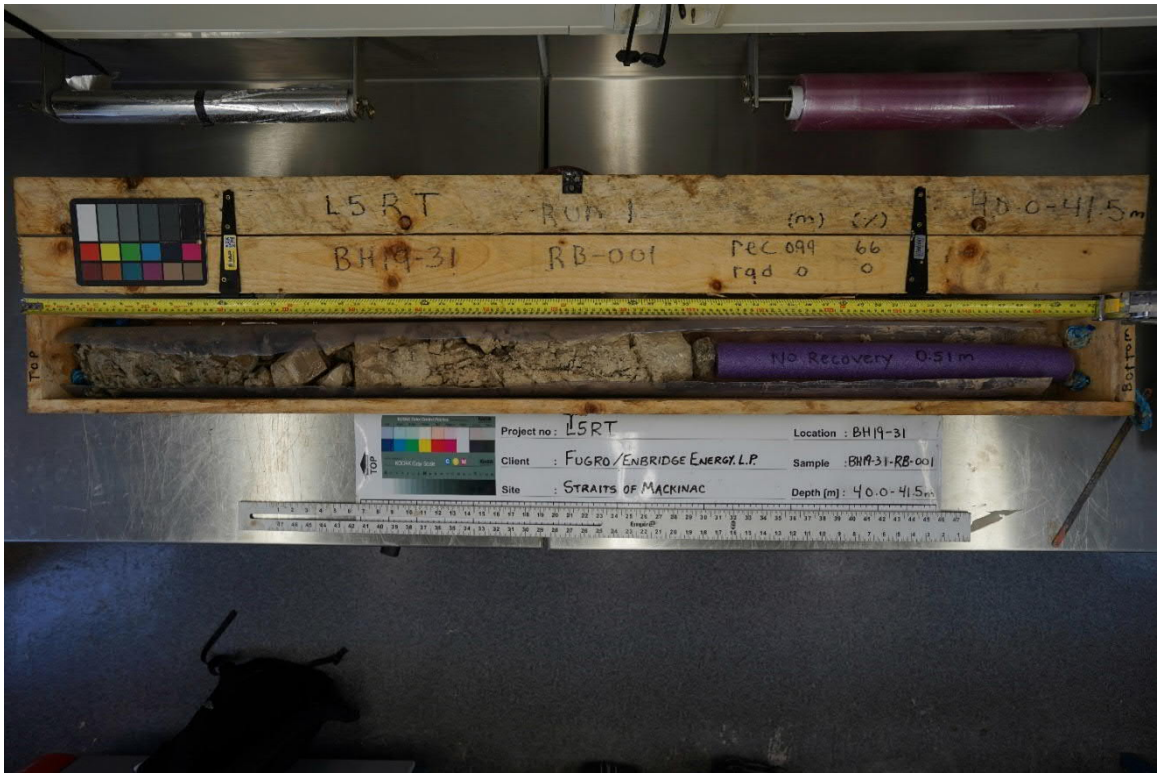
BH19-28-RB-025 (Dry)

BH19-28-RB-025 (Wet)

BH19-28-RB-026 (Dry)

BH19-28-RB-026 (Wet)

BH19-31-RB-001 (Dry)



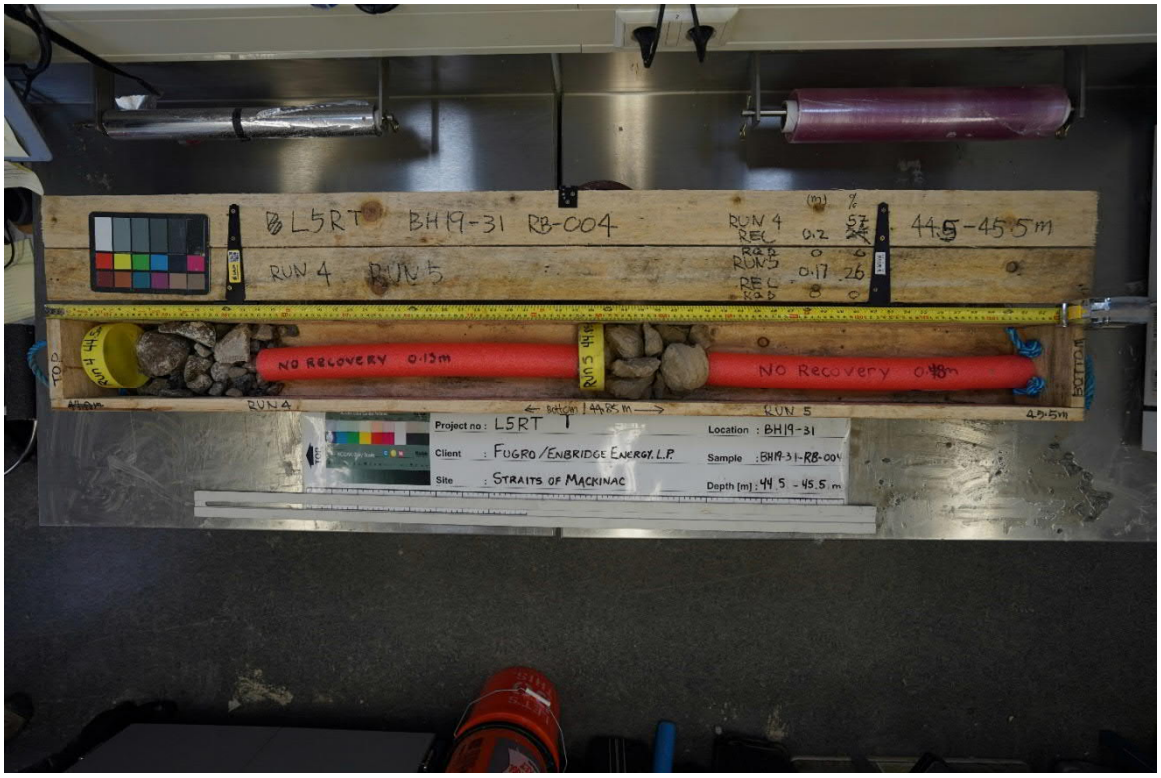
BH19-31-RB-001 (Wet)

BH19-31-RB-002 (Dry)

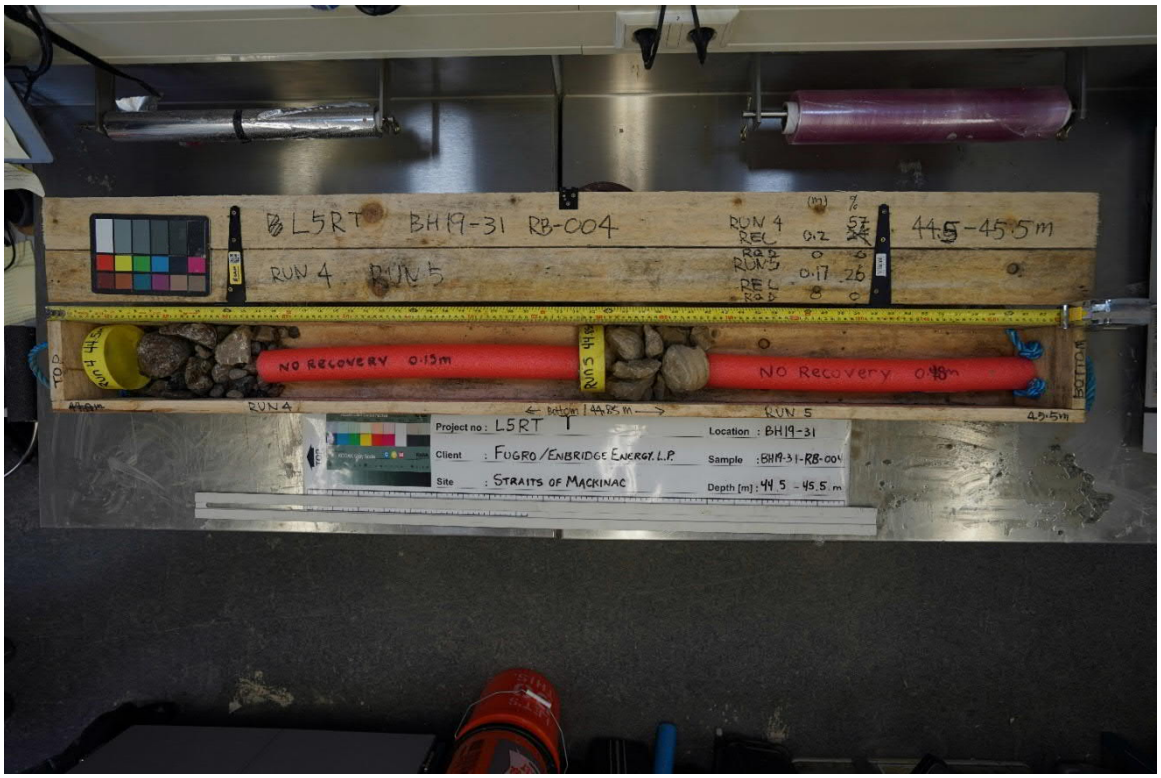
BH19-31-RB-002 (Wet)

BH19-31-RB-003 (Dry)

BH19-31-RB-003 (Wet)



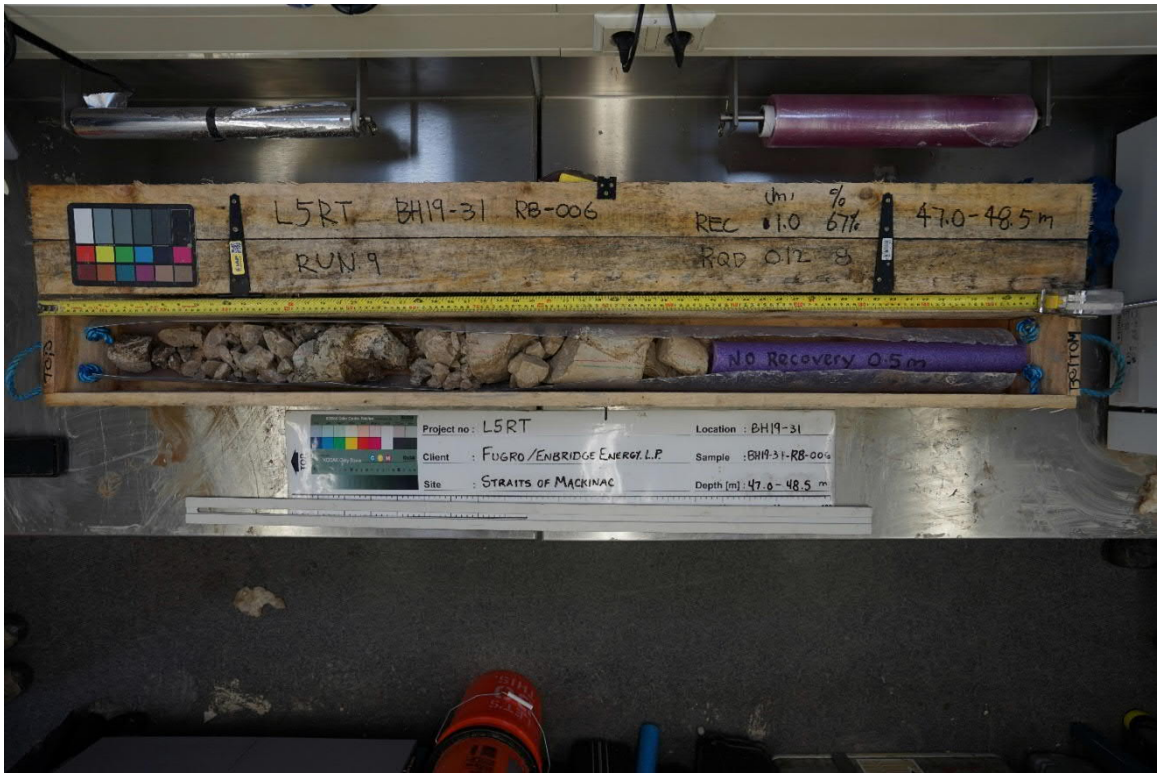
BH19-31-RB-004 (Dry)



BH19-31-RB-004 (Wet)

BH19-31-RB-005 (Dry)

BH19-31-RB-005 (Wet)



BH19-31-RB-006 (Dry)

BH19-31-RB-006 (Wet)

BH19-31-RB-007 (Dry)

BH19-31-RB-007 (Wet)

BH19-31-RB-008 (Dry)

BH19-31-RB-008 (Wet)

BH19-31-RB-009 (Dry)

BH19-31-RB-009 (Wet)

BH19-31-RB-010 (Dry)

BH19-31-RB-010 (Wet)

BH19-31-RB-011 (Dry)

BH19-31-RB-011 (Wet)

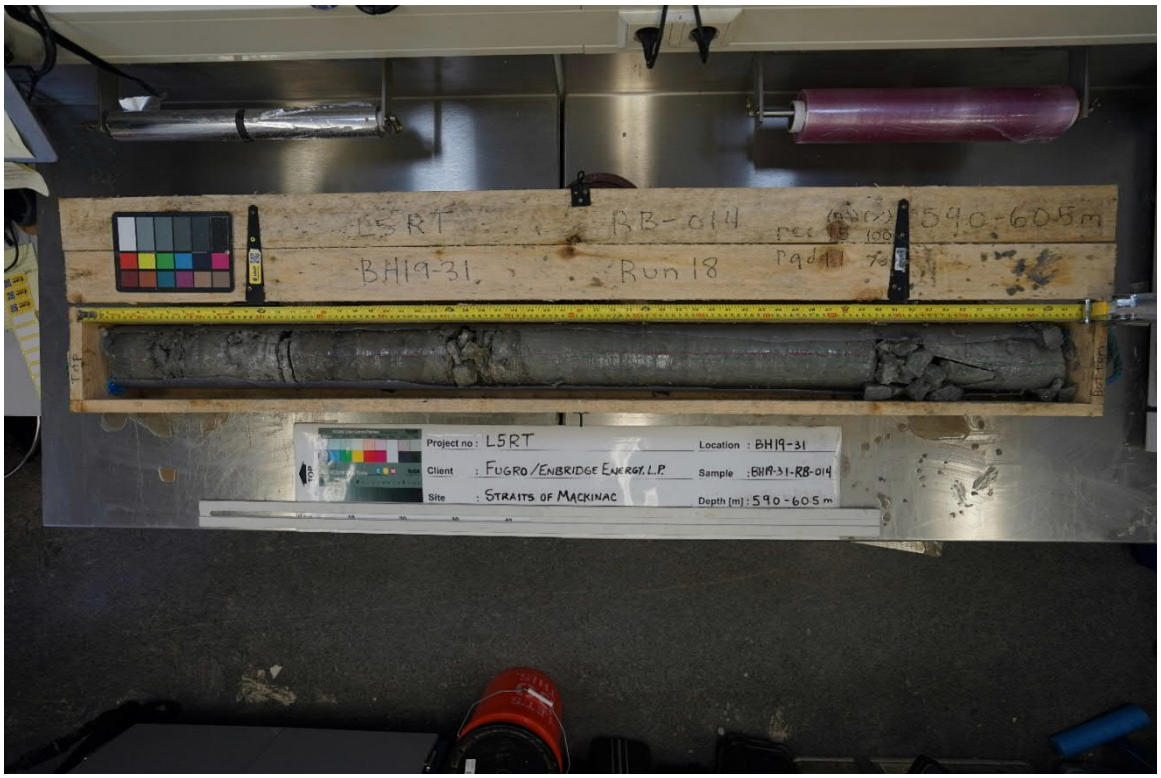
BH19-31-RB-012 (Dry)

BH19-31-RB-012 (Wet)

BH19-31-RB-013 (Dry)

BH19-31-RB-013 (Wet)

BH19-31-RB-014 (Dry)

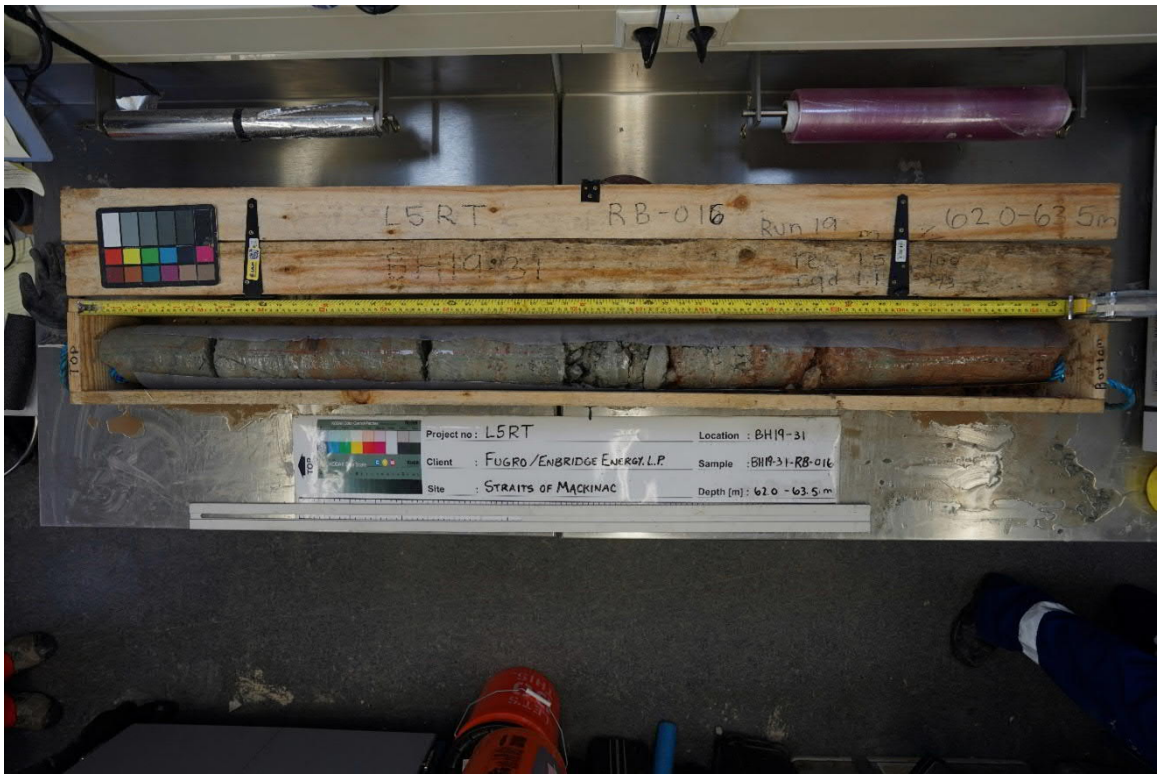


BH19-31-RB-014 (Wet)

BH19-31-RB-015 (Dry)

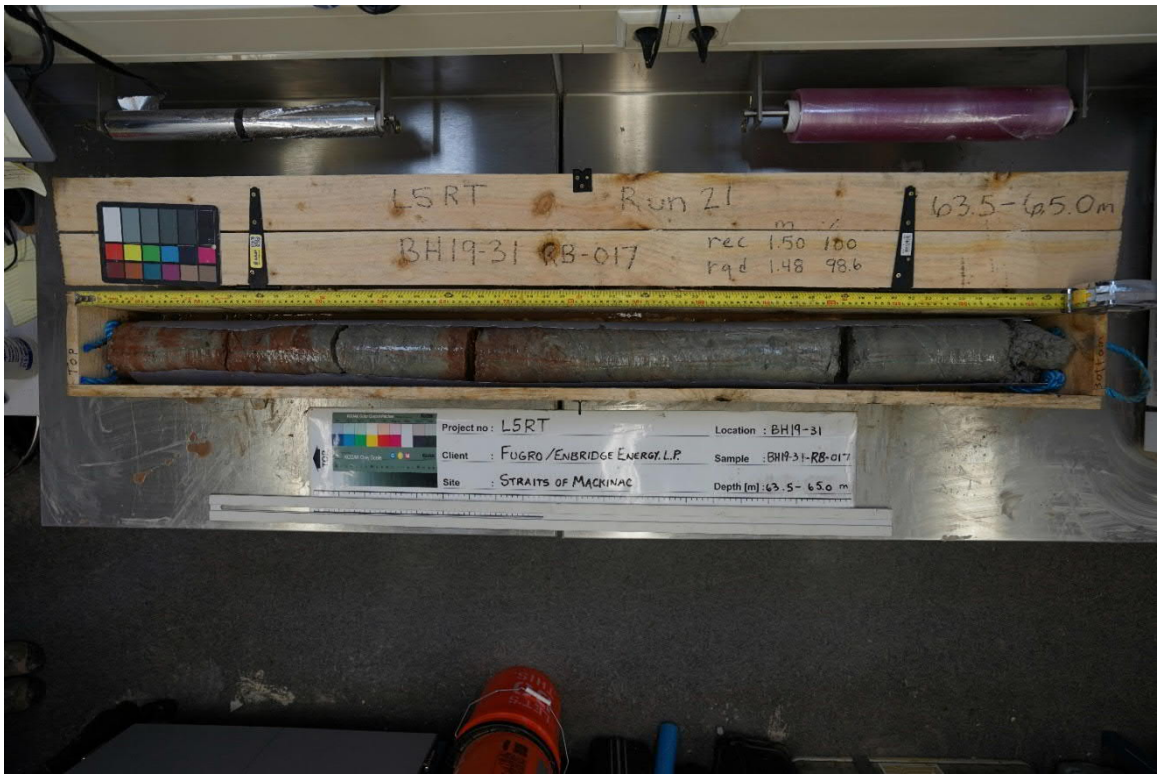
BH19-31-RB-015 (Wet)

BH19-31-RB-016 (Dry)

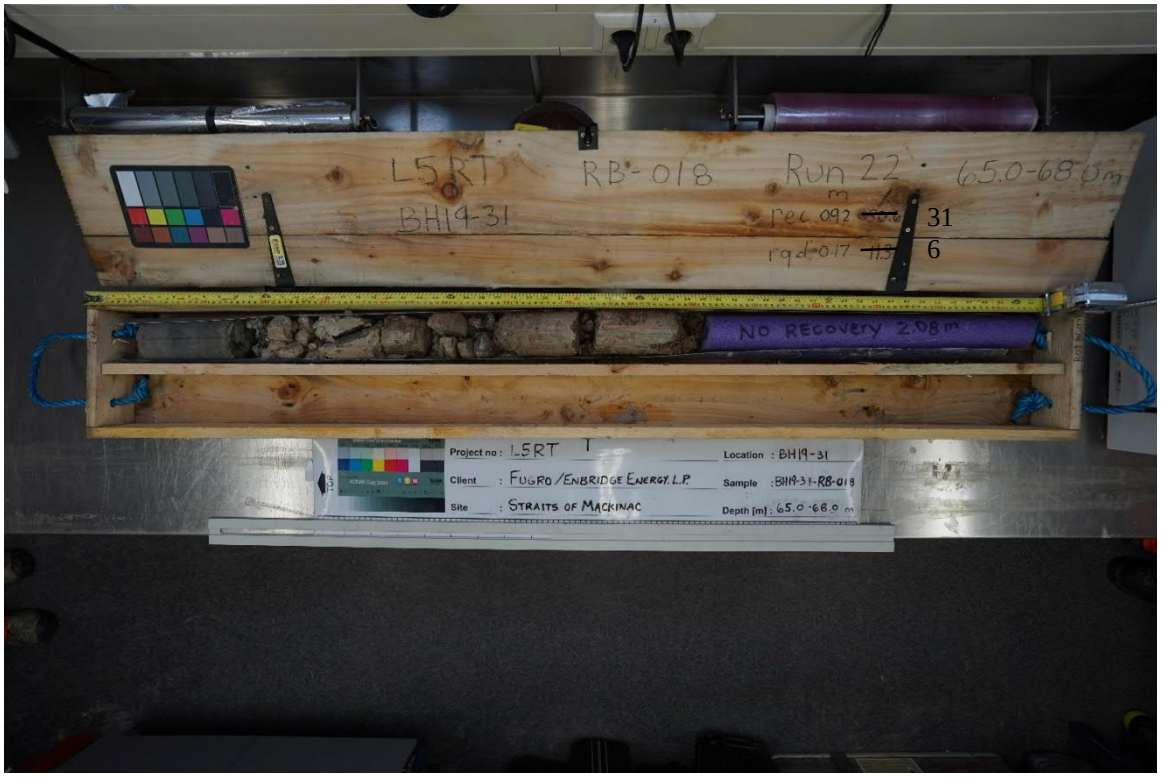


BH19-31-RB-016 (Wet)

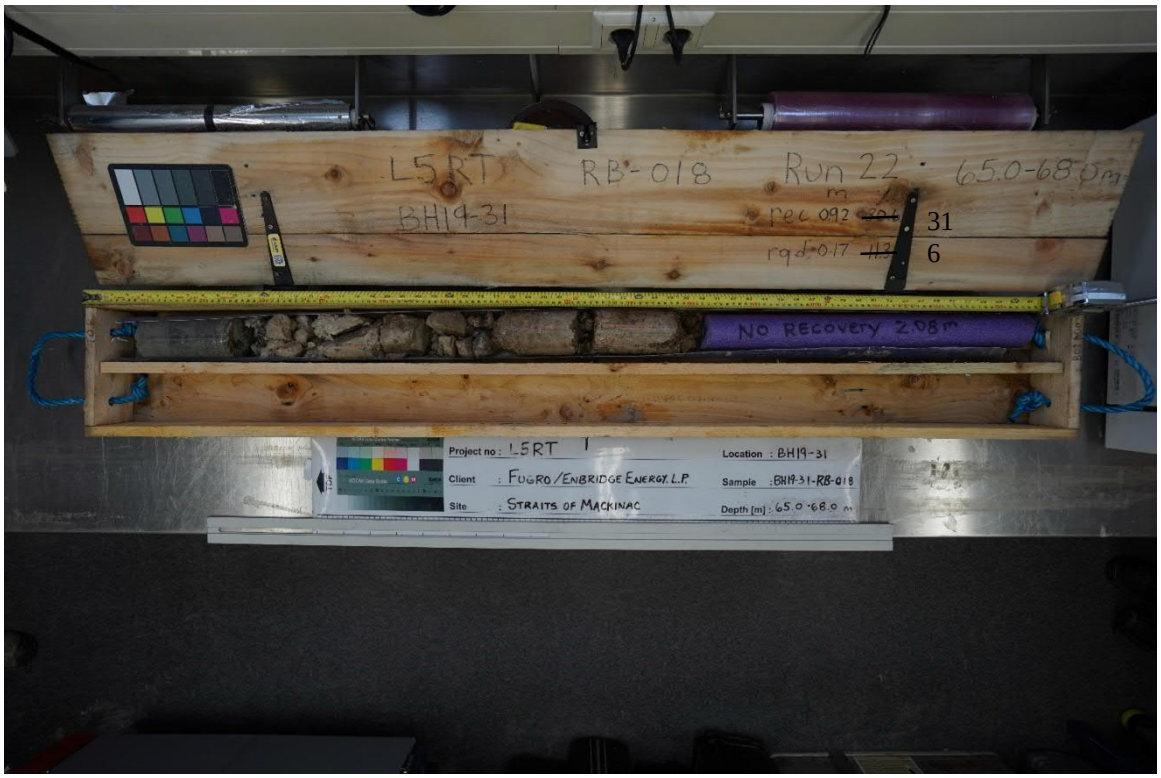
BH19-31-RB-017 (Dry)



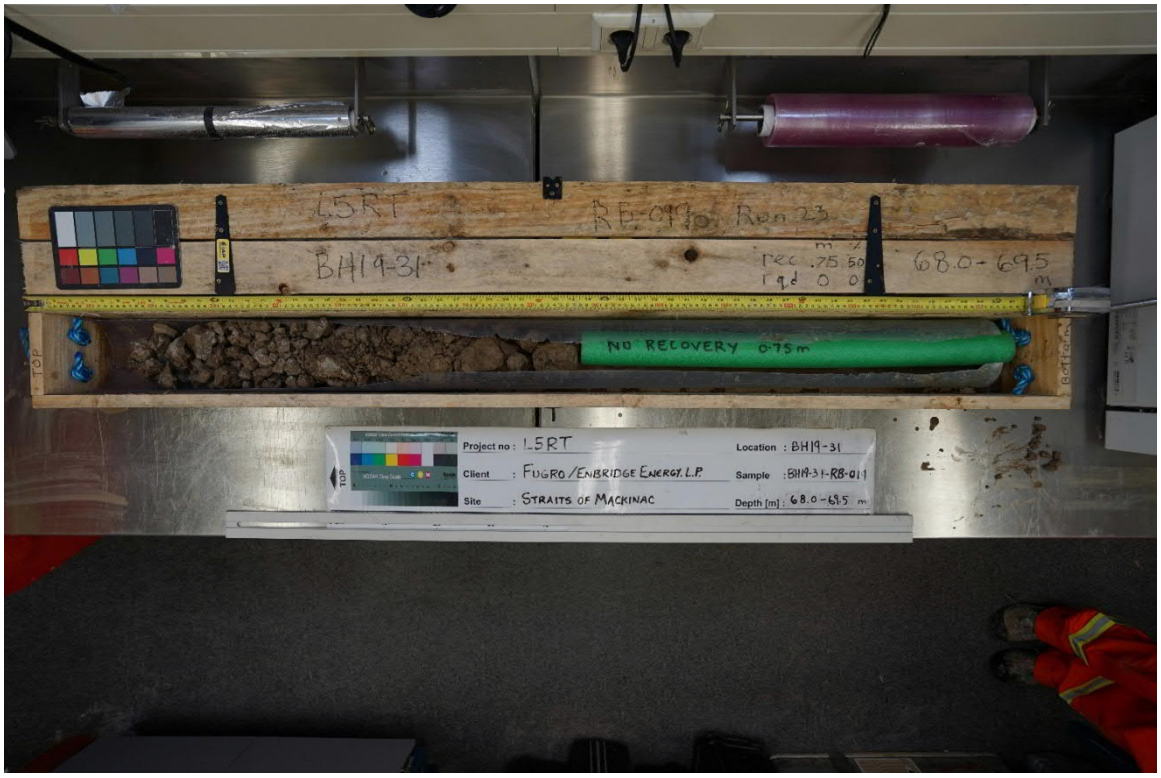
BH19-31-RB-017 (Wet)



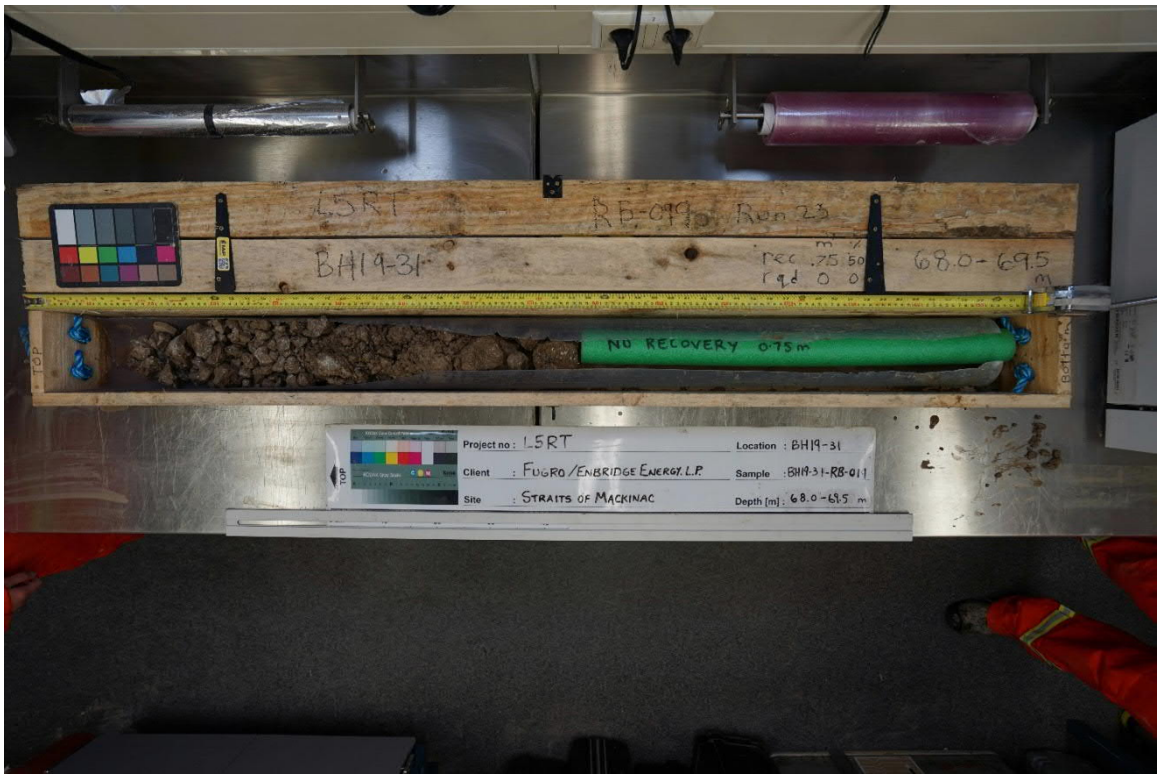
BH19-31-RB-018 (Dry)



BH19-31-RB-018 (Wet)



BH19-31-RB-019 (Dry)



BH19-31-RB-019 (Wet)

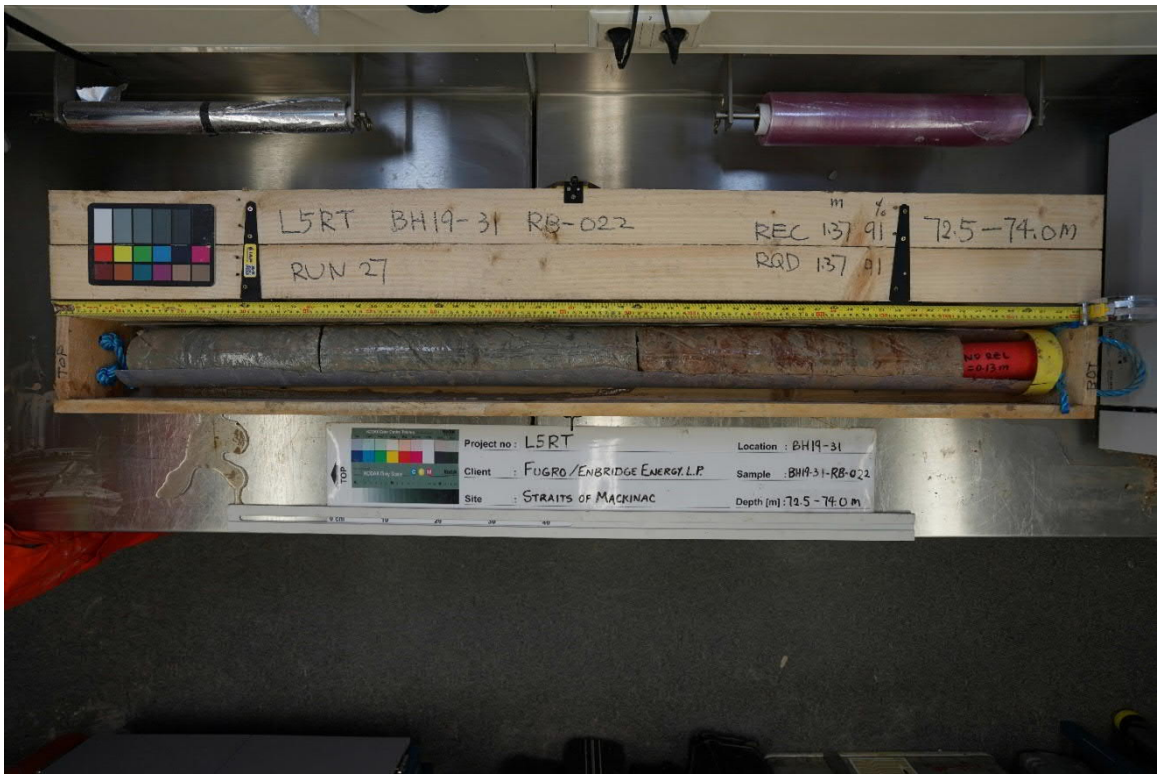
BH19-31-RB-020 (Dry)

BH19-31-RB-020 (Wet)

BH19-31-RB-021 (Dry)

BH19-31-RB-021 (Wet)

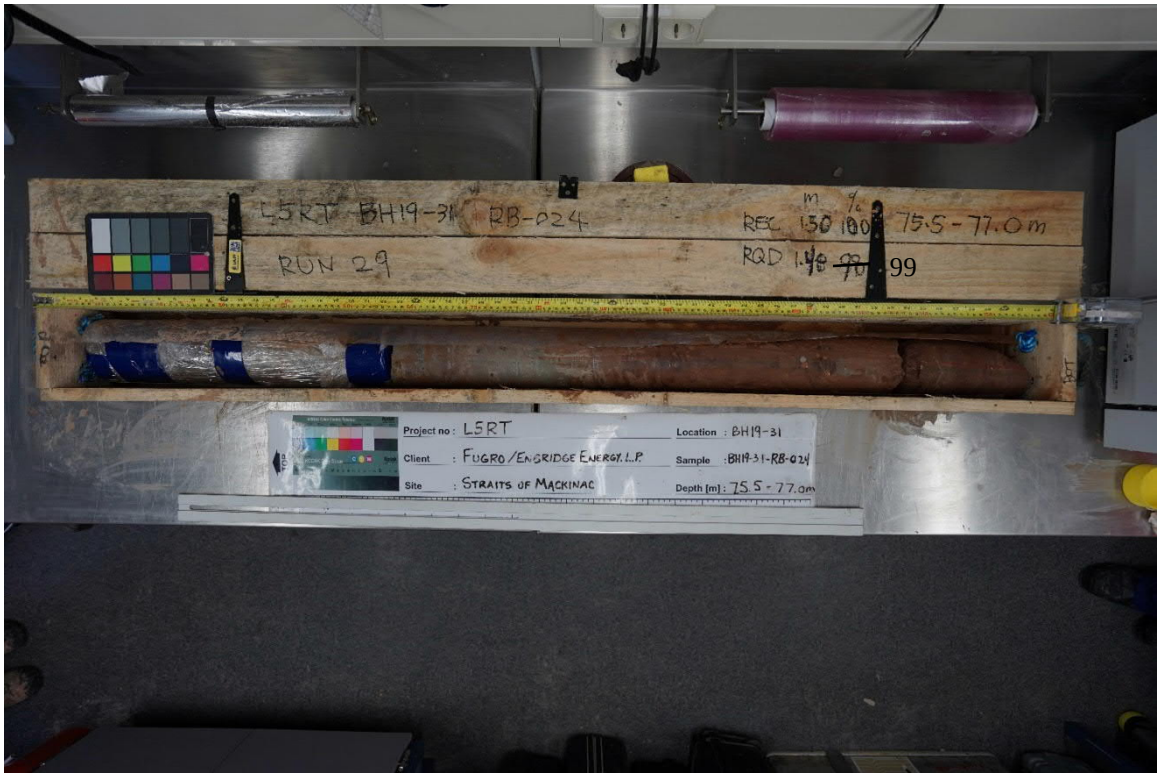
BH19-31-RB-022 (Dry)



BH19-31-RB-022 (Wet)

BH19-31-RB-023 (Dry)

BH19-31-RB-023 (Wet)

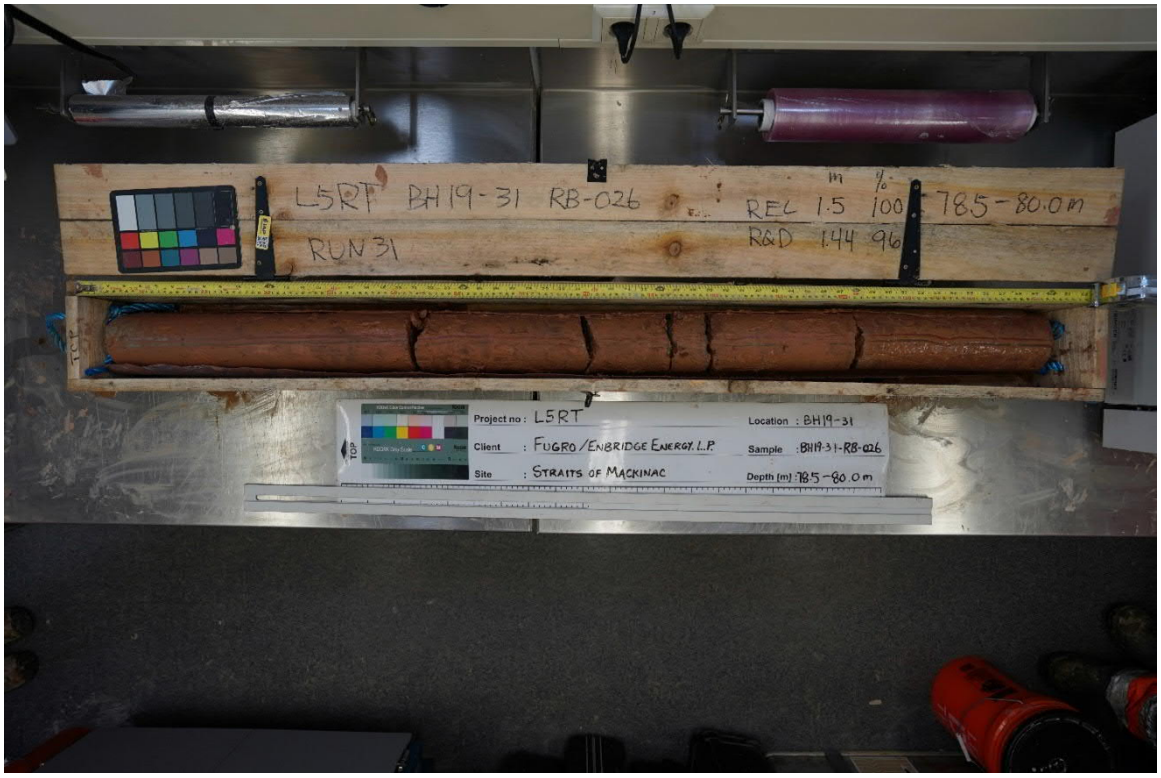


BH19-31-RB-024 (Dry)

BH19-31-RB-024 (Wet)

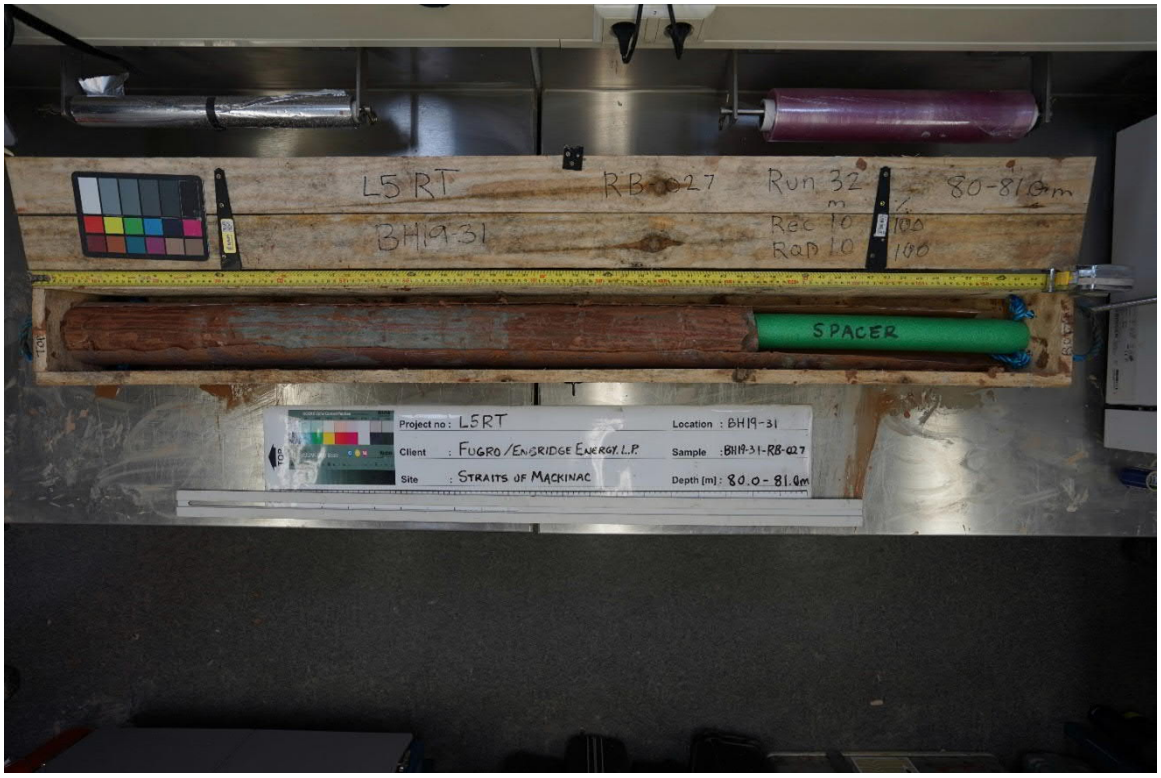
BH19-31-RB-025 (Dry)

BH19-31-RB-025 (Wet)

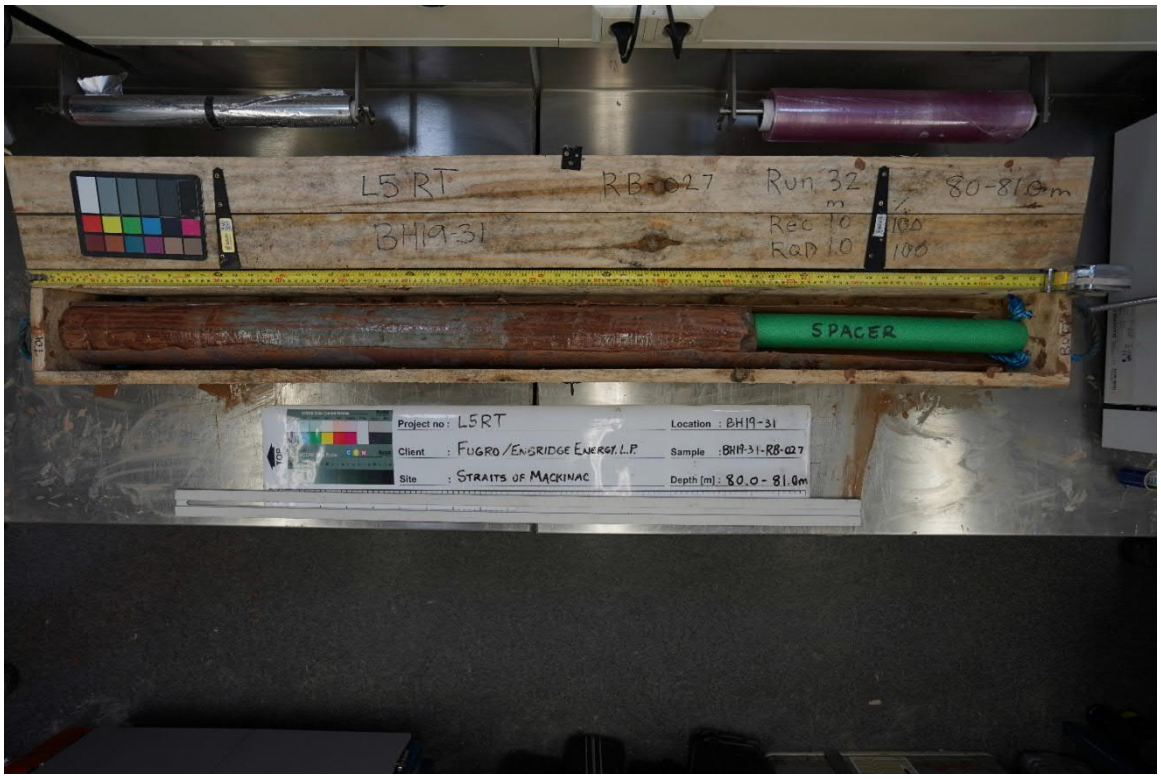


BH19-31-RB-026 (Dry)

BH19-31-RB-026 (Wet)



BH19-31-RB-027 (Dry)



BH19-31-RB-027 (Wet)

BH19-32-RB-001

BH19-32-RB-002

BH19-32-RB-003

BH19-32-RB-004

BH19-32-RB-005

[Intentionally Left Blank]

BH19-32-RB-006 (Dry)

BH19-32-RB-006 (Wet)

BH19-32-RB-007 (Dry)

BH19-32-RB-007 (Wet)

BH19-32-RB-008 (Dry)

BH19-32-RB-008 (Wet)

BH19-32-RB-009 (Dry)

BH19-32-RB-009 (Wet)

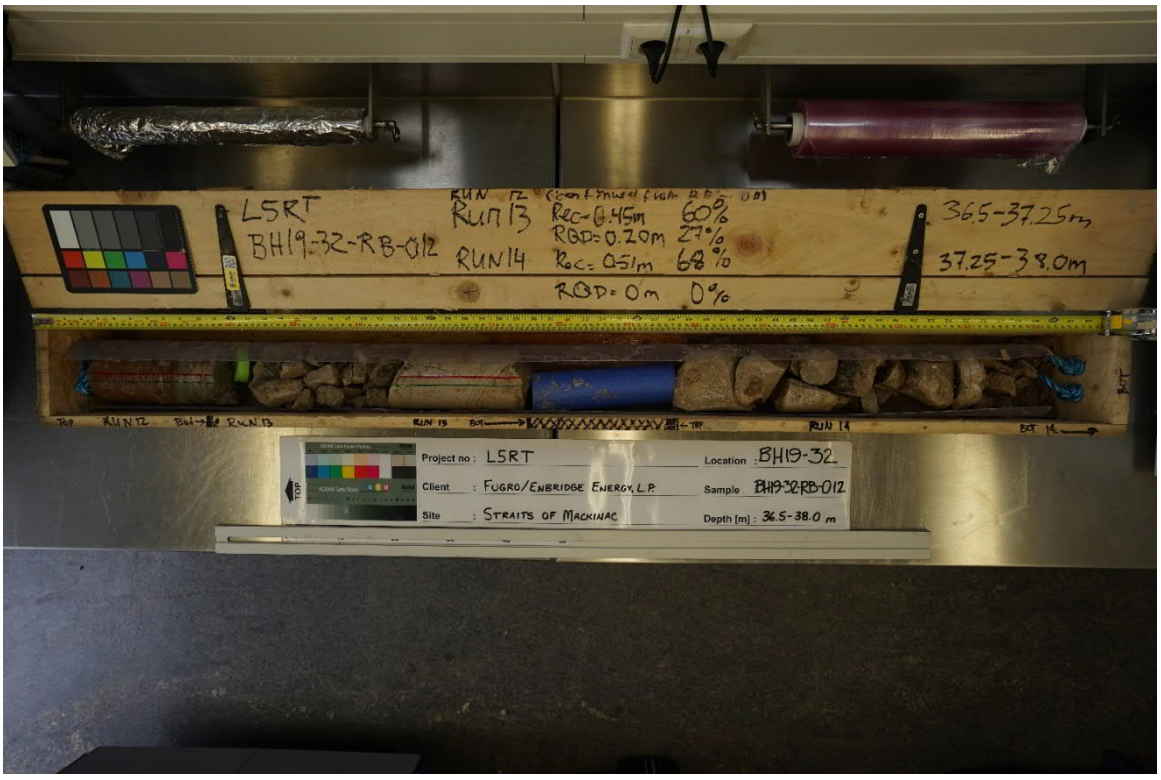
BH19-32-RB-010 (Dry)

BH19-32-RB-010 (Wet)

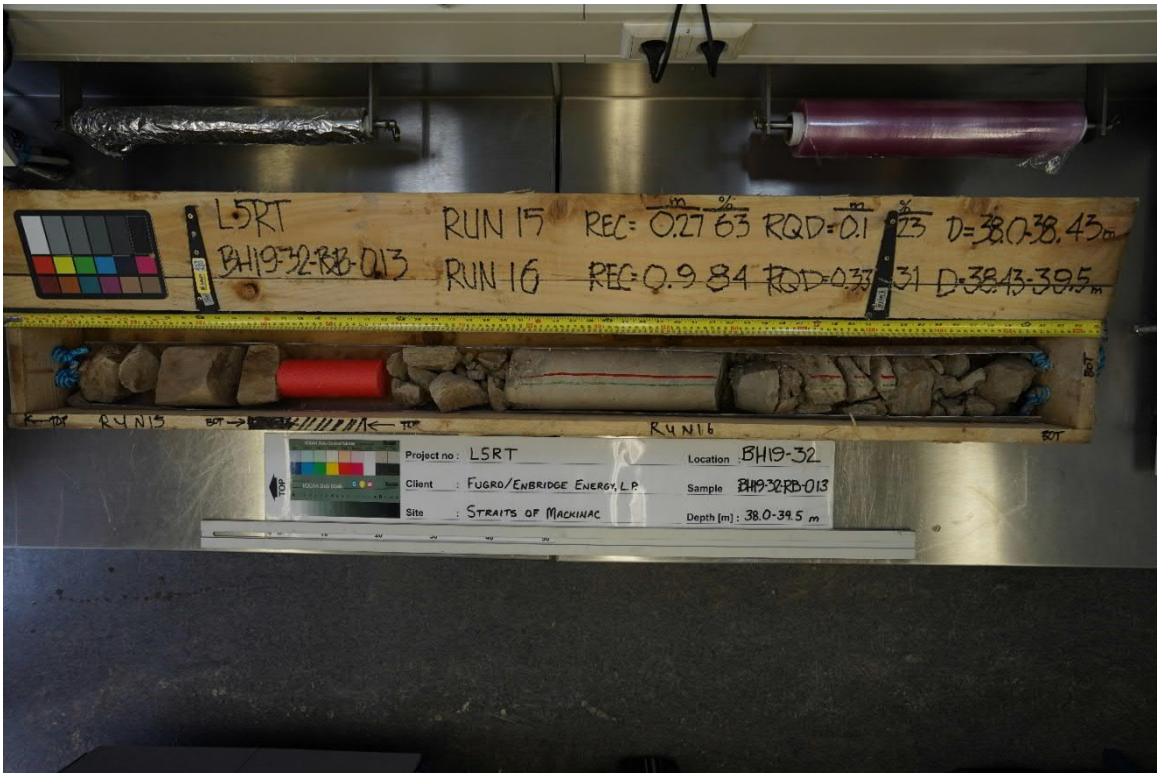
BH19-32-RB-011 (Dry)

BH19-32-RB-011 (Wet)

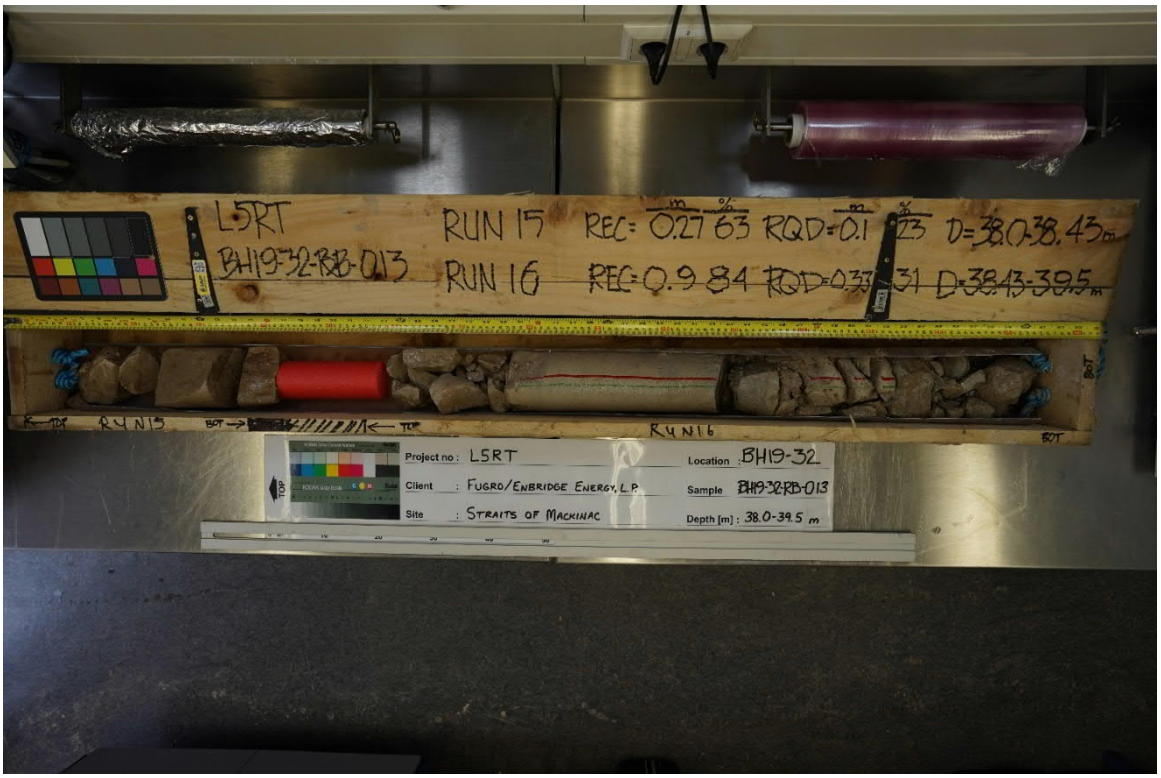
BH19-32-RB-012 (Dry)



BH19-32-RB-012 (Wet)



BH19-32-RB-013 (Dry)



BH19-32-RB-013 (Wet)

BH19-32-RB-014 (Dry)

BH19-32-RB-014 (Wet)

BH19-32-RB-015 (Dry)

BH19-32-RB-015 (Wet)

BH19-32-RB-016 (Dry)

BH19-32-RB-016 (Wet)

BH19-32-RB-017 (Dry)

BH19-32-RB-017 (Wet)

BH19-32-RB-018 (Dry)

BH19-32-RB-018 (Wet)

BH19-32-RB-019 (Dry)

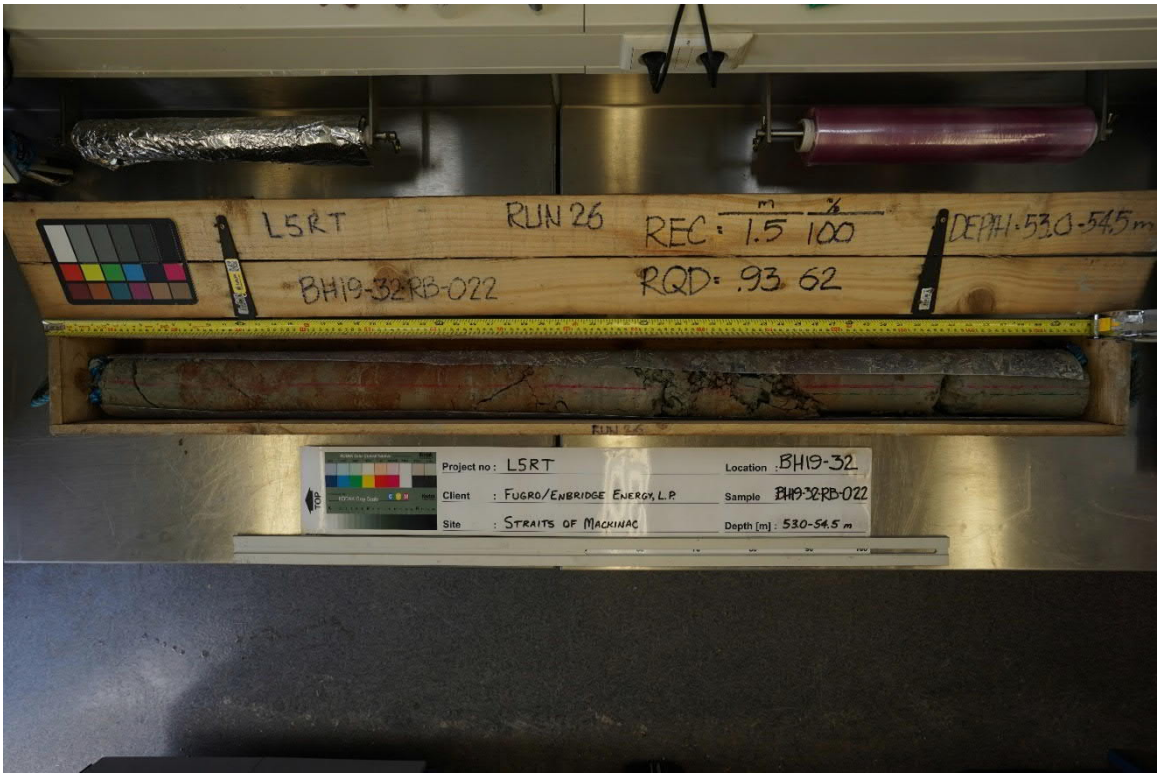
BH19-32-RB-019 (Wet)

BH19-32-RB-020 (Dry)

BH19-32-RB-020 (Wet)

BH19-32-RB-021 (Dry)

BH19-32-RB-021 (Wet)

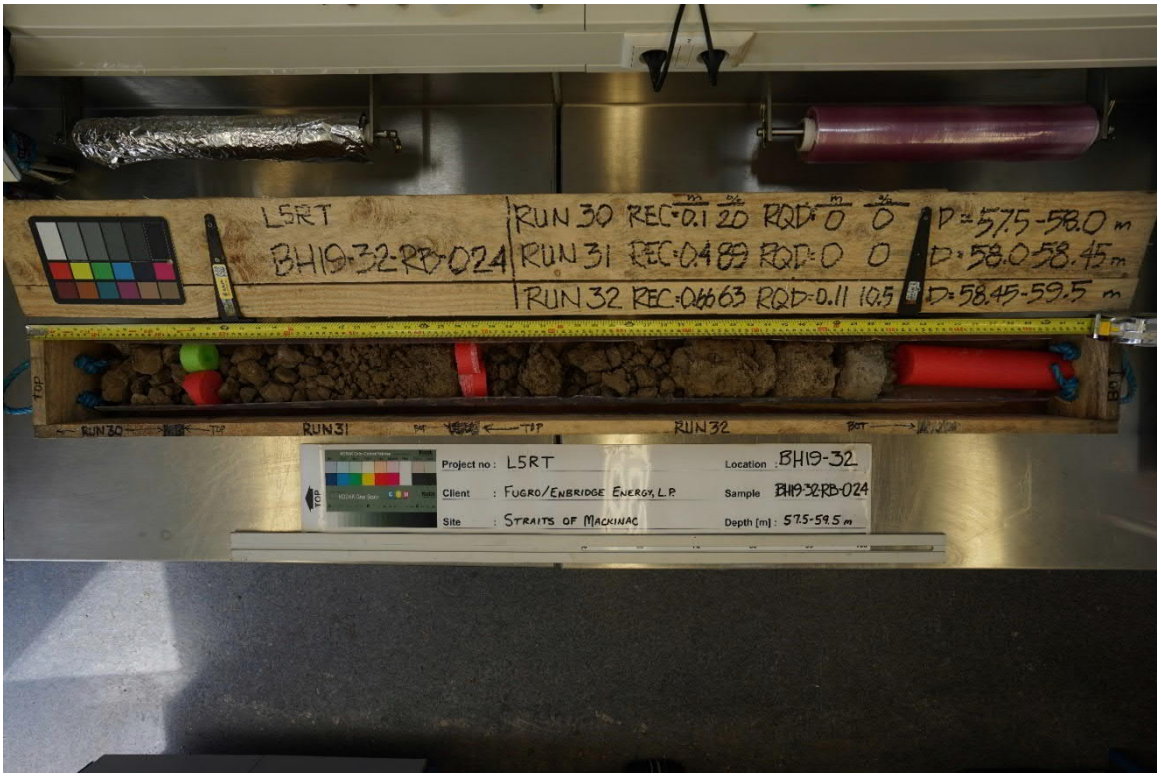


BH19-32-RB-022 (Dry)

BH19-32-RB-022 (Wet)

BH19-32-RB-023 (Dry)

BH19-32-RB-023 (Wet)

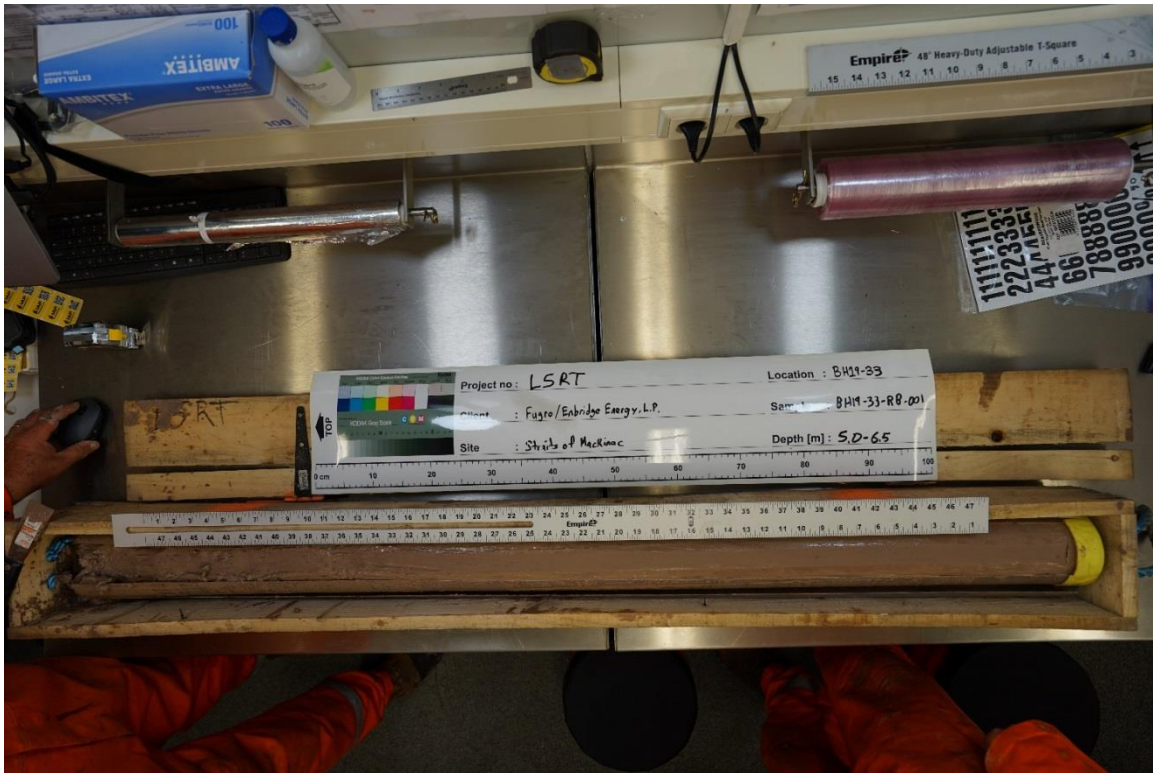


BH19-32-RB-024 (Dry)

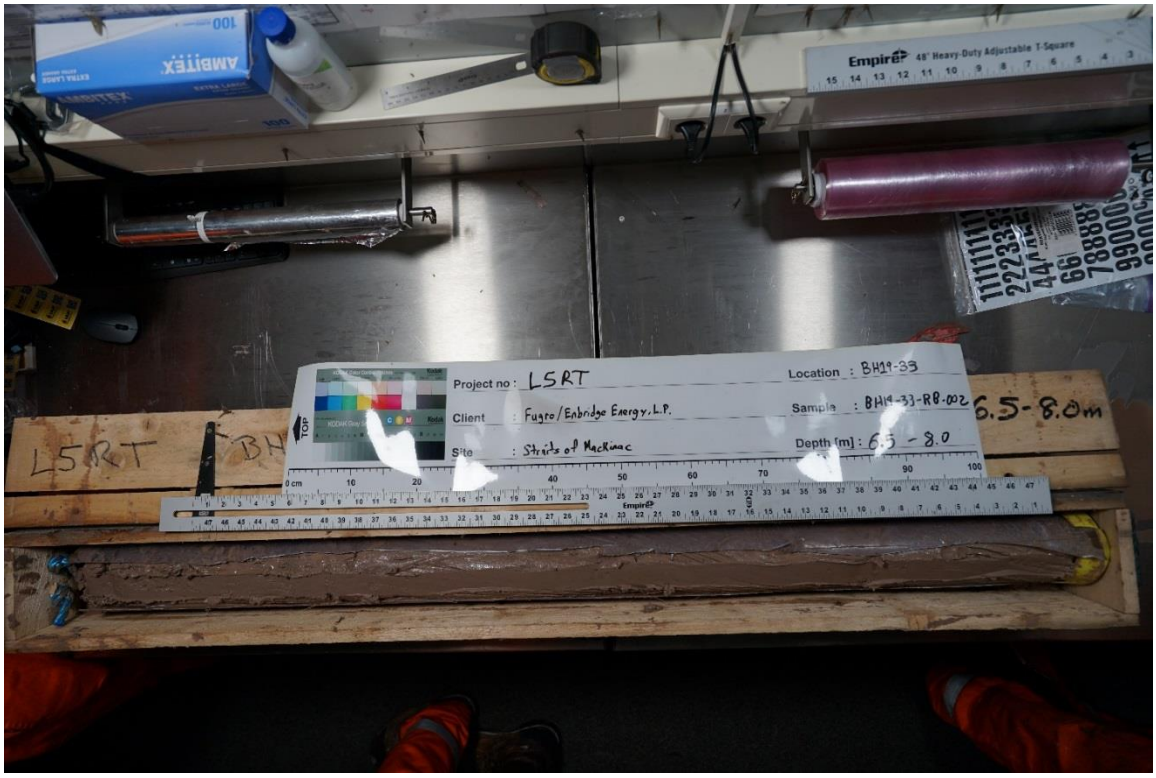
BH19-32-RB-024 (Wet)

BH19-32-RB-025 (Dry)

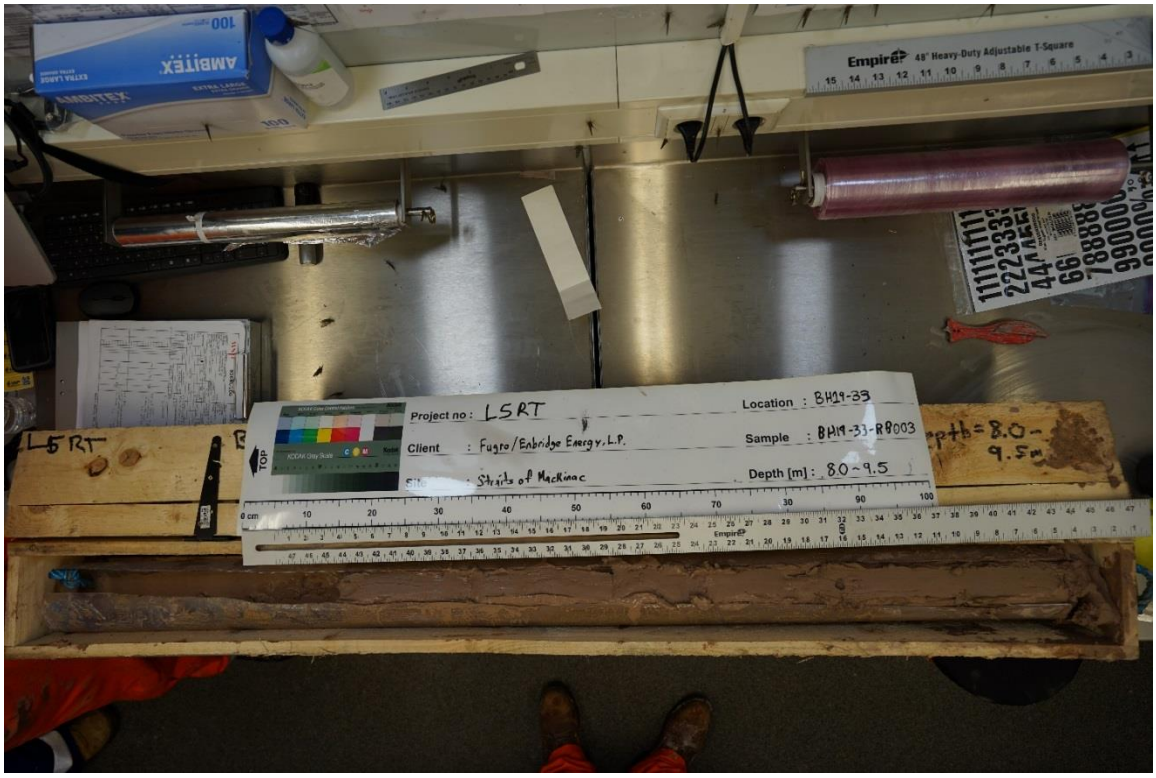
BH19-32-RB-025 (Wet)



BH19-33-RB-001

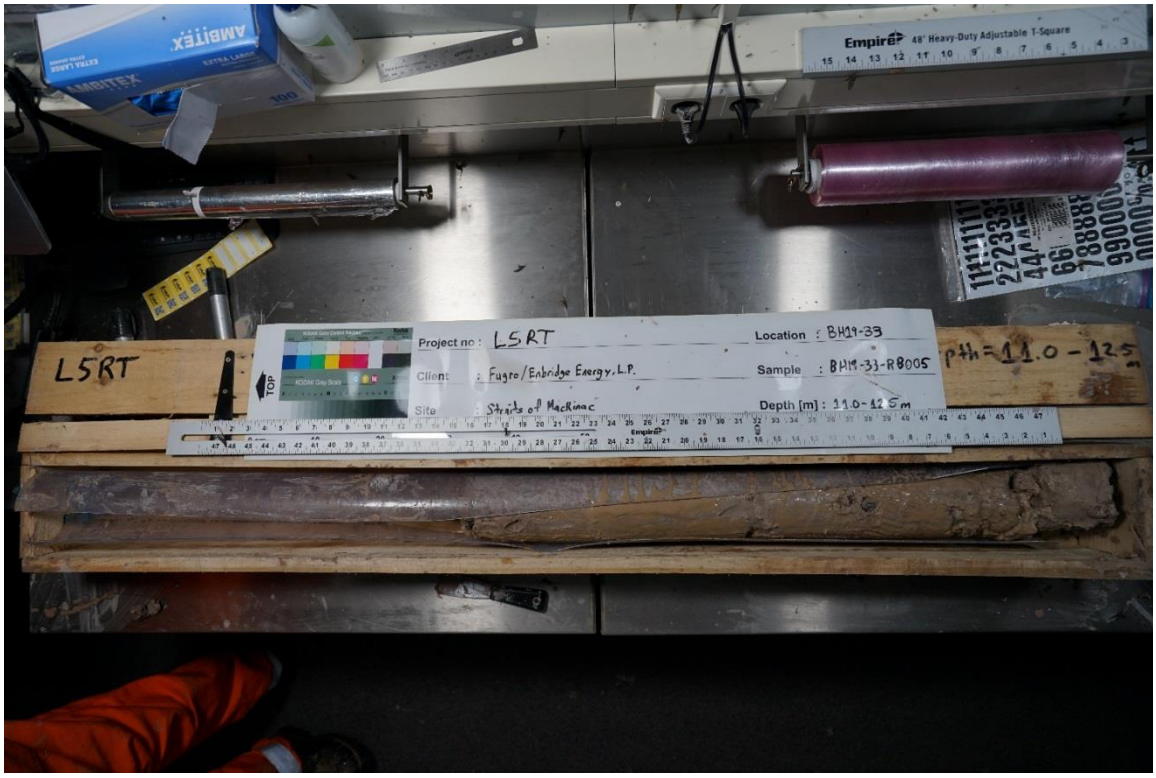


BH19-33-RB-002

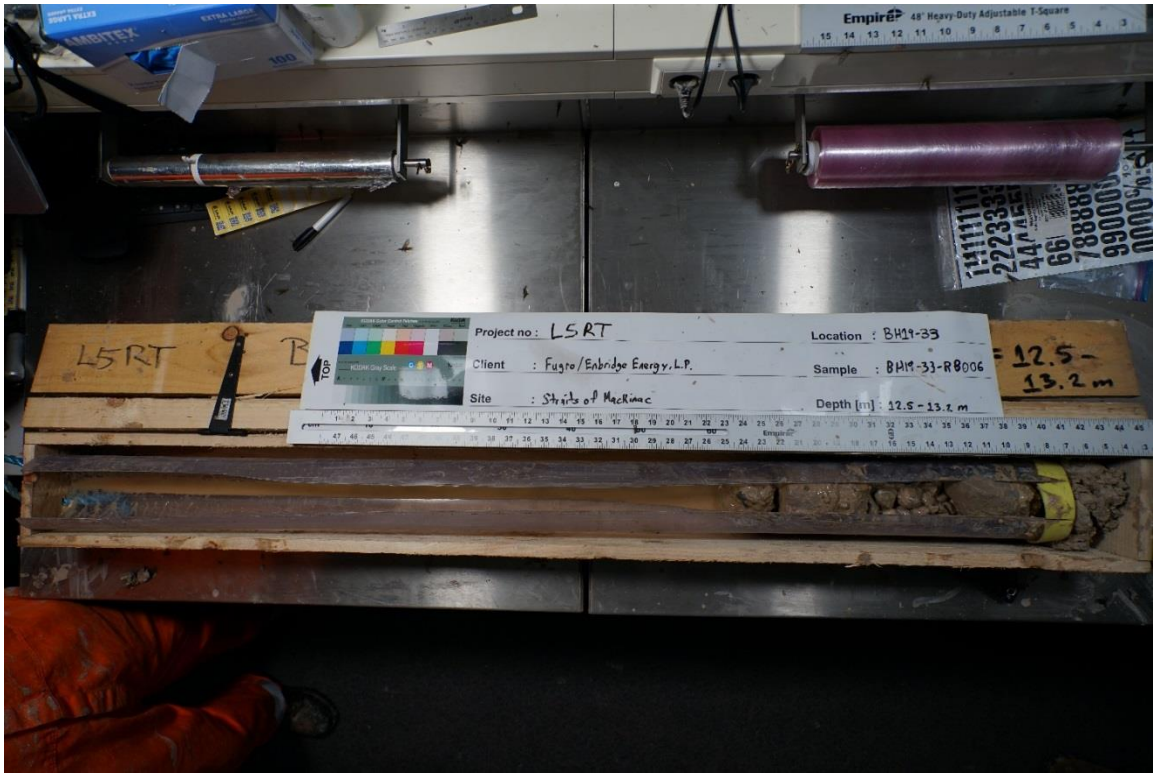


BH19-33-RB-003

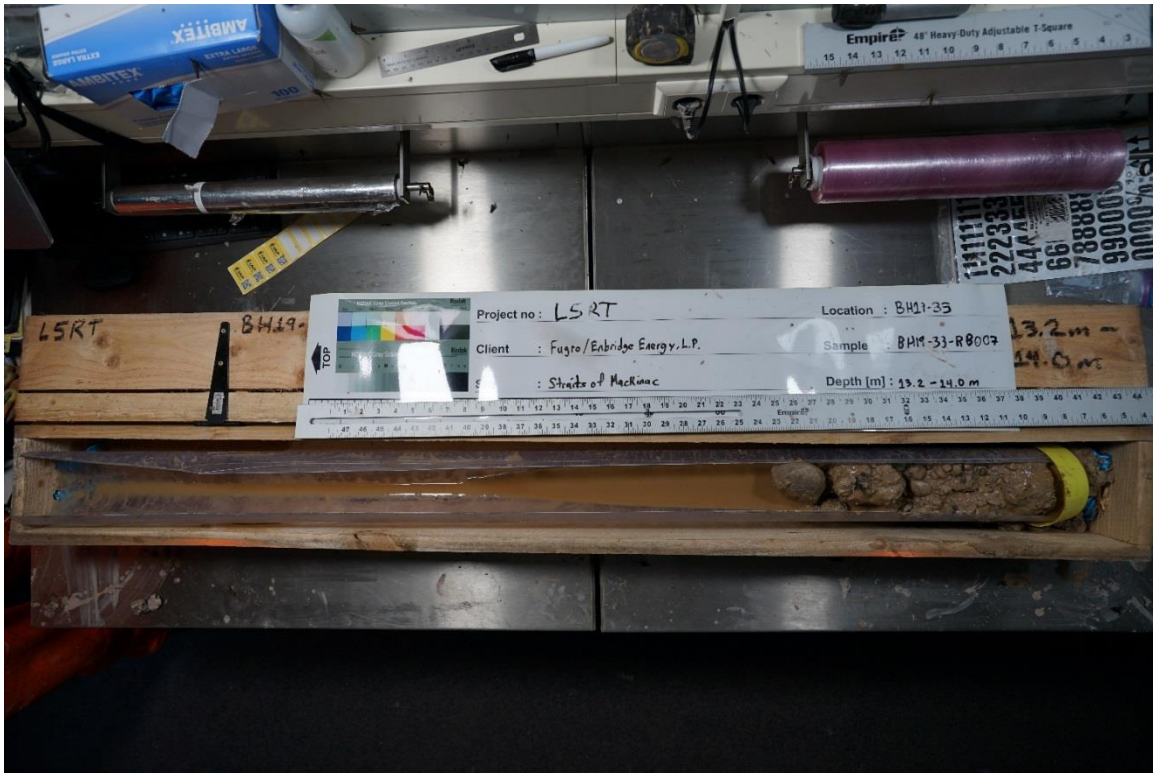
BH19-33-RB-004



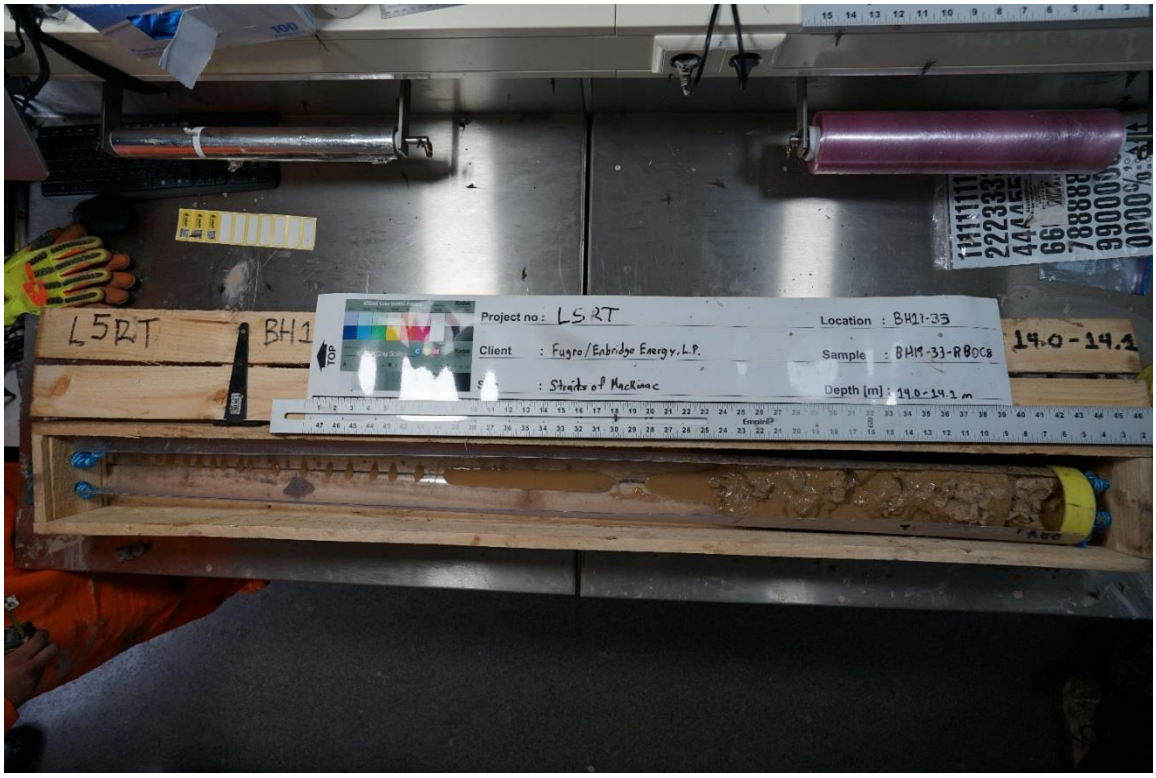
BH19-33-RB-005



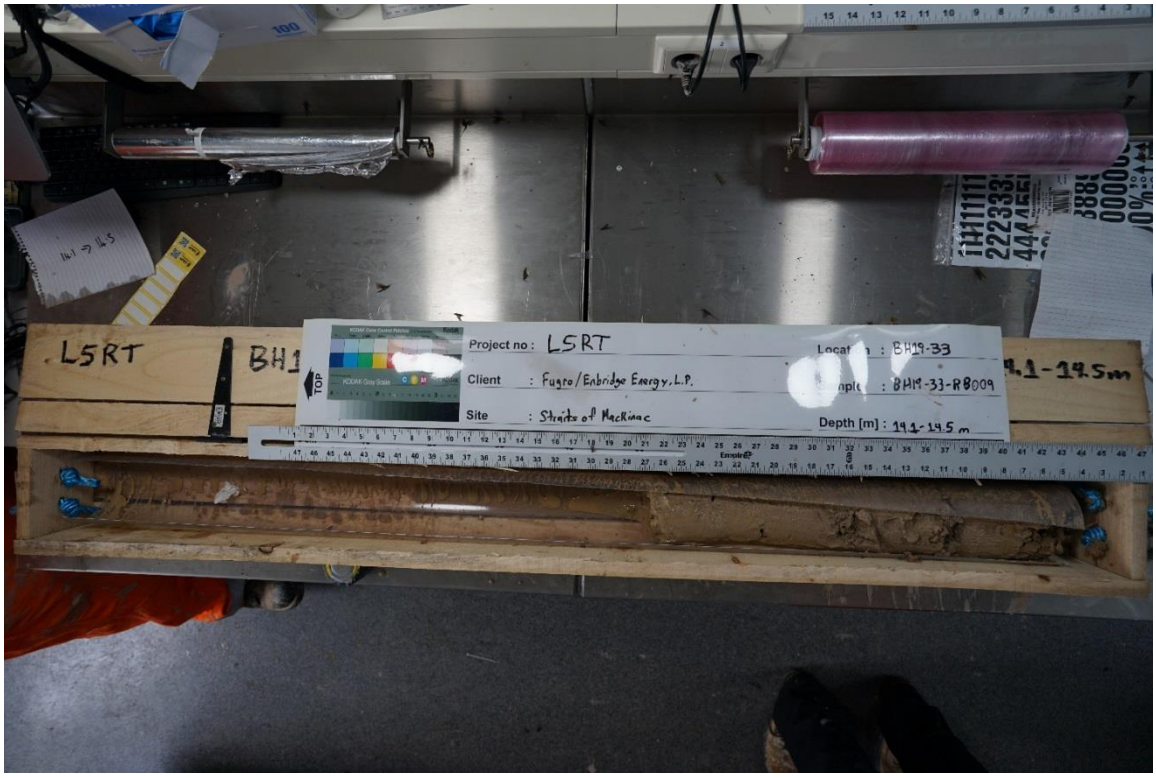
BH19-33-RB-006



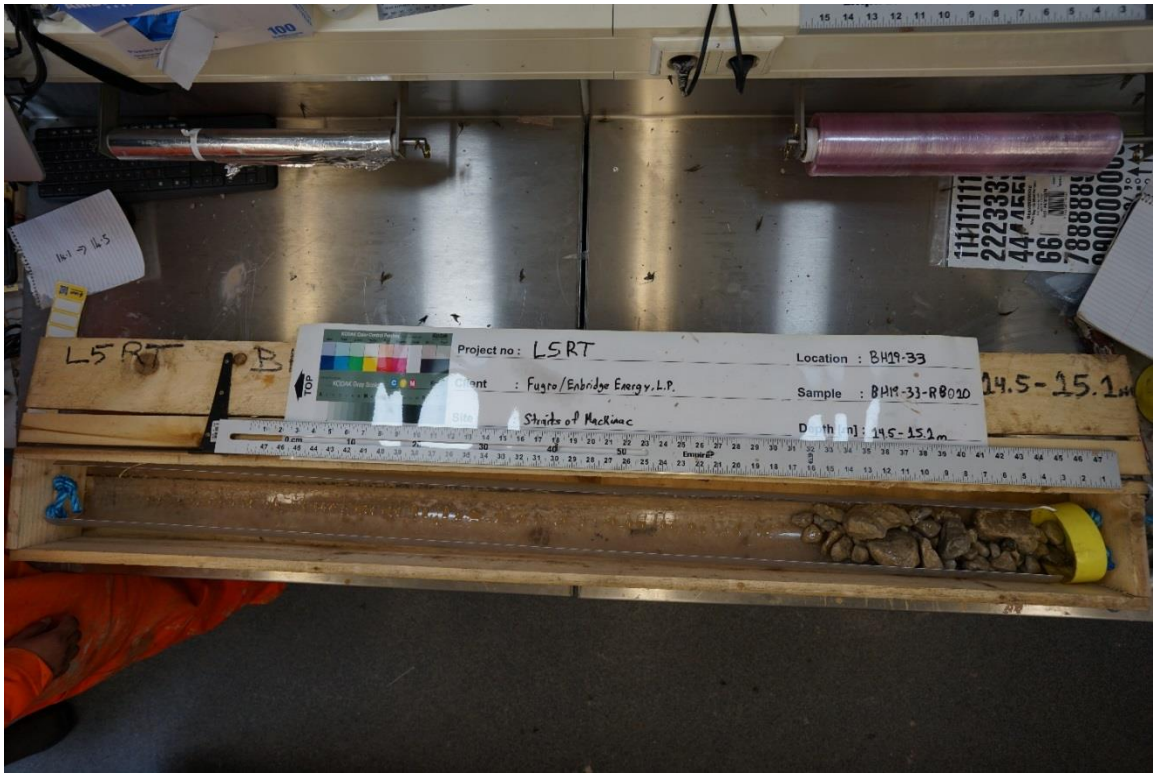
BH19-33-RB-007



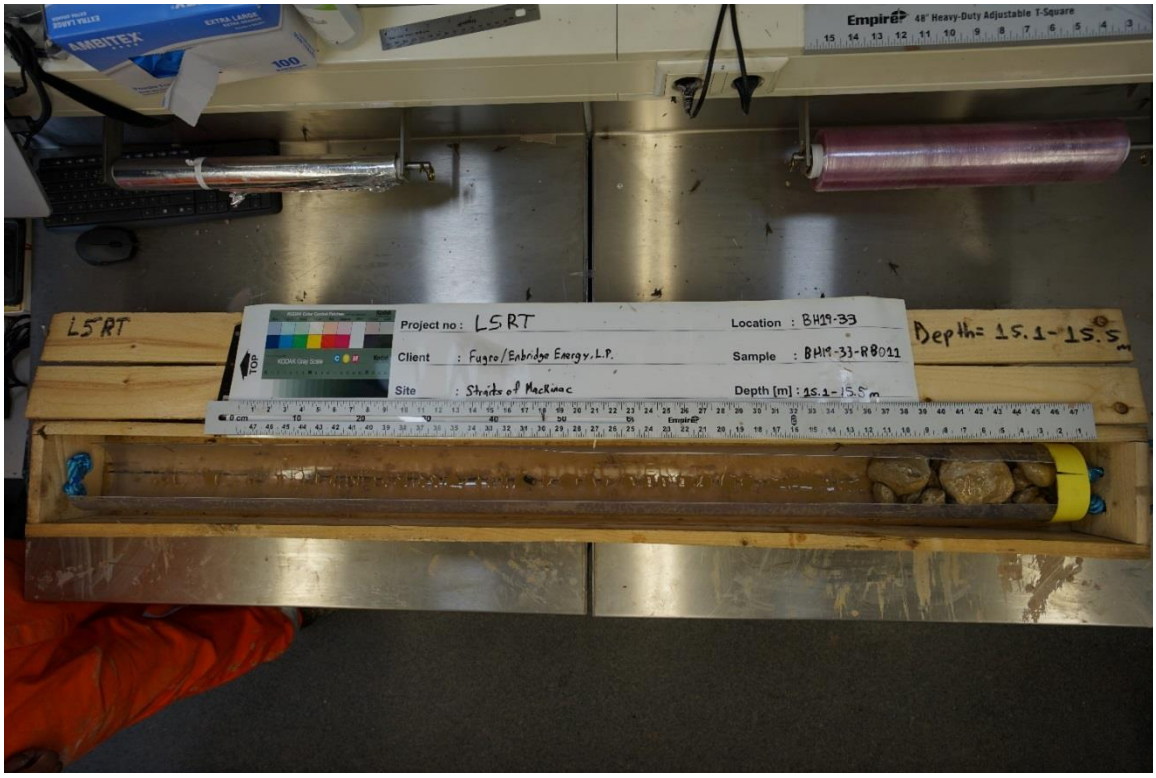
BH19-33-RB-008



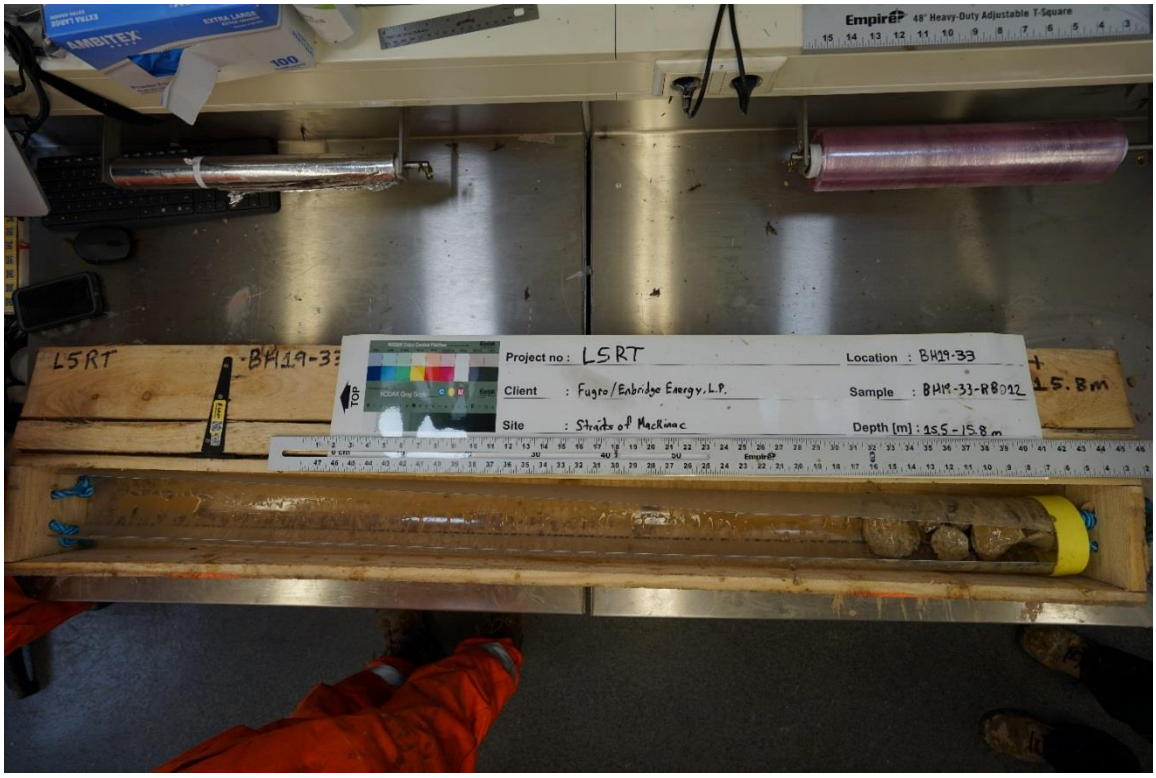
BH19-33-RB-009



BH19-33-RB-010

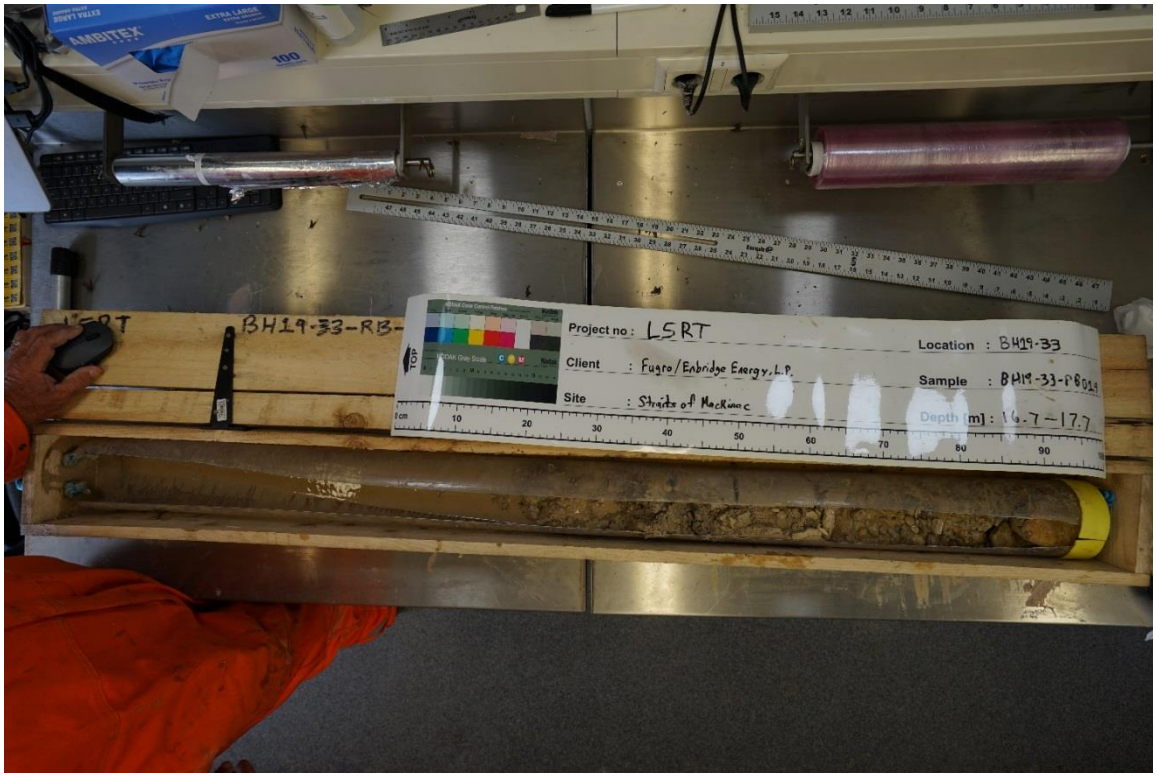


BH19-33-RB-011



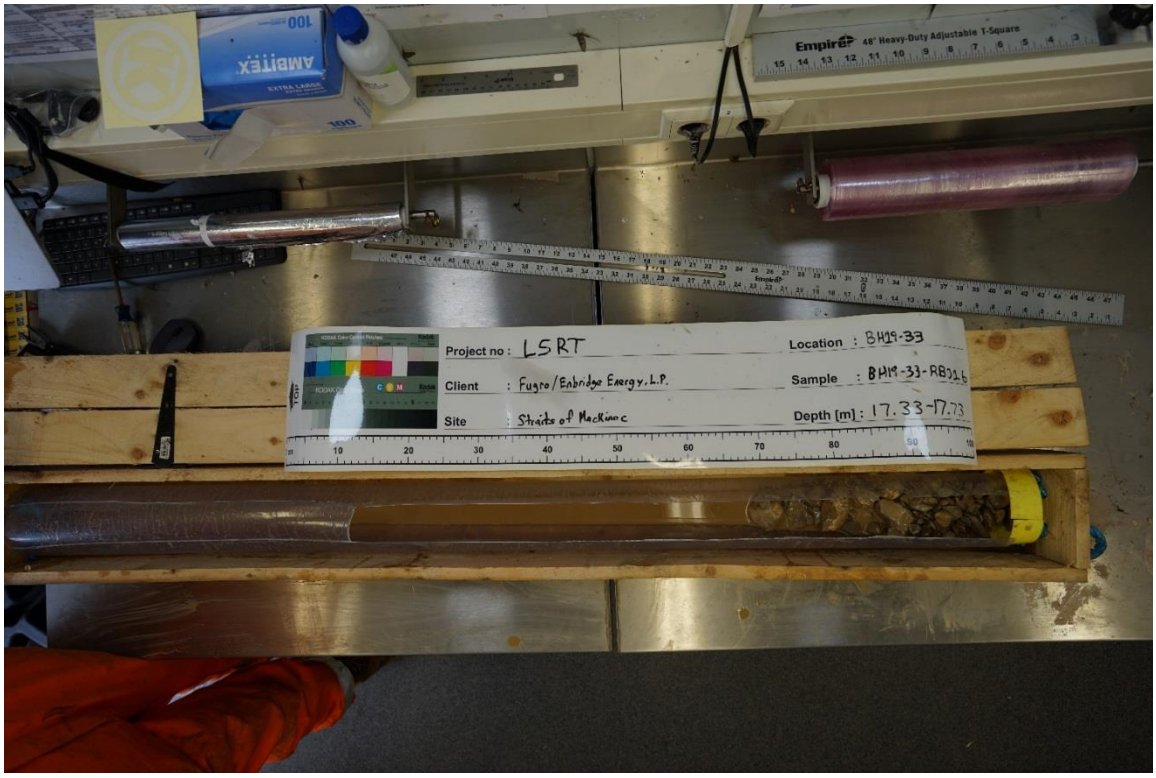
BH19-33-RB-012

BH19-33-RB-013



BH19-33-RB-014

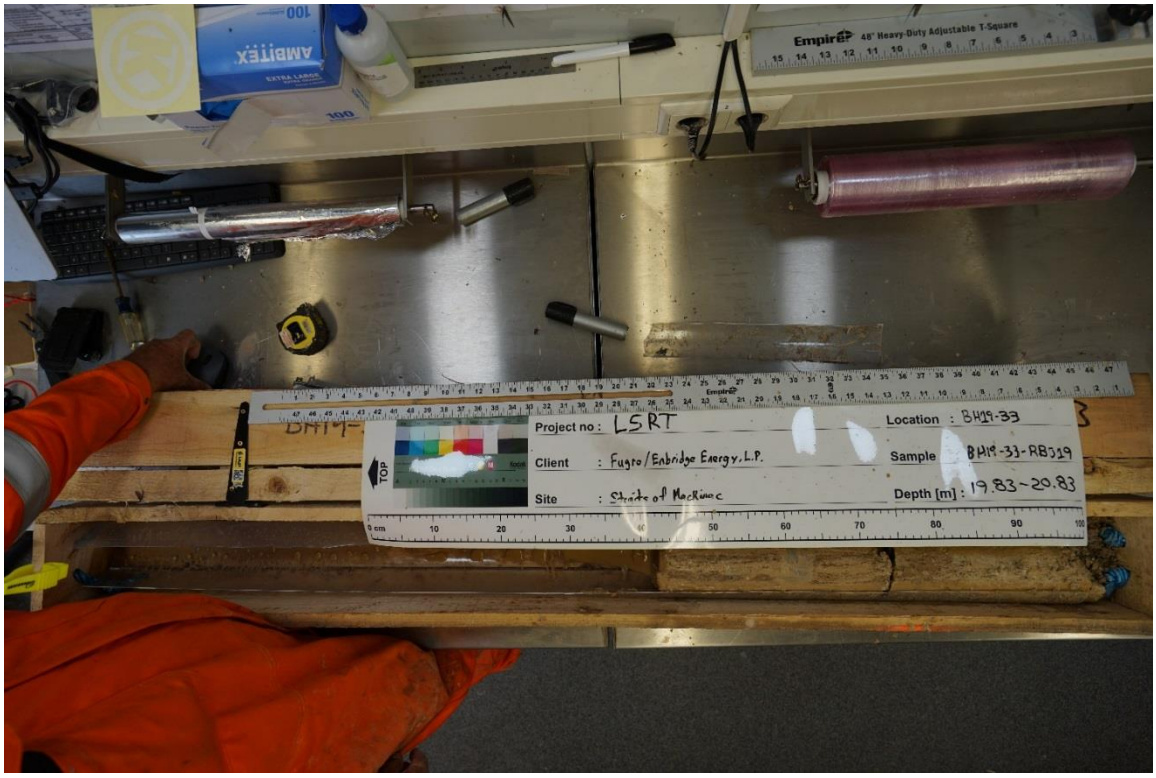
BH19-33-RB-015



BH19-33-RB-016

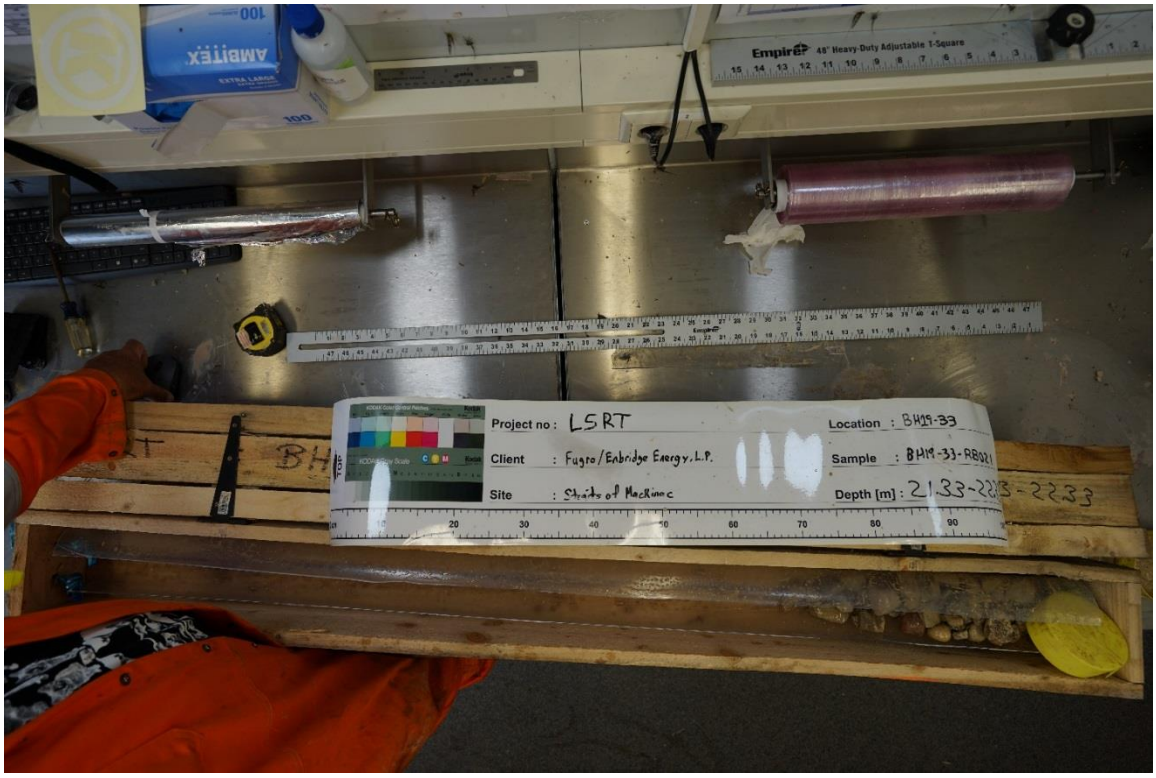
BH19-33-RB-017

BH19-33-RB-018



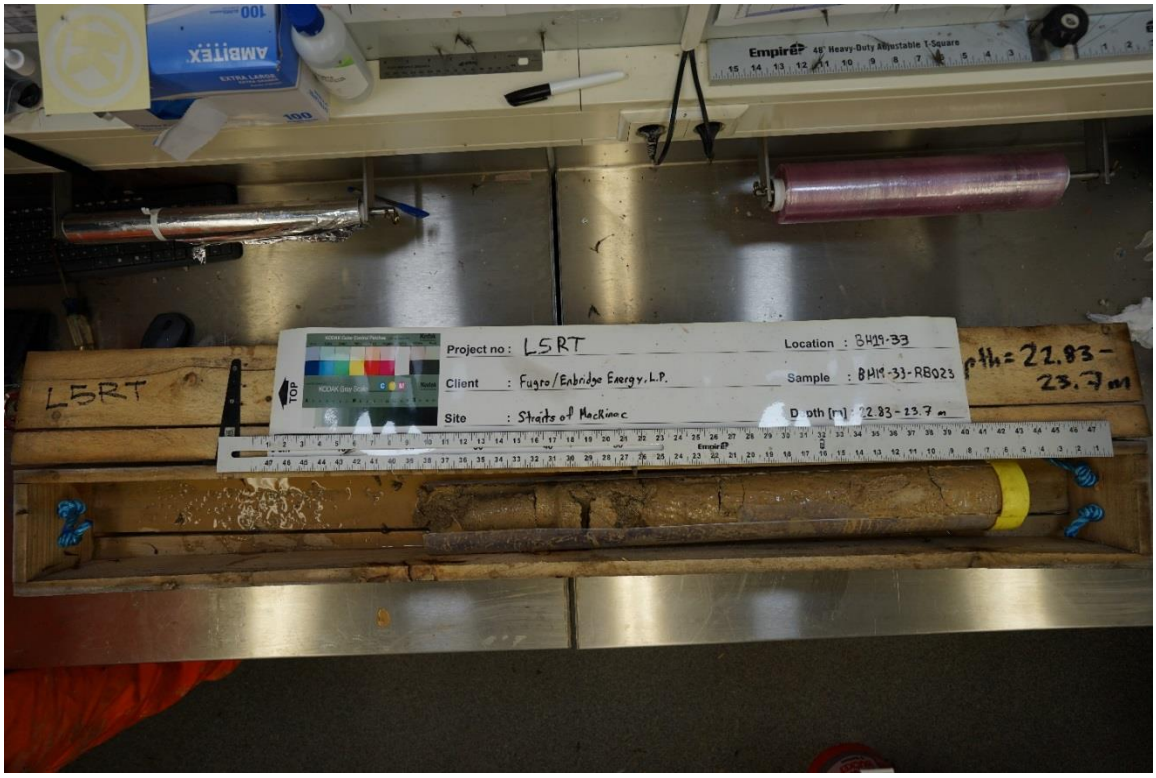
BH19-33-RB-019

BH19-33-RB-020



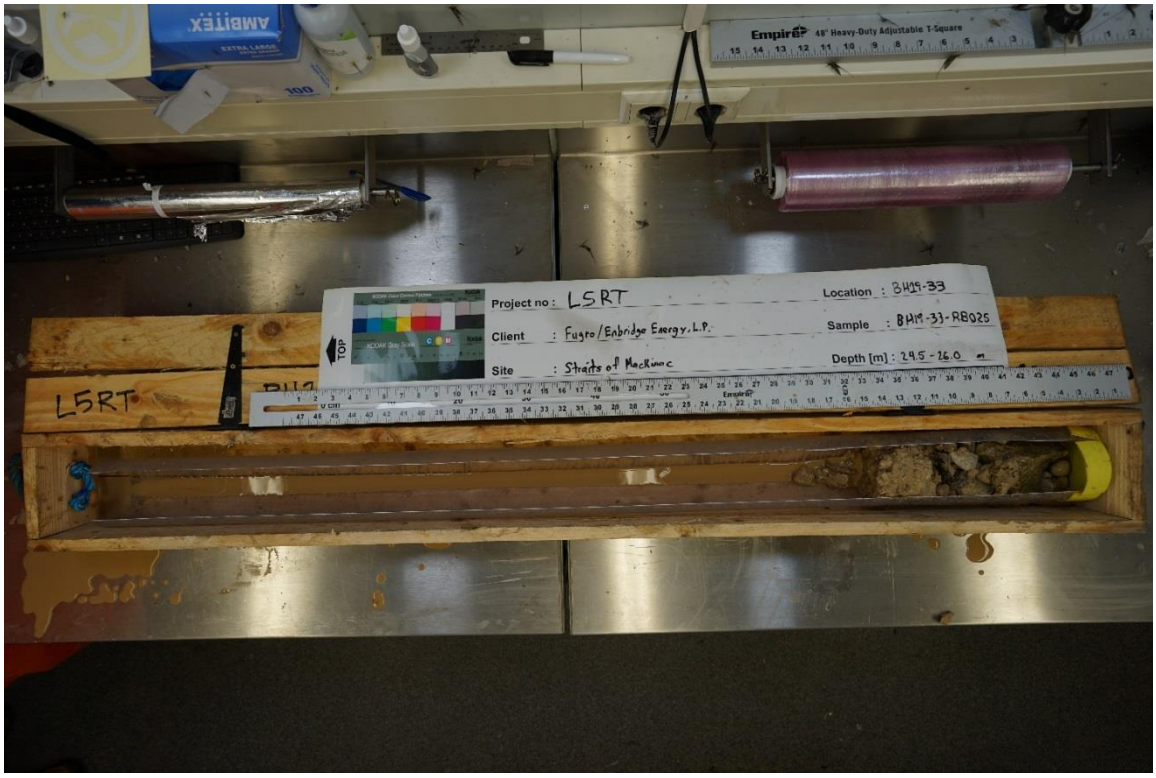
BH19-33-RB-021

BH19-33-RB-022

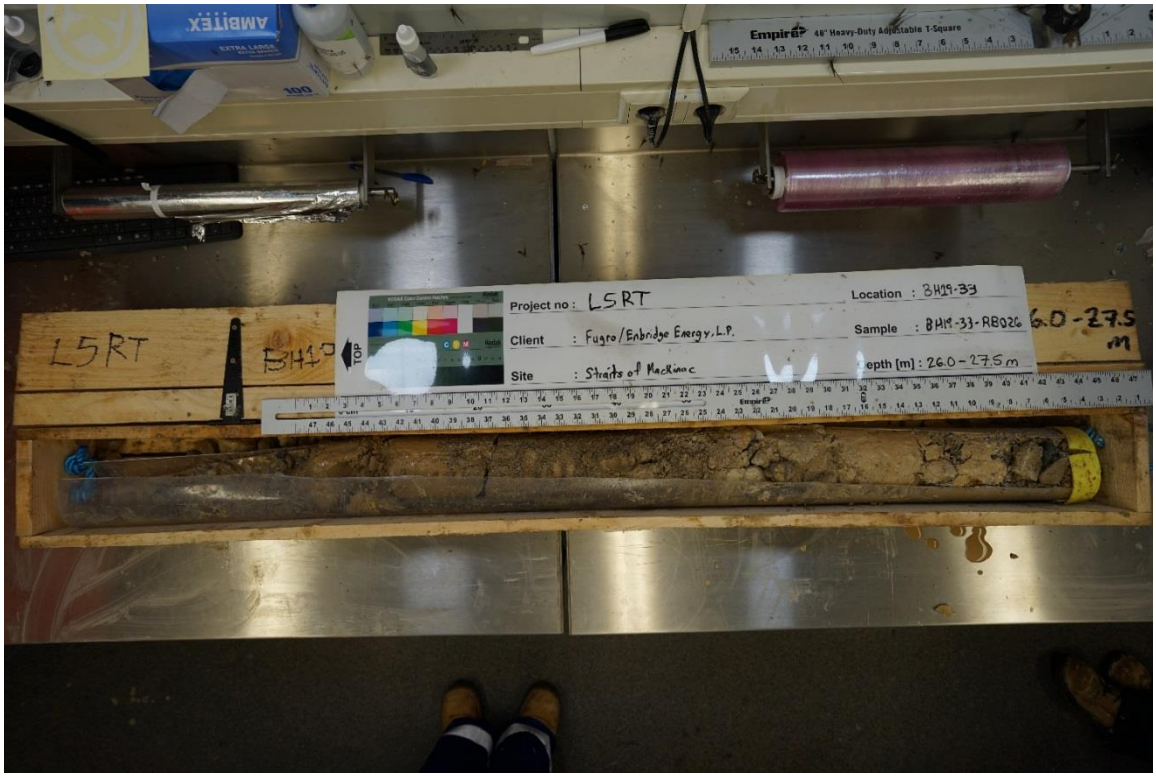


BH19-33-RB-023

BH19-33-RB-024



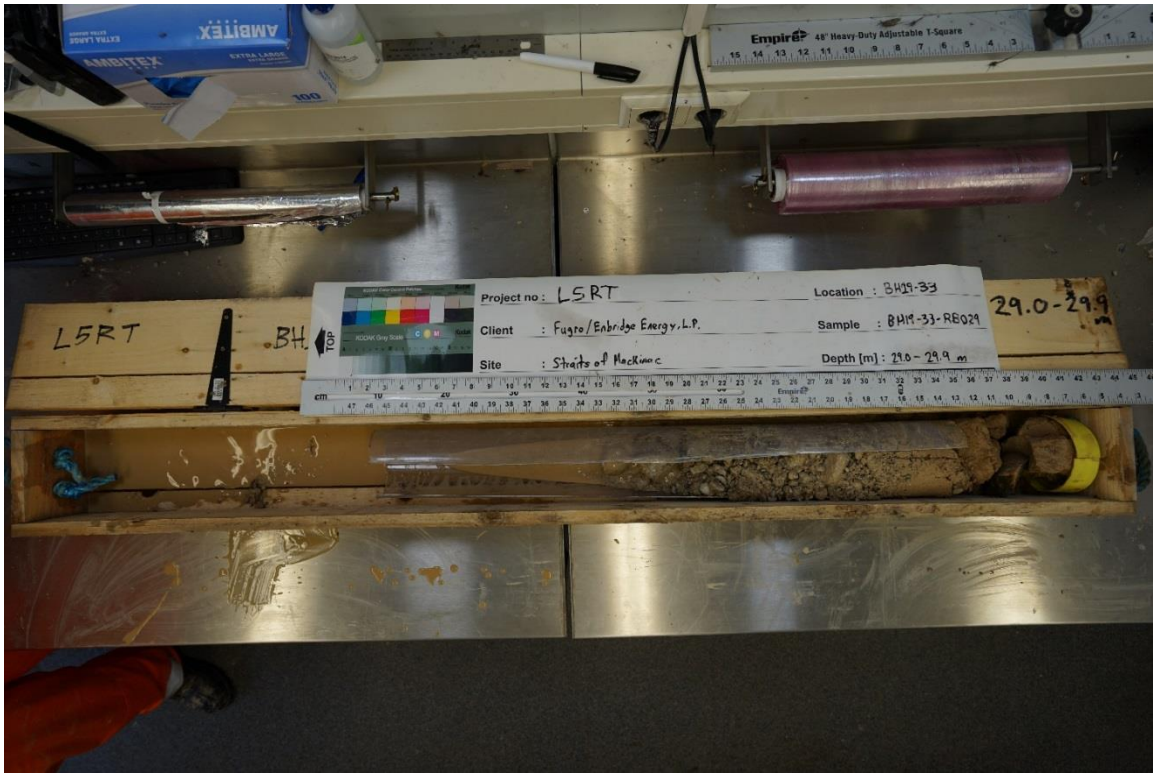
BH19-33-RB-025



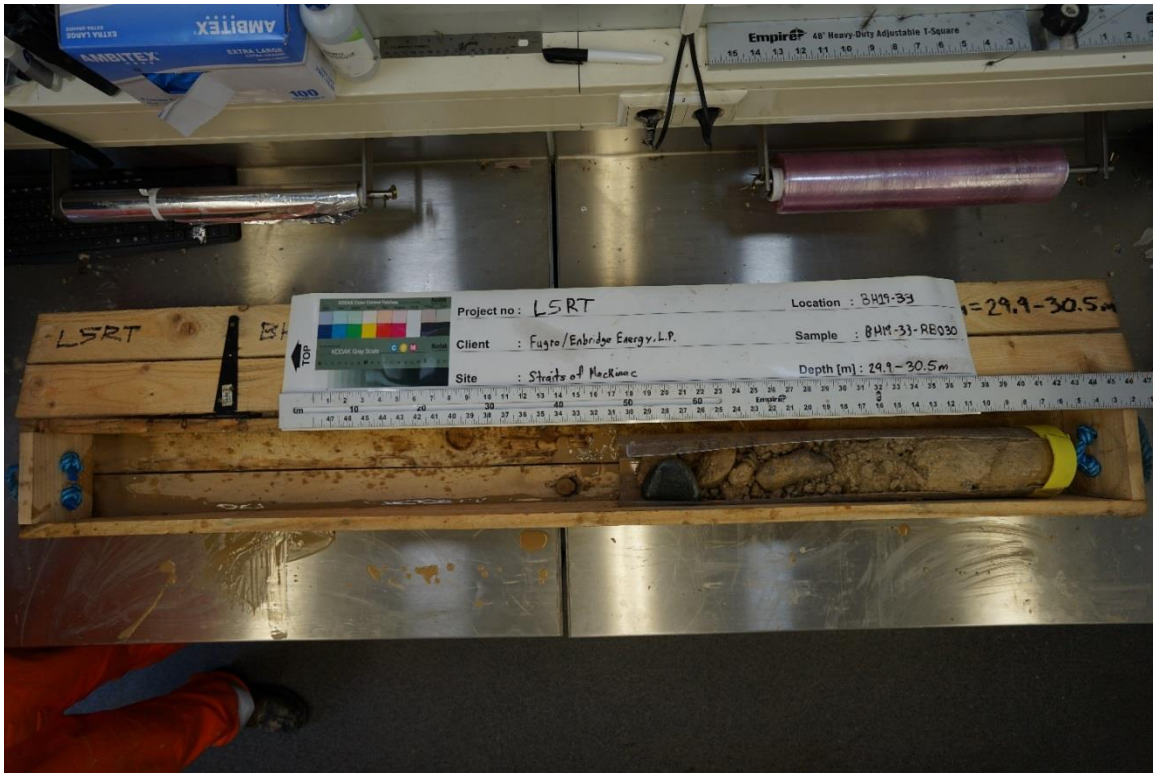
BH19-33-RB-026

BH19-33-RB-027

BH19-33-RB-028



BH19-33-RB-029



BH19-33-RB-030

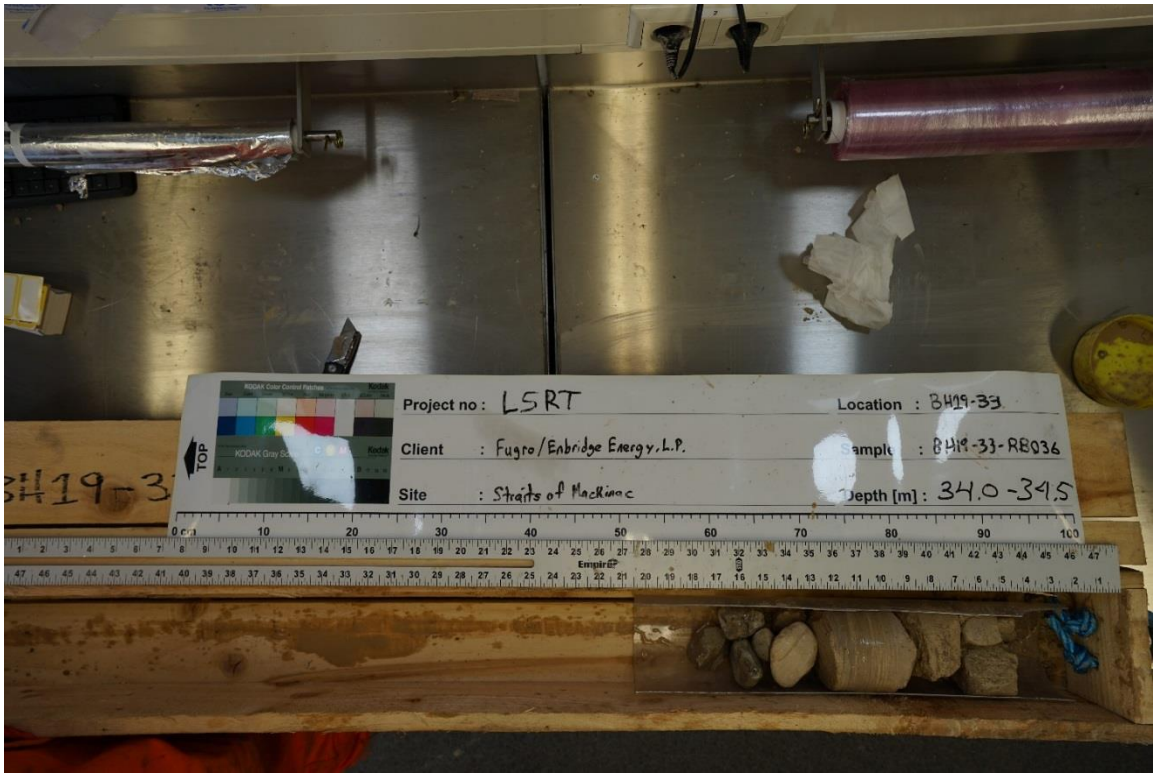
BH19-33-RB-031

BH19-33-RB-032

BH19-33-RB-033

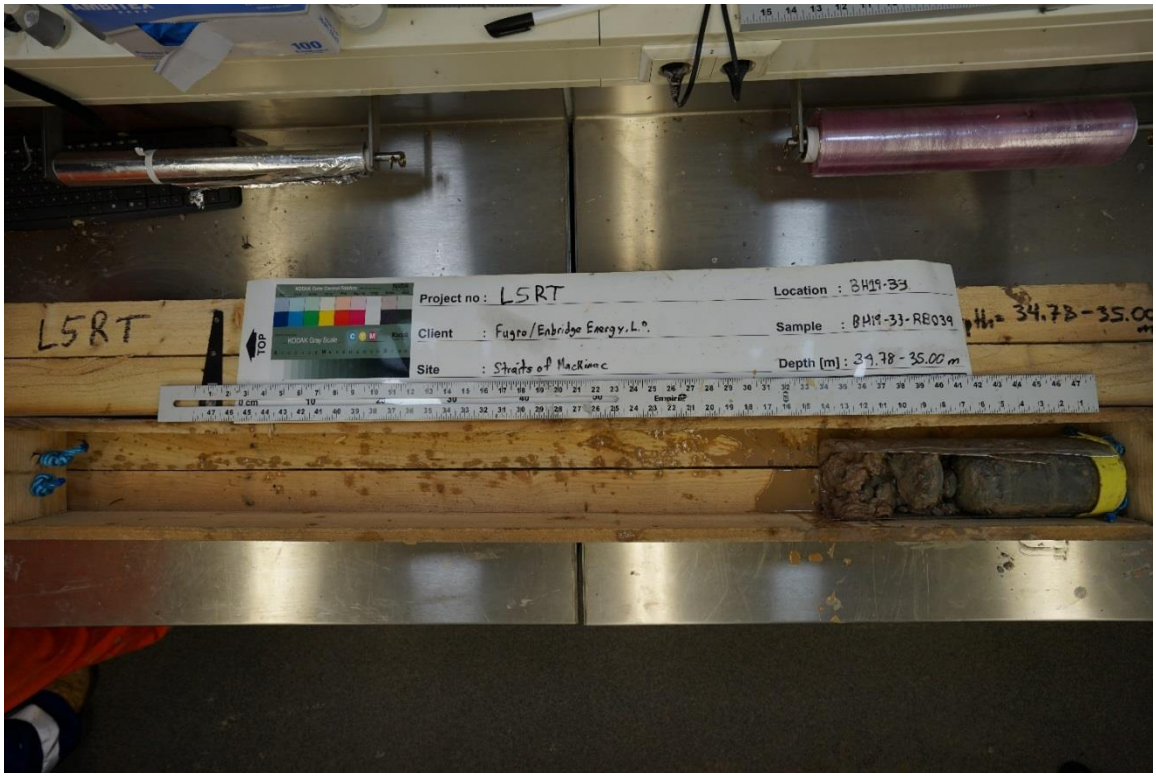
BH19-33-RB-034

BH19-33-RB-035



BH19-33-RB-036/RB-037

BH19-33-RB-038

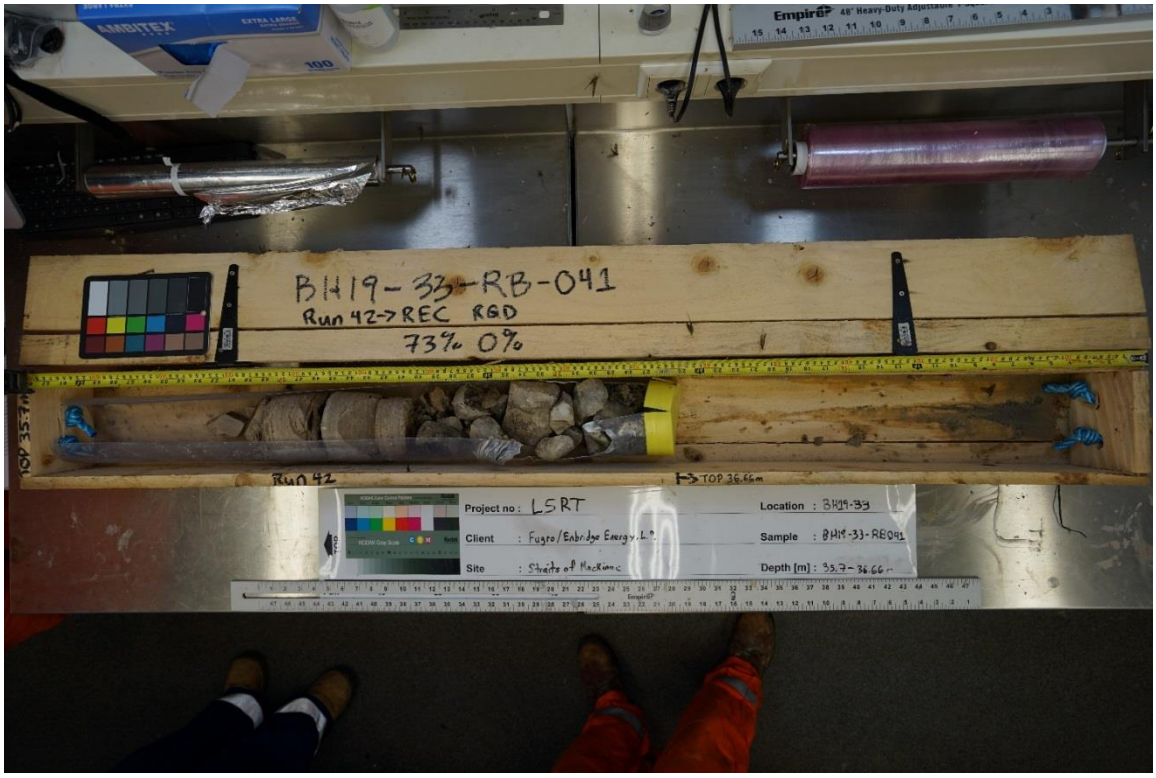


BH19-33-RB-039

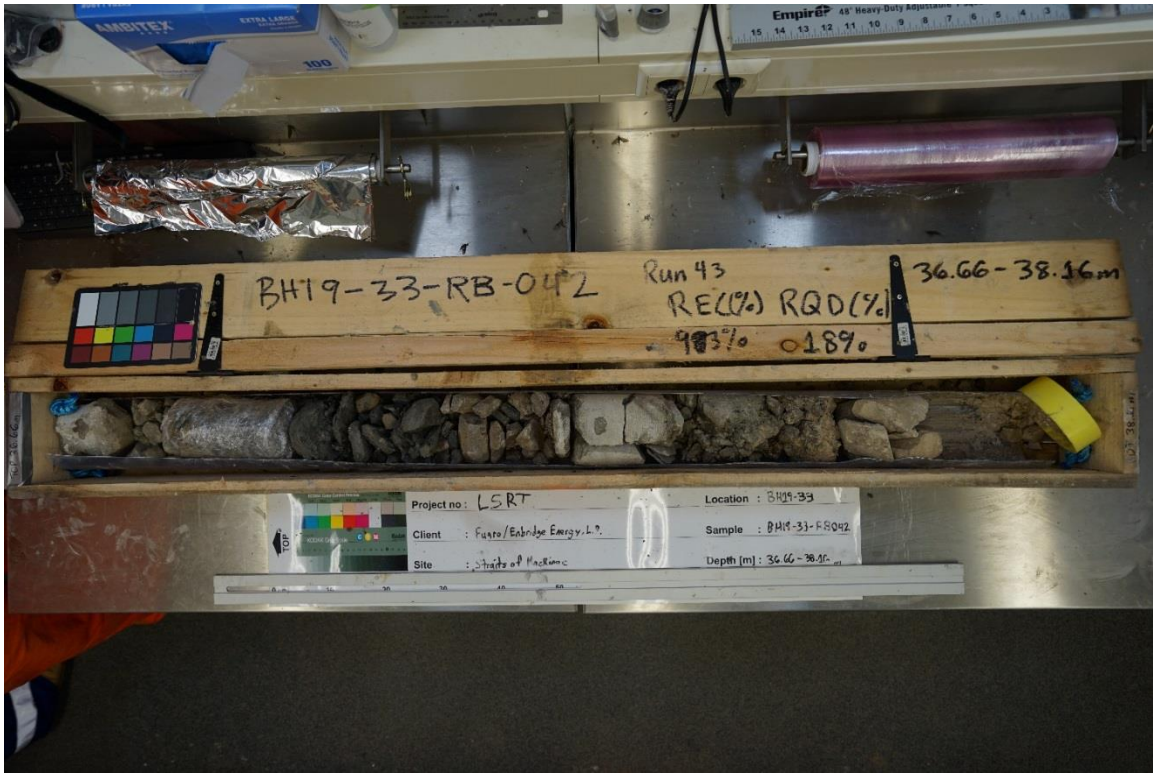
BH19-33-RB-040

[Intentionally Left Blank]

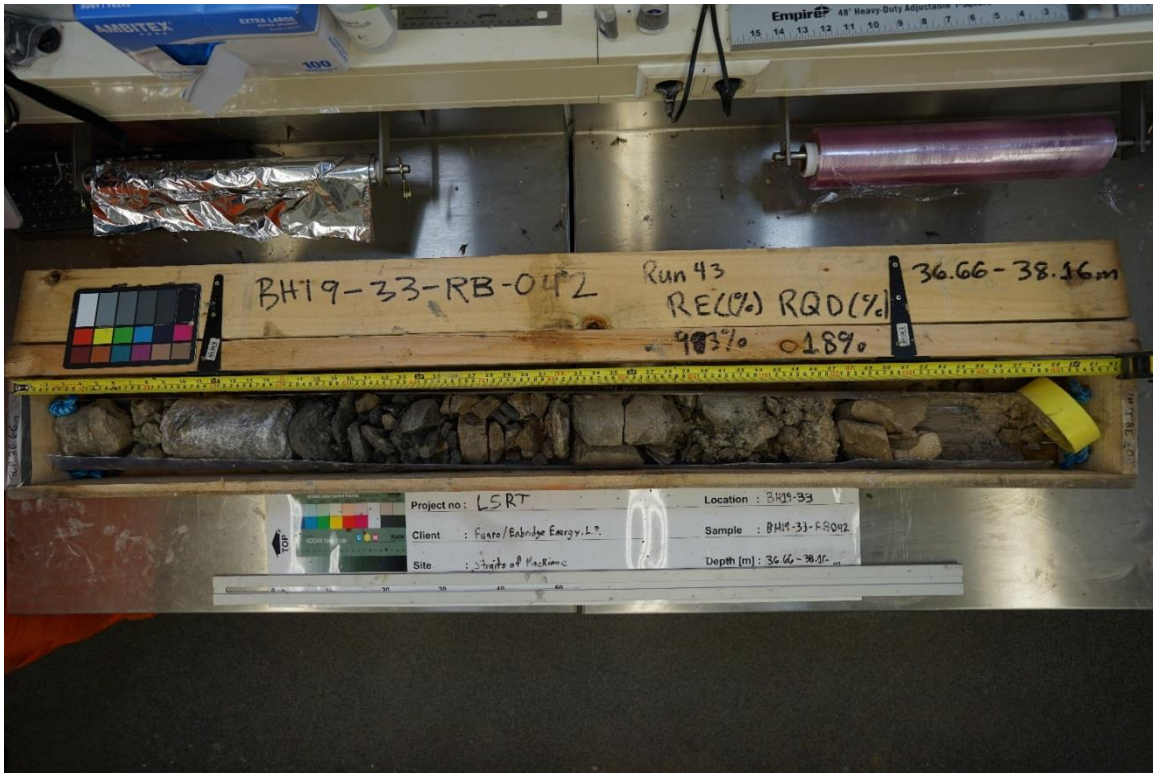
BH19-33-RB-041 (Dry)



BH19-33-RB-041 (Wet)



BH19-33-RB-042 (Dry)



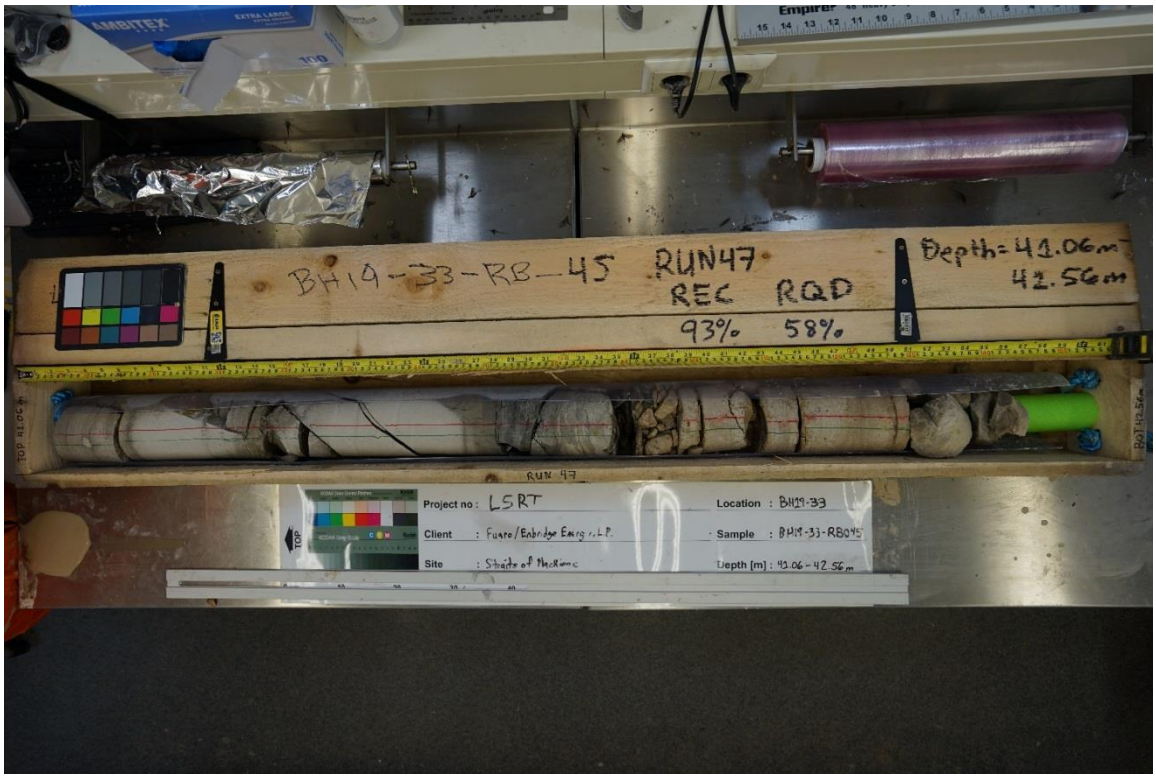
BH19-33-RB-042 (Wet)

BH19-33-RB-043 (Dry)

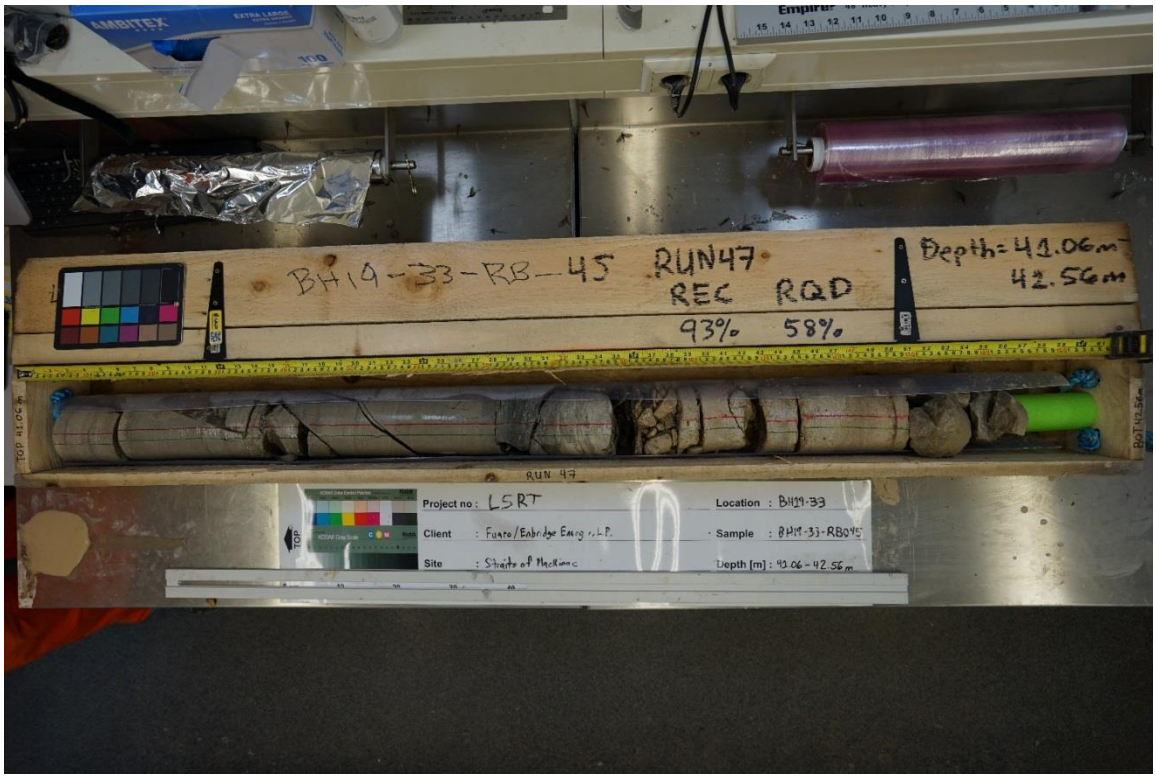
BH19-33-RB-043 (Wet)

BH19-33-RB-044 (Dry)

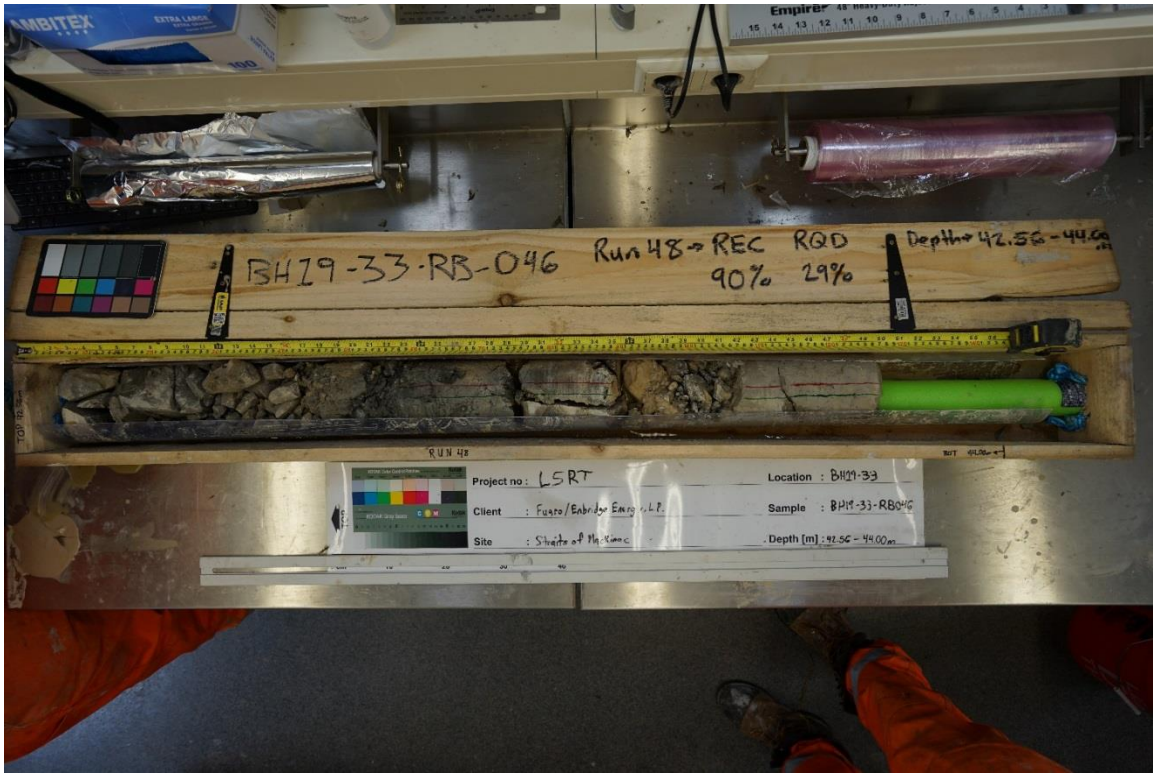
BH19-33-RB-044 (Wet)



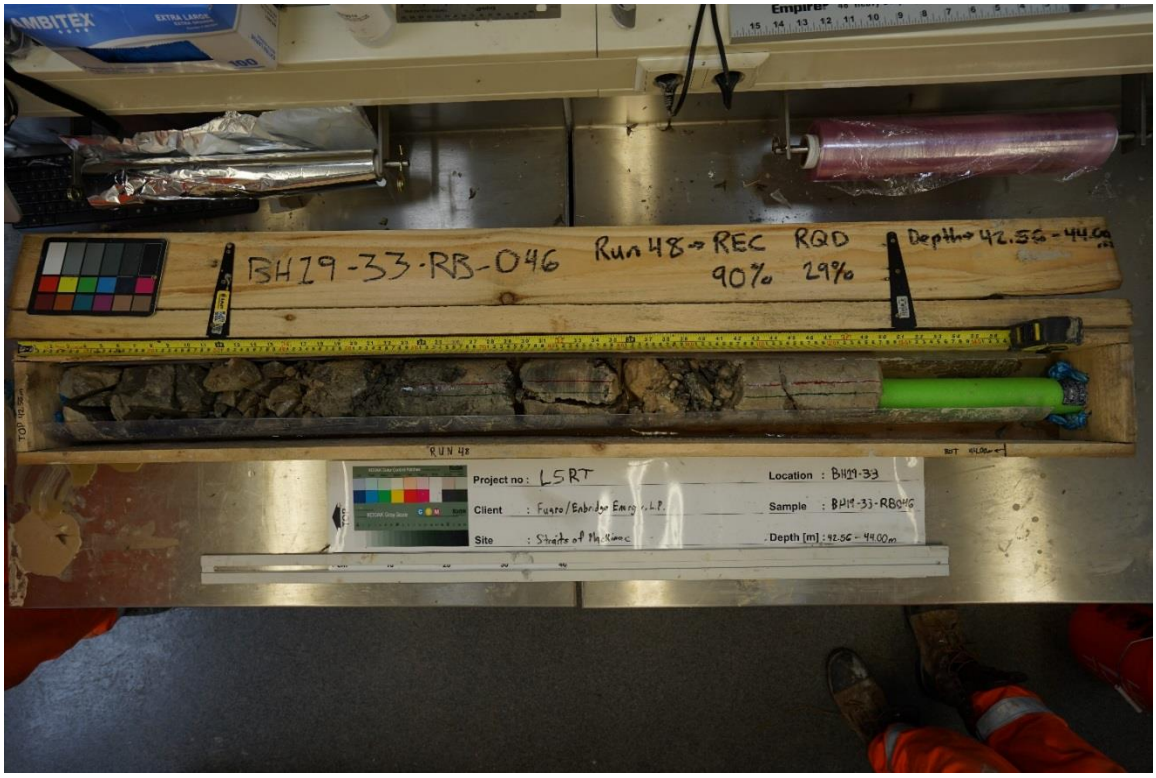
BH19-33-RB-045 (Dry)



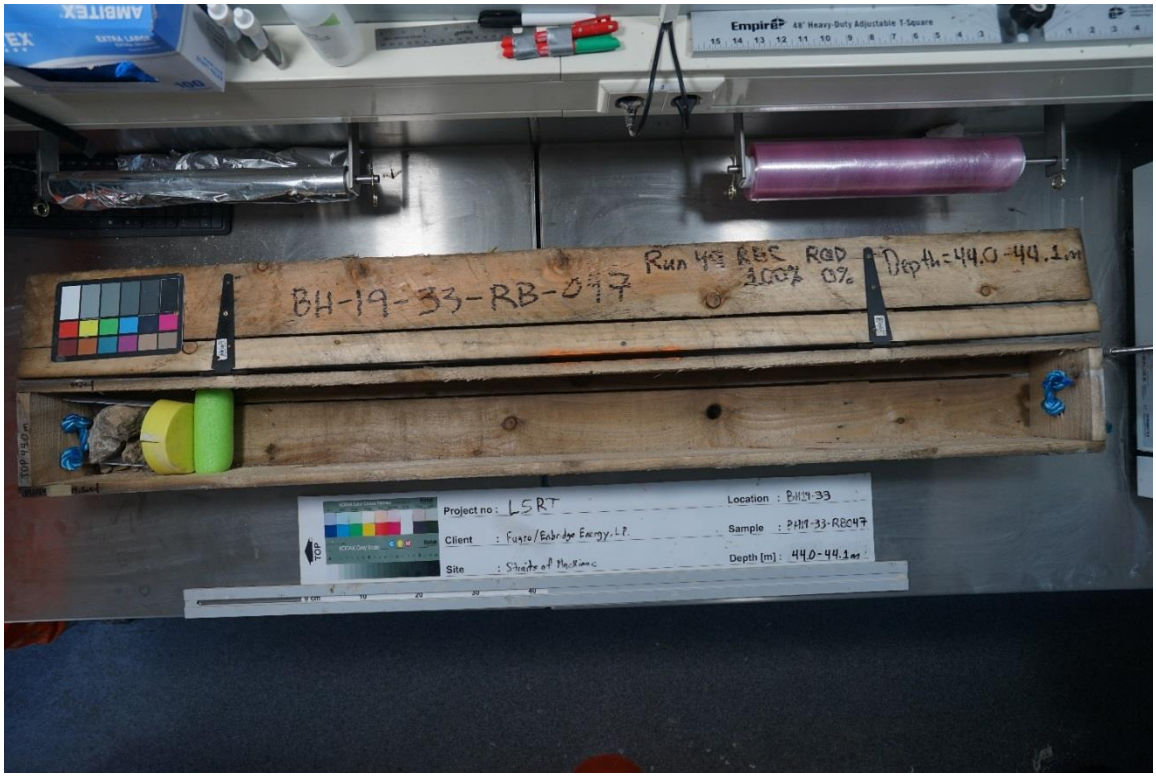
BH19-33-RB-045 (Wet)



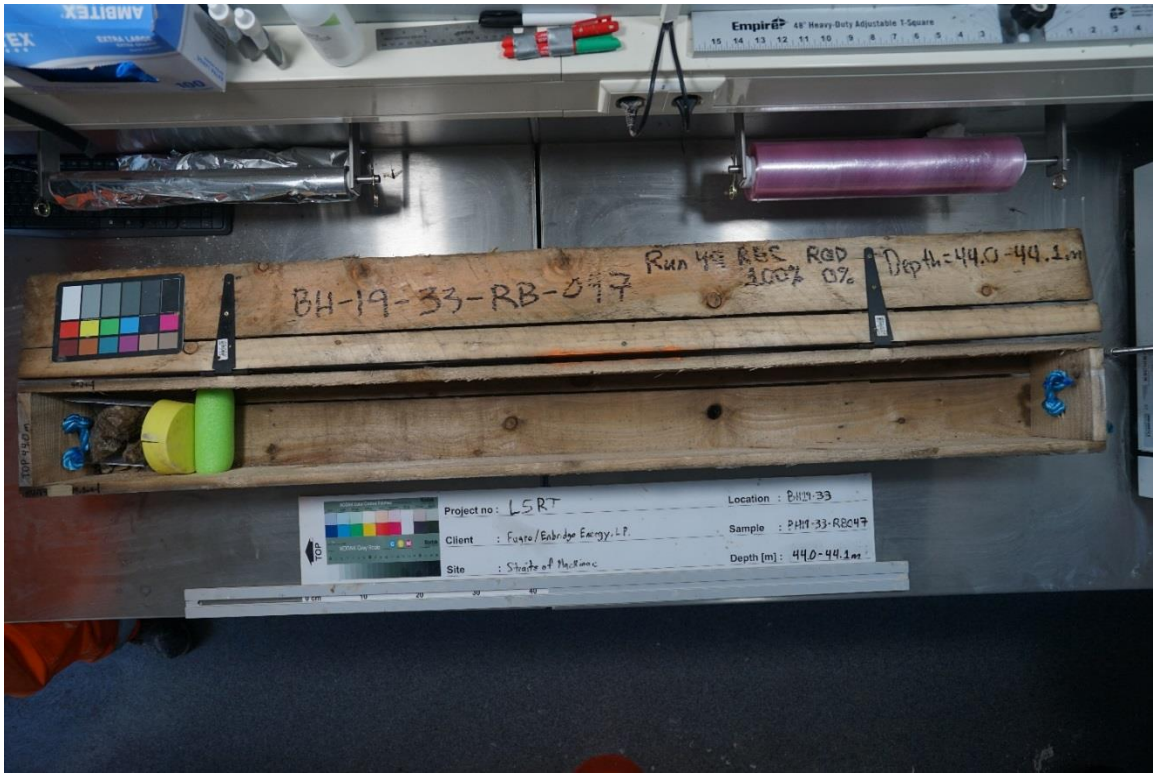
BH19-33-RB-046 (Dry)



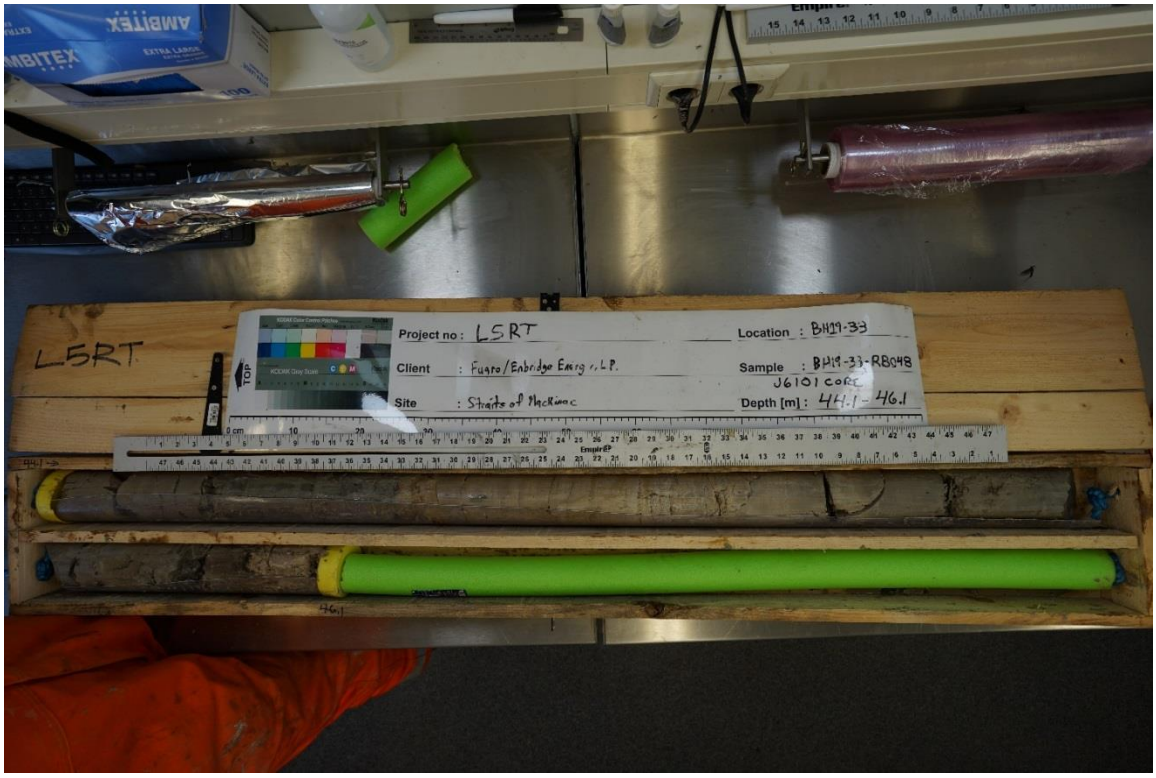
BH19-33-RB-046 (Wet)



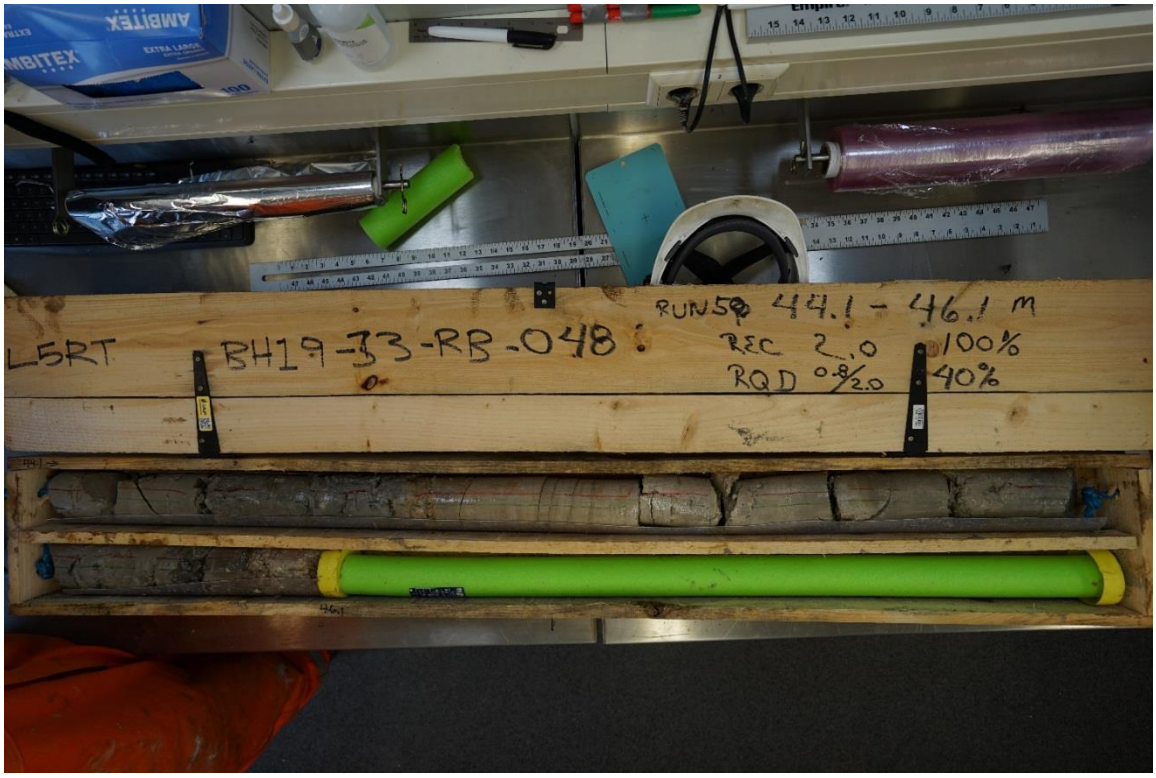
BH19-33-RB-047 (Dry)



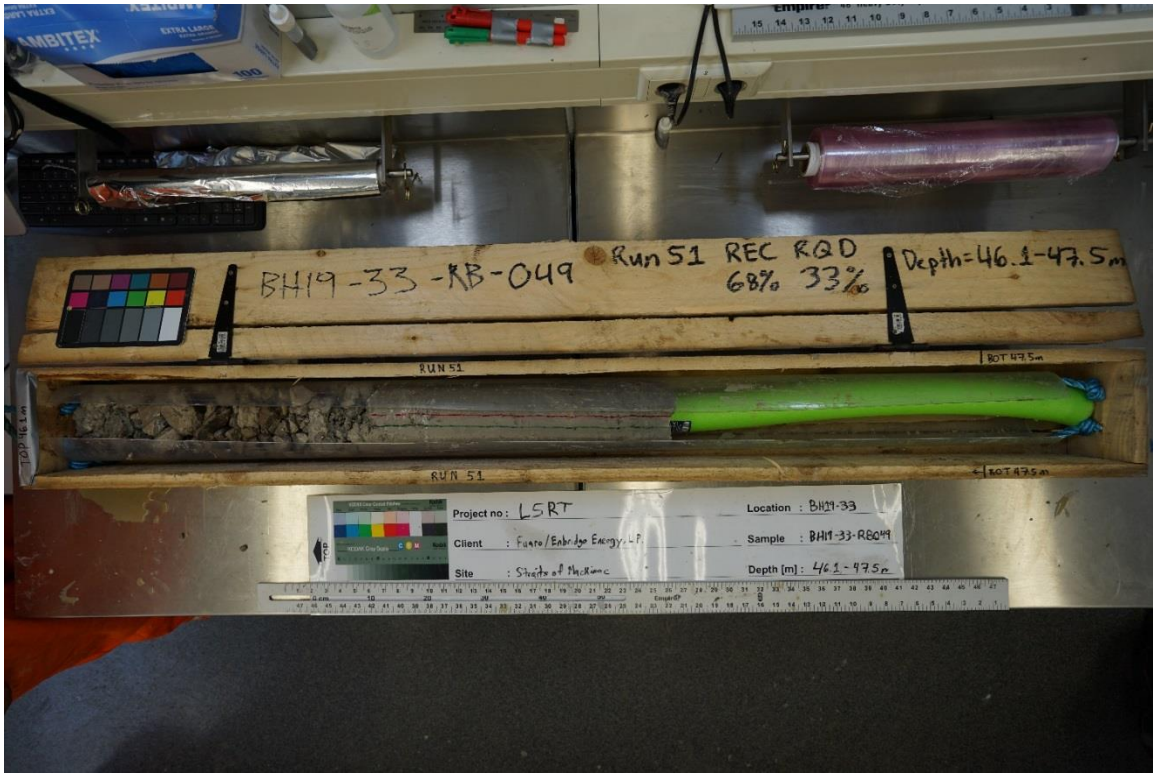
BH19-33-RB-047 (Wet)



BH19-33-RB-048 (Dry)



BH19-33-RB-048 (Wet)



BH19-33-RB-049 (Dry)

BH19-33-RB-049 (Wet)

BH19-33-RB-050 (Dry)

BH19-33-RB-050 (Wet)

BH19-33-RB-051 (Dry)

BH19-33-RB-051 (Wet)

BH19-33-RB-052 (Dry)

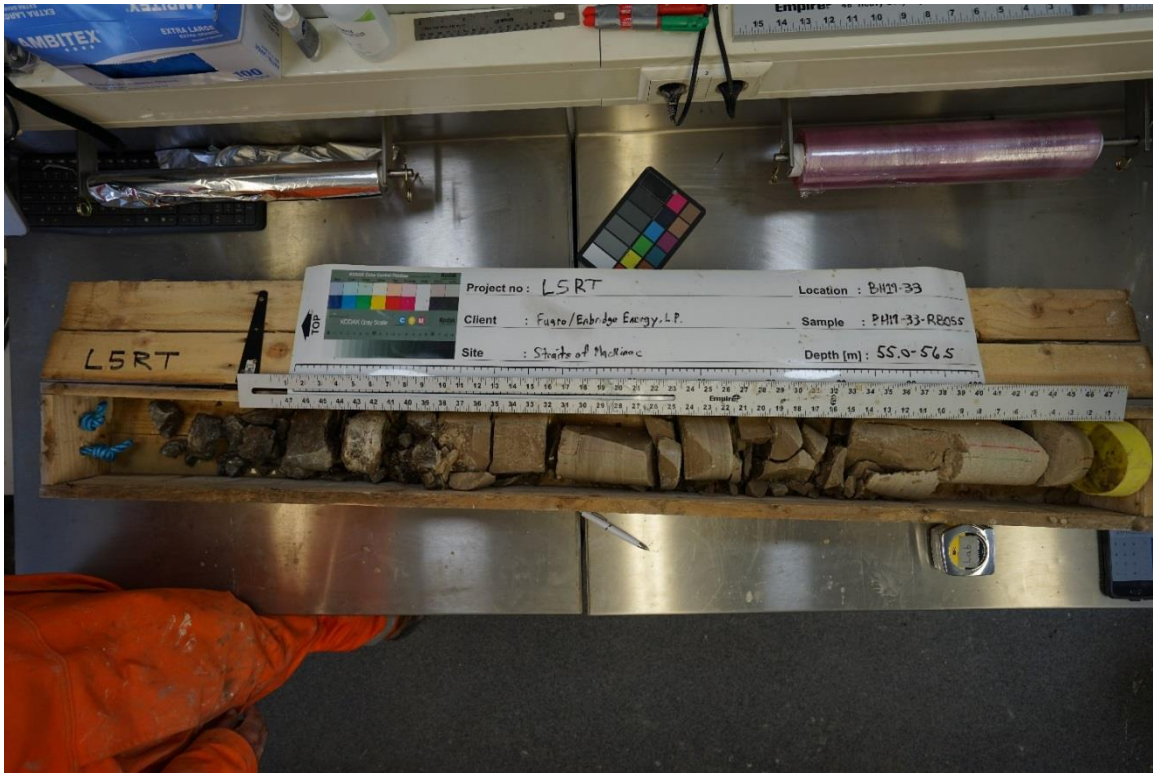
BH19-33-RB-052 (Wet)

BH19-33-RB-053 (Dry)

BH19-33-RB-053 (Wet)

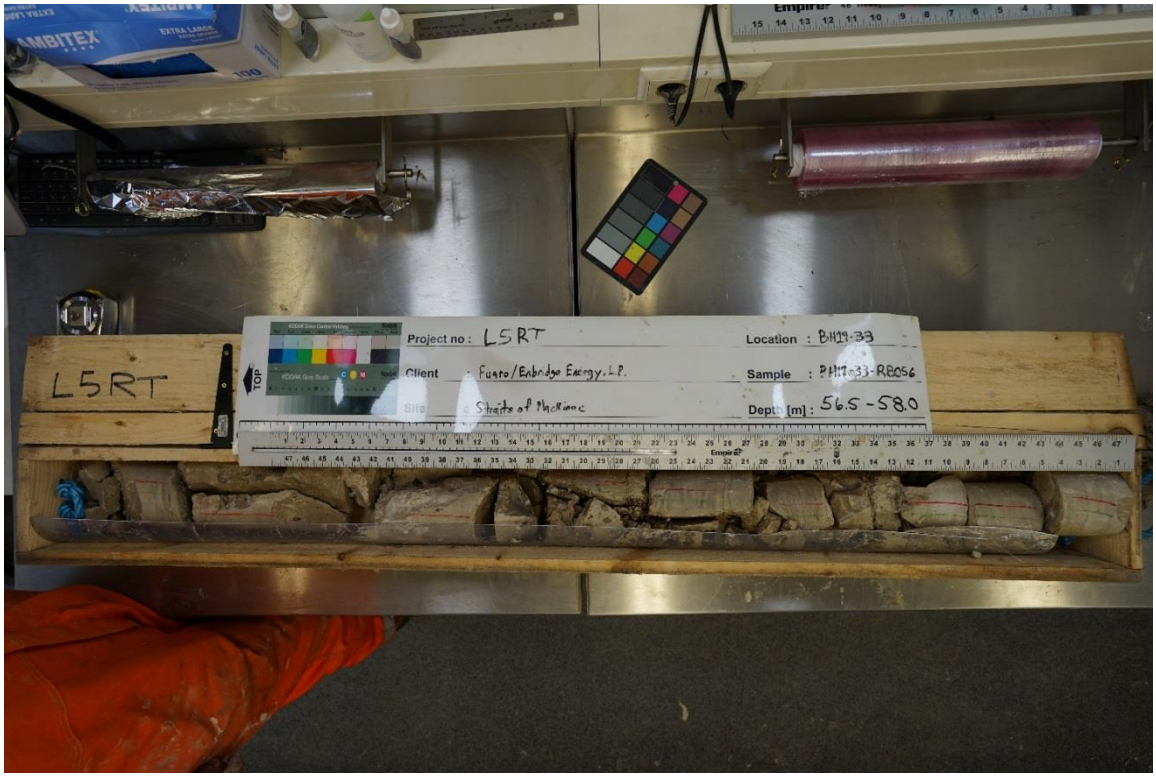
BH19-33-RB-054 (Dry)

BH19-33-RB-054 (Wet)

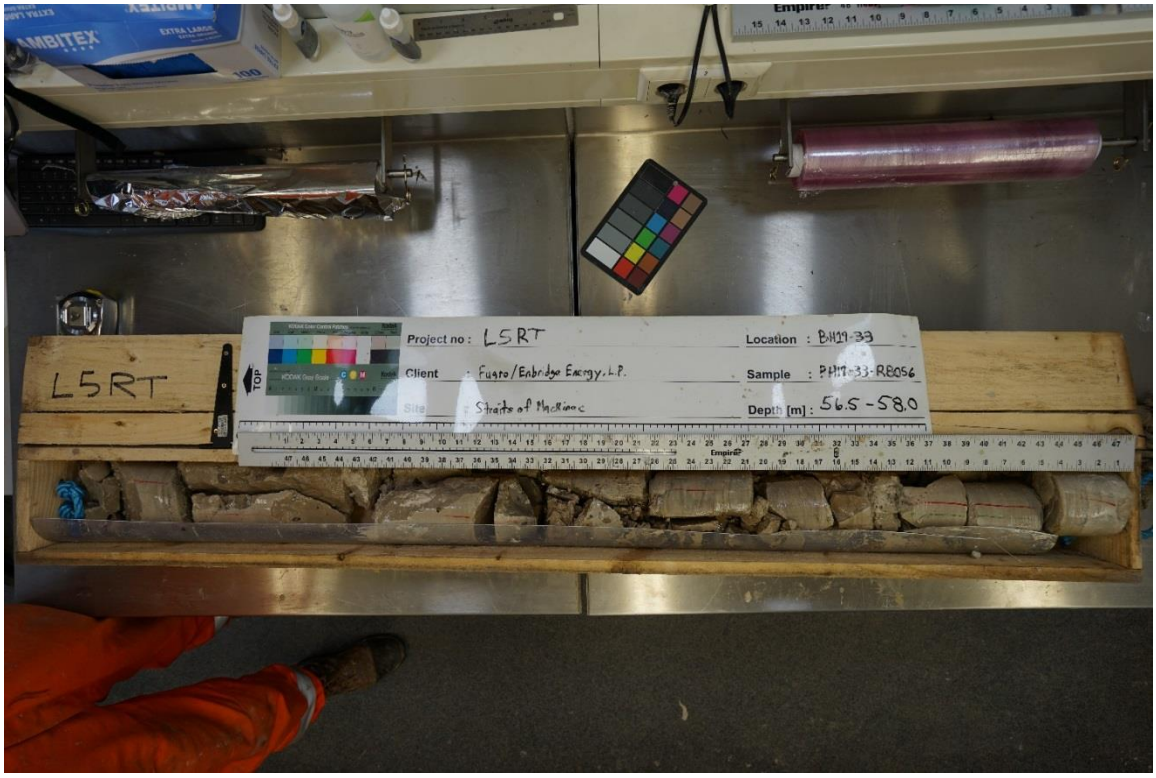


BH19-33-RB-055 (Dry)

BH19-33-RB-055 (Wet)



BH19-33-RB-056 (Dry)



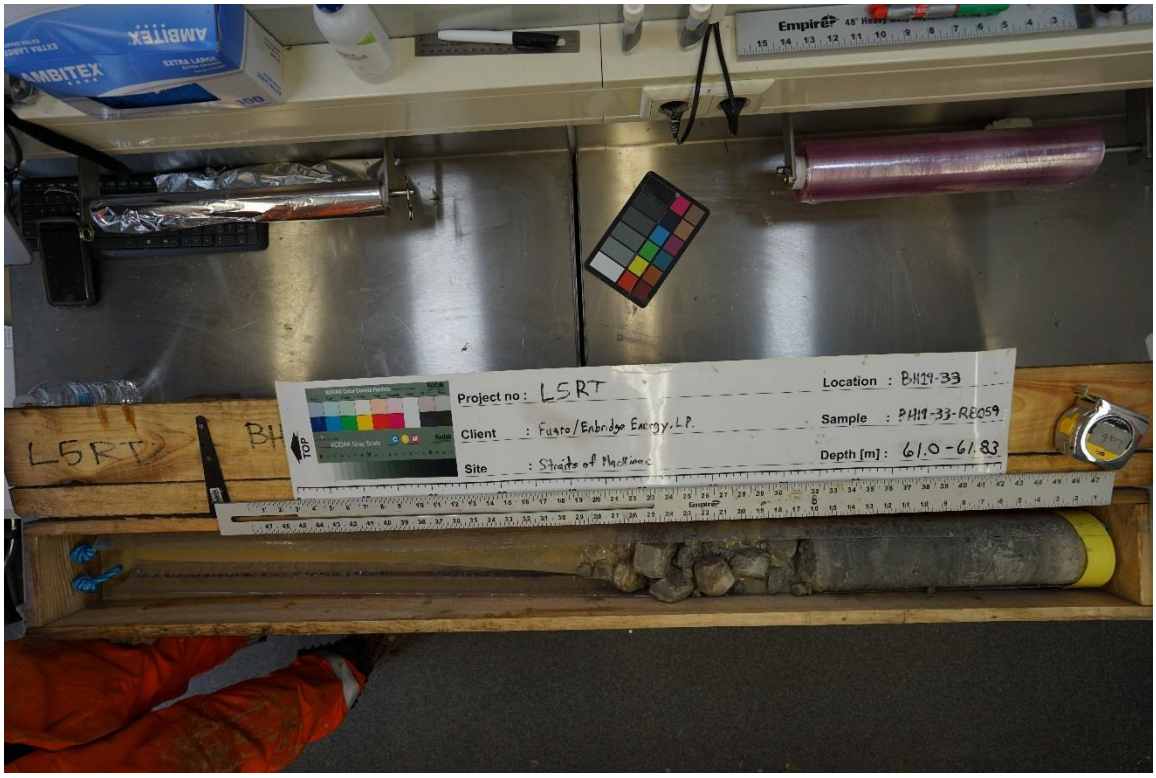
BH19-33-RB-056 (Wet)

BH19-33-RB-057 (Dry)

BH19-33-RB-057 (Wet)

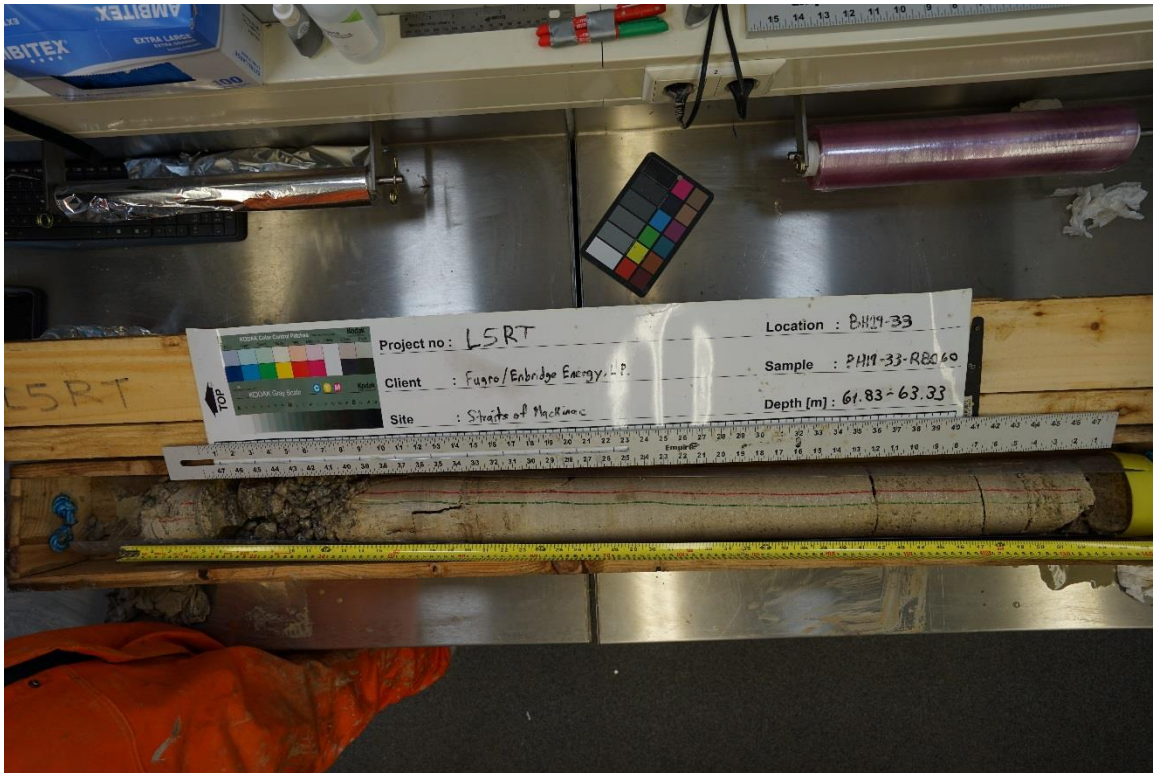
BH19-33-RB-058 (Dry)

BH19-33-RB-058 (Wet)



BH19-33-RB-059 (Dry)

BH19-33-RB-059 (Wet)



BH19-33-RB-060 (Dry)

BH19-33-RB-060 (Wet)

BH19-33-RB-061 (Dry)

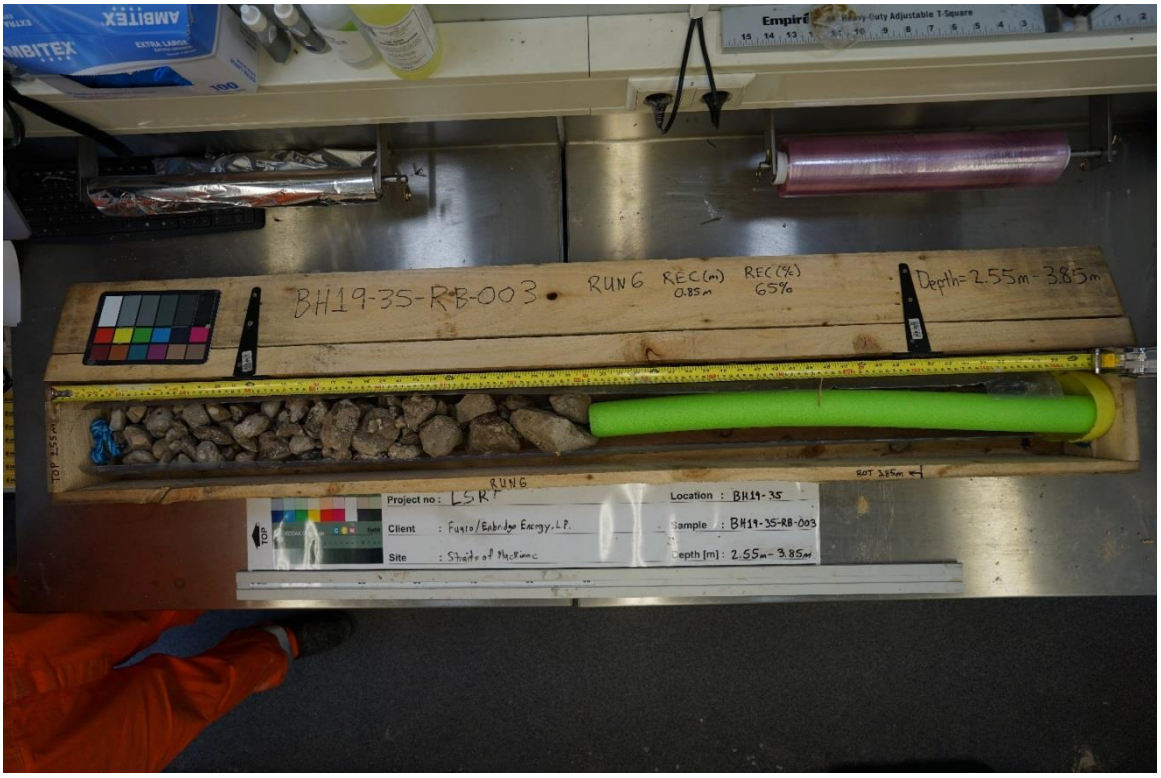
BH19-33-RB-061 (Wet)

BH19-33-RB-062 (Dry)

BH19-33-RB-062 (Wet)

BH19-35-RB-001

BH19-35-RB-002



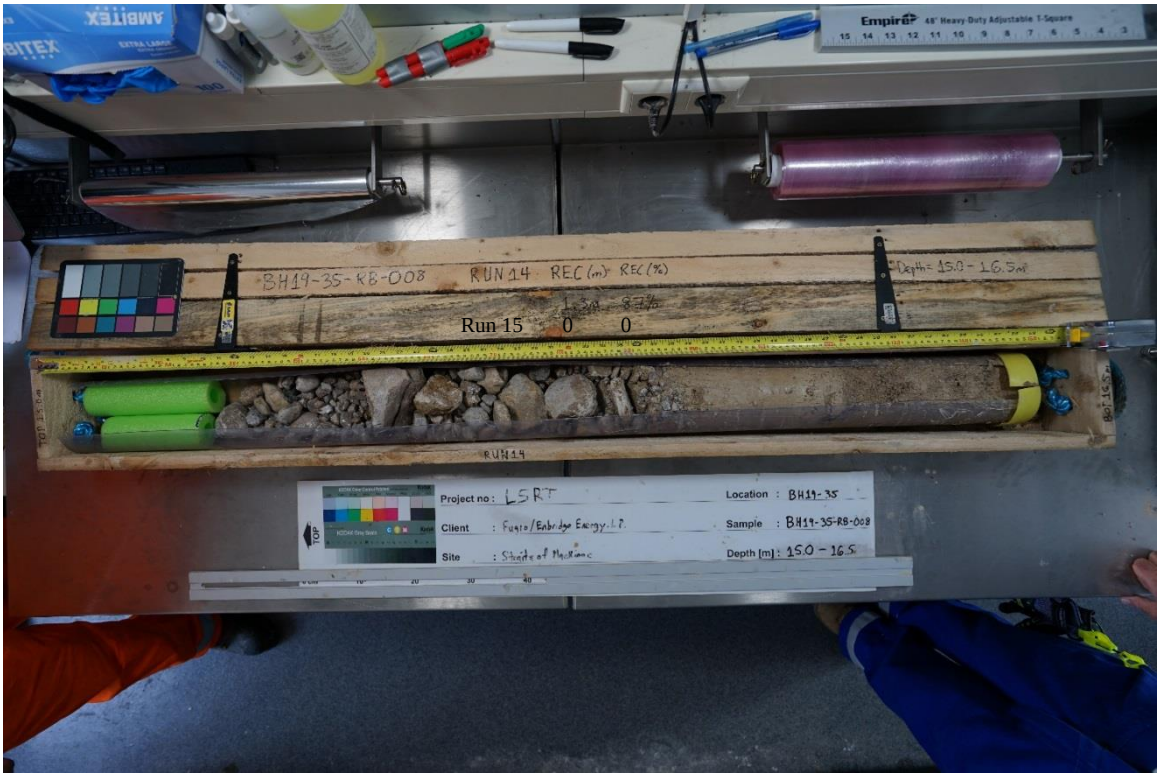
BH19-35-RB-003

BH19-35-RB-004

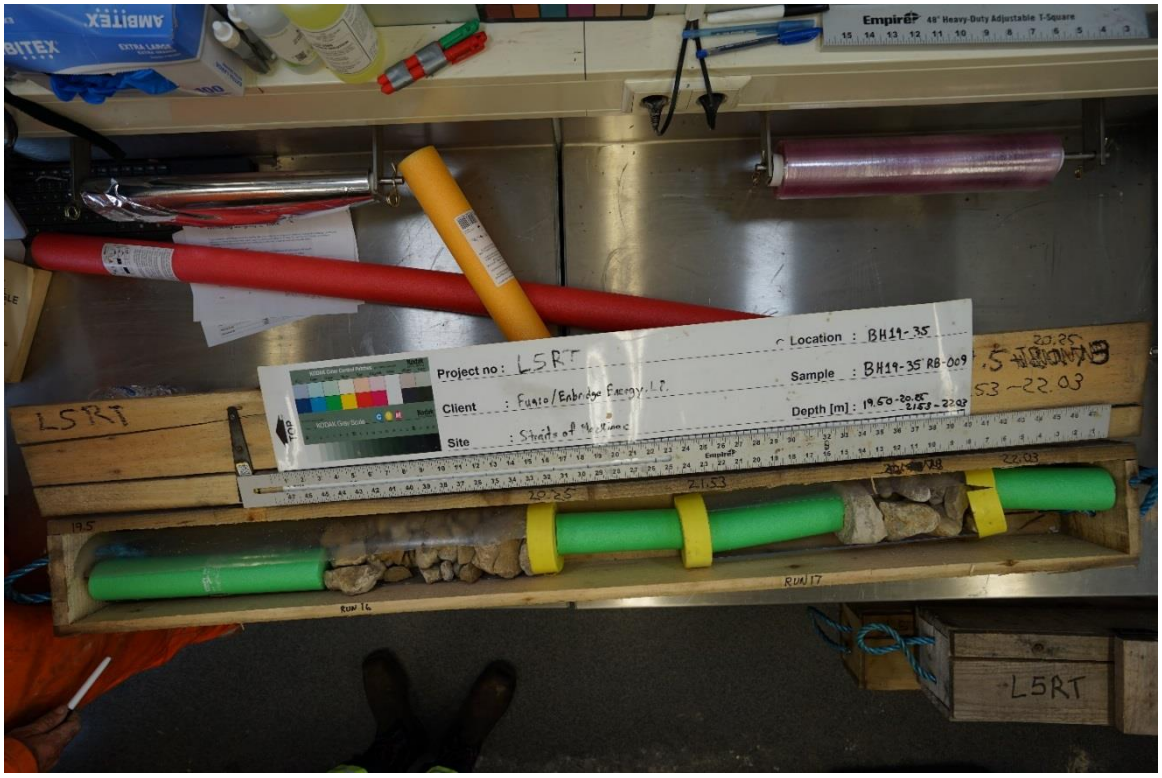
BH19-35-RB-005

BH19-35-RB-006

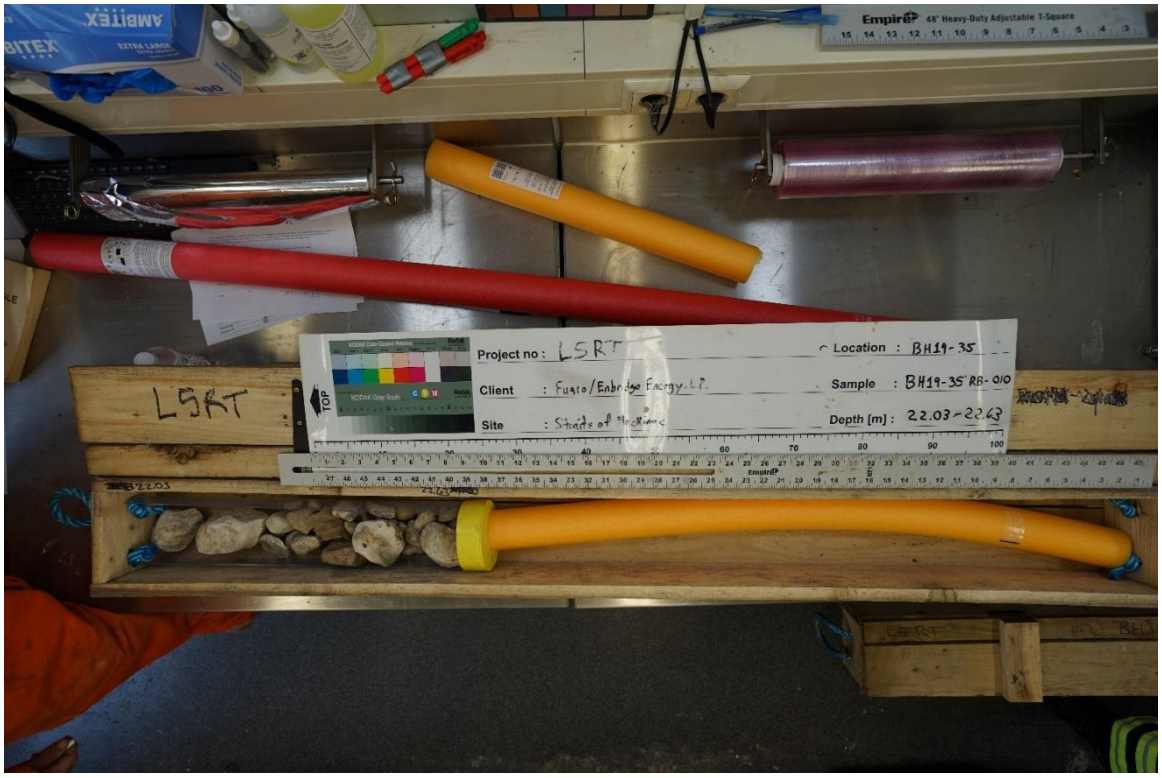
BH19-35-RB-007



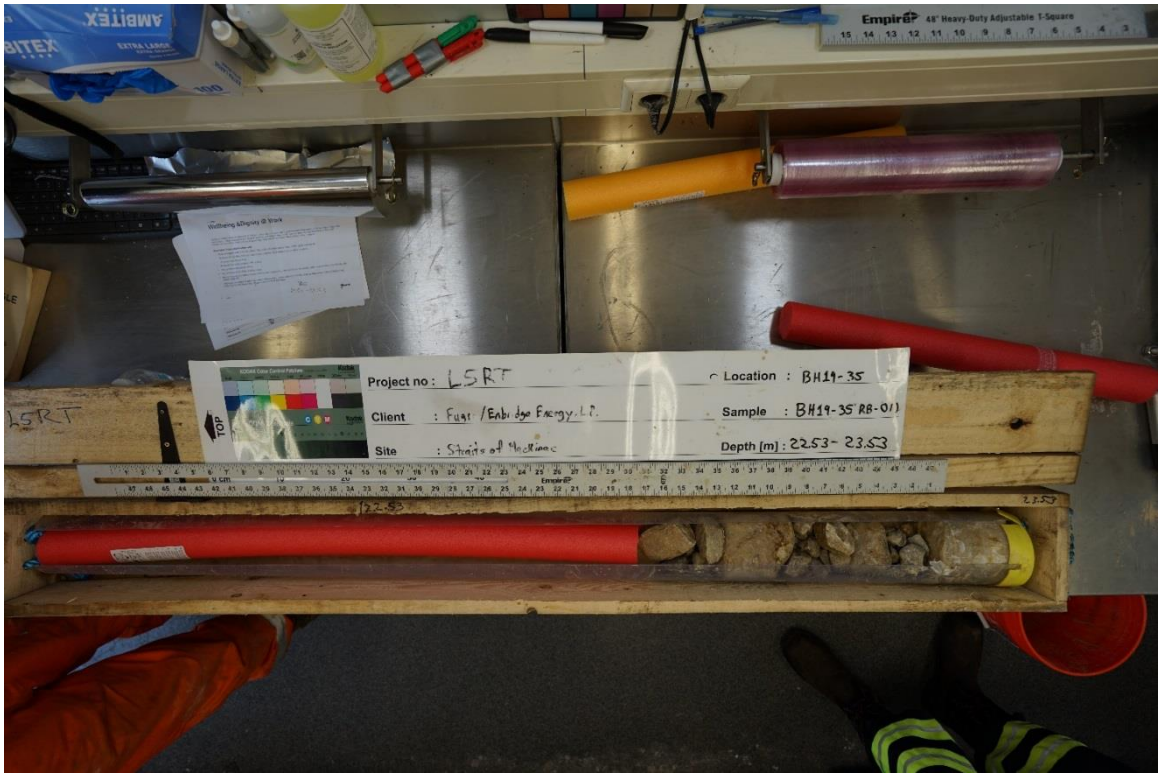
BH19-35-RB-008



BH19-35-RB-009



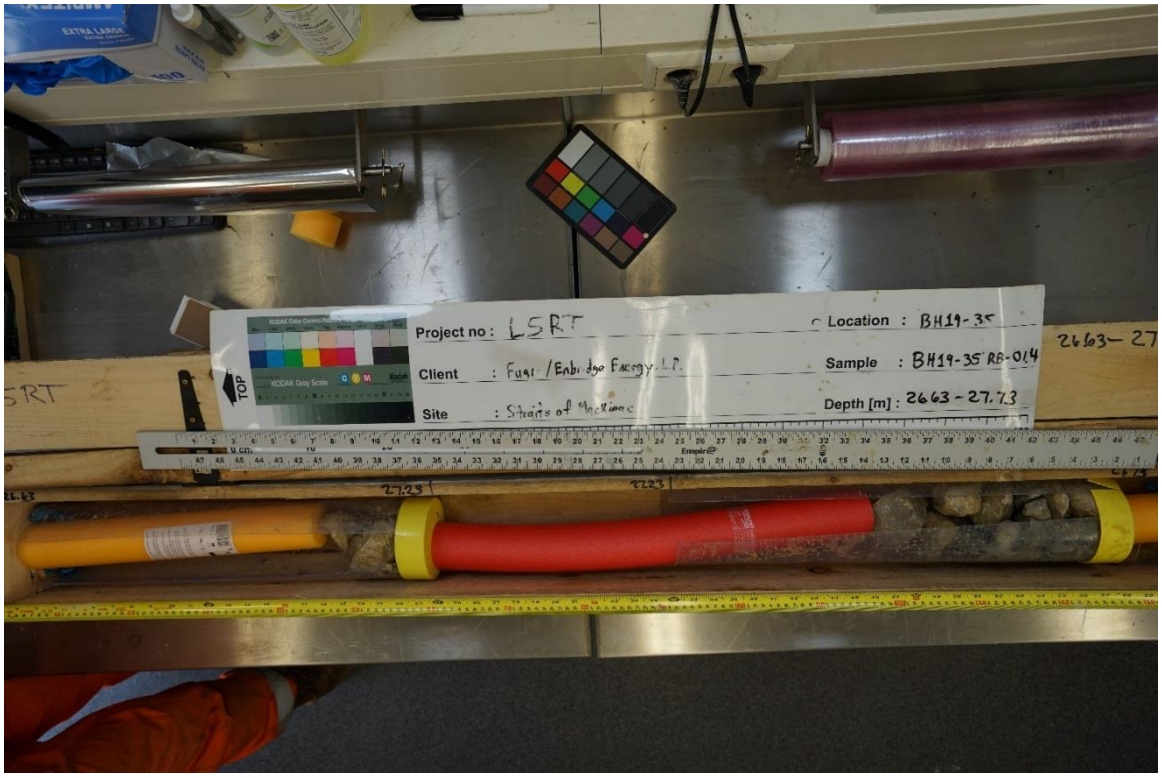
BH19-35-RB-010



BH19-35-RB-011

BH19-35-RB-012

BH19-35-RB-013

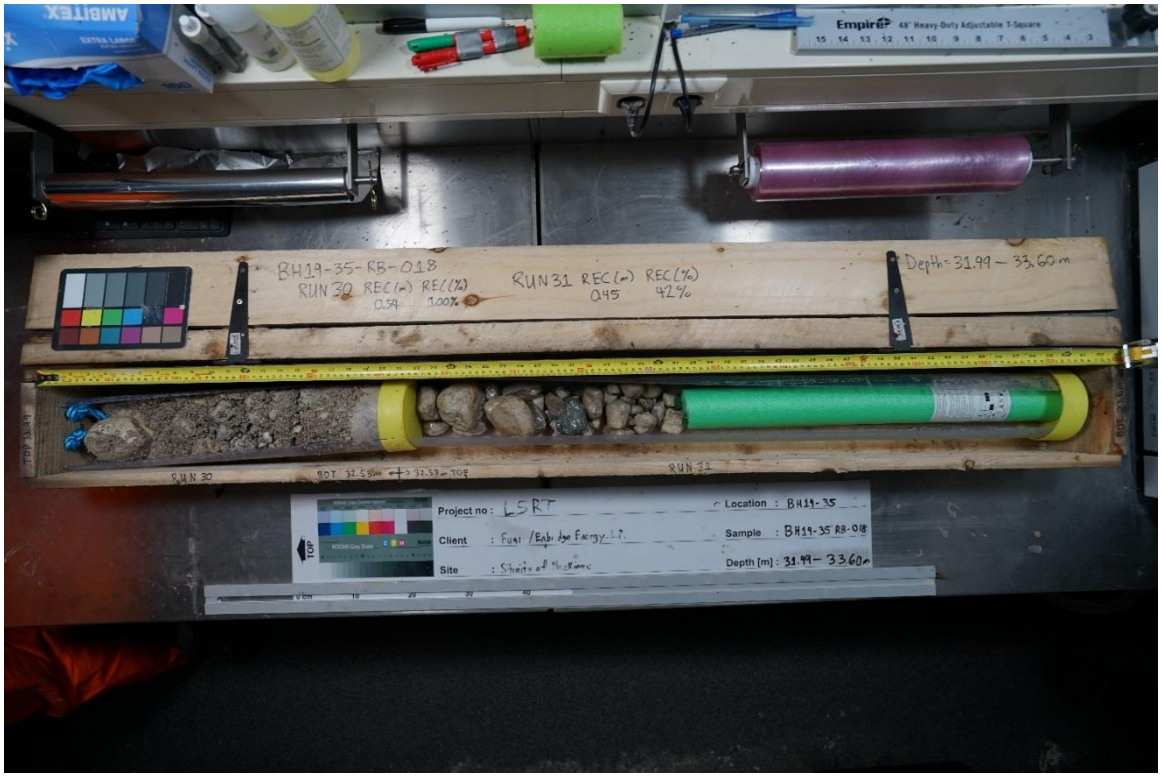


BH19-35-RB-014

BH19-35-RB-015

BH19-35-RB-016

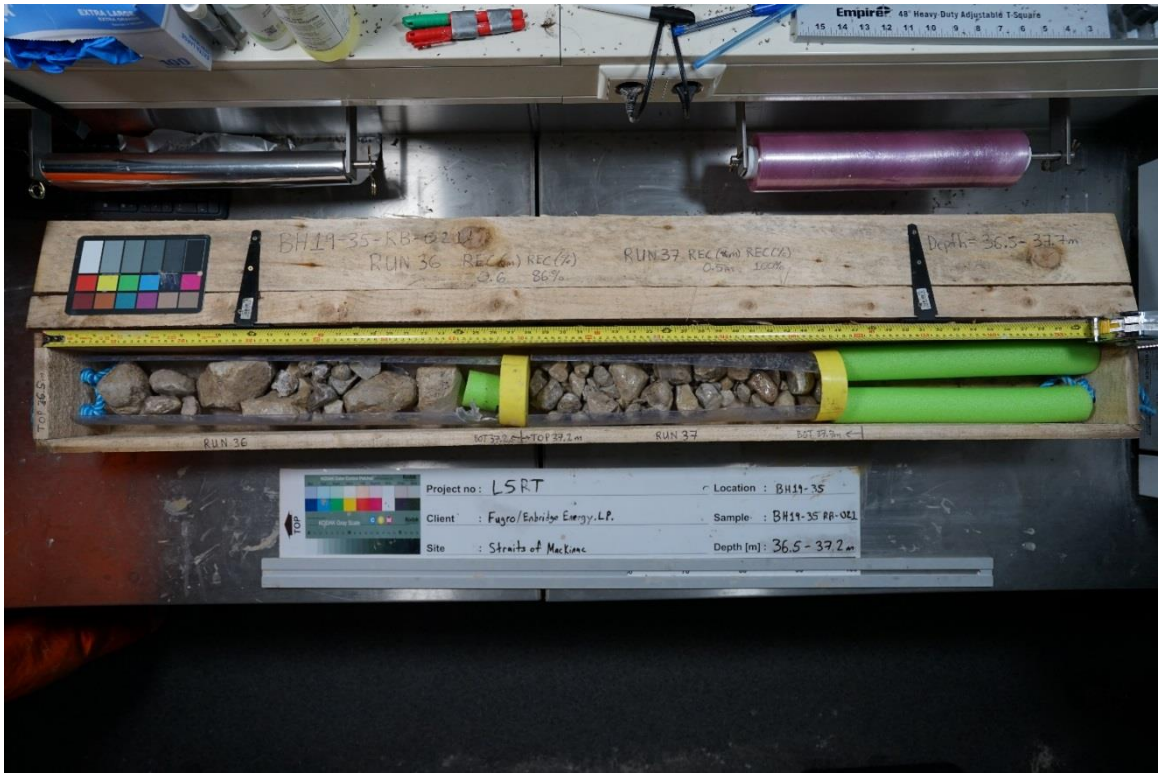
BH19-35-RB-017



BH19-35-RB-018

BH19-35-RB-019

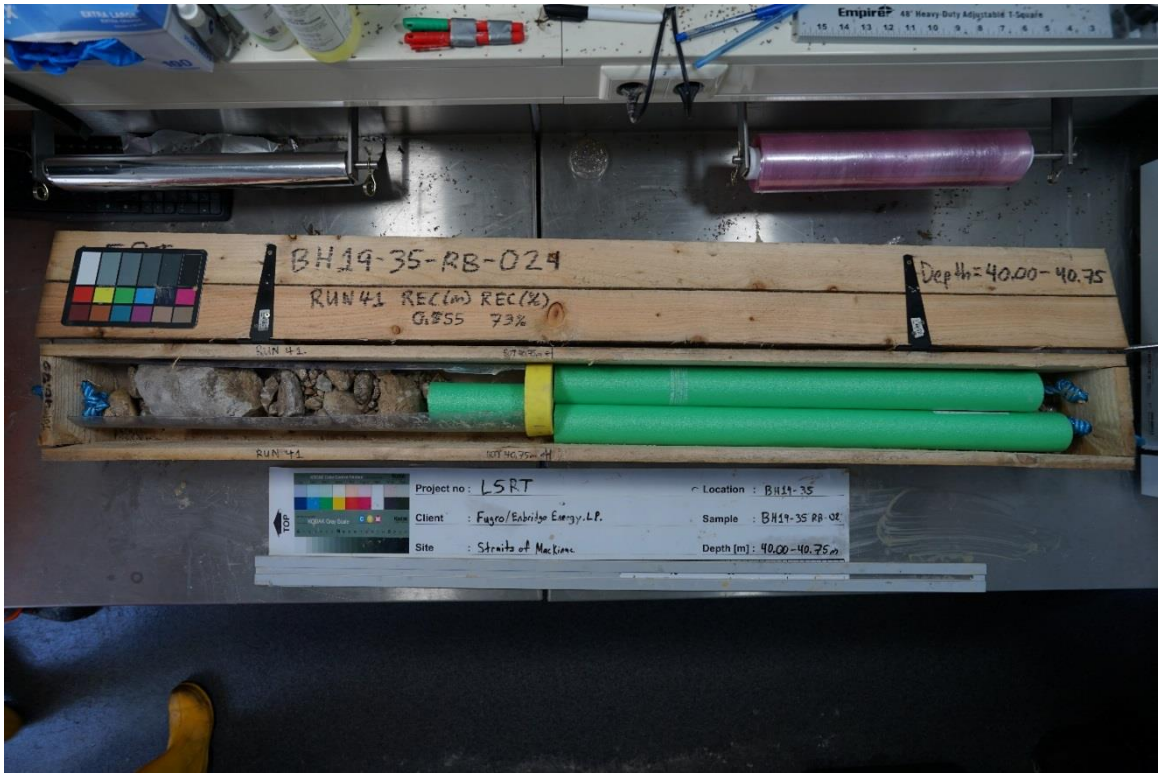
BH19-35-RB-020



BH19-35-RB-021

BH19-35-RB-022

BH19-35-RB-023

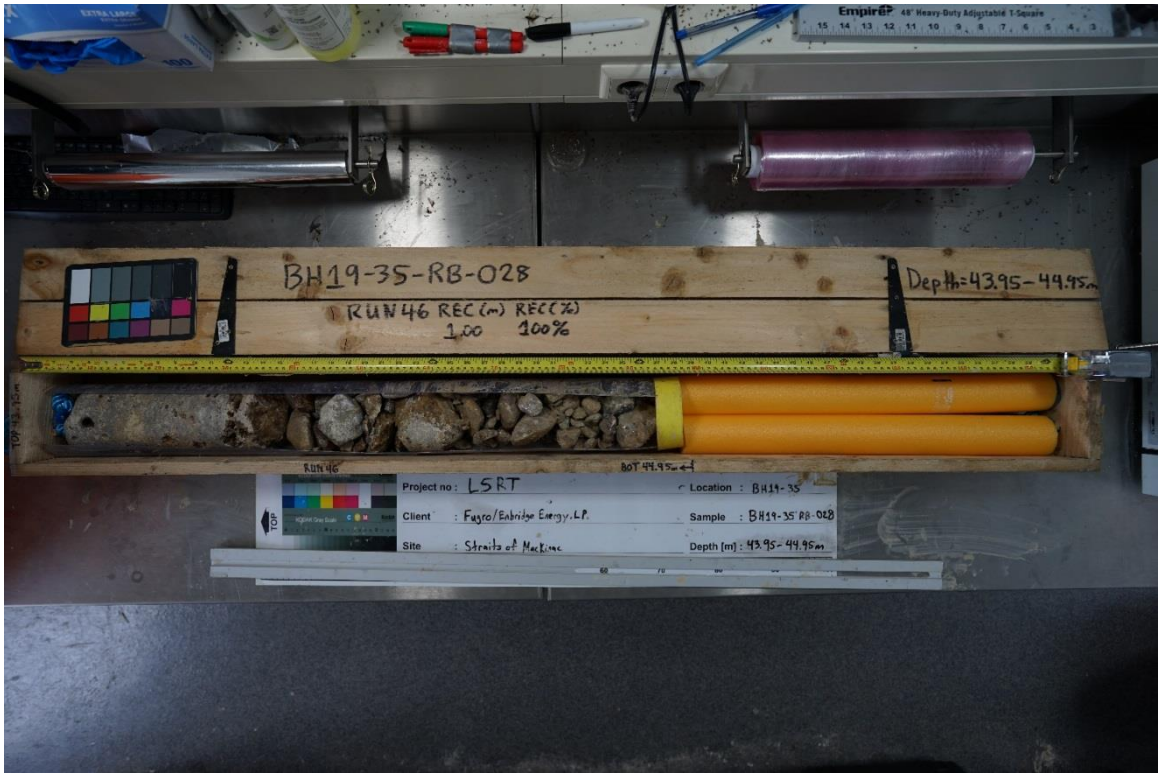


BH19-35-RB-024

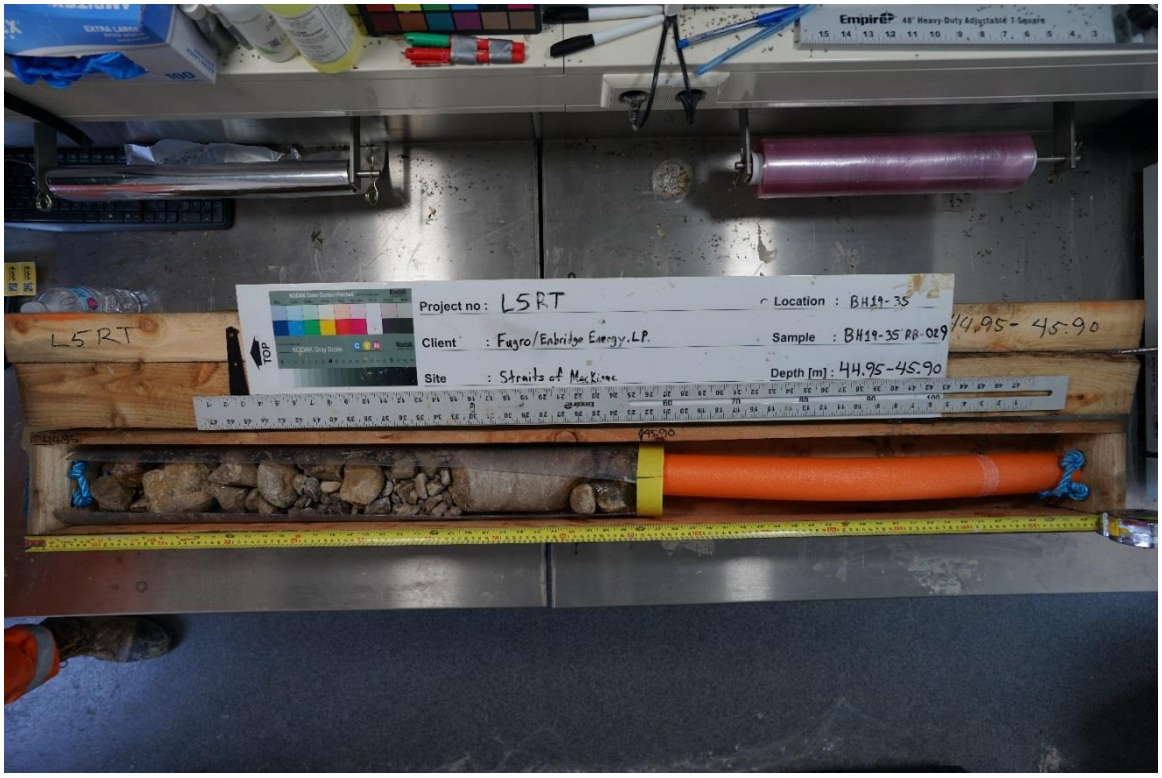
BH19-35-RB-025

BH19-35-RB-026

BH19-35-RB-027



BH19-35-RB-028



BH19-35-RB-029

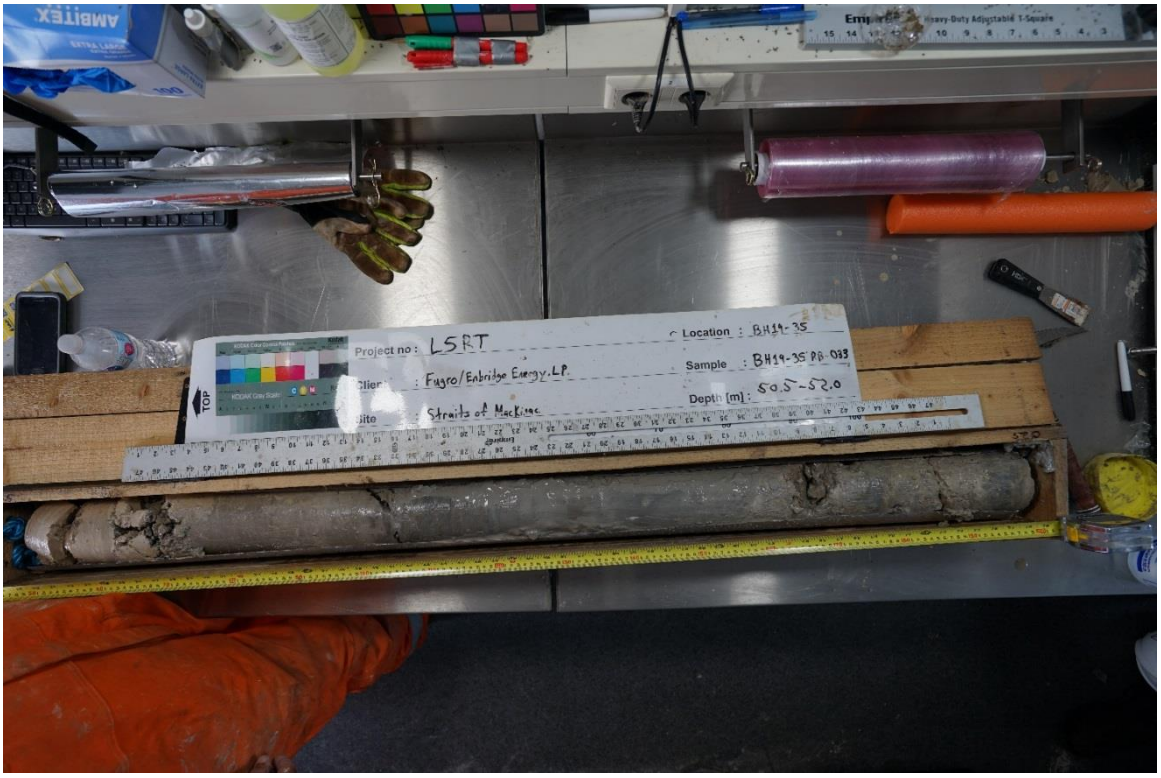
BH19-35-RB-030

BH19-35-RB-031 (Dry)

BH19-35-RB-031 (Wet)

BH19-35-RB-032 (Dry)

BH19-35-RB-032 (Wet)

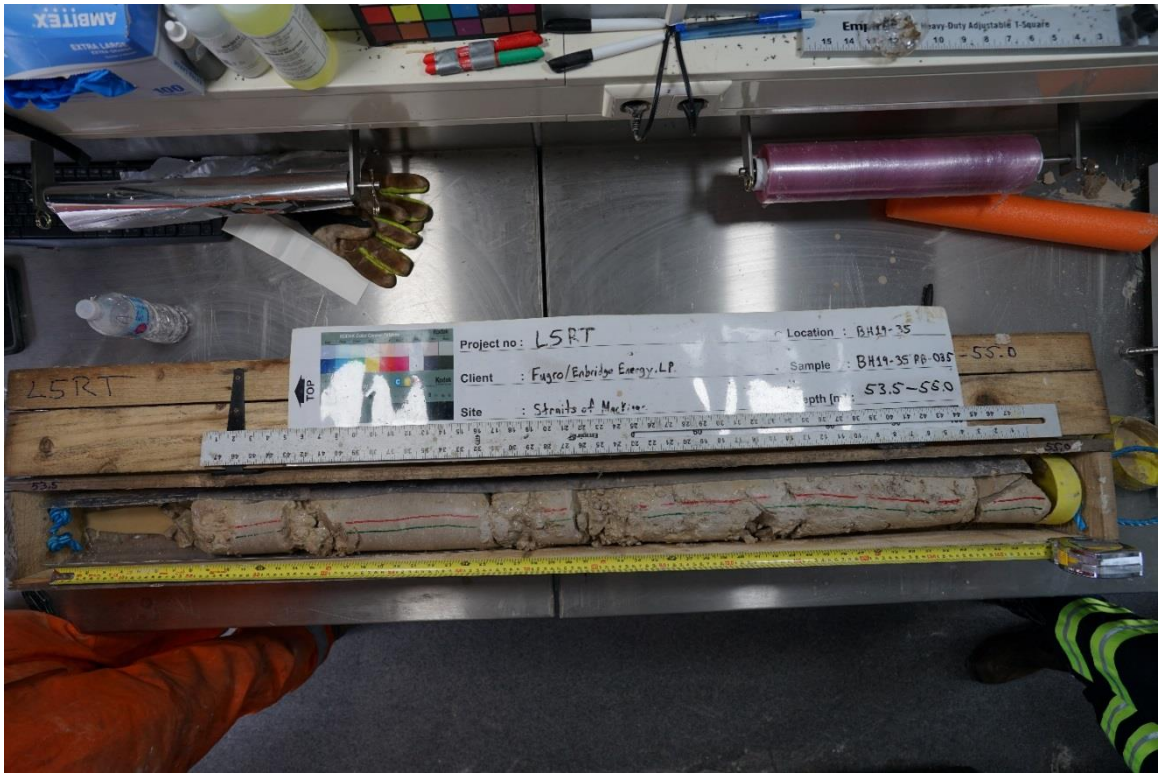


BH19-35-RB-033 (Dry)

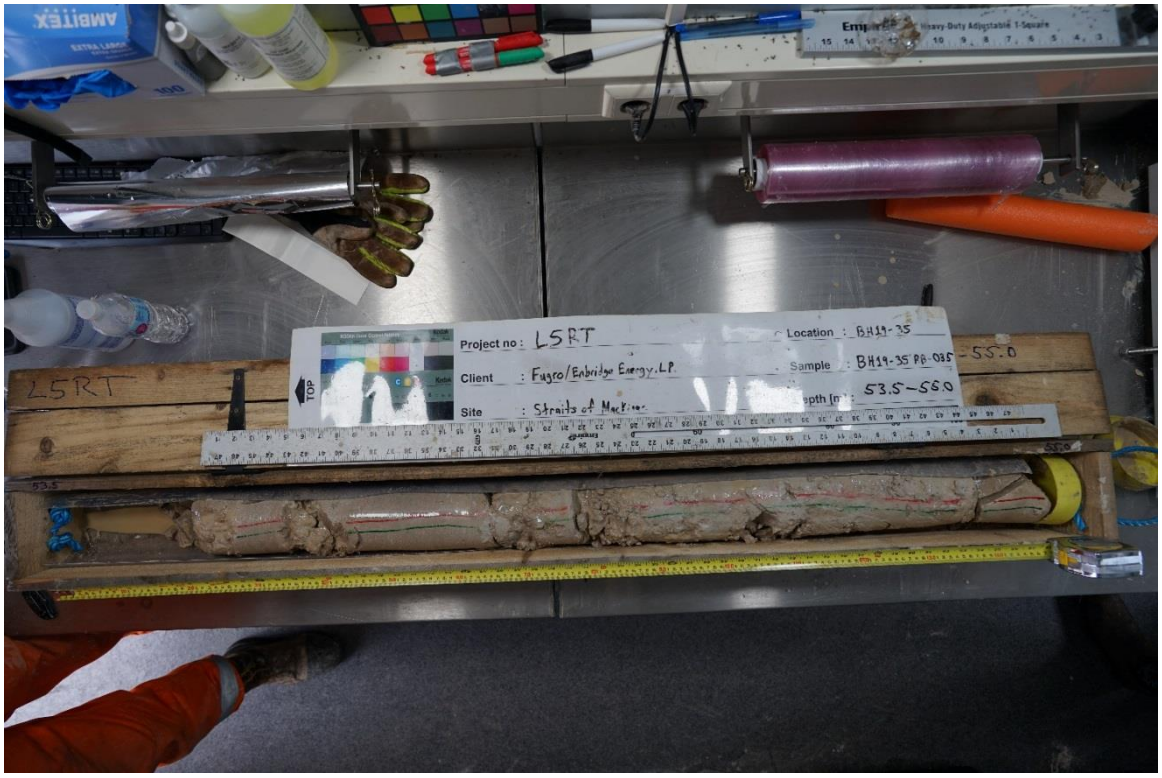
BH19-35-RB-033 (Wet)

BH19-35-RB-034 (Dry)

BH19-35-RB-034 (Wet)



BH19-35-RB-035 (Dry)



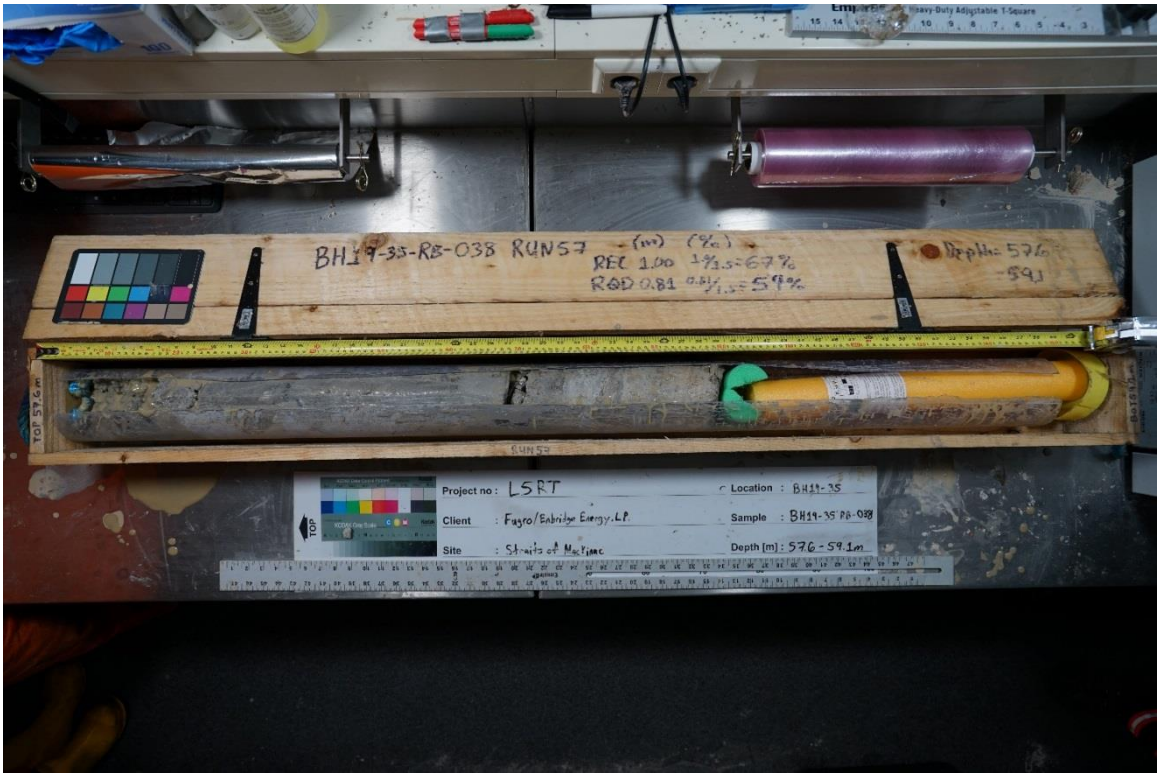
BH19-35-RB-035 (Wet)

BH19-35-RB-036 (Dry)

BH19-35-RB-036 (Wet)

BH19-35-RB-037 (Dry)

BH19-35-RB-037 (Wet)

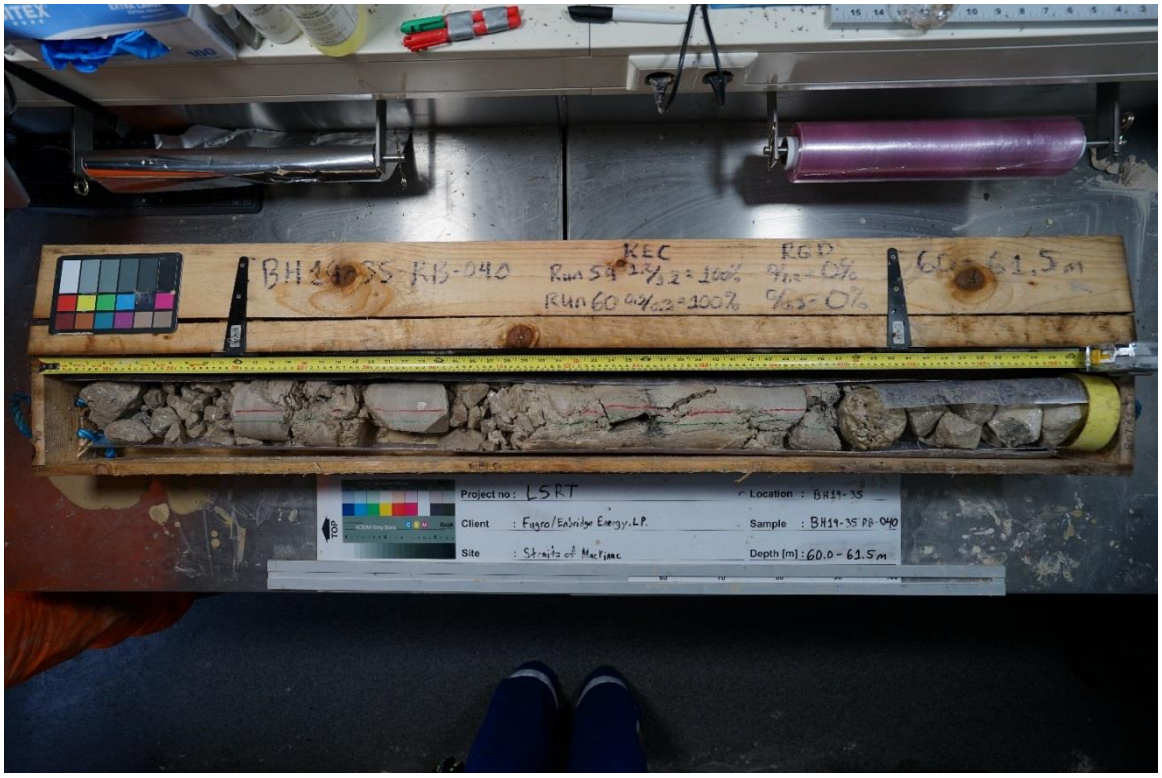


BH19-35-RB-038 (Dry)

BH19-35-RB-038 (Wet)

BH19-35-RB-039 (Dry)

BH19-35-RB-039 (Wet)



BH19-35-RB-040 (Dry)

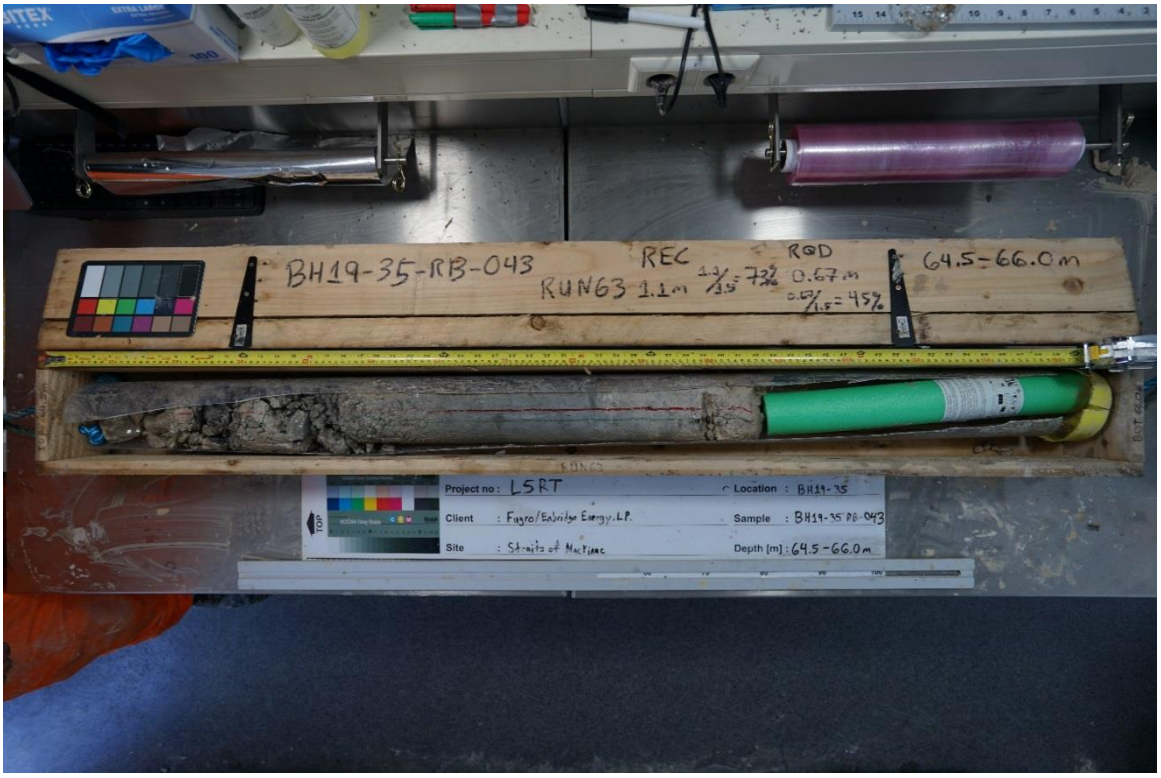
BH19-35-RB-040 (Wet)

BH19-35-RB-041 (Dry)

BH19-35-RB-041 (Wet)

BH19-35-RB-042 (Dry)

BH19-35-RB-042 (Wet)



BH19-35-RB-043 (Dry)

BH19-35-RB-043 (Wet)

BH19-35-RB-044 (Dry)

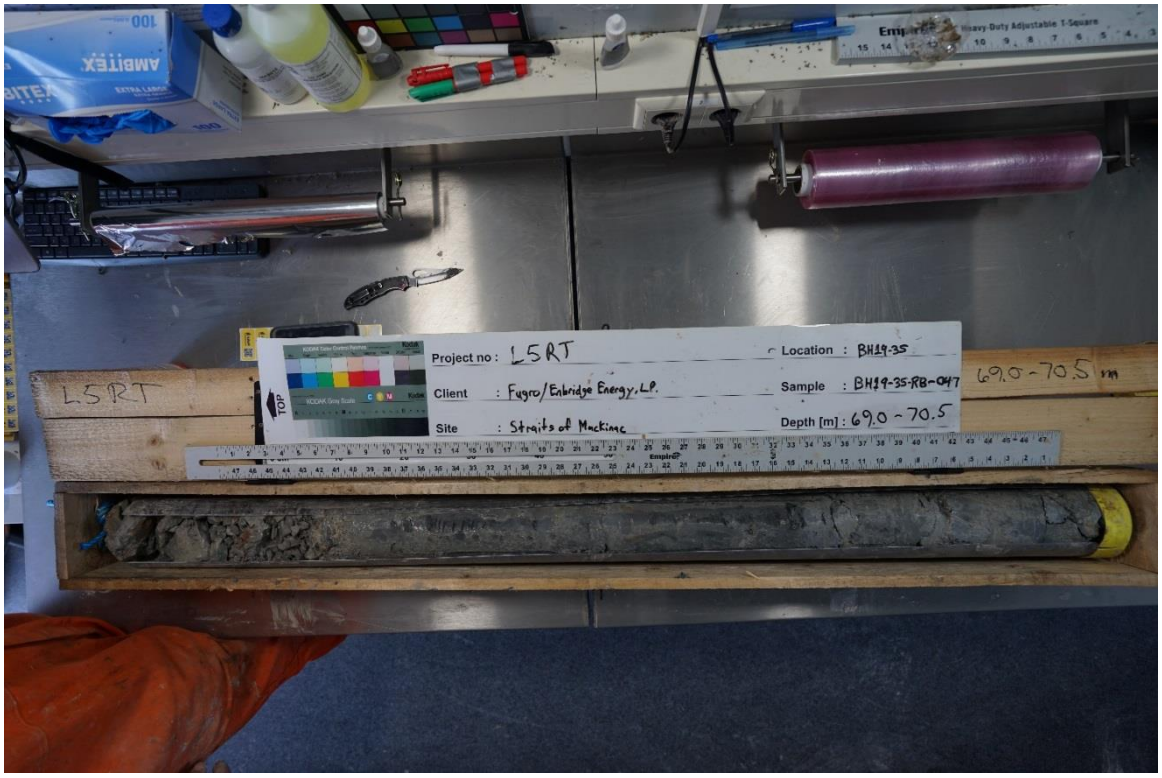
BH19-35-RB-044 (Wet)

BH19-35-RB-045 (Dry)

BH19-35-RB-045 (Wet)

BH19-35-RB-046 (Dry)

BH19-35-RB-046 (Wet)

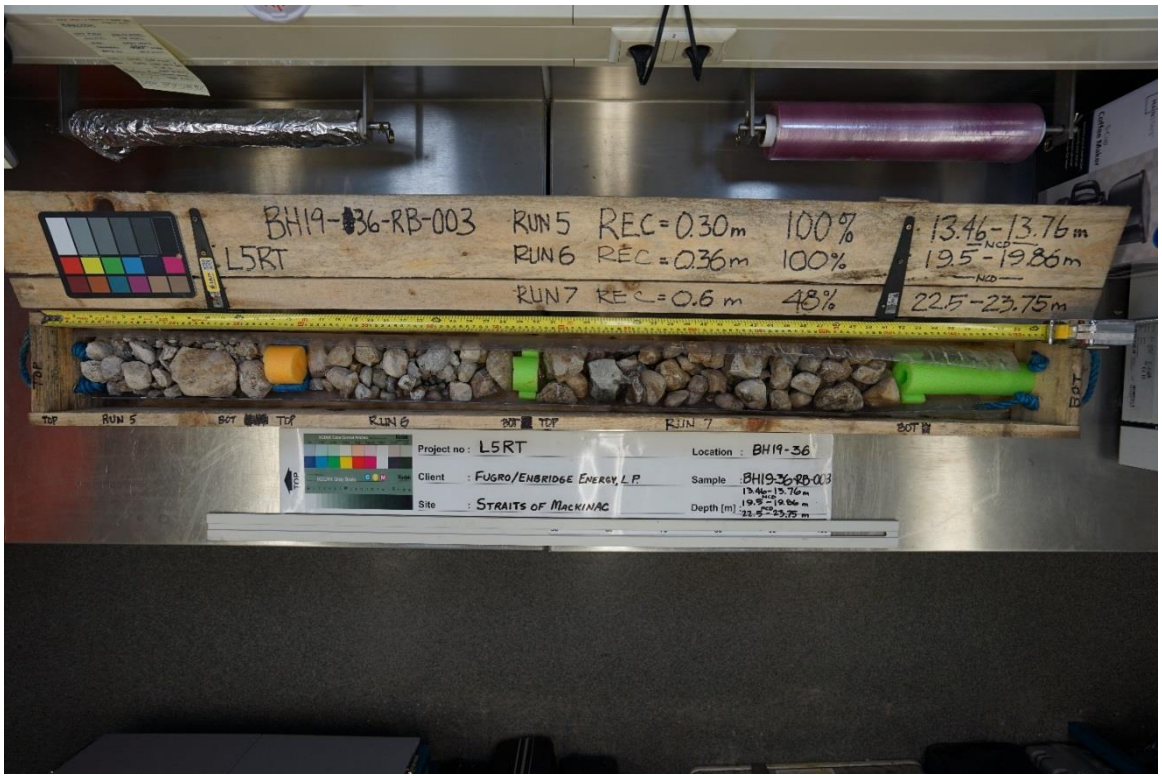


BH19-35-RB-047 (Dry)

BH19-35-RB-047 (Wet)

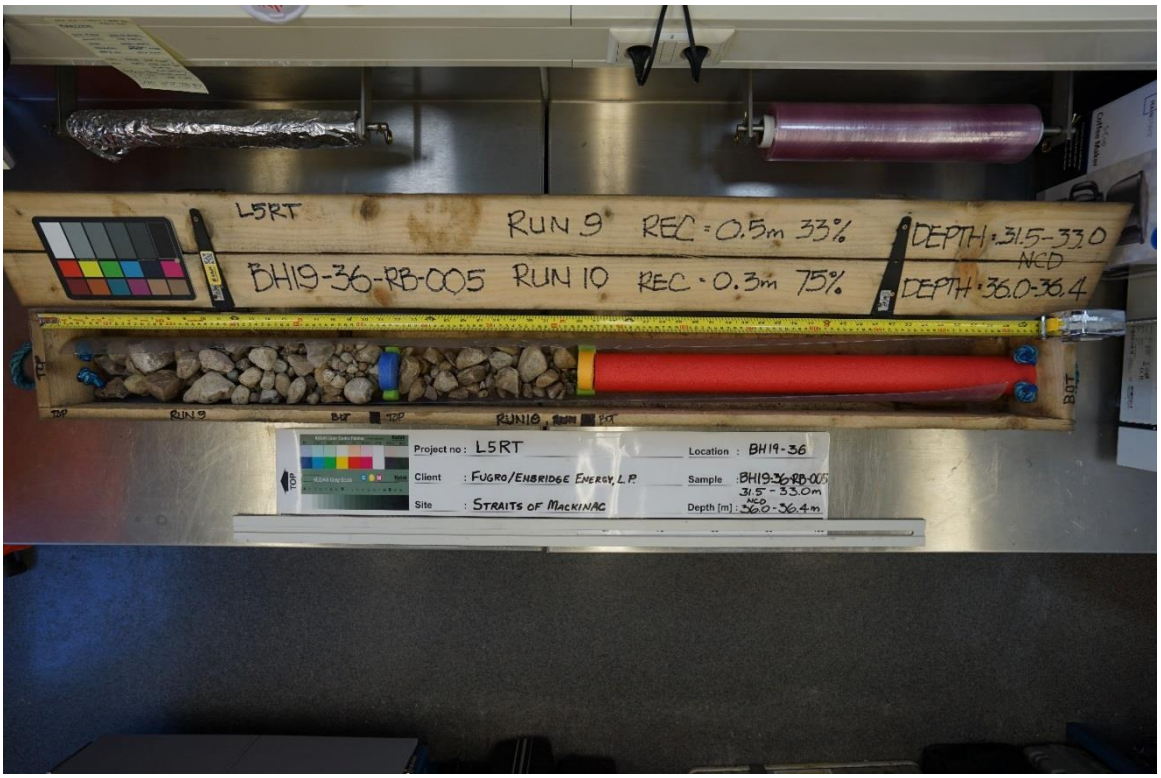
BH19-36-RB-001

BH19-36-RB-002



BH19-36-RB-003

BH19-36-RB-004



BH19-36-RB-005

[LEFT INTENTIONALLY BLANK]

BH19-36-RB-006 (Dry)

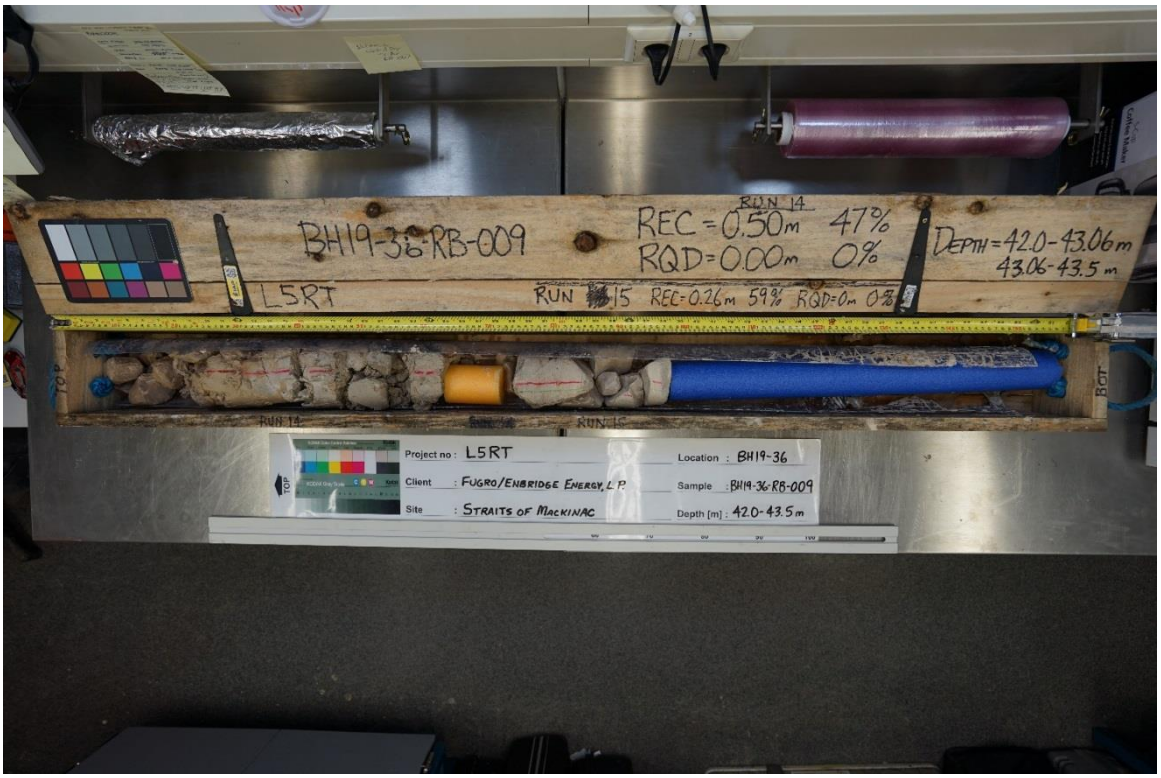
BH19-36-RB-006 (Wet)

BH19-36-RB-007 (Dry)

BH19-36-RB-007 (Wet)

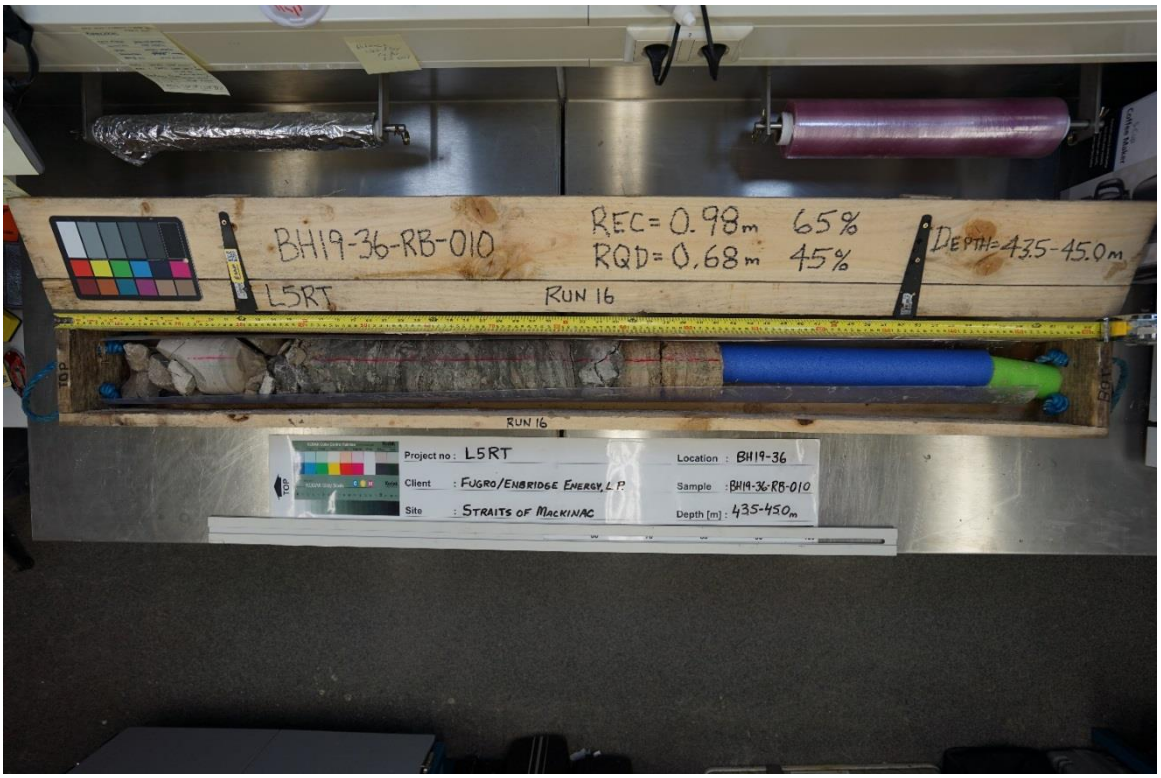
BH19-36-RB-008 (Dry)

BH19-36-RB-008 (Wet)

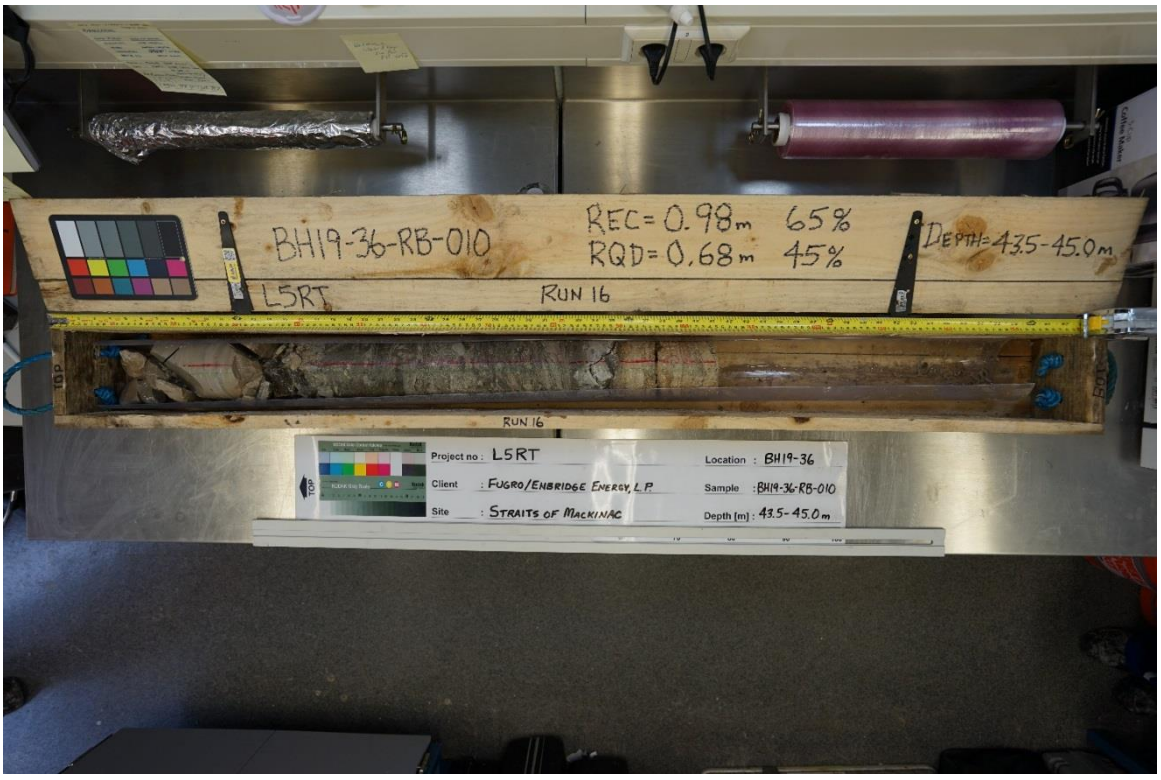


BH19-36-RB-009 (Dry)

BH19-36-RB-009 (Wet)



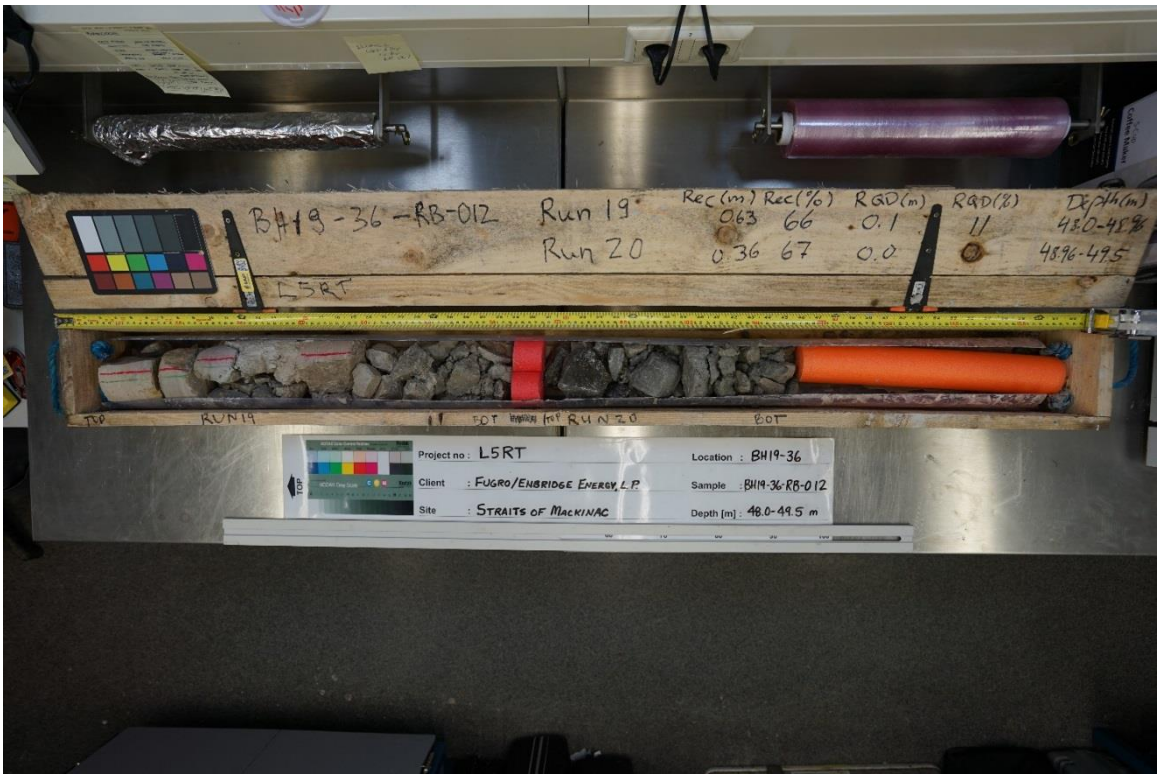
BH19-36-RB-010 (Dry)



BH19-36-RB-010 (Wet)

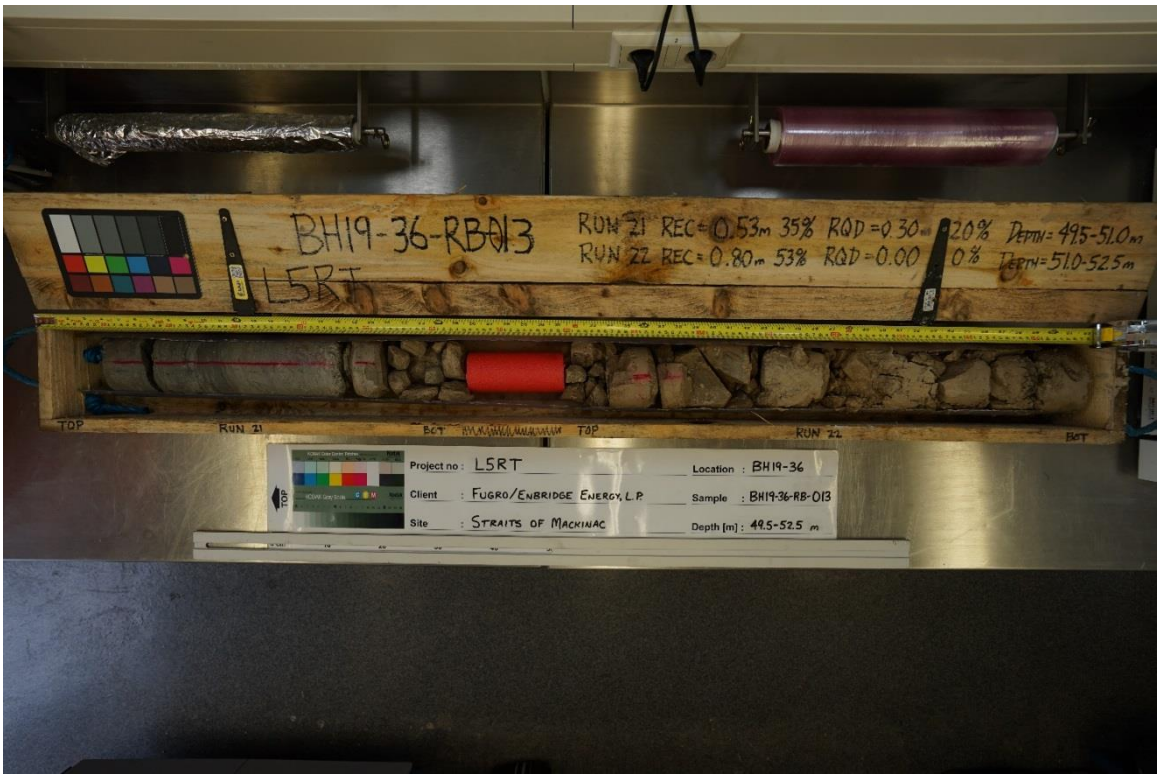
BH19-36-RB-011 (Dry)

BH19-36-RB-011 (Wet)



BH19-36-RB-012 (Dry)

BH19-36-RB-012 (Wet)

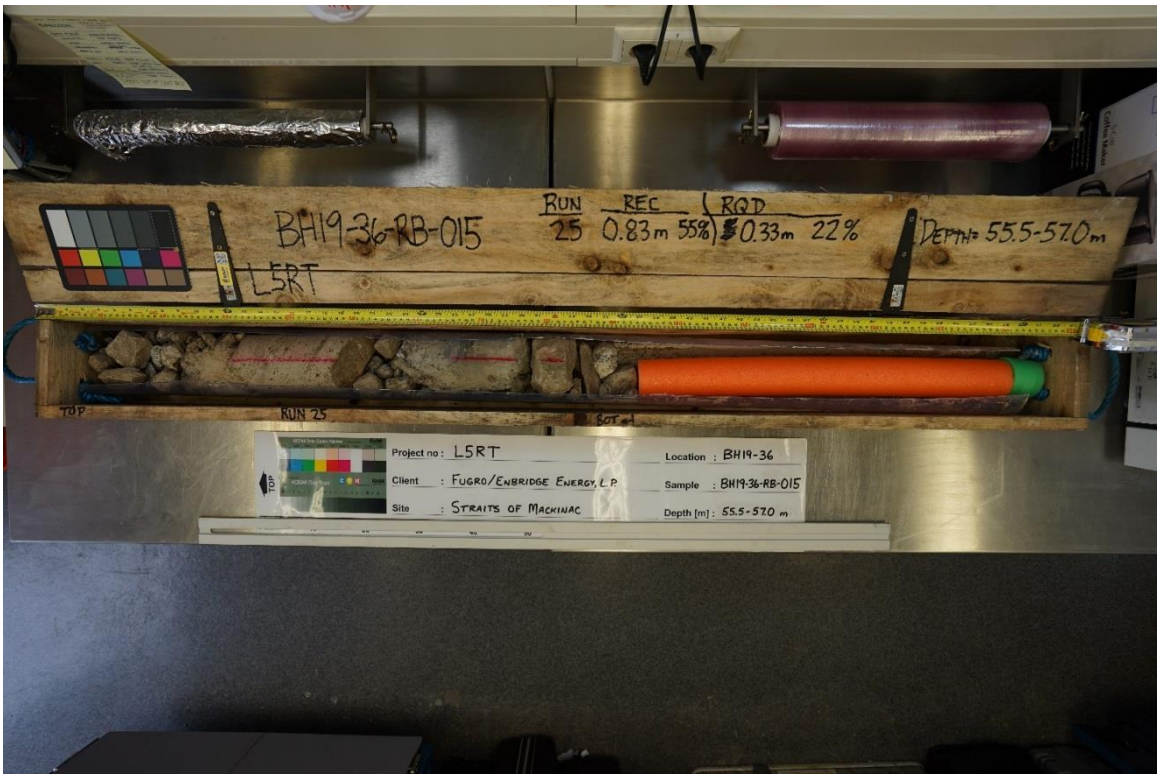


BH19-36-RB-013 (Dry)

BH19-36-RB-013 (Wet)

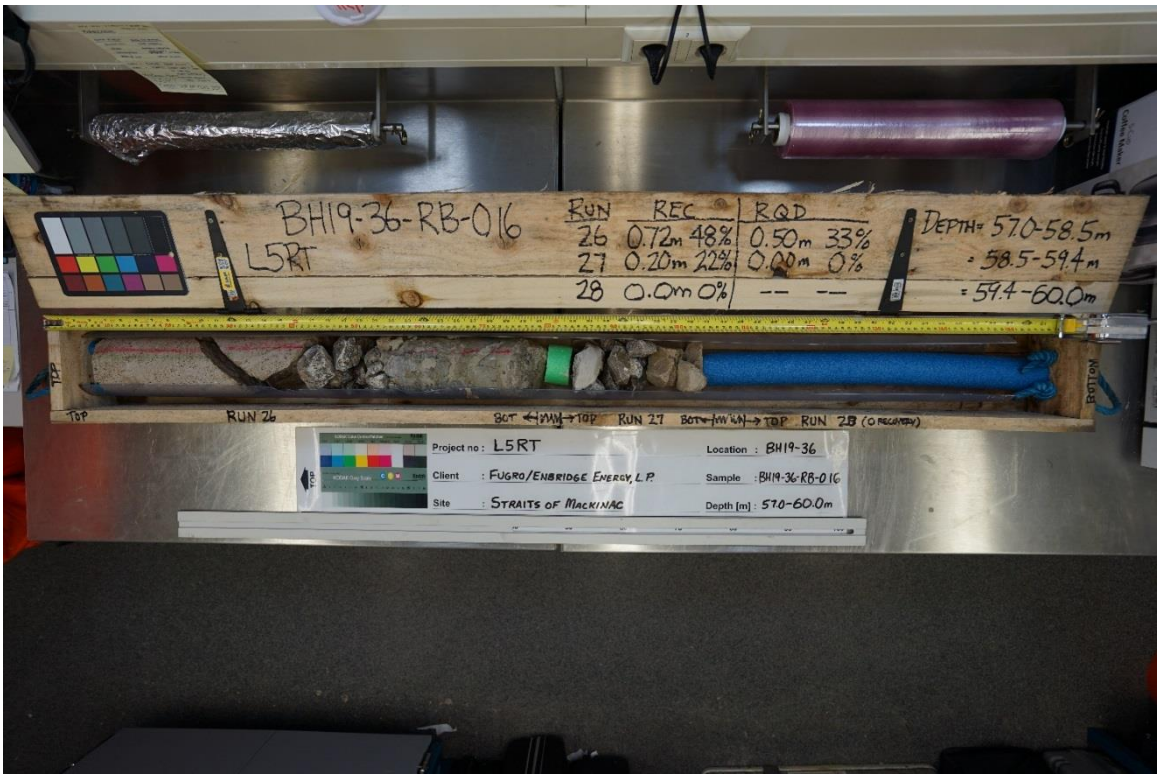
BH19-36-RB-014 (Dry)

BH19-36-RB-014 (Wet)



BH19-36-RB-015 (Dry)

BH19-36-RB-015 (Wet)



BH19-36-RB-016 (Dry)

BH19-36-RB-016 (Wet)

BH19-36-RB-017 (Dry)

BH19-36-RB-017 (Wet)

BH19-36-RB-018 (Dry)

BH19-36-RB-018 (Wet)

BH19-36-RB-019 (Dry)

BH19-36-RB-019 (Wet)

BH19-36-RB-020 (Dry)

BH19-36-RB-020 (Wet)

BH19-36-RB-021 (Dry)

BH19-36-RB-021 (Wet)

APPENDIX

D IN-SITU TESTING

APPENDIX

D-1 *IN-SITU TESTING EXCLUDING DEEPWATER PRESSUREMETER AND CONE PENETROMETER TESTS*

APPENDIX

METHODOLOGY

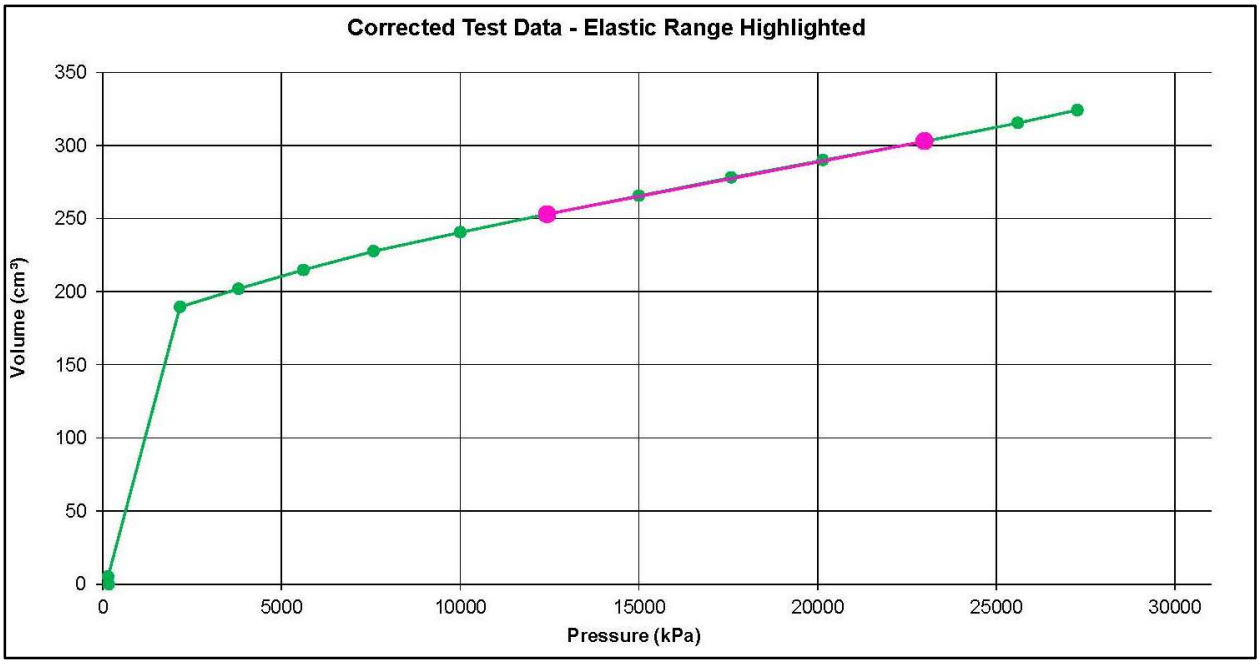
Dilatometer Methodology

A pressuremeter test is performed to deform a mass of rock to determine the load the formation in question is capable of withstanding. Because this method is carried out in-situ, in a borehole, it expands the mass of rock from the inside. Thus, it is frequently referred to as a **Dilatometer** test. Using the resulting data, the limit of the pressure (P_L) and pressuremeter modulus (E) of the formation will define the stress/strain (or volume/pressure) of the soil and rock at each depth. The resulting information can then be used to predict the deformability, creep characteristics, rebound, and permanent set of the test zone. Also, the in-situ modulus of the rock mass deformation can be found, although this requires that the Poisson ratio of the tested formation to be known from other tests.

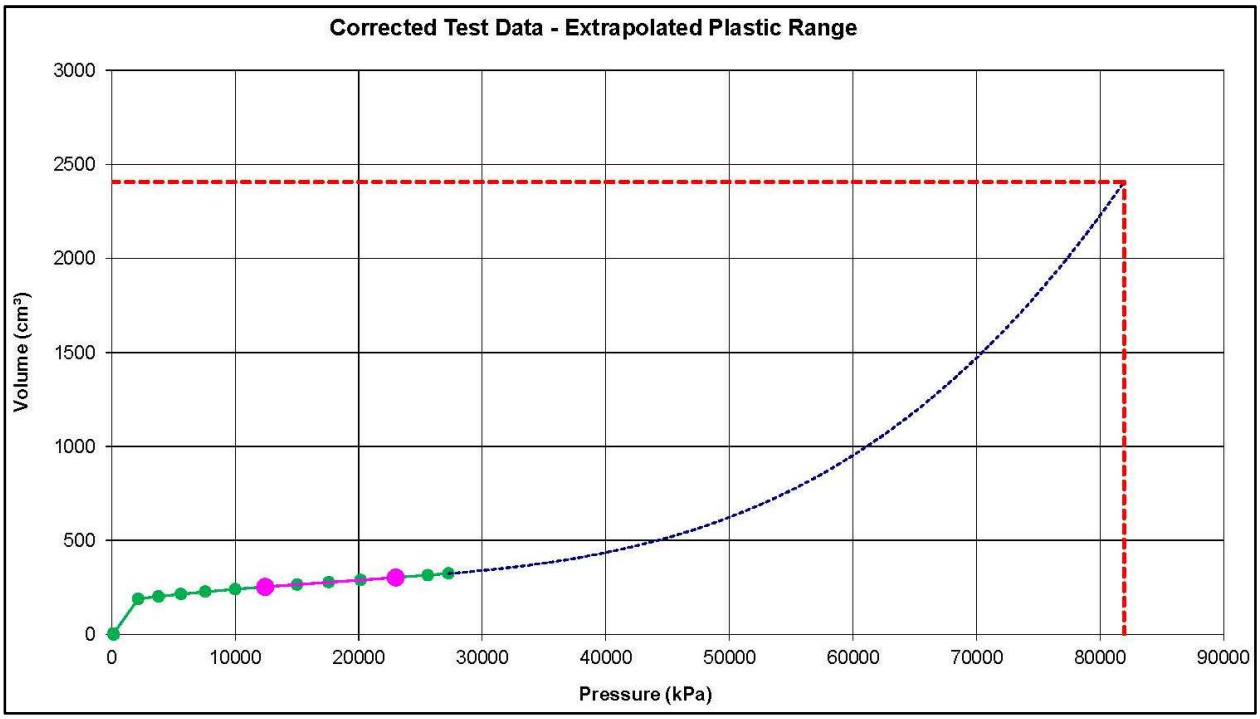
The RocTest Probex Dilatometer (Pressuremeter) consists of the following:

- Readout unit
- Hydraulic and Electrical Communication lines
- Probex borehole instrument
- Hand pump with pressure transducer, inflation gauge, and deflation gauge

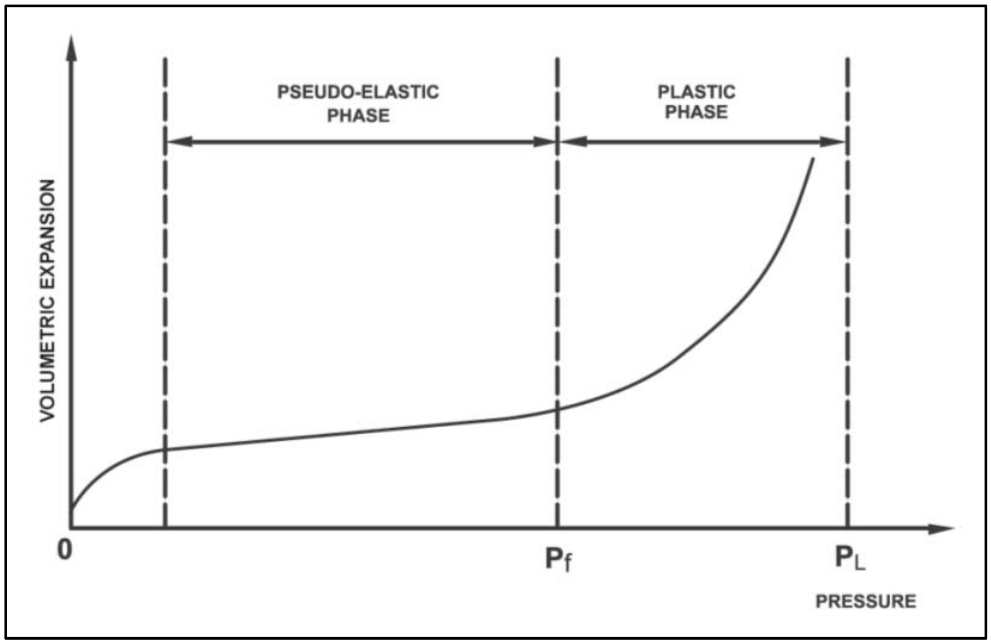
Before testing the formation, the condition of the hole must be favorable. The pressure meter requires a borehole to be of NQ/NX/NW size (about 3 inch diameter) with minimal to no open fractures at the test location (solid walls to accept the pressure). This can be determined by examining core samples, caliper log data, or televiewer data. If the borehole does not meet these requirements, the resulting data will be compromised, and damage to the instrument can occur. If the borehole meets the size and integrity requirement, it is calibrated for both pressure and volume. Using the drill rig, the instrument is lowered to the desired depth and the test is performed. The pressure is raised in consistent increments and recorded, along with the resulting volume increase. Rock deformation is plotted as a function of pressure applied. The mean elastic modulus (E) is proportional to the slope of the plot of elastic deformation.



If the formation can be pushed into its plastic deformation phase, before the probe reaches its 30 MPa or 500 cm^3 limits, the plastic range can be mathematically extrapolated to estimate an Ultimate Pressure (P_L) or Pressure Limit.



In a homogeneous formation, the ideal pressure-volume curve has the following shape:



The curve can be divided into three parts:

From **P = 0** to **P = P_0**
This portion of the curve corresponds to the probe seating against the borehole wall. The wall Disturbance induced by drilling has considerable influence on this segment of the curve. The difference in borehole and probe diameters also affects this segment.

From **P = P_0** to **P = P_f**
This segment represents the pseudo-elastic behavior of the tested material. The probe is in contact with the borehole walls. The loading is uniform along the probe length. This segment is rather linear and defines E, the deformation modulus of the tested material. Should the probe be in contact with the borehole walls before applying pressure, the mass would exhibit pseudo-elastic behavior from the outset.

From **P = P_f** to **P = P_L**
P_f by definition is the pressure at which the mass enters a plastic state. Above P_f, the loaded mass' deformation accelerates up to the complete failure point. The pressure that defines failure is the limit pressure P_L. This fundamental mechanical characteristic of the mass is used to evaluate the stability of foundations in accordance with pressuremeter methods.

Provided by Colog on October 9th, 2019

A. Optical and Acoustic Televiewers

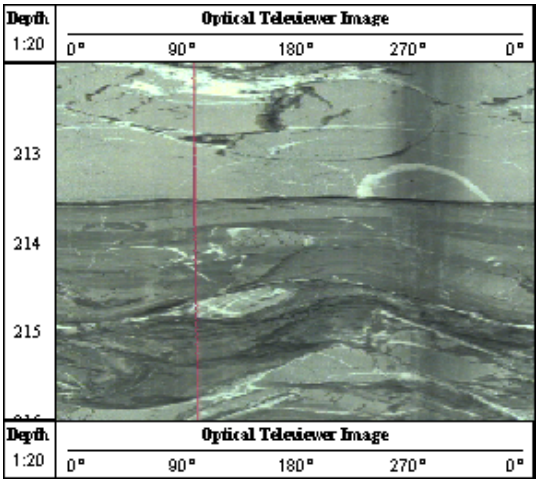
The OBI-40 optical televiewer and the ABI-40 acoustic televiewer (and its predecessor, the FAC40), from Advanced Logic Technologies (ALT), provide the highest resolution available for fracture and feature analysis in boreholes. Precise dip direction and angle measurements of bedding, fractures, and joint planes, along with other geological analyses, are possible.

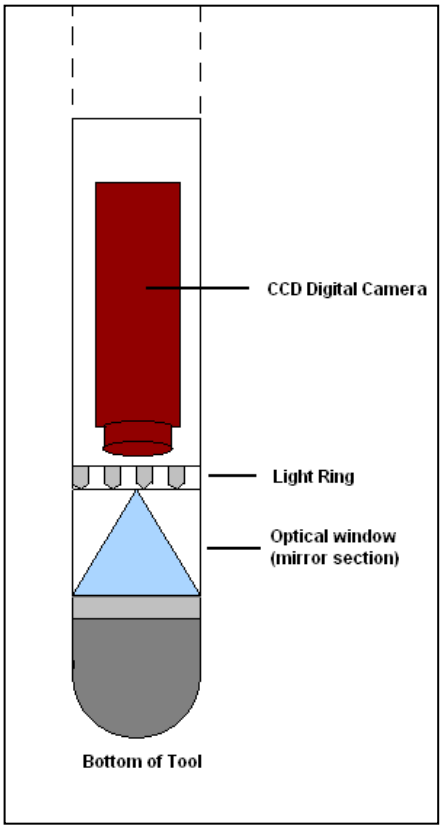
The optical televiewer technology is based on direct optical observation of the borehole wall face and can be utilized in both air and clear fluid filled boreholes. The acoustic televiewer technology is based on the return amplitude and time of an acoustic wave reflected off the borehole wall face; it can be utilized in clear or murky fluid-filled boreholes, but not in air.

Varying borehole conditions often exist which preclude the usage of one or the other tool; therefore, the optical televiewer and acoustic televiewer are often used in conjunction to image the entire borehole. When doing so, it must be kept in mind that optical and acoustic properties are not necessarily yielding the same data set. For example, a transition between two similarly-colored beds may not stand out visually, but it may stand out acoustically if the densities of the two materials are different.

Optical Televiewer – Theory of Operation

The OBI-40 optical televiewer provides a detailed, oriented optical image of the borehole wall. A small ring of lights illuminates the borehole wall allowing a camera to directly image the borehole wall face. A conical mirror housed in a clear cylindrical window focuses a 360° optical "slice" of the borehole wall onto the camera's lens. As the optical televiewer tool is lowered down the hole, the video signal from the camera is transmitted uphole via the wireline to the recording instrumentation.





Figures: Example of OBI40 optical Televiewer data (left) and sketch of OBI40 optical tool head (right).

Provided by Colog on October 9th, 2019

The signal is digitized in real time by capturing up to 720 pixels from the conical optical image. A digital magnetometer and accelerometer package is used to determine the orientation of the probe, and thus the digital image, for each conical image capture. The conical image rings are stacked and unwrapped to a 2-D, oriented image of the borehole wall.

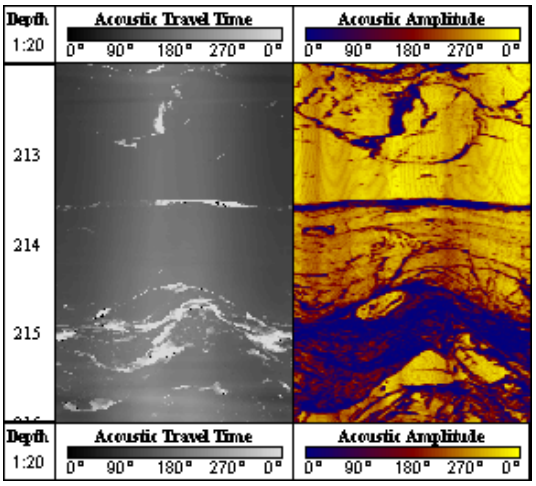
Precise borehole trajectory/deviation and image orientation are achieved using a 3-axis magnetometer and three accelerometers. When the tool is well-centralized, azimuthal accuracy is to ±1.0 degrees and inclination accuracy is to ±0.5 degrees. Deviated or rugous boreholes and outside magnetic interference can contribute to reduced orientation accuracy of the tool, and thus the oriented image. The pink line seen in the example data above represents a fixed point on the tool; it is used in orienting the data with respect to magnetic north.

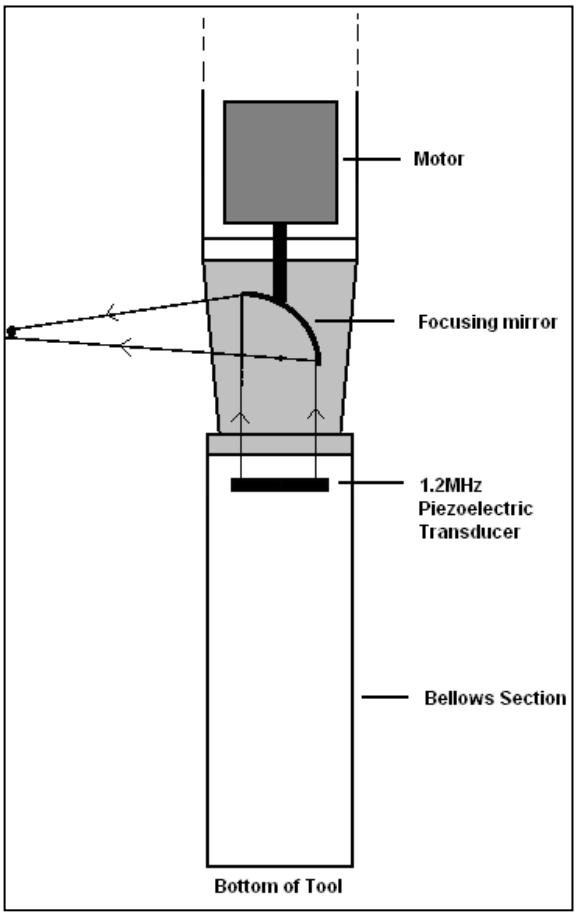
Tool image colors are calibrated in shop to true-color, however, varying light conditions downhole often lead to color images that are somewhat false-colored. This should be taken into account when reviewing images.

Main applications of the optical televiewer include: fracture detection and evaluation, detection of thin beds, determination of bedding dip, lithological characterization, and casing inspection.

Acoustic Televiewer (ATV) – Theory of Operation

The ABI-40 acoustic televiewer, from Advanced Logic Technologies (ALT), provides a detailed, oriented image of acoustic reflections from the borehole wall. A unique focusing system resolves bedding features as small as 2 mm and is capable of detecting fractures with apertures as small as 0.1 mm.





Figures: Example ABI40 acoustic televiewer data (left) and sketch of ABI40 acoustic head (right).

The acoustic televiewer transmits ultrasonic pulses from a rotating sensor (mirror) and records the signals reflected from the interface between the borehole fluid and the borehole wall. The amplitude of these reflections is

Provided by Colog on October 9th, 2019

representative of the hardness of the formation surrounding the borehole, while the travel time represents the borehole shape and diameter. As many as 288 reflections may be recorded per revolution at up to 10 revolutions per second. The conical image rings are stacked and unwrapped to a 2-D, oriented image of the borehole wall. The digital amplitude and travel time data are presented using a variety of color schemes.

Precise borehole trajectory/deviation and acoustic image orientation are achieved using a 3-axis magnetometer and three accelerometers. When the tool is well-centralized, azimuthal accuracy is to ±1.0 degrees and inclination accuracy is to ±0.5 degrees. Deviated or rugous boreholes and outside magnetic interference can contribute to reduced orientation accuracy of the tool, and thus the oriented image.

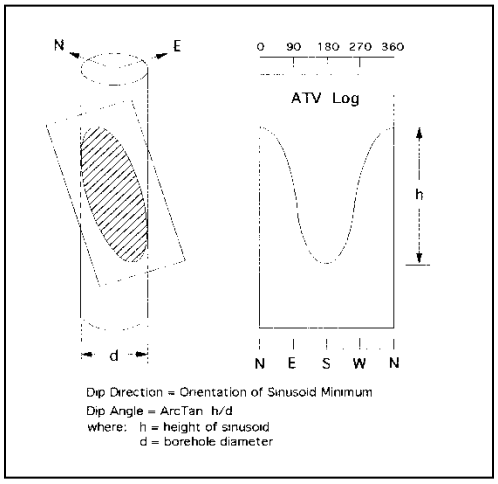
The high-resolution reflection images and the precise travel time measurements make the ABI-40 acoustic televiewer a versatile tool. Possible applications include: fracture detection and evaluation, detection of thin beds, determination of bedding dip, lithological characterization, casing inspection, and high-resolution caliper measurements.

Acoustic Televiewer Caliper Log

An unconventional caliper log may be generated from the travel time data acquired by the ABI-40 acoustic televiewer. Using WellCAD software, an estimation of the distance from the probe to the borehole wall can be made by incorporating the travel time of the acoustic signal with an estimation of the velocity of the borehole fluid. The time it takes the acoustic signal to travel through a known viscous medium and back to the probe is directly related to the distance between the signal generator and the borehole wall provided the borehole fluid viscosity remains constant and the probe is properly centralized. The distance from the probe to the borehole wall is then corrected for the radius of the probe, producing a borehole diameter value.

Understanding 2-D Televiewer Images

For both the optical and acoustic televiewer, the 2-D picture of the borehole wall is unwrapped from north to north. Planar features that intersect the borehole appear to be sinusoids on the unwrapped image. To calculate the dip angle of a fracture or bedding feature, the amplitude of the sinusoid (h) and the borehole diameter (d) are required. The angle of dip is equal to the arc tangent of h/d, and the dip direction is picked at the trough of the sinusoid.



Provided by Colog on October 9th, 2019

Figure: Geometric representation of a north-dipping fracture plane and corresponding log.

Interpreting Optical and/or Acoustic Televiewer Data

Sinusoidal features are picked throughout the boreholes by visual inspection of the digital optical and acoustic televiewer images using the interactive software WellCAD. These sinusoidal feature *projections* can directly overlay the televiewer images or be plotted alongside the televiewer images.

The features can also be represented by *tadpoles*. The tail of the tadpole points in the azimuthal direction of dip, where north is up, east is 90° to the right, etcetera. The head of the tadpole is located vertically on the plot, at the projection's inflection point, that is, halfway between the peak and the trough depth of the sinusoidal projection. The horizontal head location represents the dip angle, with shallow features near the left side of the plot and steeper features near the right side.

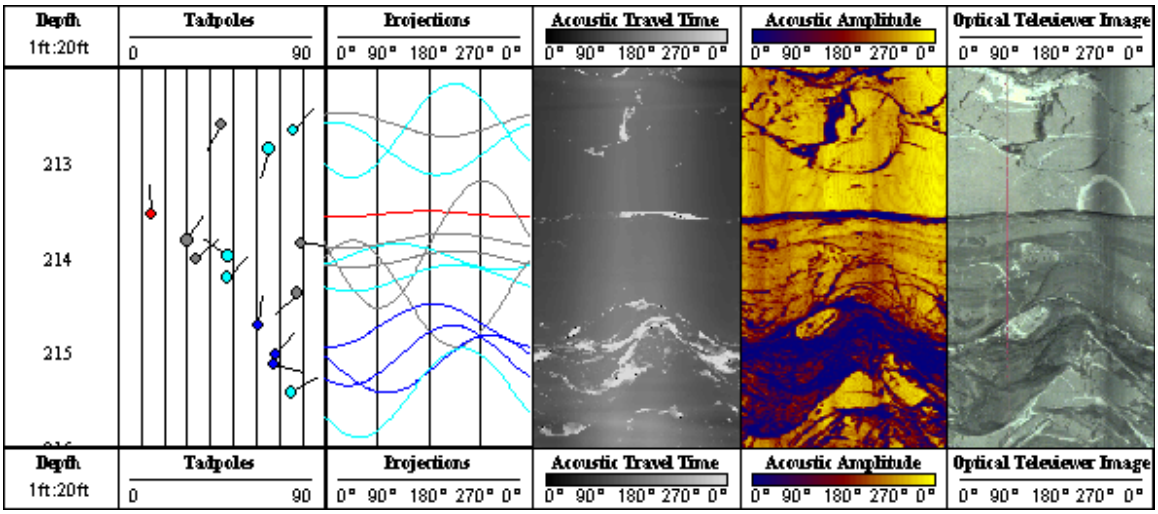


Figure: Example projections and tadpoles for corresponding optical and acoustic televiewer data sets.

The WellCAD software calculates the true feature orientation (dip direction and angle) in either deviated or vertical boreholes. Depths are assigned to the fractures or bedding features at the inflection points (middles) of the sinusoids. Features are subjectively ranked for flow potential using *COLOG's Ranking System for Optical Televiewer Features*, included in this report. The features picked, along with their assigned ranks, orientations and depths are exported and presented in tables for each well. Orientations are based on magnetic north and are not corrected for magnetic declination, unless specified.

From the feature data tables, stereonet plots and rose diagrams are generated, as necessary. Stereonet plots and rose diagrams provide useful information concerning the statistical distribution and possible patterns or trends that may exist from the optical and/or acoustic televiewer feature orientation data set.

Rose Diagrams

A rose diagram is a polar diagram in which radial length of the petals indicates the relative frequency (percentage) of observation of a particular angle or fracture dip direction or range of angles or dip directions. Rose diagrams are used to identify patterns (if any) in the frequency of

dip angles or directions for a particular data set. The following rose diagrams and stereonet plots all come from the same data set to help illustrate the relationships between the plot types.

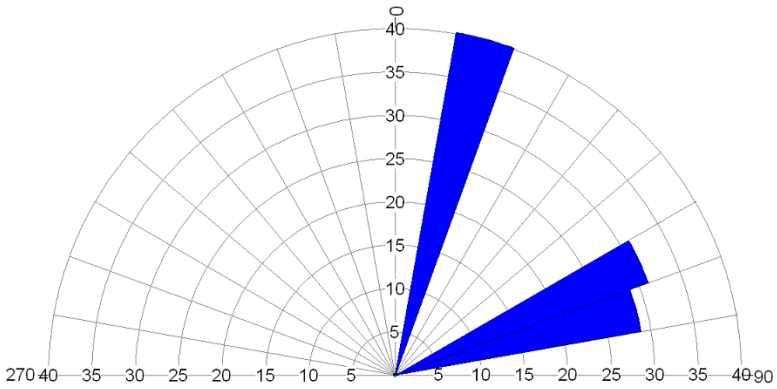


Figure: Example rose diagram from an optical televiewer data set illustrating the frequency (%) of dip angles.

With a quick glance at the above rose diagram of dip angle values, one can see two distinct sets of dip angles; one set with lower dip angles and one set with higher dip angles. Specifically, 40 percent of the features have a dip angle between 10° and $<20^{o}$, and 60 percent of the features have a dip angle between 60° and $<80^{o}$. The left-hand side of the above rose diagram will always be blank by convention of positive dip angle values only.

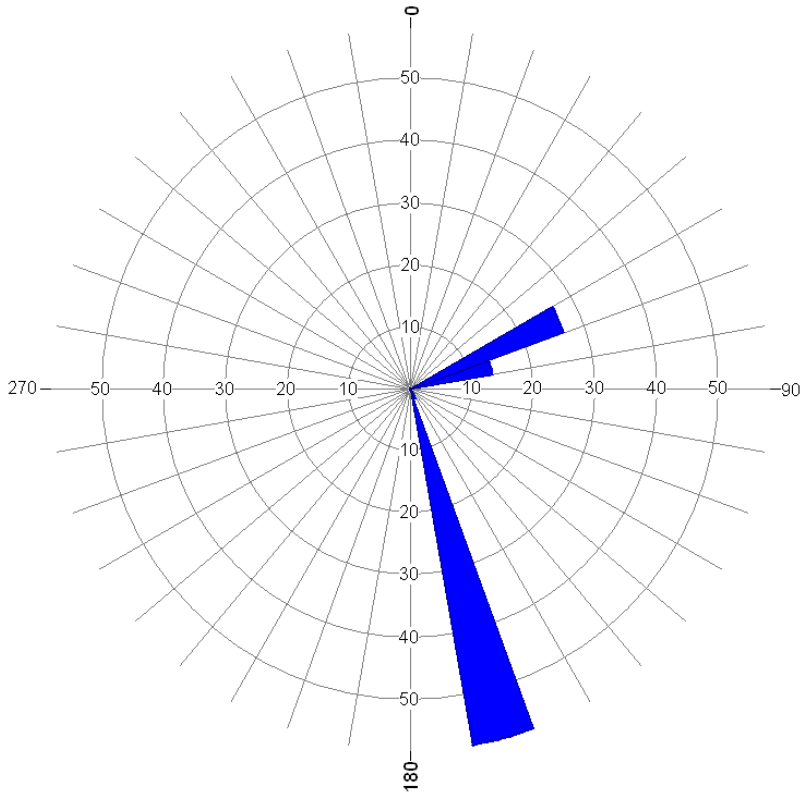


Figure: Example rose diagram from an optical televiewer data set illustrating the frequency (%) of dip direction (azimuth).

Provided by Colog on October 9th, 2019

With a quick glance at the above rose diagram of dip direction values, one can see that the features (and/or fractures) in this data set have two primary dip directions. Specifically, 40 percent of the features dip to the east-northeast between 60° degrees and <80° in azimuth and 60 percent of the features dip to the south-southeast between 160° and <170° in azimuth.

Stereonets

For stereonets, Colog utilizes a southern-hemisphere projected, equal-area Schmidt net to plot the poles to the feature planes. These plots are often used in plotting geologic data such as the dips and orientations of structural features. Here, the azimuthal angle indicates dip direction of the plane's pole (which dips 180 degrees opposite in azimuth from the plane's dip direction at a complementary angle). The distance from the center indicates the dip magnitude. The further from the center the steeper the dip angle; the closer to the center the more horizontal the feature is.

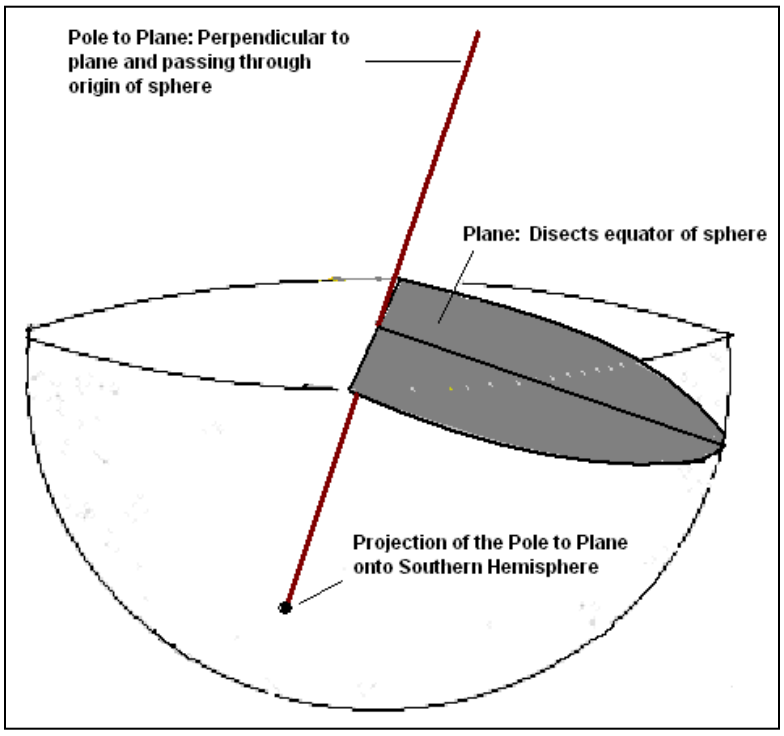


Figure: The above cartoon demonstrates the relationship between a plane and its pole, as projected onto the southern hemisphere of a sphere.

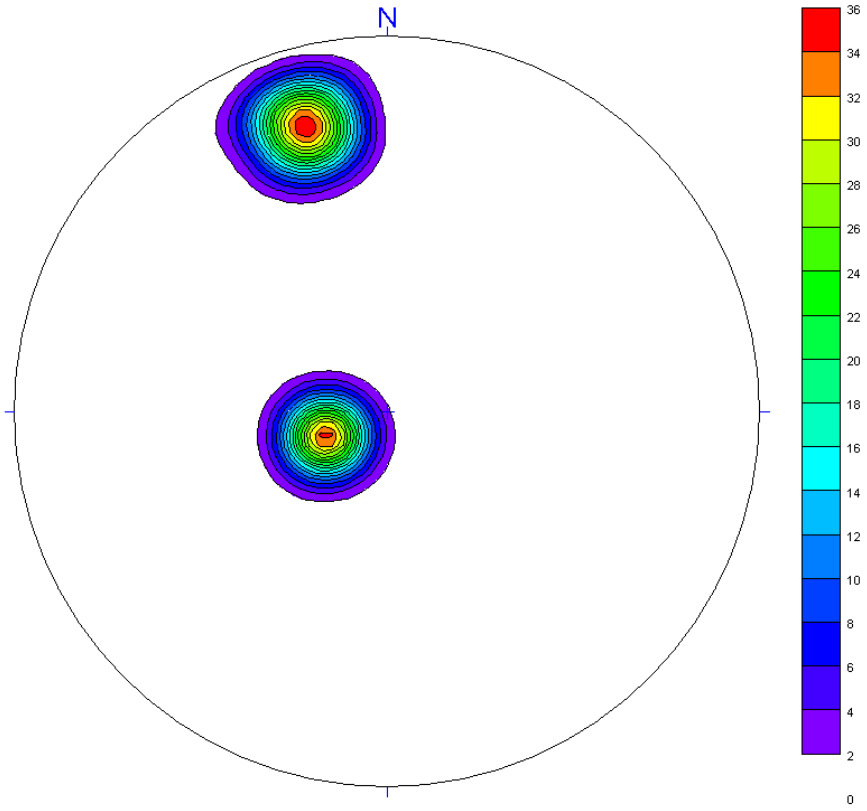
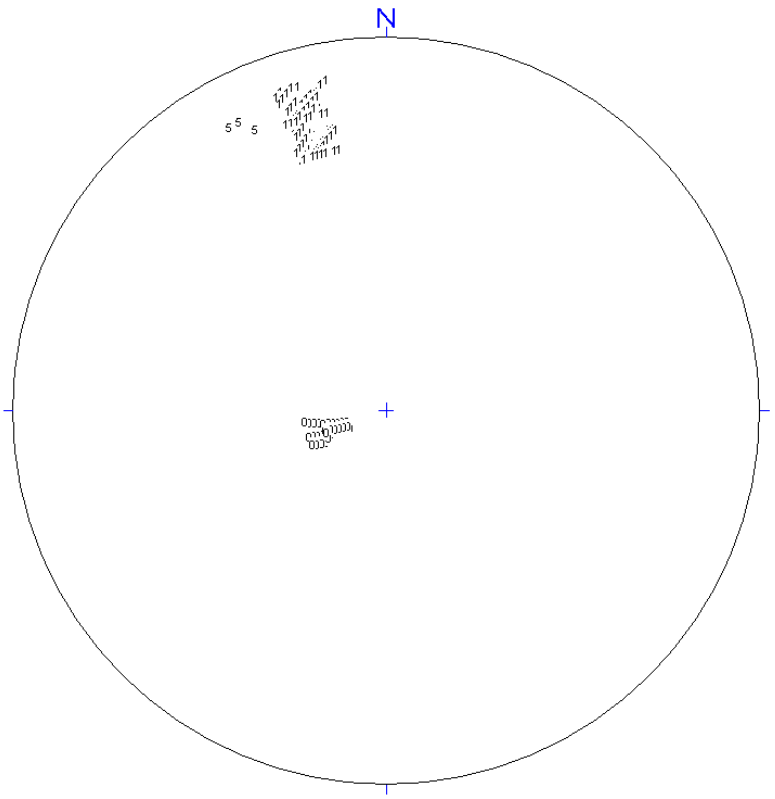


Figure: Example stereonet from an optical televiewer data set illustrating the frequency (%) of dip direction and dip angle.

The figure above is an example stereonet diagram from the same televiewer data set of fractures and features as used previously to describe rose diagrams. It was created by binning the density (frequency) of poles per area. The figure below indicates, with a quick glance, that two distinct patterns exist in the example data set. A cluster of fractures/features with similar dip directions of approximately 160-170 degrees with steep dip angles of around 60-80 degrees is apparent. A second cluster is apparent with similar dip directions of approximately 60-80 degrees with moderate dip angles of approximately 10-20 degrees. The white areas indicate low to zero density of poles.

Provided by Colog on October 9th, 2019



Colog also often provides a Schmidt net with the qualitative rank of each fracture/feature plotted at the location of its planar pole. Please refer to the *Ranking System for Optical/Acoustic Televiewer Features,* included in the report, for an explanation of the qualitative ranks assigned each optical/acoustic televiewer feature identified.

With a quick glance at the above Schmidt net, one can see that the low dip angle features which dip to the east-northeast are bedding features, ranked “0”; the high dip angle features dipping to the south-southeast are primarily weak or partial fractures, ranked “1”; and there are several major fracture zones, ranked “5”, with strike/dip very similar to the majority of the partial/weak fractures in the well.

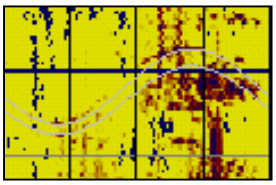
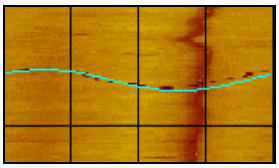
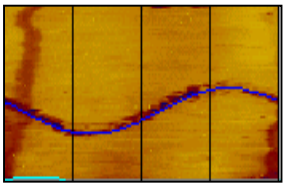
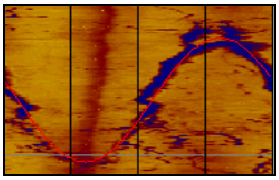
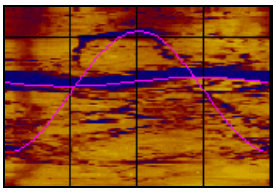
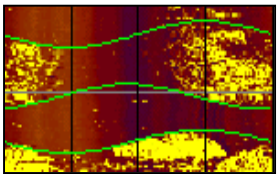
Ranking System for Optical Televiewer Features

	Rank	Color Code	Observation	Flow Rating System
	0	Gray	Non-flow feature (bedding, healed fracture, staining, foliation, vein, etc.)	Sealed, no flow
	1	Cyan	Weak feature (not continuous around the borehole)	Partial open crack
	2	Blue	Clean, distinct feature	Continuous Open crack
	3	Red	Distinct feature with apparent aperture	Wide open crack Or cracks
	4	Magenta	Very distinct, wide possible interconnected fracture	Very wide crack or multiple interconnected fractures
	5	Green	Major fracture zone with large openings.	Major fracture with large openings or breakouts

This ranking system is based on a system developed and applied by Paillet (USGS, WRD, Borehole Research Project) as a subjective evaluation of permeability potential. In general, the higher the rank, the greater the likelihood of fracture interconnection and subsequent increased permeability. Tadpoles represent individual features, where the tail points in the direction of dip (clockwise from the top, 0-359). The head is positioned vertically according to the median depth of the feature and positioned horizontally according to the feature dip angle (0-90 from horizontal).

Provided by Colog on October 9th, 2019

Ranking System for Acoustic Televiewer Features

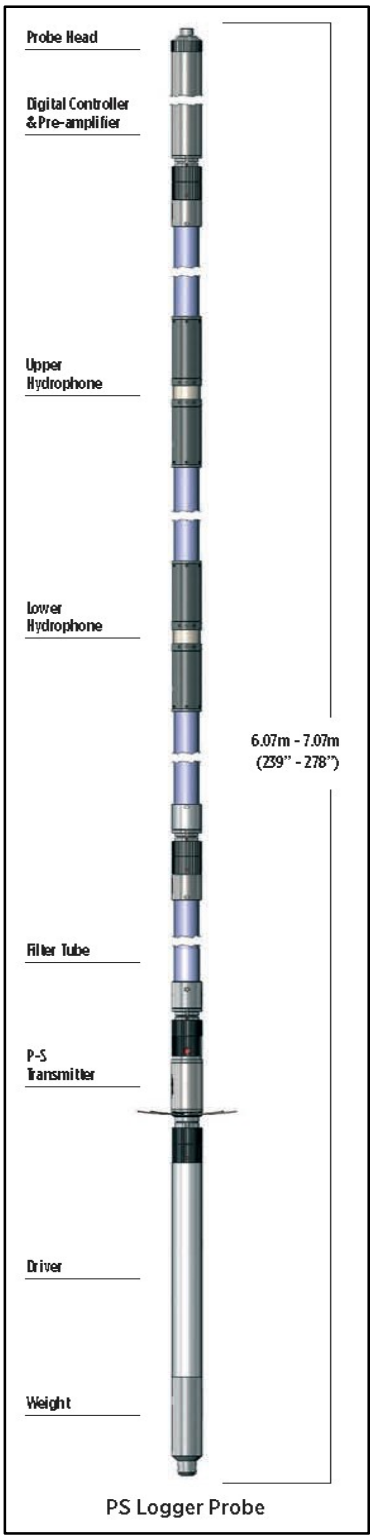
	Rank	Color Code	Observation	Flow Rating System
	0	Gray	Non-flow feature (bedding, healed fracture, vein, etc.)	Sealed, no flow
	1	Cyan	Weak feature (not continuous around the borehole)	Partial open crack
	2	Blue	Clean, distinct feature	Continuous Open crack
	3	Red	Distinct feature with apparent aperture (visible on travel-time image)	Wide open crack Or cracks
	4	Magenta	Very distinct, wide possible interconnected fracture	Very wide crack or multiple interconnected fractures
	5	Green	Major fracture zone, visible on both the amplitude and travel time images	Major fracture with large openings or breakouts

This ranking system is based on a system developed and applied by Paillet (USGS, WRD, Borehole Research Project) as a subjective evaluation of permeability potential. In general, the higher the rank, the greater the likelihood of fracture interconnection and subsequent increased permeability.

Provided by Colog on October 9th, 2019

P&S Suspension Log Methodology

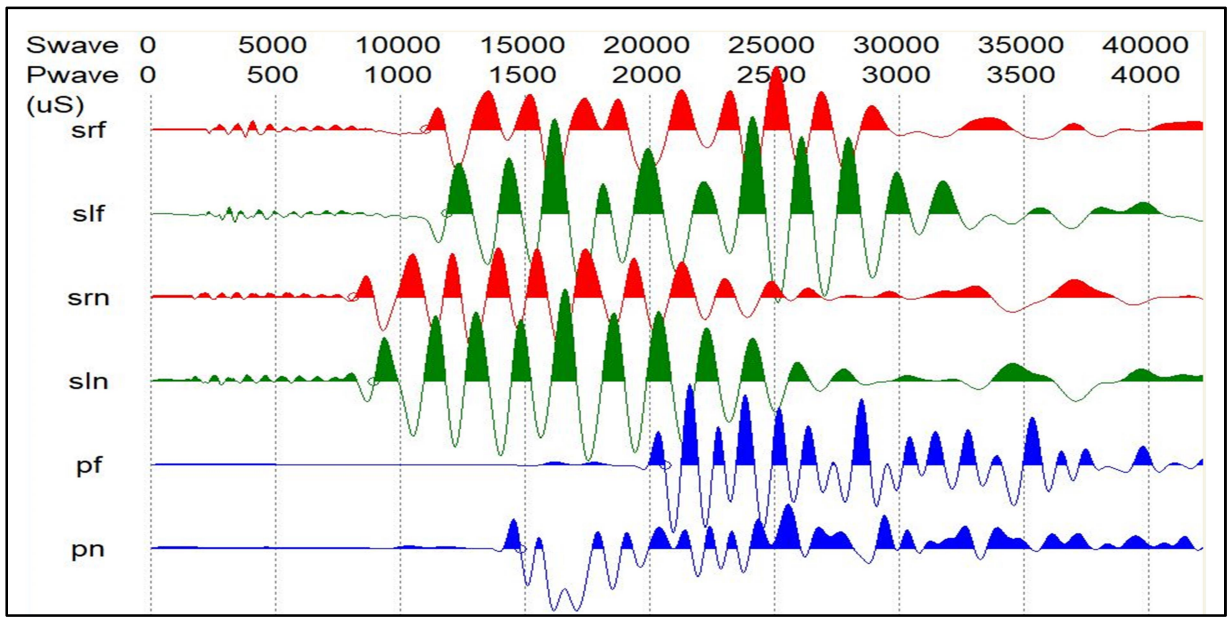
The P & S Digital Suspension Logger provides high-resolution compressional/pressure-wave (P) and shear-wave (S) velocities in rock and soil from within a single borehole. It is a cost-effective alternative to down-hole or cross-hole seismic surveys. The probe contains a powerful hammer source and two receivers, separated by acoustic damping tubes. The hammer strikes plates on opposite sides of the probe in turn, setting up a pressure doublet in the surrounding fluid. As the waves propagate parallel to the borehole axis, they are detected by the two neutral-buoyancy 3-D hydrophone receivers. Motion parallel to the borehole axis is compressional, while motion normal to the borehole axis is shear. Shear waves are detected in both X and Y directions. As the waves pass each detector, the difference in arrival times gives us wave slowness, the inverse of wave velocity. This instrument functions in a fluid filled borehole allowing the waves to propagate without significant attenuation. Together with calibrated density data, the P & S wave velocities may be used to calculate Poisson's Ratio, Bulk Modulus, Shear Modulus, Young's Modulus, and Bulk Compressibility.



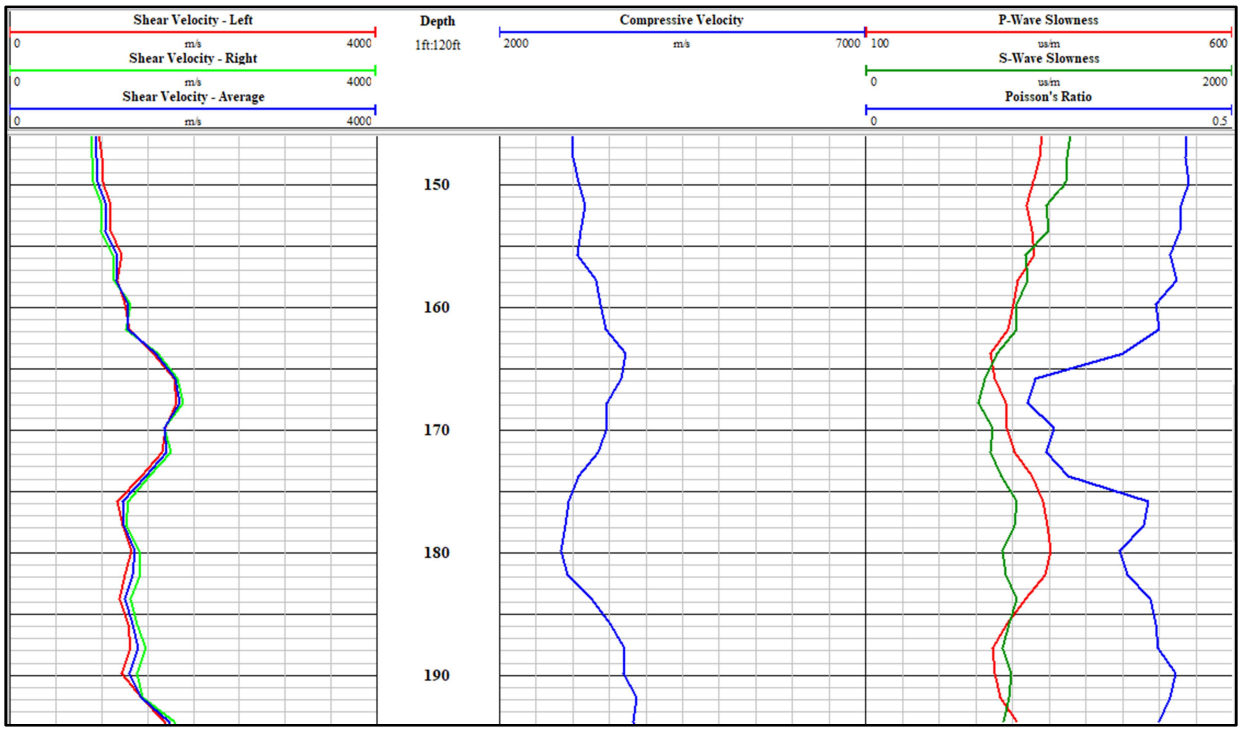
PS Logger Probe

Measurements are typically taken at 2 ft intervals starting at the lowest possible depth. The size of the tool restricts the tool from reaching the lowest point in the borehole since the measurement depth is at the mid-point between the two receivers (Hydrophones) and there are several feet of tool below this point. Multiple shots are made with the tool static in the hole. Increasing the number of shots at each depth increases the quality of the ultimate stacked waveform. This process can take considerably more time than other logging instruments.

The stack at each station is inspected in real-time. If the shot doesn't pass QC, then adjustments are made and the series of shots may be repeated. Acceptable waveforms are recorded and plotted in order to pick P and S wave arrival times. The resulting graphs appeared similar to the following.



The difference in wave arrival times between the near and far receivers is defined as the rock slowness (time/distance). Slowness is the inverse of velocity (distance/time). The slowness and velocity are picked and calculated for both P-waves and S-waves, and together they can be used to obtain Poisson's ratio.



Provided by Colog on October 9th, 2019

Electric Log Methodology

All electrical logs require the presence of the borehole fluid to carry the current from the probe to the formation, and therefore these devices only operate below fluid level. Quantitative formation electrical resistivity, spontaneous potential, and qualitative single point resistance can be measured with a combination tool. The operational feature of each measurement is discussed under the measurement heading.

16-inch and 64-inch Normal Resistivities

Formation resistivity is dependent on the fluid salinity, permeability, and connected fracture paths within the depth of investigation of the measurement. Measured resistivity is also controlled by particle surface conduction in clastic environments. The resistivity measurement decreases in larger diameter boreholes and areas in which the borehole has been broken out, and/or highly fractured. The above responses allow interpretation of lithologic types, correlation of beds, estimation of fluid quality and possible fractured zones.

A constant current is supplied to the downhole current electrode and the resulting voltage drop is measured on the return electrodes 16" and 64" away from the current electrode. The resistivity of the surrounding media (which includes the borehole fluid) is derived from Ohm's Law and the geometry of the electrode arrangement. The static electric field which results from the geometric arrangement of electrodes is ideally a sphere 16" or 64" in radius (for the short and long normal functions respectively). The presence of the borehole diameter and mudcake affects the measurement sphere by decreasing the lateral extent, and increasing the vertical extent. Borehole corrections based on the borehole fluid resistivity can be made, but these corrections do not address the effects of vertical averaging. Accurate interpretation of the logs minimizes this averaging effect. The influence of the borehole size becomes less with smaller diameter boreholes. Calibration of the 16" and 64" normals is performed in the field with a resistance box which tests a range of known resistivities from 0.0 ohm-m to 1,000 ohm-m.

Single Point Resistance (SPR)

The SPR measurement is controlled by rock and fluid parameters in much the same way as resistivity logs. SPR is a simple system of two electrodes (the resistivity current electrode) and a surface electrode. Current is passed through the formation and voltage differences are measured between the two electrodes. The measured resistance includes the resistance of the cable, borehole fluid, and the formation around the borehole. The current density is higher near the borehole electrode and surface electrode. Since the current density at the surface electrode is constant, formation variations close to the probe produce the resistance changes visible on the logs. Since there is a single downhole electrode, not an array, the log effectively shows a point measurement. This gives a very "responsive", high vertical resolution measurement. Though the single point resistance cannot be calibrated quantitatively, its instantaneous response is a good boundary indicator, and does show a more well-defined response than the 16" or 64" normals.

Spontaneous Potential (SP)

The SP is a measurement of the naturally occurring potential in the borehole. This naturally occurring potential is most often caused by a concentration gradient between the borehole fluid and formation fluid (electro-chemical), and requires the presence of a clay rich/porous media interface to occur. Reduction/oxidation (redox) interfaces and streaming potentials (electro-kinetic) caused by the flow of fluid in or out of the borehole are also causes for the occurrence of spontaneous potential.

Provided by Colog on October 9th, 2019

In fresh water environments where the drilling fluid is natural or the salinity is near the formation pore fluid salinity the electro-chemical potential is minimized. The absence of sulfide mineralization or fluid movement into or out of the formation may minimize the redox and streaming potentials.

Natural Gamma

The natural gamma log (also known as gamma or gamma ray log) provides a measurement recorded in counts per second (CPS), that is proportional to the natural radioactivity of the formation. Actual counts depend upon the detector size and efficiency but are often normalized to API units. 200 API units equal the detector response in a specially constructed physical model designed to simulate the typical shale. For most of COLOG's gamma probes, 1 API unit is approximately equal to 1.25 CPS. The depth of investigation for the gamma log is typically 10 to 12 inches. Gamma logs provide formation clay and shale content and general stratigraphic correlation in sedimentary formations. In general, the natural gamma ray activity of clay-bearing sediments is much higher than that of quartz sands and carbonates. Gamma logs are also used in hard rock environments to differentiate between different rock types and in mining applications for assessment of radioactive mineralization such as uranium, potash, etc.

Gamma radiation is measured with scintillation NaI detectors. The gamma-emitting radioisotopes that naturally occur in geologic materials are Potassium40 and nuclides in the Uranium238 and Thorium232 decay series. Potassium40 occurs with all potassium minerals, including potassium feldspars. Uranium238 is typically associated with dark shales and uranium mineralization. Thorium232 is typically associated with biotite, sphene, zircon and other heavy minerals.

The usual interpretation of the gamma log, for hydrogeology applications, is that measured counts are proportional to the quantity of clay minerals present. This assumes that the natural radioisotopes of potassium, uranium, and thorium occur in exchange ions, which are attached to the clay particles. Thus, the correlation is between gamma counts and the cation exchange capacity (CEC). Usually gamma logs show an inverse linear correlation between gamma counts and the average grain size (higher counts indicate smaller grain size, lower counts indicate larger grain size). This relation can become invalid if there are radioisotopes in the mineral grains themselves (immature sandstones or arkose), and if there are differences in the CEC of clay minerals in the different parts of the formation. Both of these situations are possible in many environments. The former situation would most likely occur in basal conglomerates composed of granitic debris, and the latter where clay occurs as a primary sediment in shale and another as an authigenic mineral deposited in pore spaces during diagenesis.

The assumption of a linear relationship between clay mineral fraction in measured gamma activity can be used to produce a shale fraction calibration for a gamma log in the form:

$$Csh = (G-Gss) / (Gsh - Gss)$$

Where Csh is the shale volume fraction, G is the measured gamma activity; Gss is the gamma activity in clean sandstone or limestone; Gsh is the gamma activity measured in shale.

Calibration of the gamma logging tool is usually performed in large physical models such as the API test pits in Houston, or the DOE uranium calibration test pits. In hydrogeology, the gamma measurement is usually a relative log and quantitative calibrations are not routinely performed. However, the stability and repeatability of the natural gamma measurement is routinely checked with a sleeve of known radioactivity. It is also common to routinely check the gamma log by repeat logging a section of a well. Natural radioactive decay follows a Gaussian distribution; that is, approximately 67% of the radioactive

response occurs within ± the square root of the count rate. For instance, if a background radiation of 100 CPS is being measured, there is approximately ± 10 CPS variability.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- The natural gamma ray log, as with all nuclear or radiation logs, have a fundamental advantage over most other logs in that they may be recorded in either cased or open holes that are fluid or air filled. Borehole fluid and casing may attenuate the gamma values.
  Excessive borehole rugosity, often caused by air drilling, may degrade natural gamma ray log.

Provided by Colog on October 9th, 2019

Fluid Temperature/Resistivity

Geothermal gradients in the near surface earth are usually dominated by conduction, and are generally linear increasing with depth due to the relative constancy of the thermal conductivity of earth materials. Convective heat flow within the borehole fluid is caused by formation fluid entering or leaving the borehole at some permeable interval. Therefore, deviations from the linear thermal gradient can be attributed to fluid movement. Both the thermal gradient and fluid resistivity profile of the borehole fluid can be obtained with the same probe. The temperature is measured with a thermistor and the fluid resistivity is measured with a closely spaced Wenner electrical array.

Slope changes in both the temperature and fluid resistivity logs may be indicative of fluid flow between the formation and the borehole. Both responses are effected by drilling method, time since circulation, mud type or additives and well development procedures.

A differential temperature log is a calculated curve that amplifies slight slope changes in the temperature gradient and can assistance in the interpretation of the fluid temperature log. As the probe is lowered downhole, small changes in the slope of the temperature curve are identified by a differential curve that is plotted from a center zero line. The differential temperature is constructed by using a temperature point at one depth and subtracting a point at a lower depth throughout the entire logged interval.

(temperature value Depth 1) - (temperature value Depth 2) = differential value

In real time the differential values are calculated across the acquisition digitizing interval (e.g. 0.1 to 0.5 ft). Because of the small digitizing interval the calculated real time differential curve may only identify larger temperature gradient deviations. Another differential temperature can be constructed in post processing over a larger sample interval (sometimes up to 2 ft). This log commonly provides a more diagnostic differential curve and is used frequently in the temperature profile interpretation.

The fluid resistivity in the borehole is controlled primarily by the salinity. Therefore, salinity stratification, or the introduction of a fluid of different water quality into the borehole, can be observed by changes in the fluid resistivity log. Often, the exchange of fluid between the formation and the borehole, influences both the temperature and the fluid resistivity so that the response is evident in both logs.

Temperature corrected resistivity can be converted to equivalent NaCl salinity in parts per million (Bateman and Konen, 1977). A salinity profile can then be plotted which indicates the general water quality trend of the borehole fluid. If the assumption is made that the borehole fluid is in equilibrium with the formation fluid, then the borehole salinity profile can be interpreted as a formation fluid salinity profile. Differences between these profiles from well to well, may contain information concerning the extent of hydraulic connectivity in the area.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- The borehole temperature log is usually the first log run in a borehole and, unlike virtually all other logs, is run while the probe is moving down the hole. The exception to running this probe first, however, would be if any optical measurement is to be acquired. The idea is that the logging of the temperature/resistivity probe may stir up the wellbore fluids inhibiting the optical device.

- The recorded borehole temperature is only that of the fluid surrounding the probe, which may or may not be representative of the temperature in the surrounding rocks.

- In most wells the geothermal gradient is considerably modified by fluid movement in the borehole and adjacent rocks.

- Temperature logs are generally recommended for uncased fluid-filled boreholes, but may be used in fluid-filled cased wells for some applications.

Provided by Colog on October 9th, 2019

1-Arm and 3-Arm Caliper

The caliper log represents the average borehole diameter determined by the extension of 1 or 3 spring-loaded arms. The measurement of the borehole diameter is determined by the change in the variable pot resistors in the probe, which are internally connected to the caliper arms.

Caliper logs may show diameter increases in cavities and, depending on drilling techniques used, in weathered zones. An apparent decrease in borehole diameter may result from mud or drill-cutting accumulation along the sides of the borehole (mudcake), a swelled clay horizon or a planned change in drill bit size. The bottom of the boring can also induce a small diameter reading from the caliper due to the caliper leaning up against on side of the borehole. The caliper log is often a useful indicator of fracturing. The log anomalies do not directly represent the true in-situ fracture size or geometry. Rather, they represent areas of borehole wall breakage associated with the mechanical weakening at the borehole-fracture intersection. Caliper anomalies may represent fractures, bedding planes, lithologic changes or solution openings. Generally, in solid bedrock, caliper log anomalies indicate the intervals where fractures intersect boreholes.

Colog records the caliper log with either a single-arm caliper measurement using the decentralization arm of the density probe or a separate stand-alone three-arm caliper. Calibrations of the probe are done routinely on the bench and in the field directly before the tool is placed into the borehole. Calibration standards consist of rings of known diameters that are placed over the extended arms as the tool response at these diameters is recorded. Additionally, as with other geophysical measurements, a repeat section may be collected and compared with the original logs for consistency and accuracy.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- Excessive borehole diameters (greater than 36 inches) may limit the range of borehole caliper measurements. Holes greater than 12 inches must be logged with extended arms for hole diameters up to 36 inches.

Since the caliper probe is an electro-mechanical device, a certain amount of error is inherent in the measurement. These errors are due to: 1) averaging hole diameter using three arms, 2) non-linearity of the measurement resistor, 3) tolerance in the mechanical movement of the caliper arms (mechanical hysteresis).

Provided by Colog on October 9th, 2019

APPENDIX

TEST RESULTS

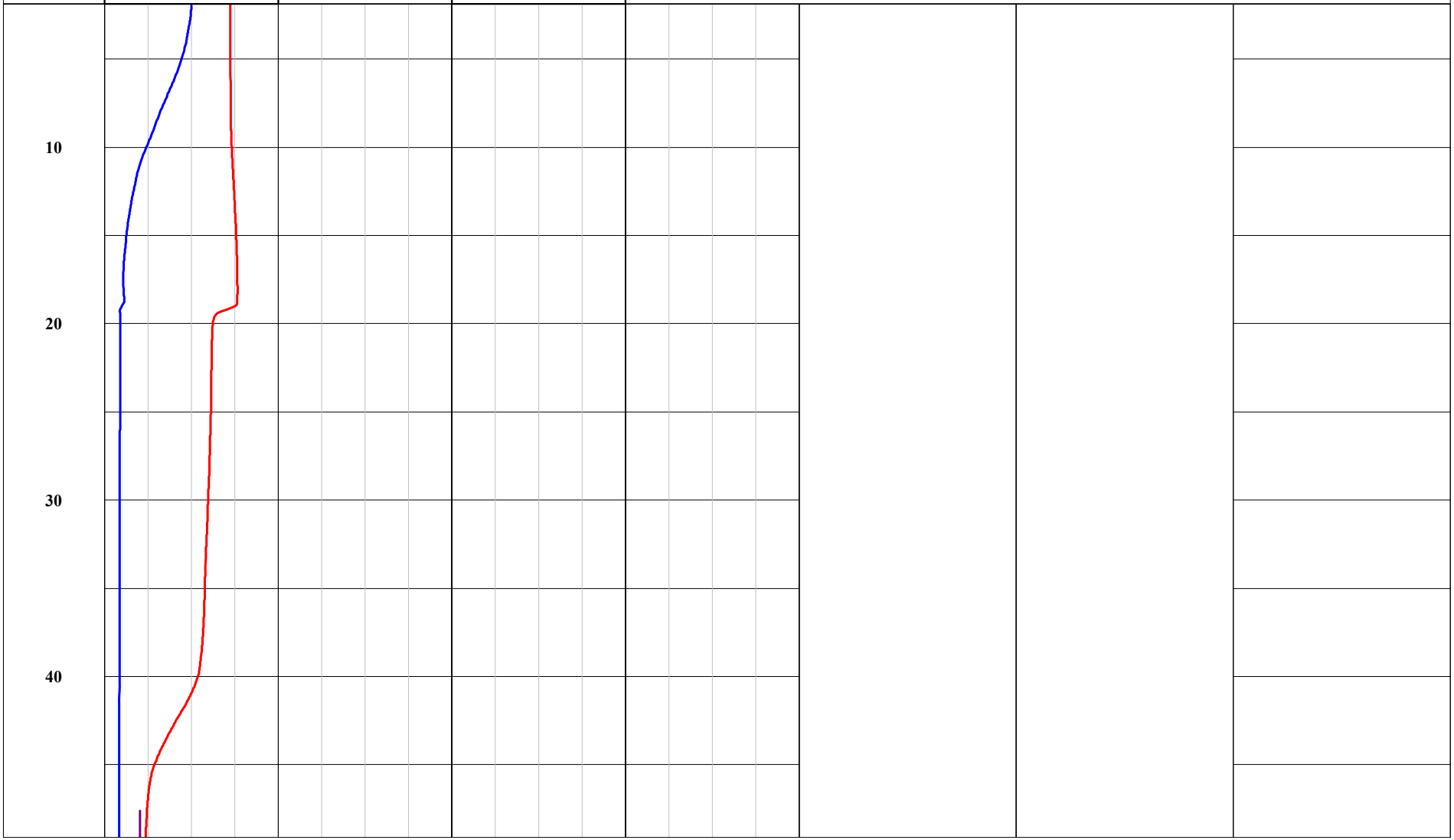
Geophysical Summary Plot

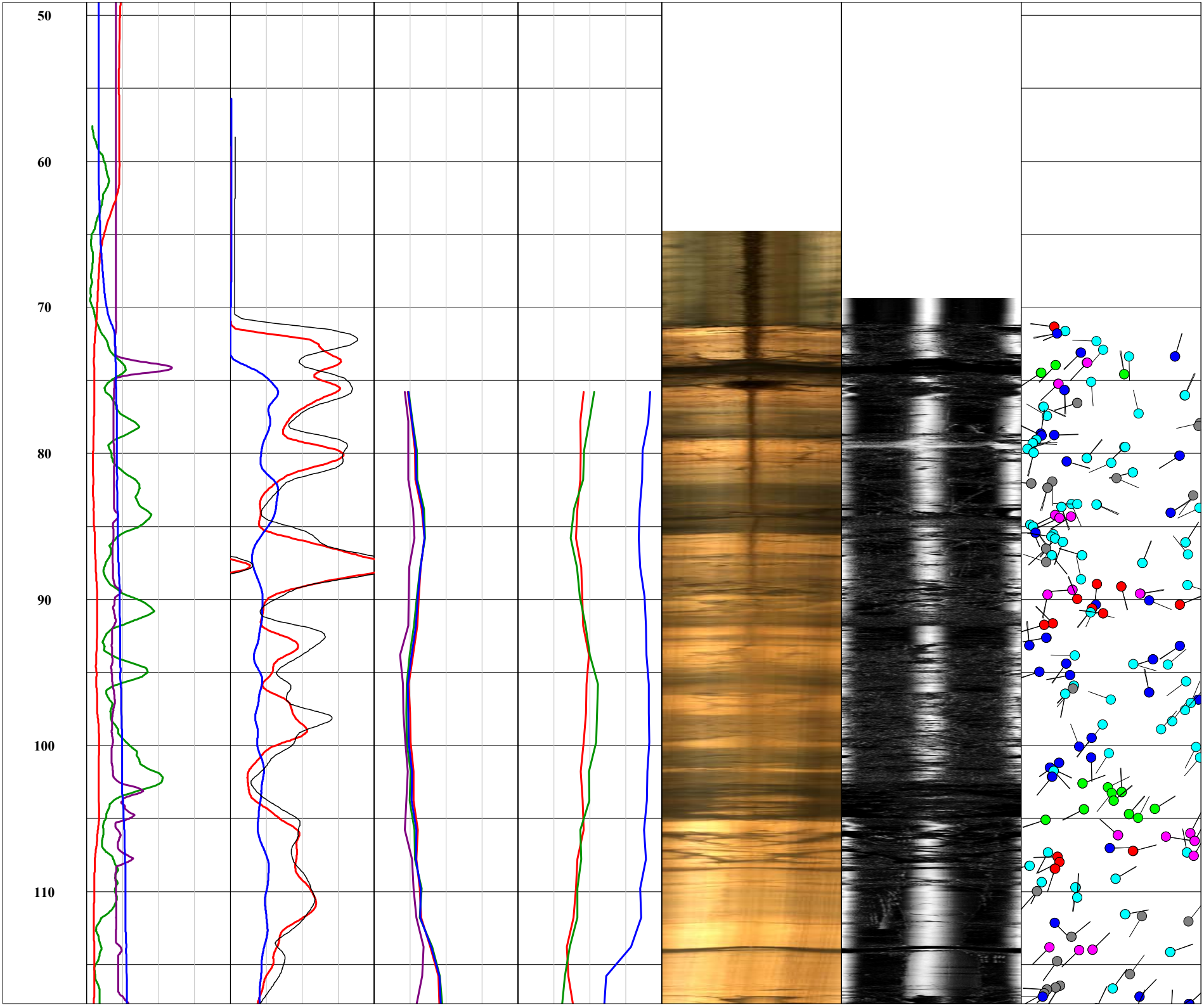
COLOG
borehole geophysics / hydrophysics

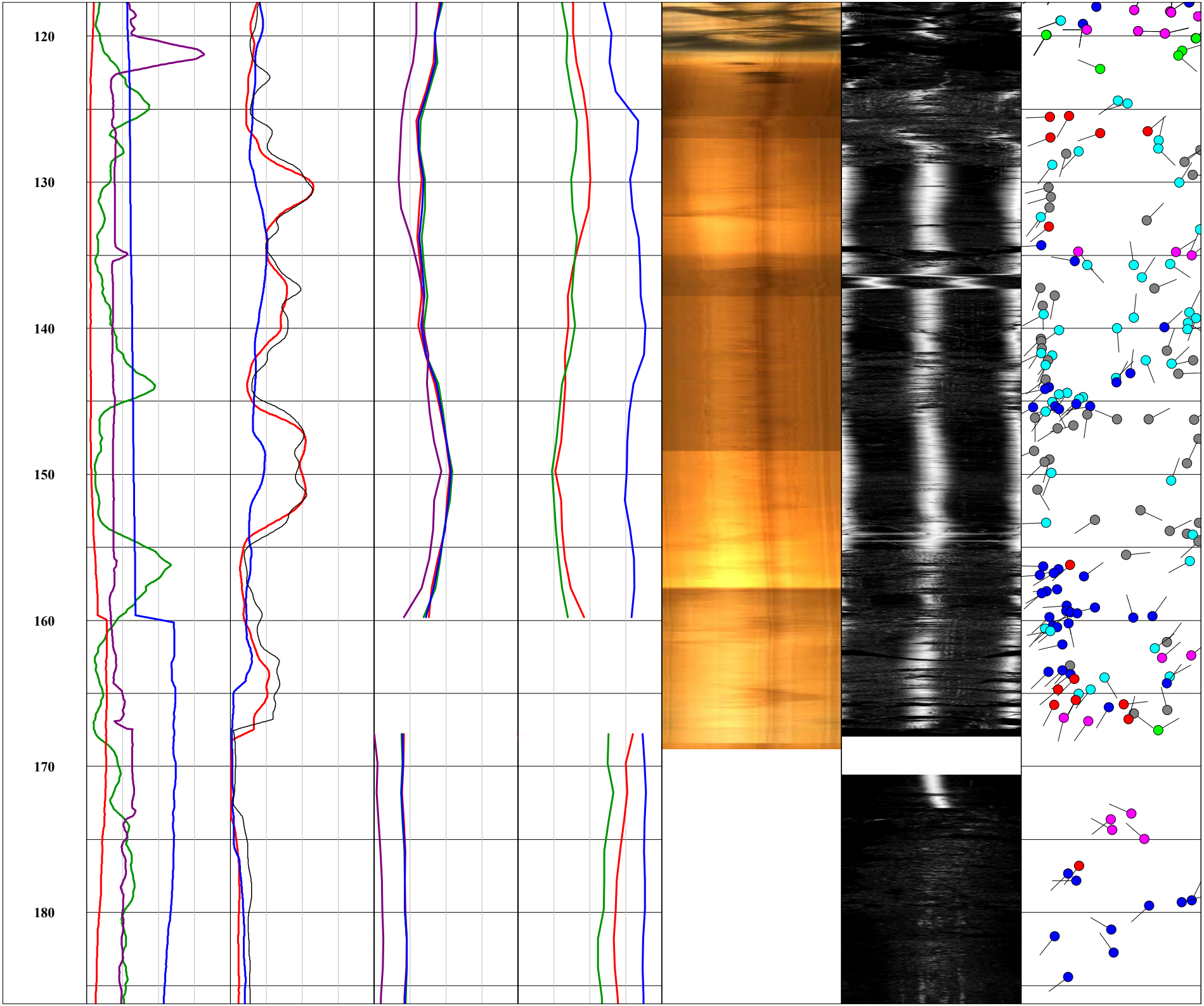
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 24,25 June 2019
WELL: BH19-07 - North Side

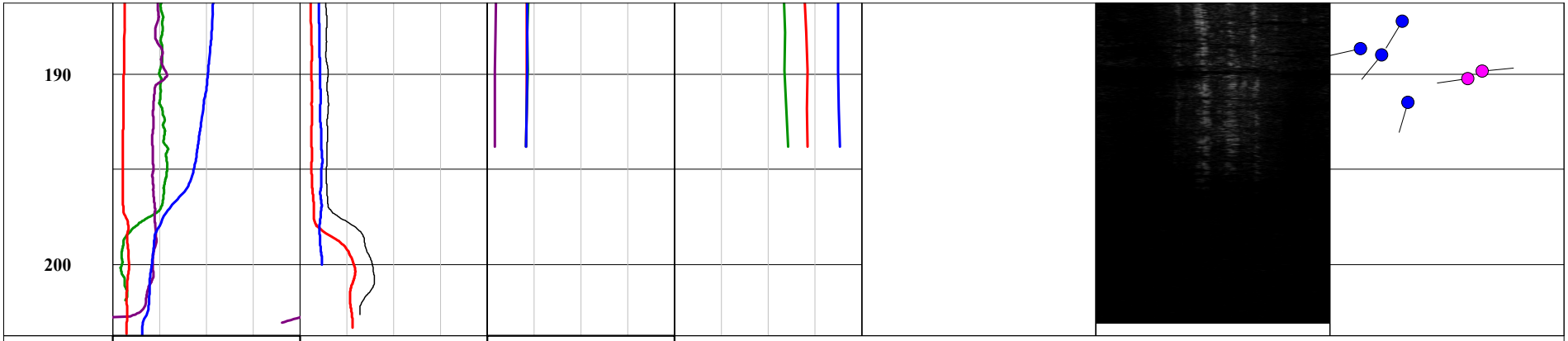
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - HS	Amplitude - HS	Tadpoles - MN
1ft:100ft	0 CPS 200	0 Ohm-m 1000	0 m/s 4000	100 us/m 600	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 Inch 10	0 Ohm-m 1000	0 m/s 4000	0 us/m 2000			
	Temperature	Single-Point Resistance	Shear Velocity - Average	Poisson's Ratio			
	10 deg C 25	0 Ohm 500	0 m/s 4000	-0.2 0.5			
	Fluid Conductivity		Compressive Velocity				
	0 uS/cm 1000		2000 m/s 7000				




50
60
70
80
90
100
110


120
130
140
150
160
170
180



	0 uS/cm 1000 **Fluid Conductivity**		2000 m/s 7000 **Compressive Velocity**				
	10 deg C 25 **Temperature**	0 Ohm 500 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Average**	-0.2 0.5 **Poisson's Ratio**			
	2 Inch 10 **3-Arm Caliper**	0 Ohm-m 1000 **64" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**			
1ft:100ft **Depth**	0 CPS 200 **Natural Gamma**	0 Ohm-m 1000 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Left**	100 us/m 600 **P-Wave Slowness**	0° 90° 180° 270° 0° **Optical Image - HS**	0° 90° 180° 270° 0° **Amplitude - HS**	0 90 **Tadpoles - MN**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-07
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-07
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83808 N
Longitude: 84.75731 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.4'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	24/25 July 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	204'			
DEPTH-LOGGER	204'			
BTM LOG INTERVAL	204.54'			
TOP LOG INTERVAL	70'			
RECORDED BY	MAC/MJC			
WITNESSED BY				
PROBE TYPE, S/N	ABI LIM #1729			
LOGGING SPEED	4.5'			
A.S.D.E. / Sample Interval	0.13' / 0.0024'			
Fluid Level / Fluid Type	19'/water			

BOREHOLE RECORD

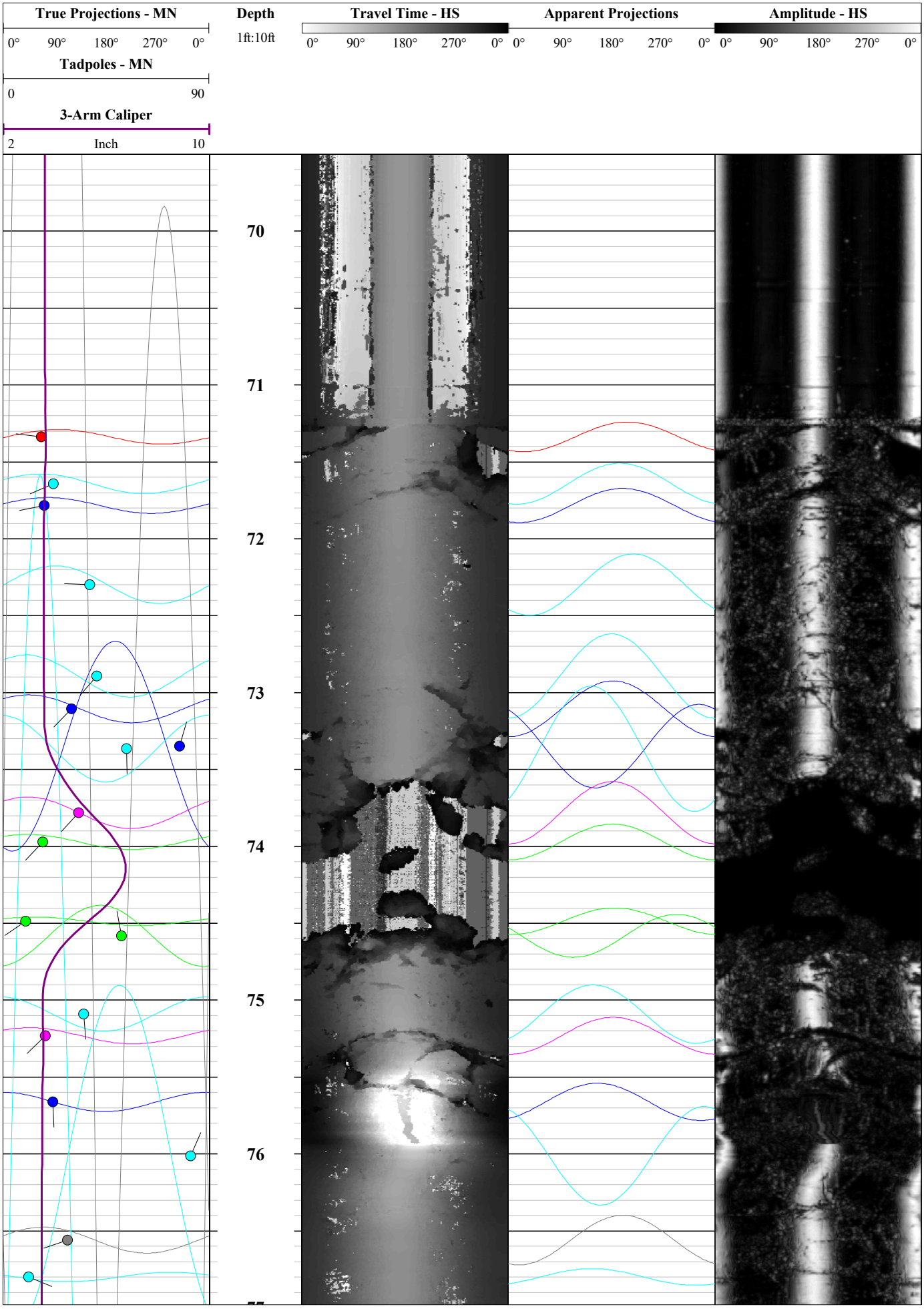
RUN No.	BIT	FROM	TO
1	HQ	70'	204'

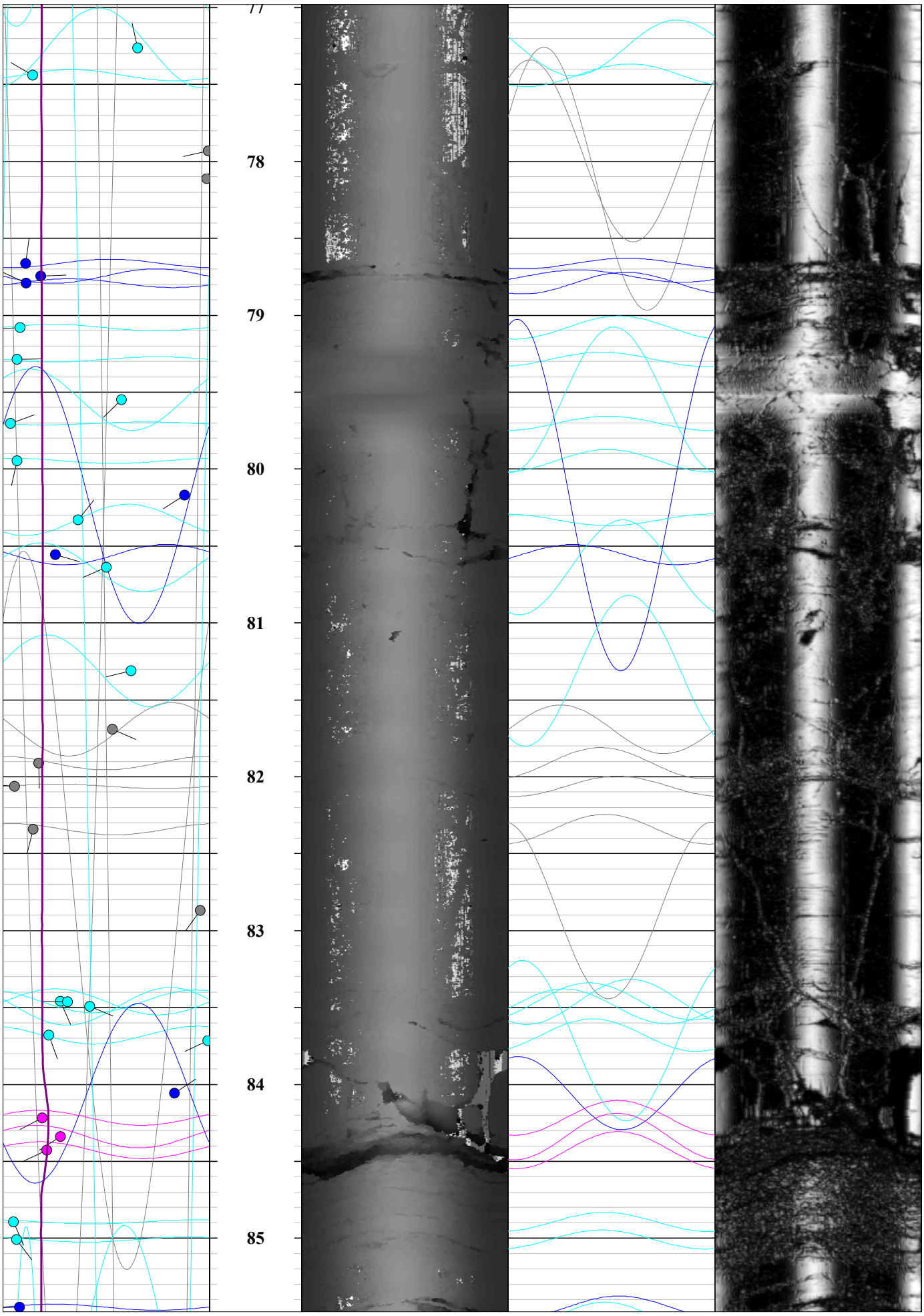
CASING RECORD

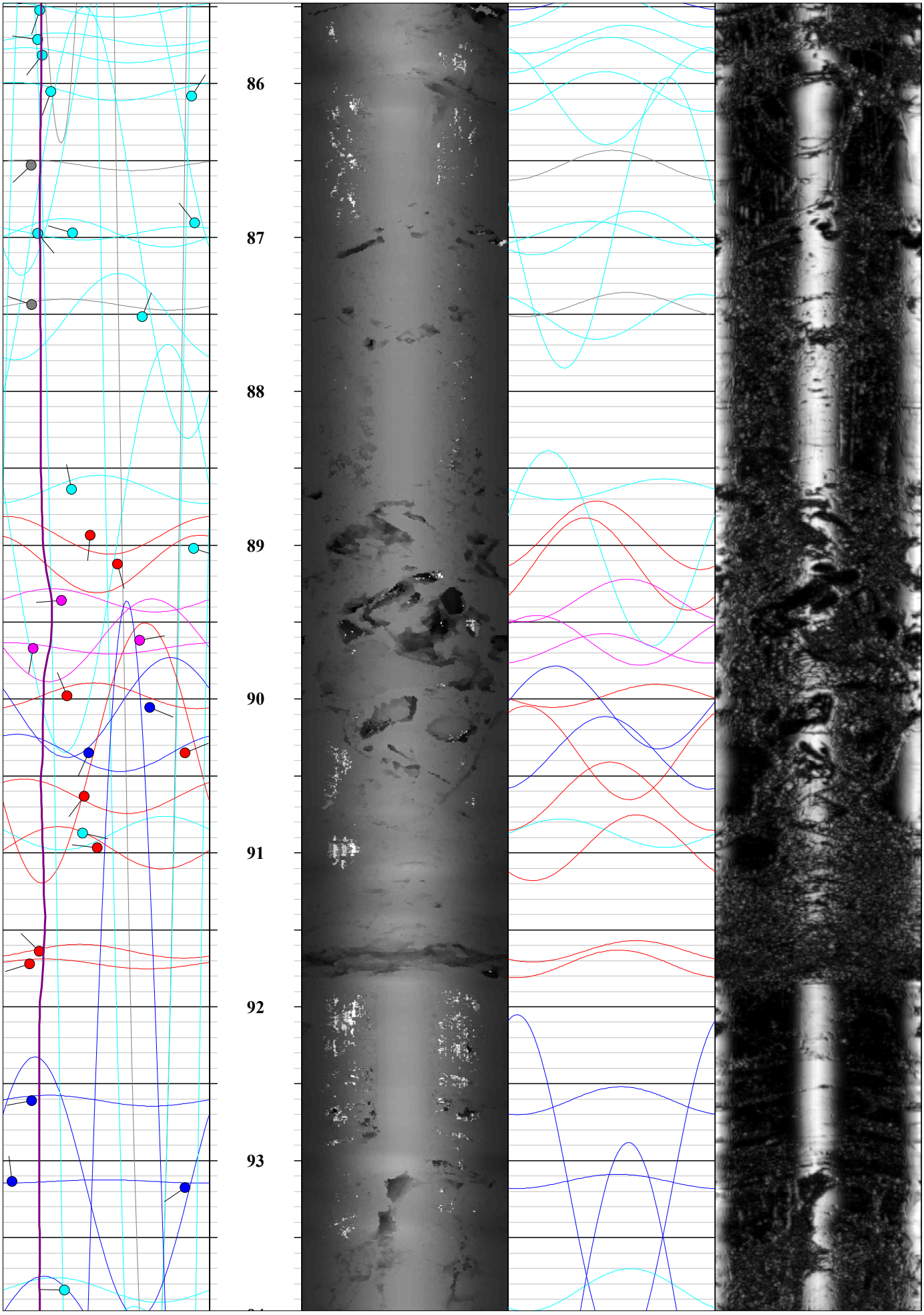
SIZE	WGT.	FROM	TO
PQ	Steel	0'	70'

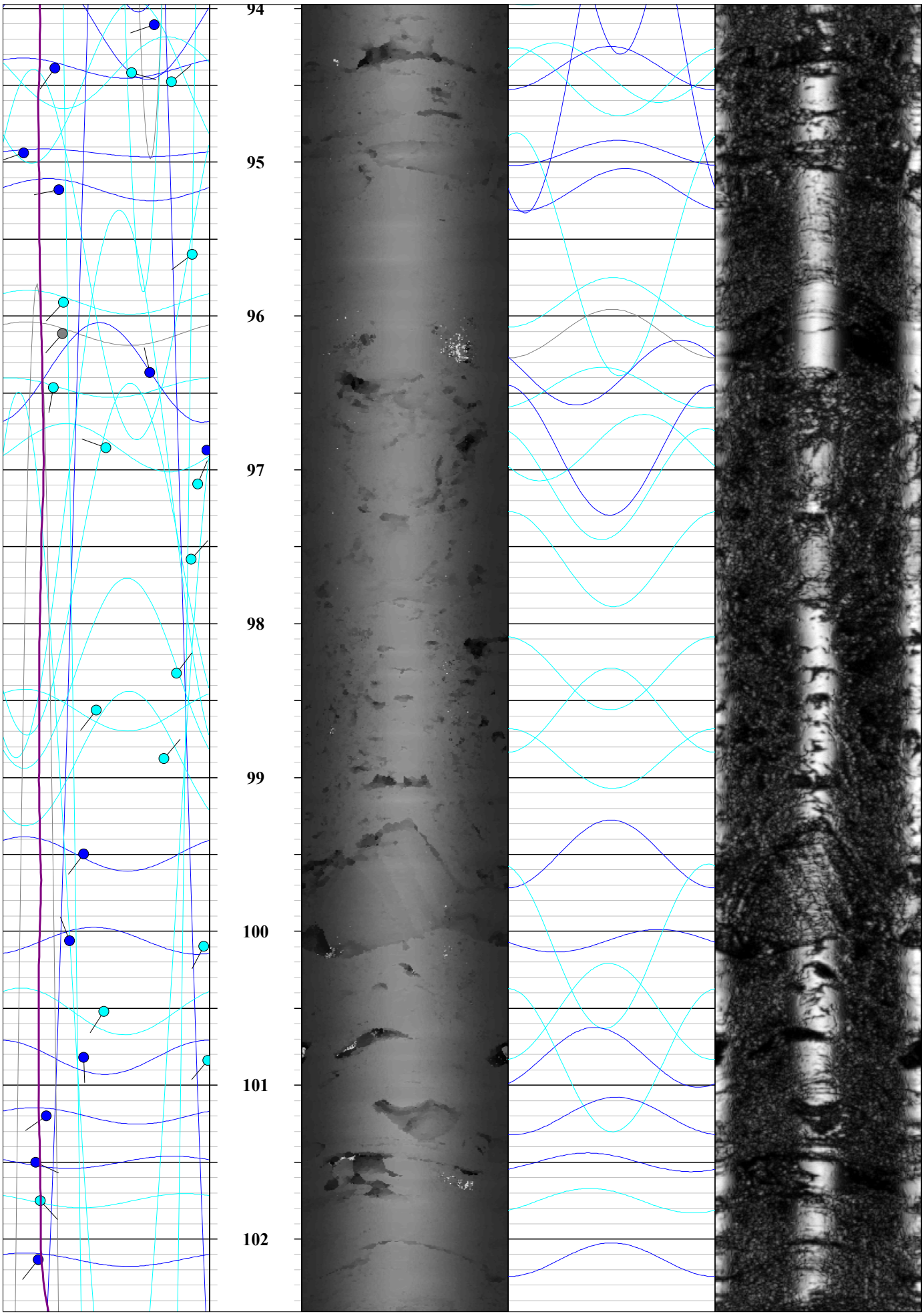
NA - Not Available, N/A - Not Applicable

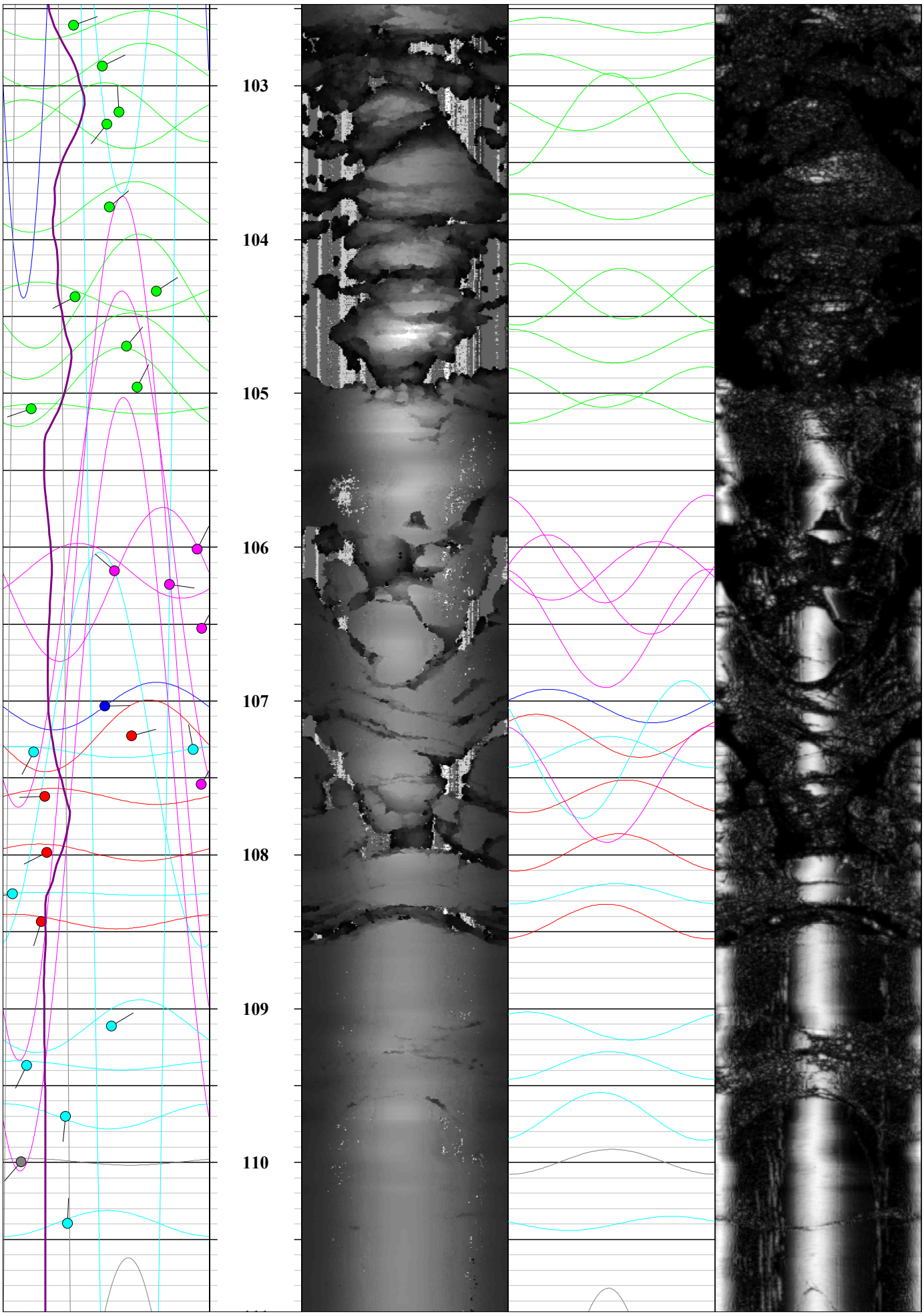
COMMENTS

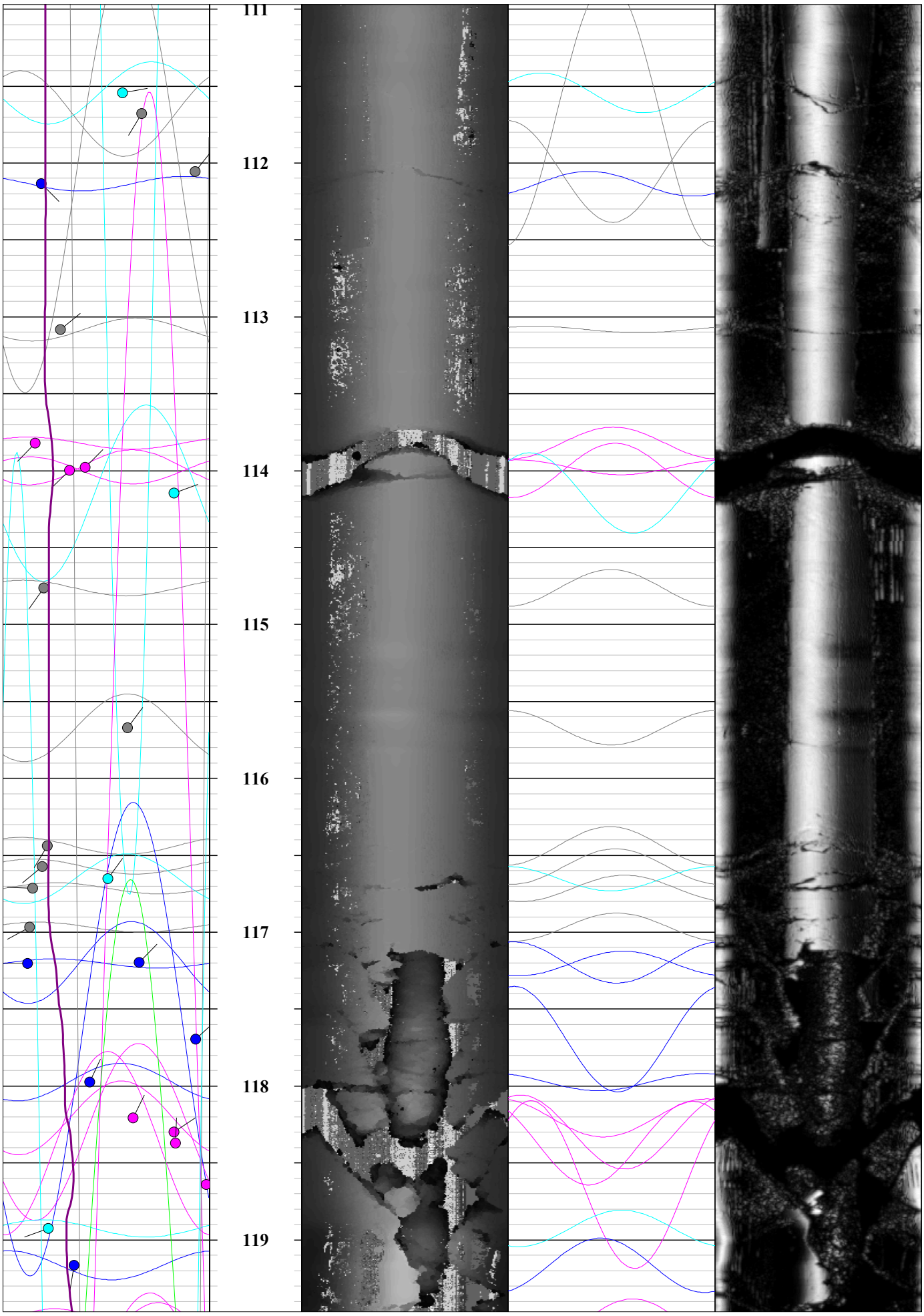

True Projections - MN
0° 90° 180° 270° 0°
Tadpoles - MN
0 90
3-Arm Caliper
2 Inch 10
Depth
1ft:10ft
Travel Time - HS
0° 90° 180° 270° 0°
Apparent Projections
0° 90° 180° 270° 0°
Amplitude - HS
0° 90° 180° 270° 0°
70
71
72
73
74
75
76

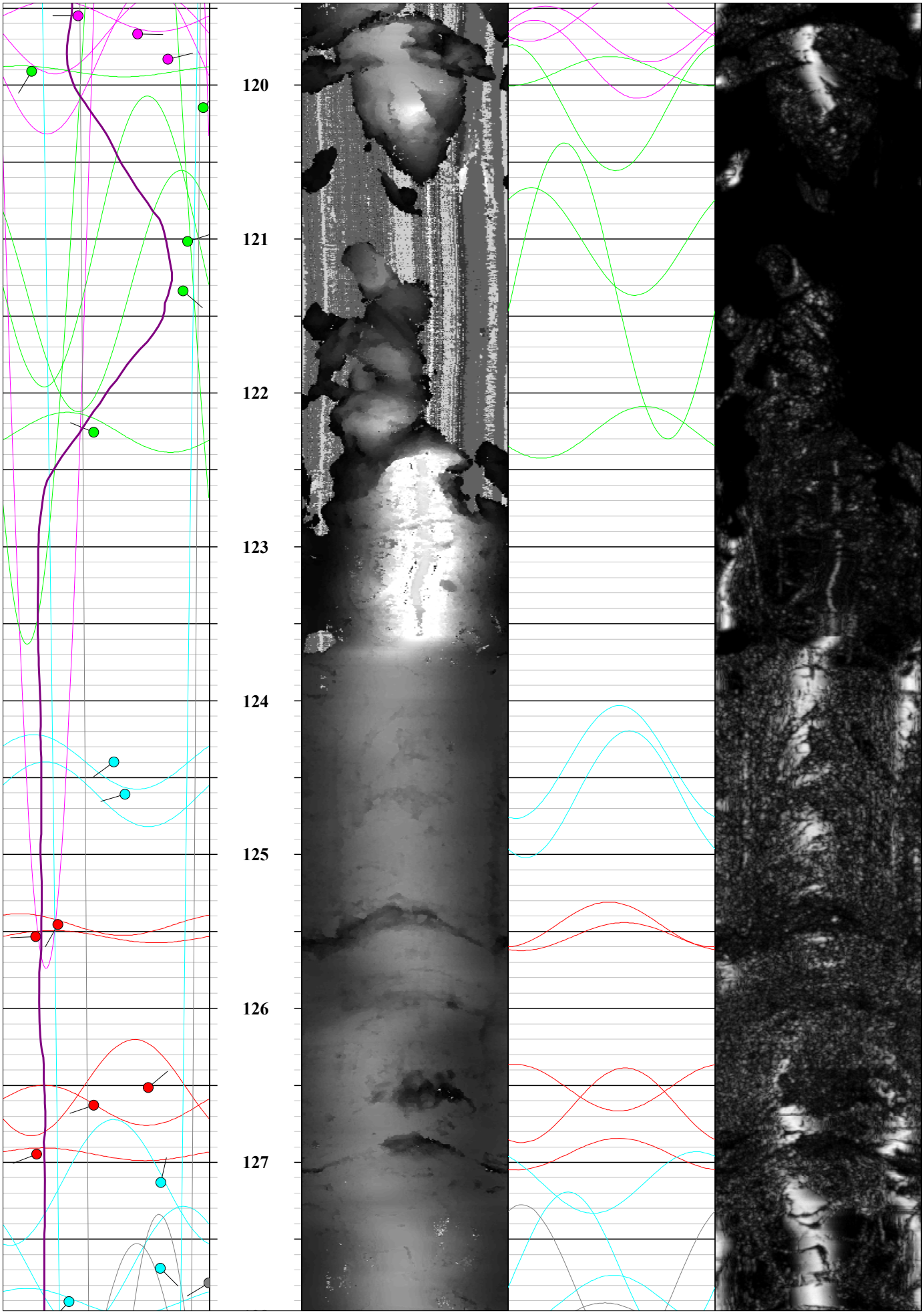

77
78
79
80
81
82
83
84
85

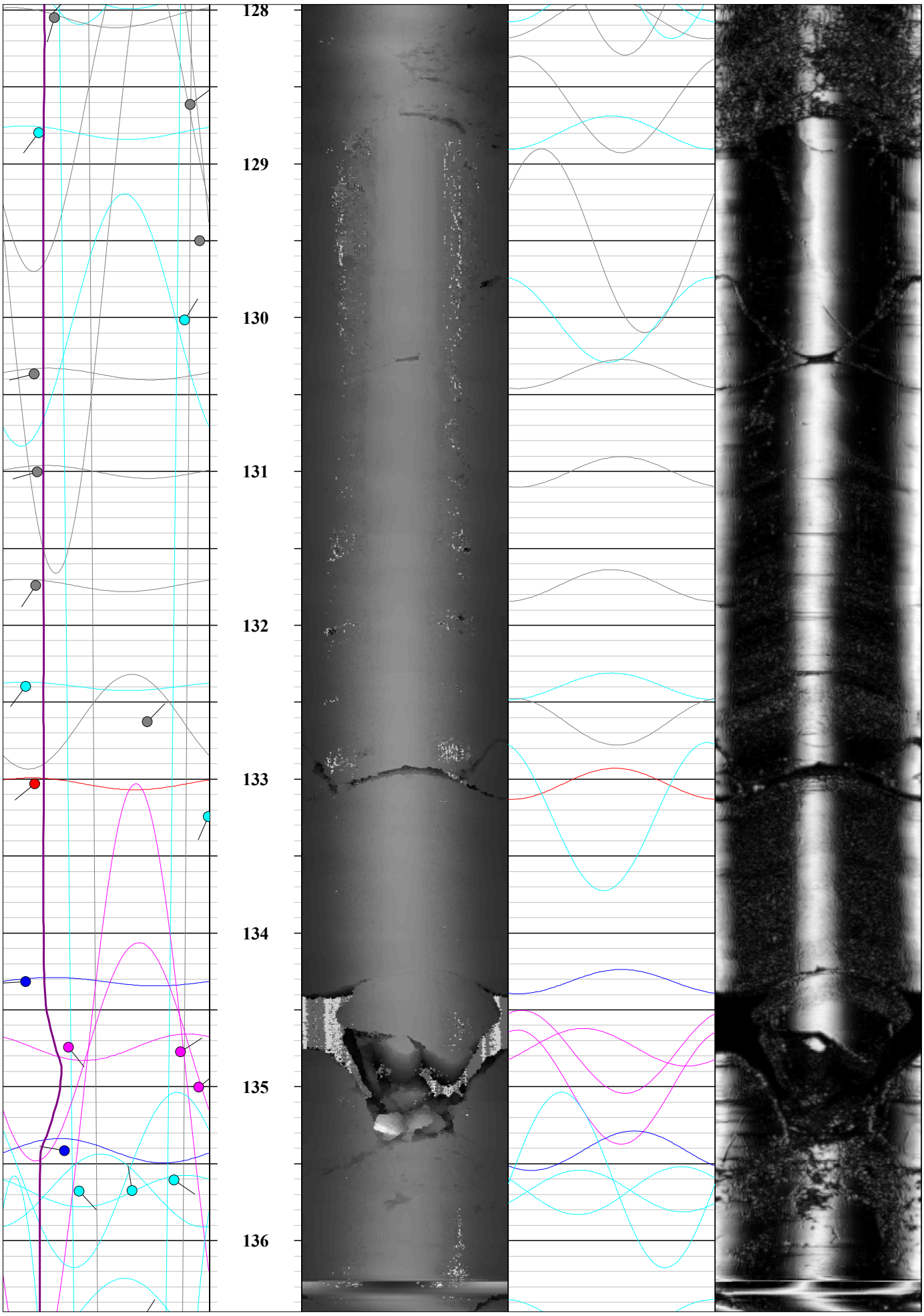

86
87
88
89
90
91
92
93

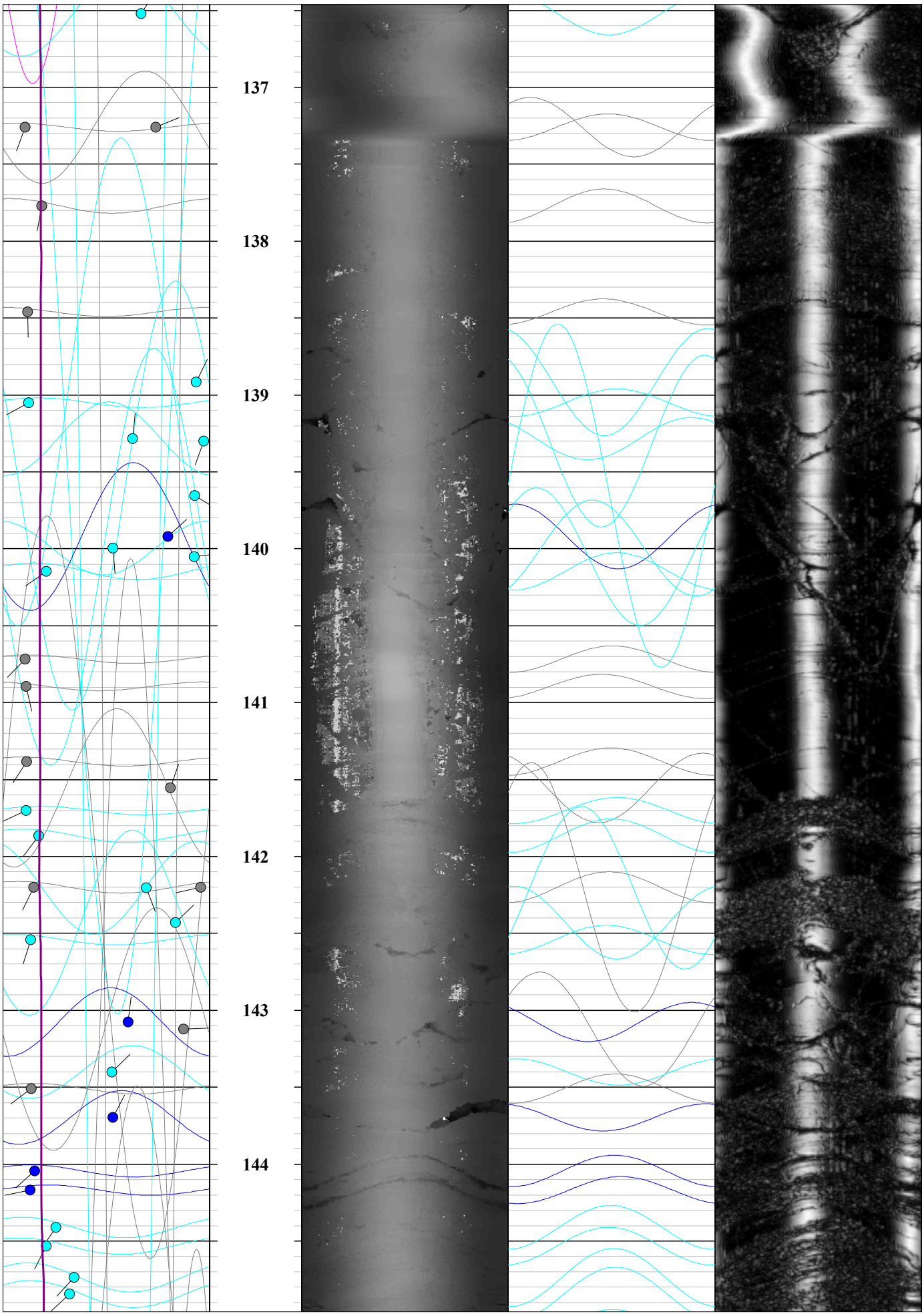

94
95
96
97
98
99
100
101
102

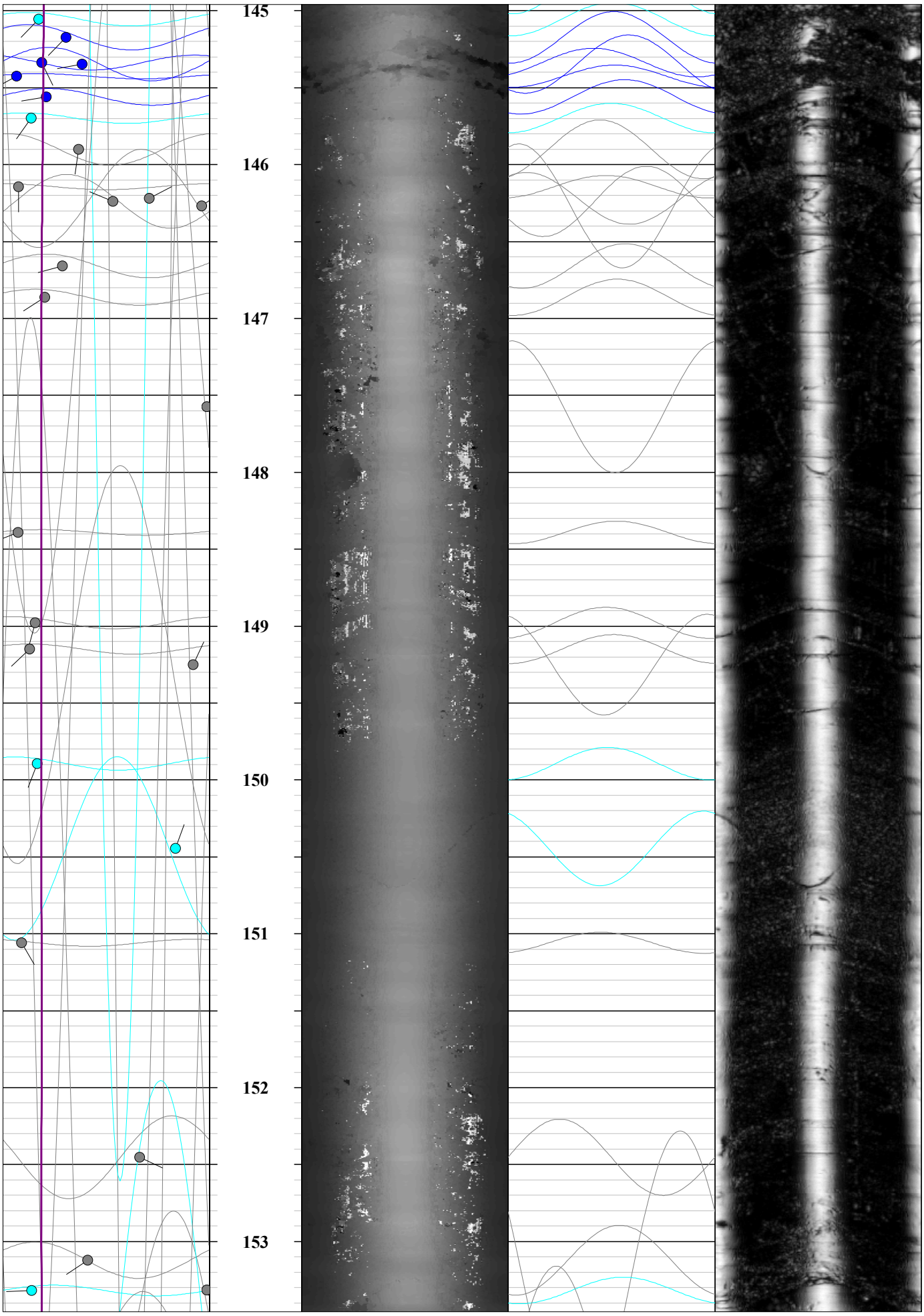

103
104
105
106
107
108
109
110

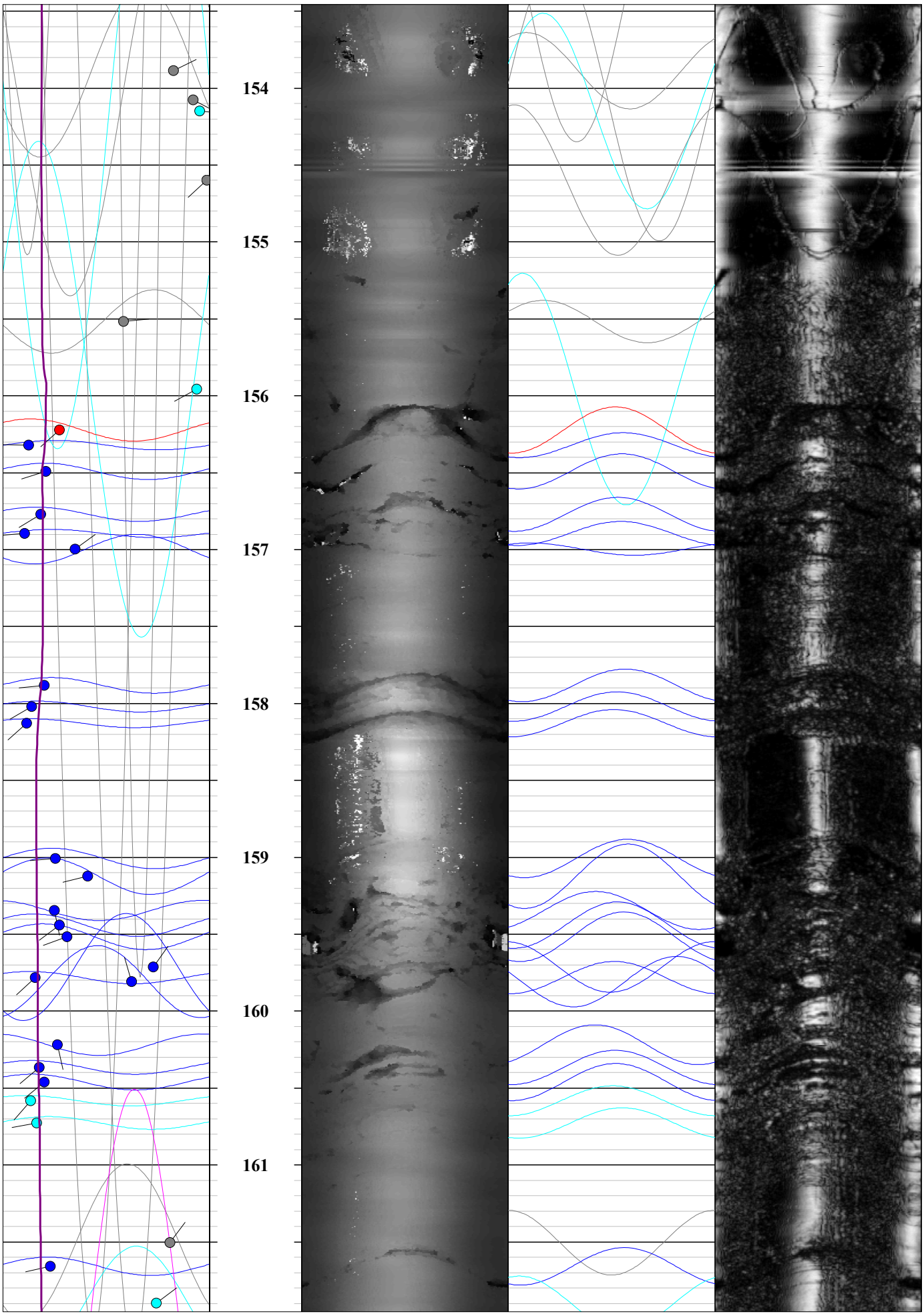

111
112
113
114
115
116
117
118
119

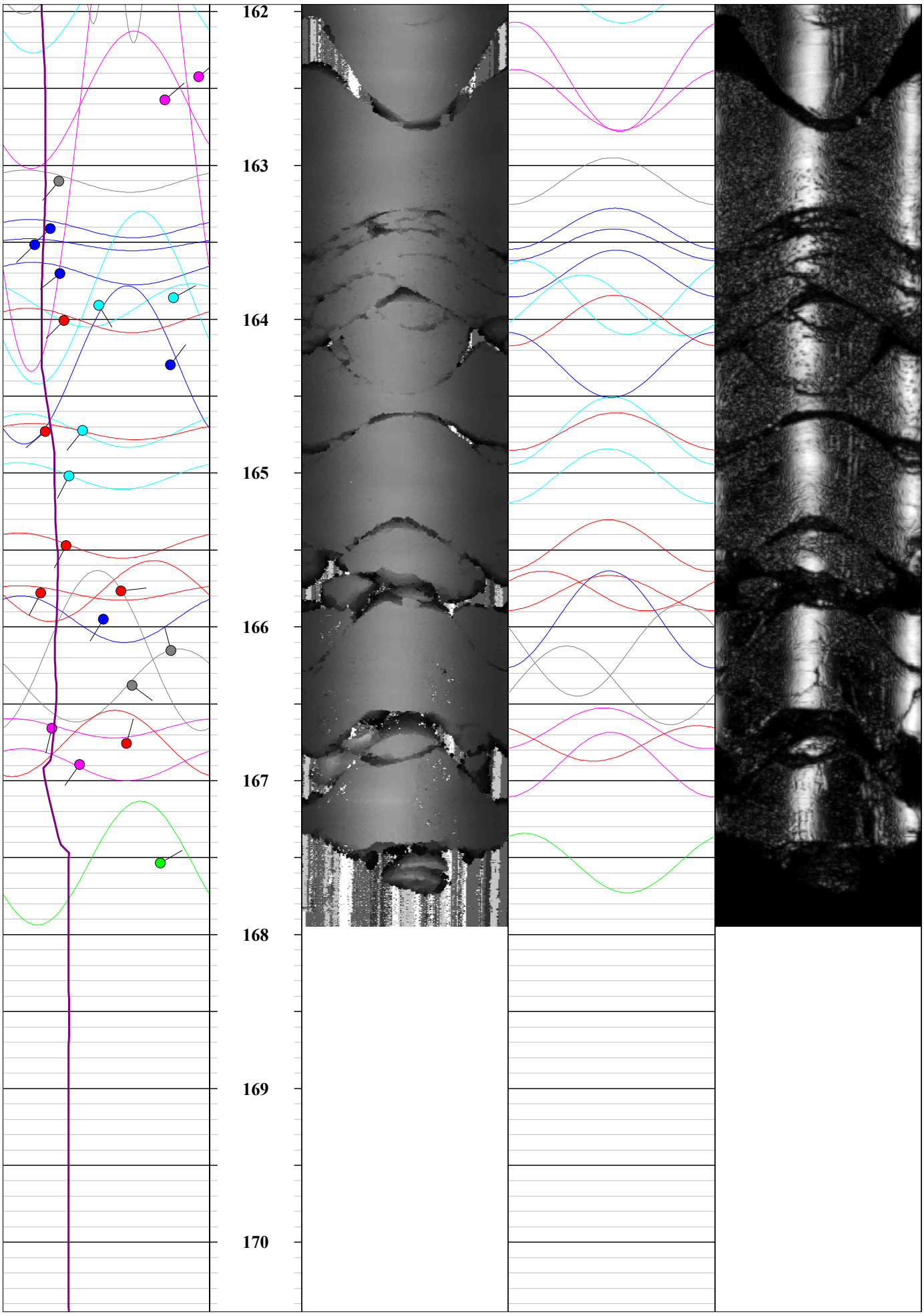

120
121
122
123
124
125
126
127

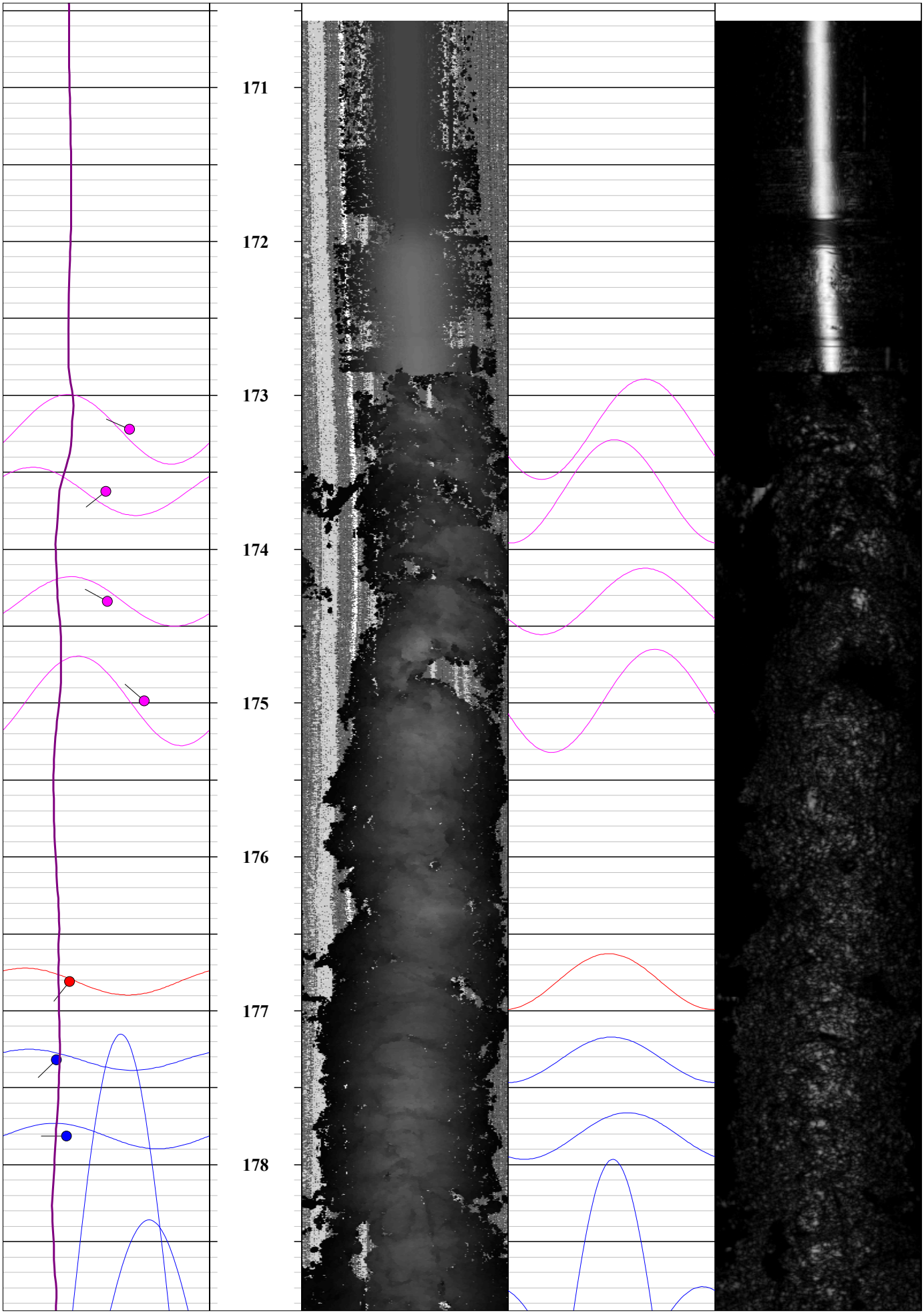

128
129
130
131
132
133
134
135
136

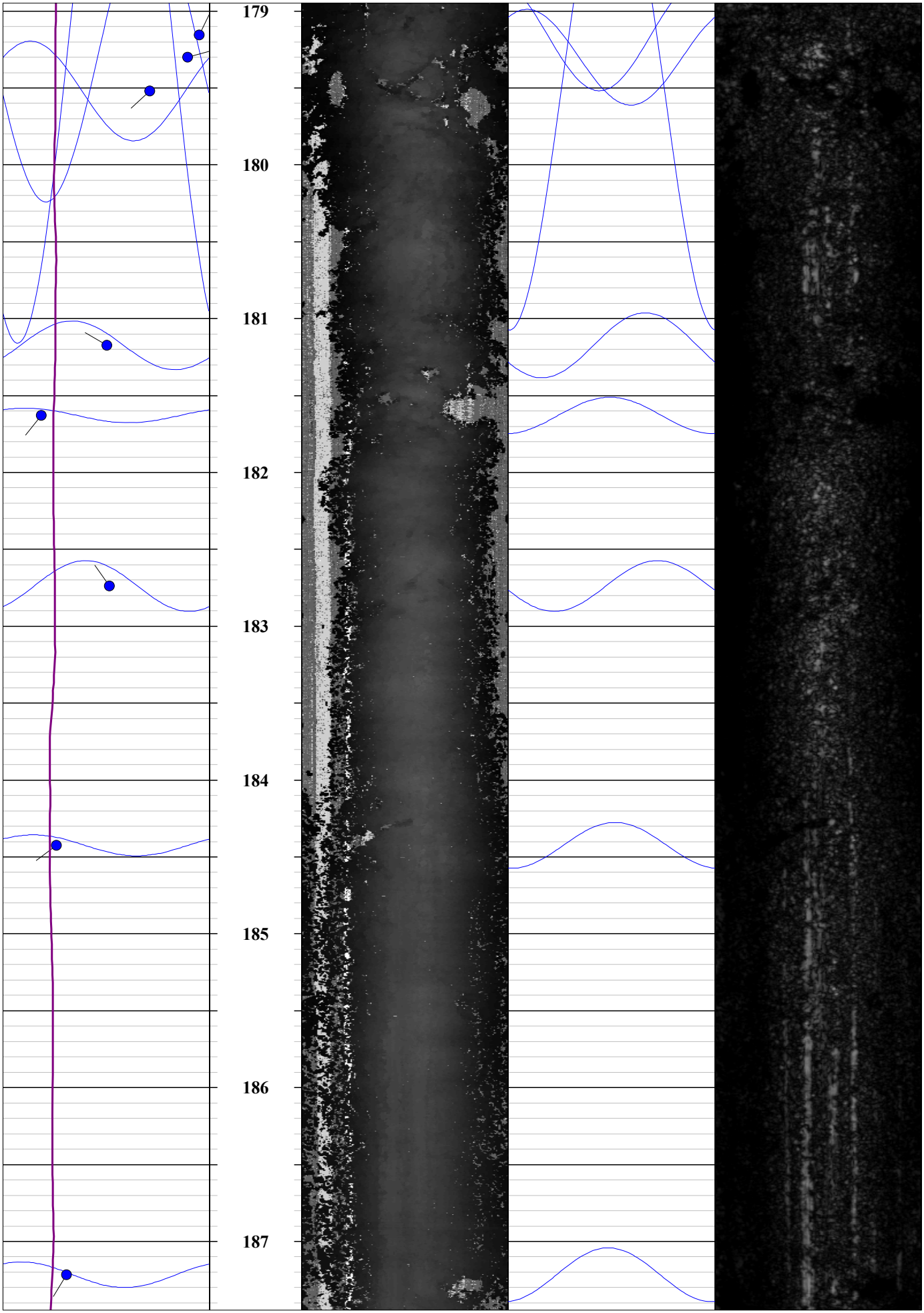

137
138
139
140
141
142
143
144

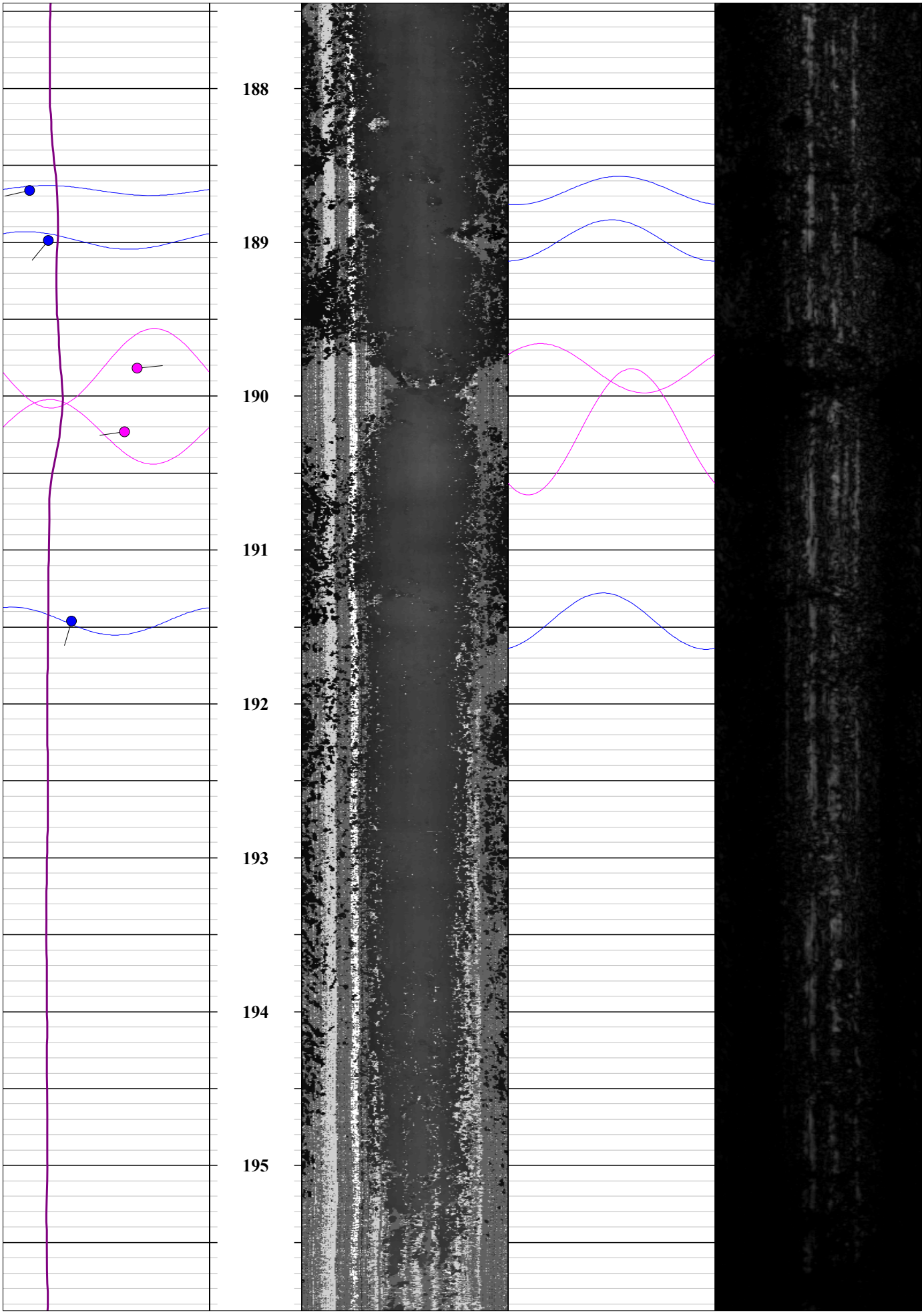

145
146
147
148
149
150
151
152
153

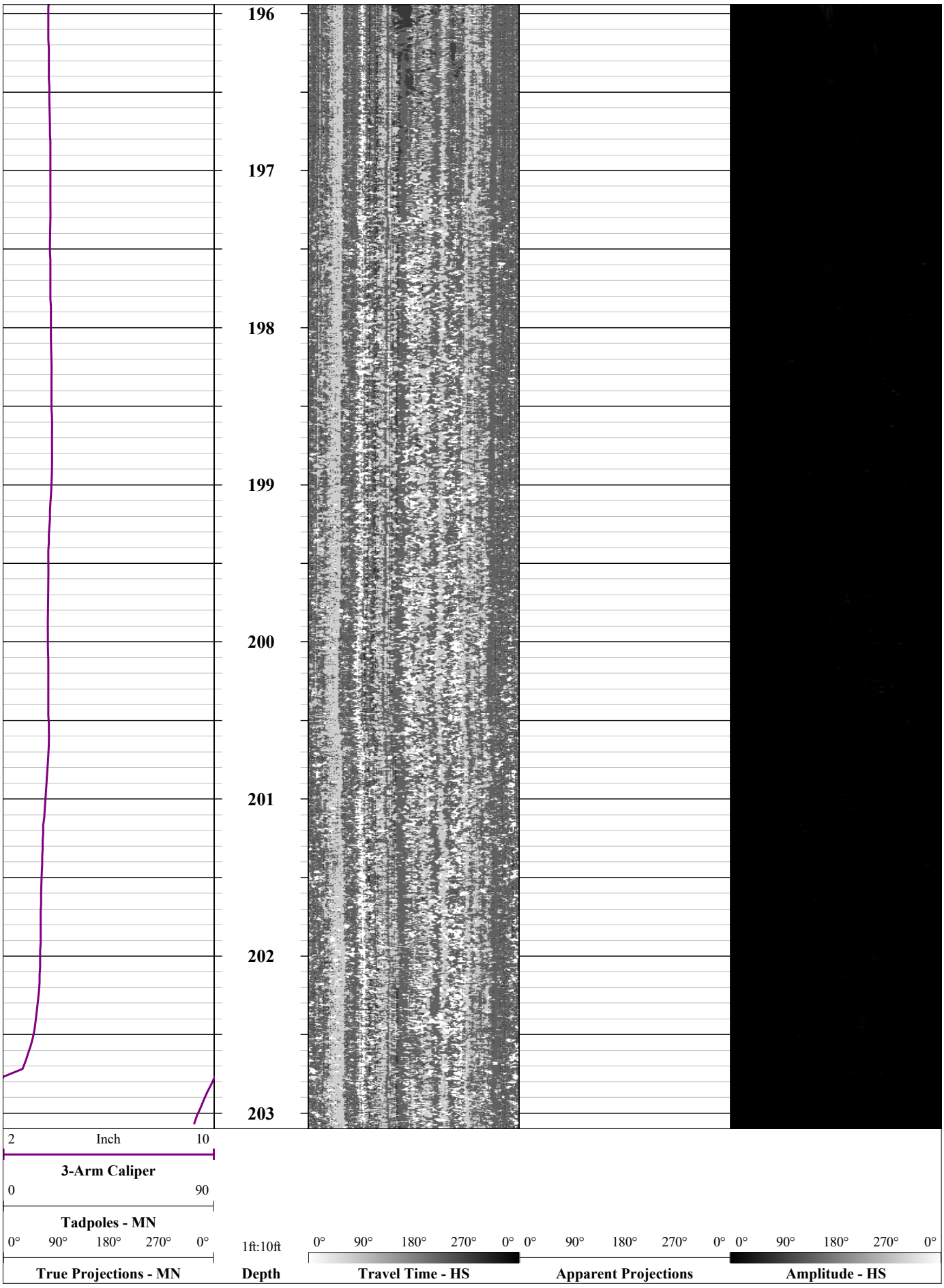

154
155
156
157
158
159
160
161


162
163
164
165
166
167
168
169
170


171
172
173
174
175
176
177
178


179
180
181
182
183
184
185
186
187


188
189
190
191
192
193
194
195


196
197
198
199
200
201
202
203
2
Inch
10
3-Arm Caliper
0
90
Tadpoles - MN
0°
90°
180°
270°
0°
True Projections - MN
1ft:10ft
Depth
0°
90°
180°
270°
0°
Travel Time - HS
0°
90°
180°
270°
0°
Apparent Projections
0°
90°
180°
270°
0°
Amplitude - HS

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-07
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-07
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83808 N
Longitude: 84.75731 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.4'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	24 July 2019	25 July 2019	25 July 2019	
RUN NUMBER	1	2	3	
LOG TYPE	Optical Televiewer	Optical Televiewer	Optical Televiewer	
DEPTH-DRILLER	204'	204'	204'	
DEPTH-LOGGER	204'	204'	204'	
BTM LOG INTERVAL	204'	100'	65'	
TOP LOG INTERVAL	172'	169.2'	122.75'	
RECORDED BY	MJC	MAC	MAC	
WITNESSED BY				
PROBE TYPE, S/N	OBI LIM #1729	OBI LIM #1729	OBI LIM #1729	
LOGGING SPEED	5 fpm	4.5 fpm	4.5 fpm	
A.S.D.E. / Sample Interval	0.11' / 0.003'	0.11' / 0.003'	0.11' / 0.003'	
Fluid Level / Fluid Type	19'/water	19'/water	19'/water	

BOREHOLE RECORD

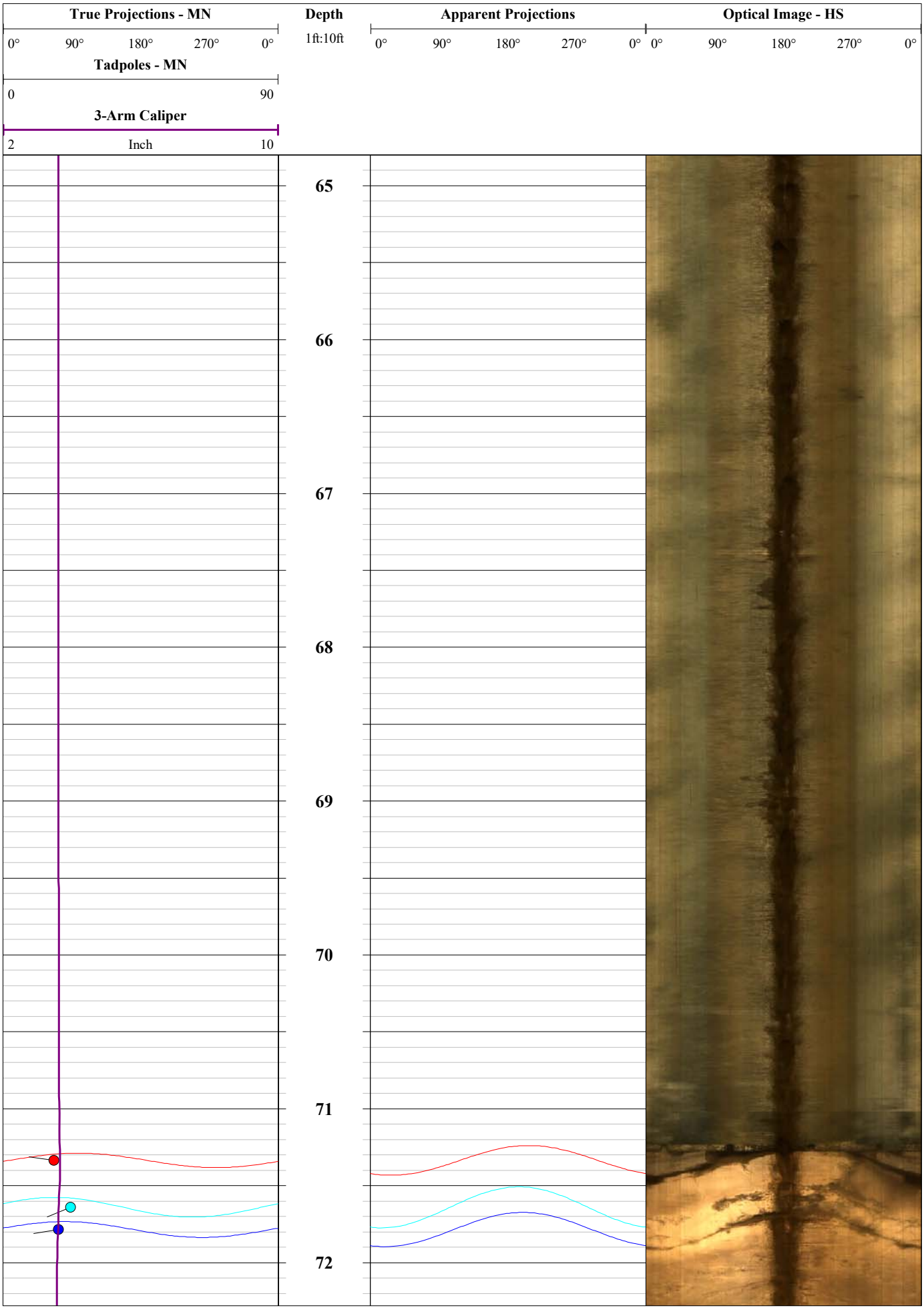
RUN No.	BIT	FROM	TO
1	HQ	0'	204'

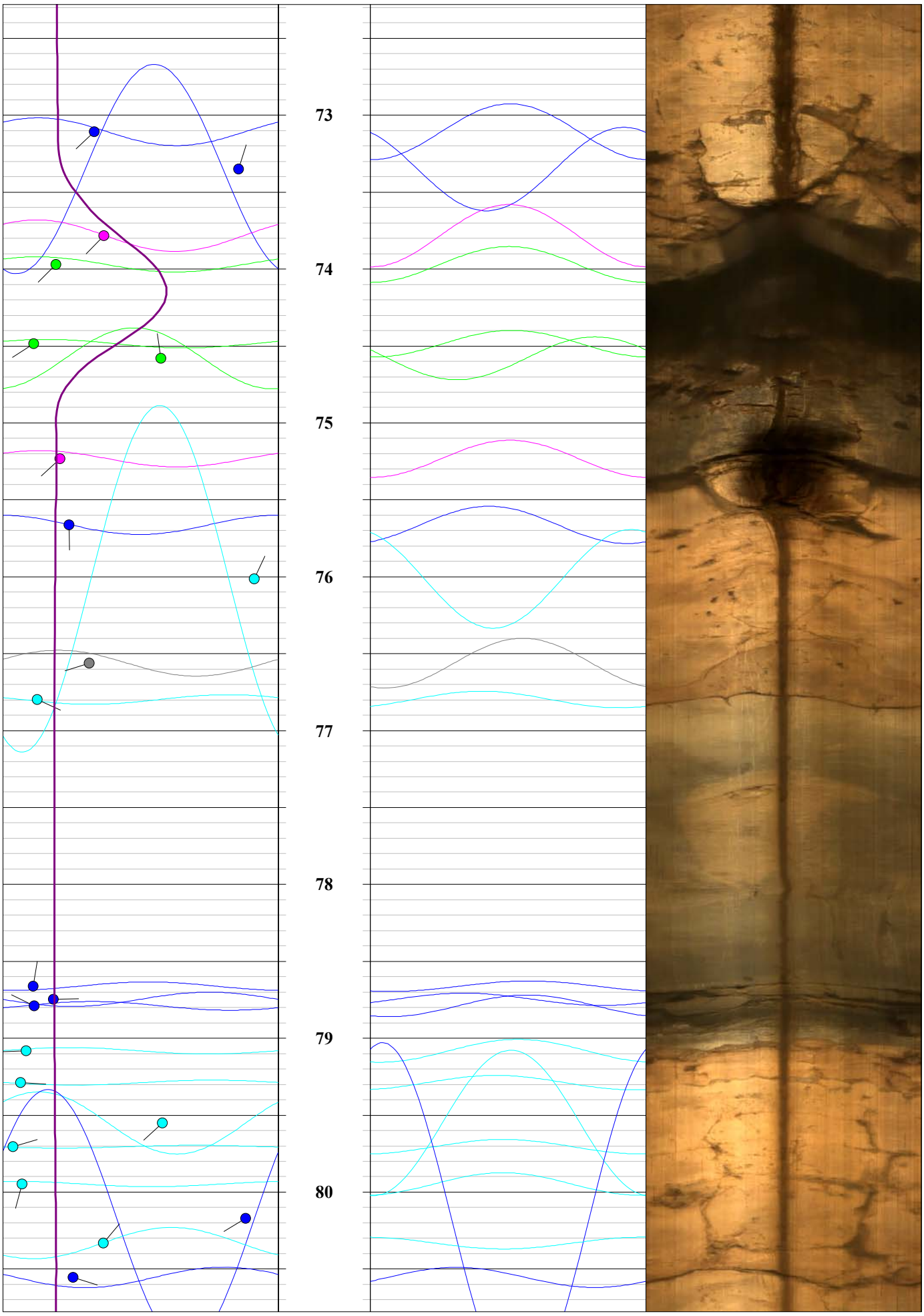
CASING RECORD

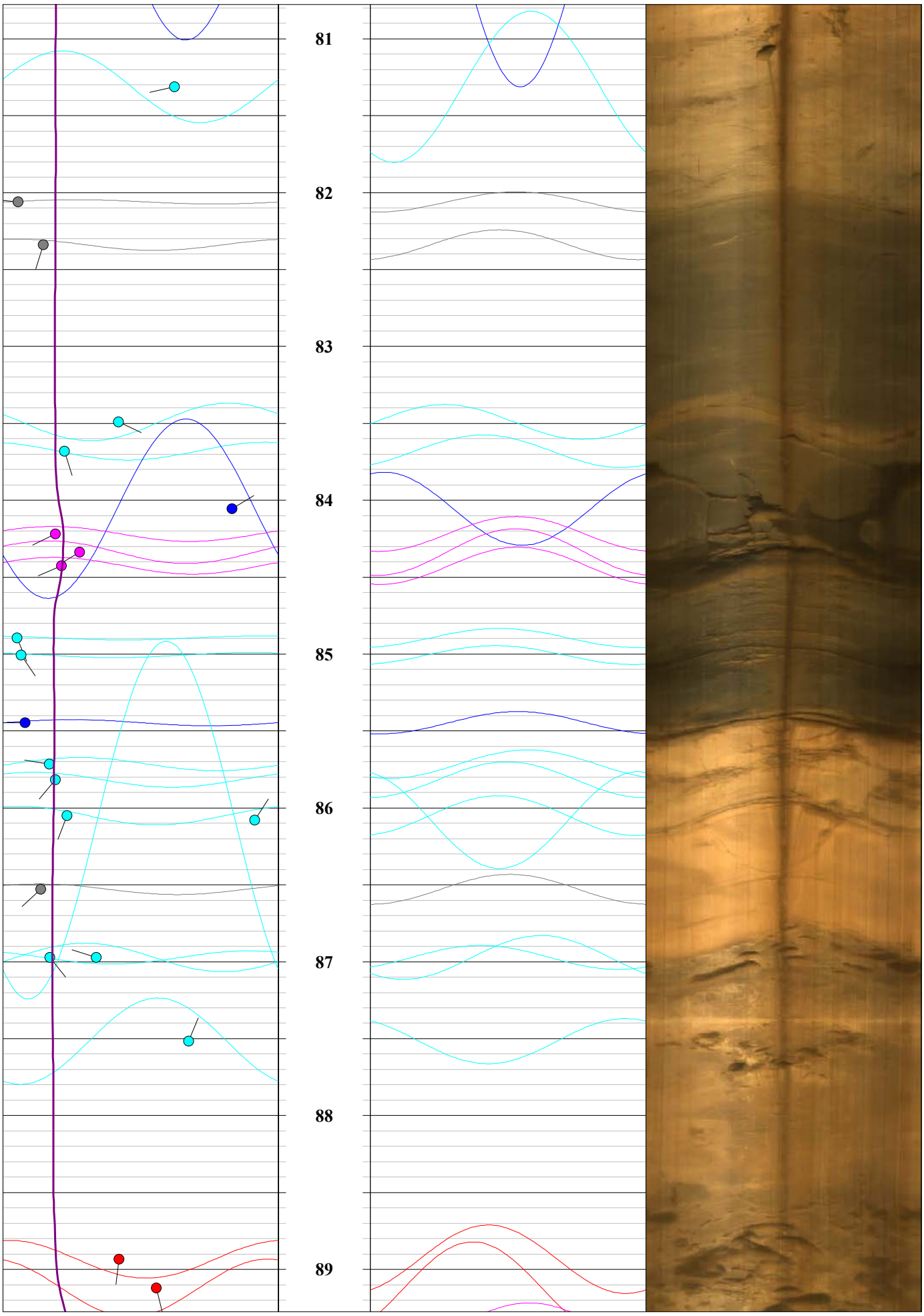
SIZE	WGT.	FROM	TO
PQ	Steel	0'	70'

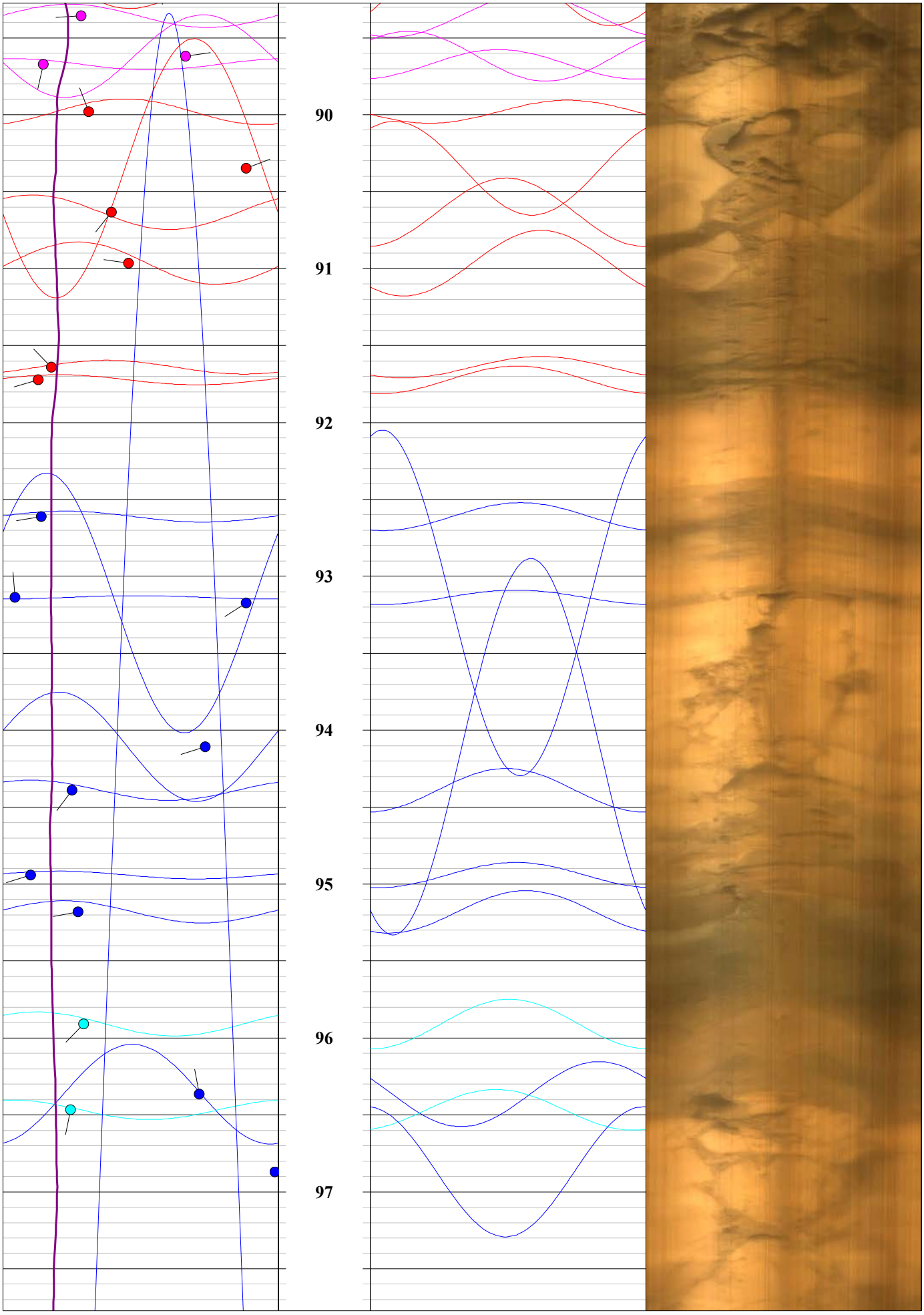
NA - Not Available, N/A - Not Applicable

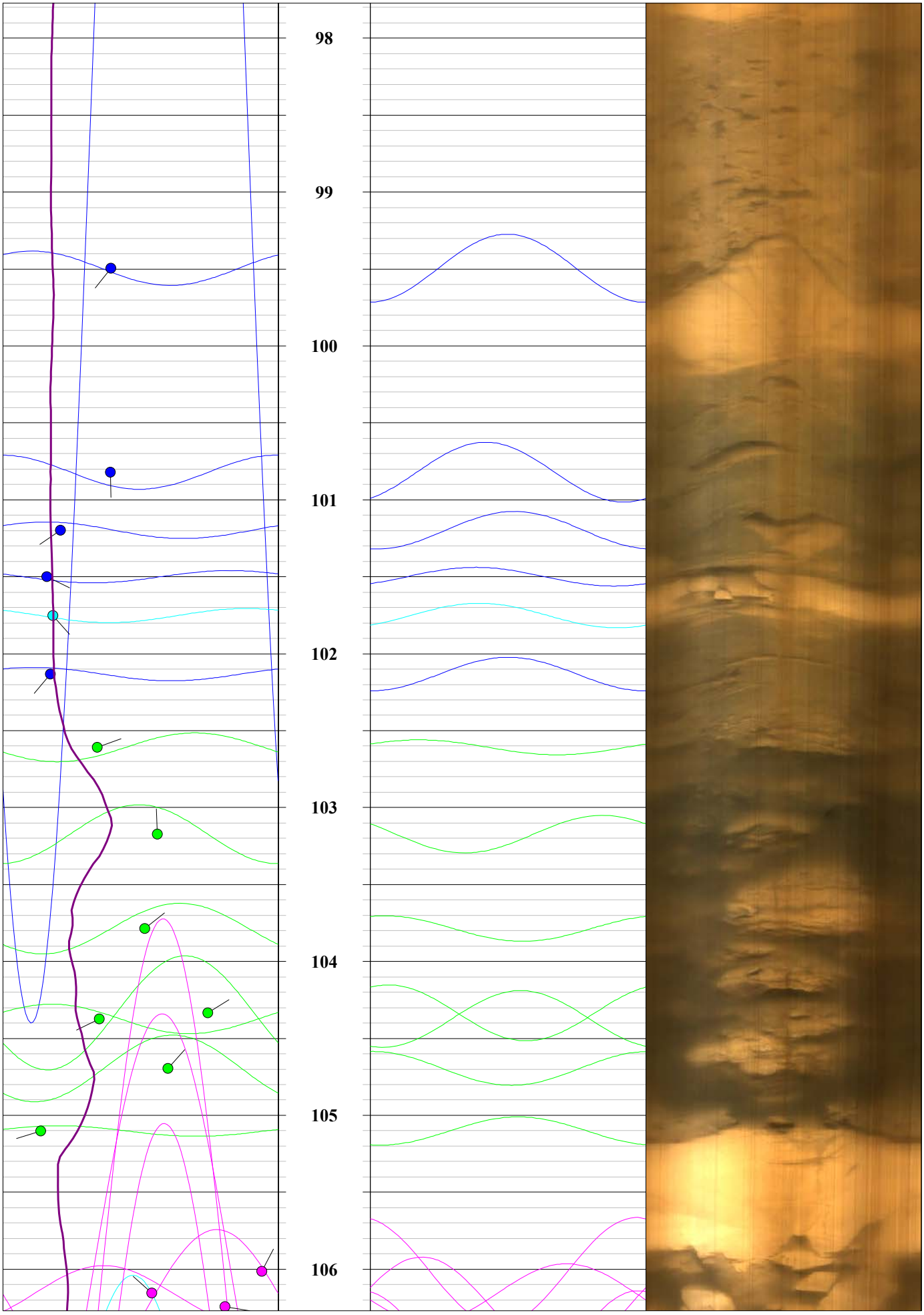
COMMENTS

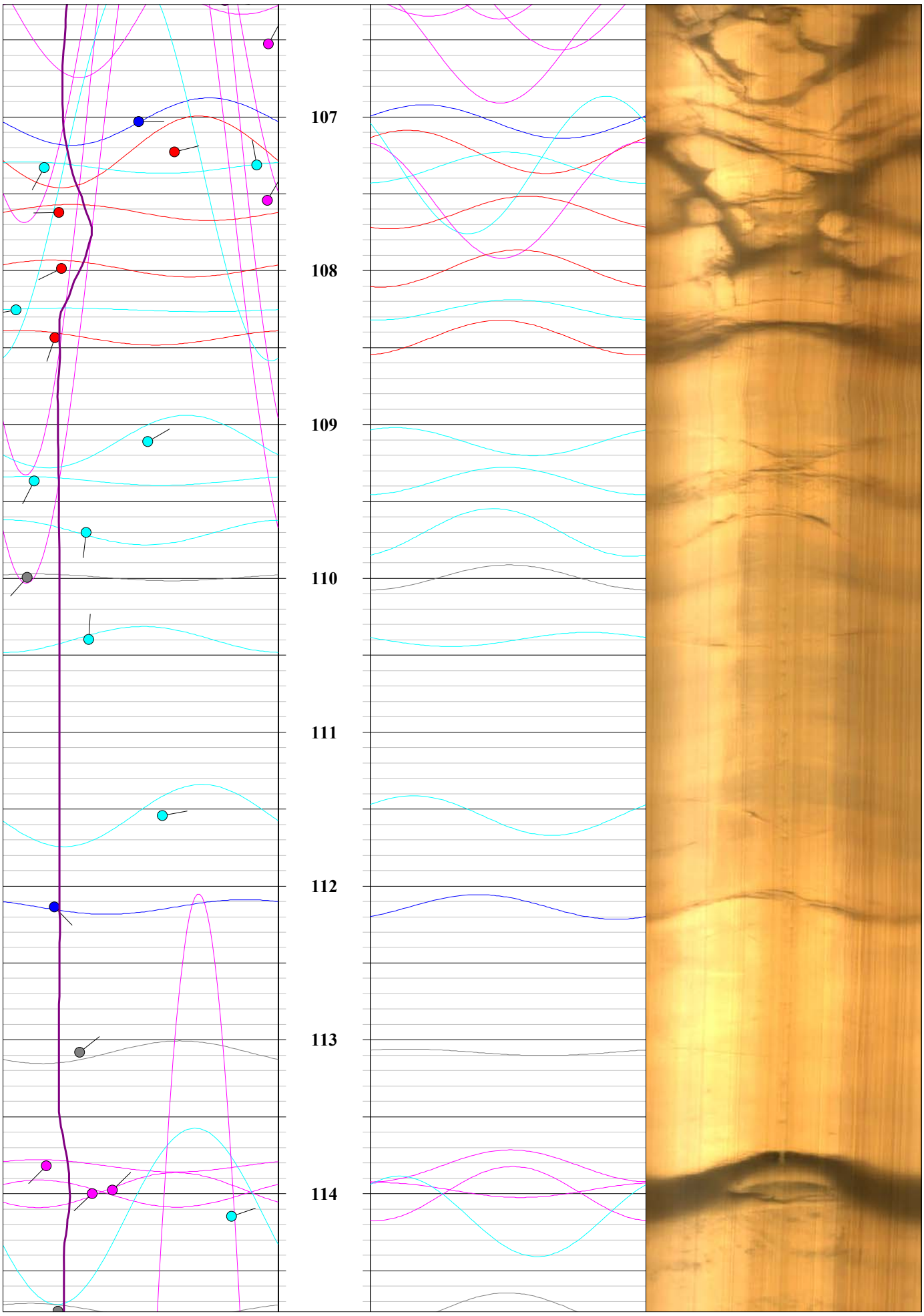

True Projections - MN
0° 90° 180° 270° 0°
Tadpoles - MN
0 90
3-Arm Caliper
2 Inch 10
Depth
1ft:10ft
65
66
67
68
69
70
71
72
Apparent Projections
0° 90° 180° 270° 0°
Optical Image - HS
0° 90° 180° 270° 0°

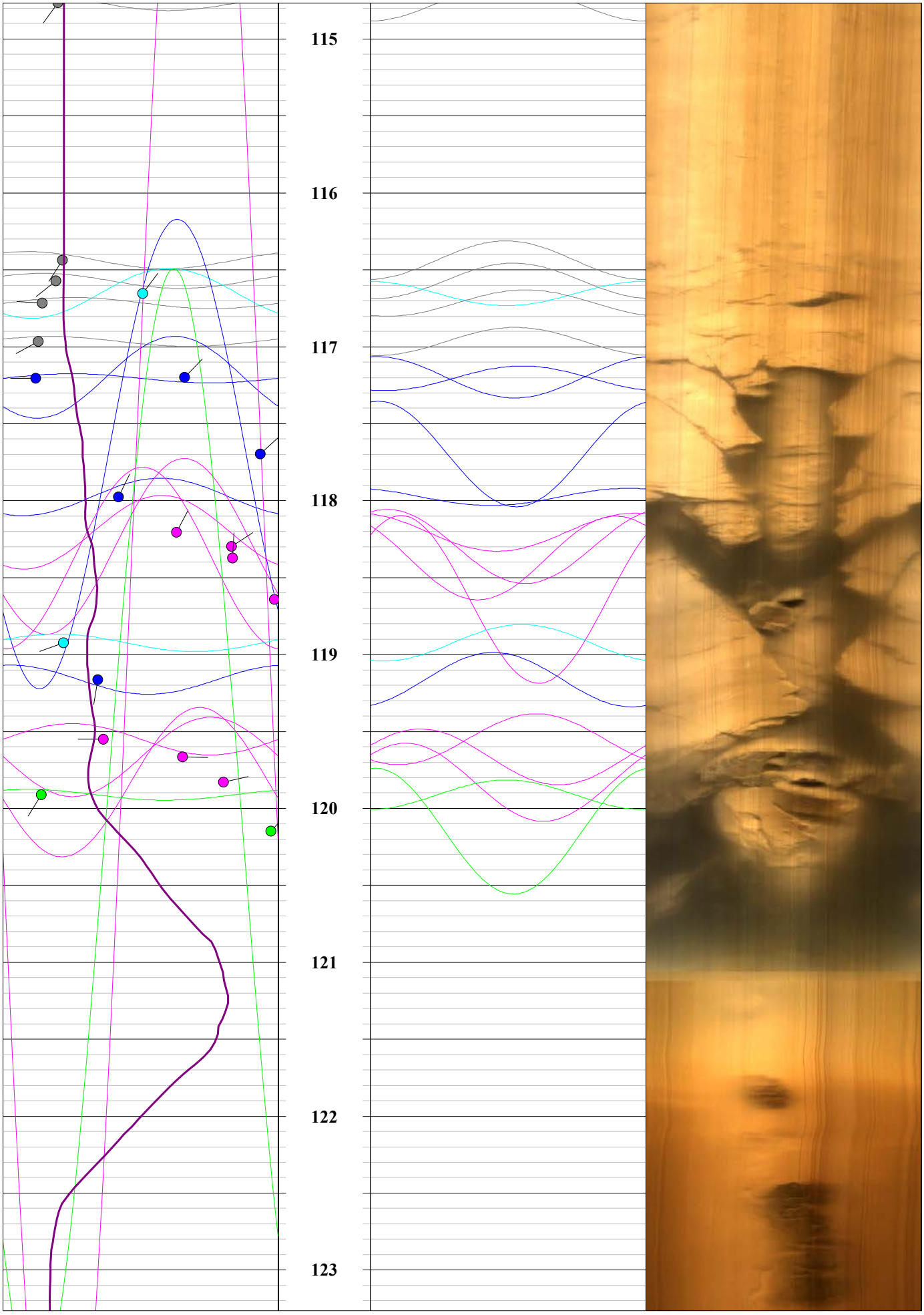

73
74
75
76
77
78
79
80

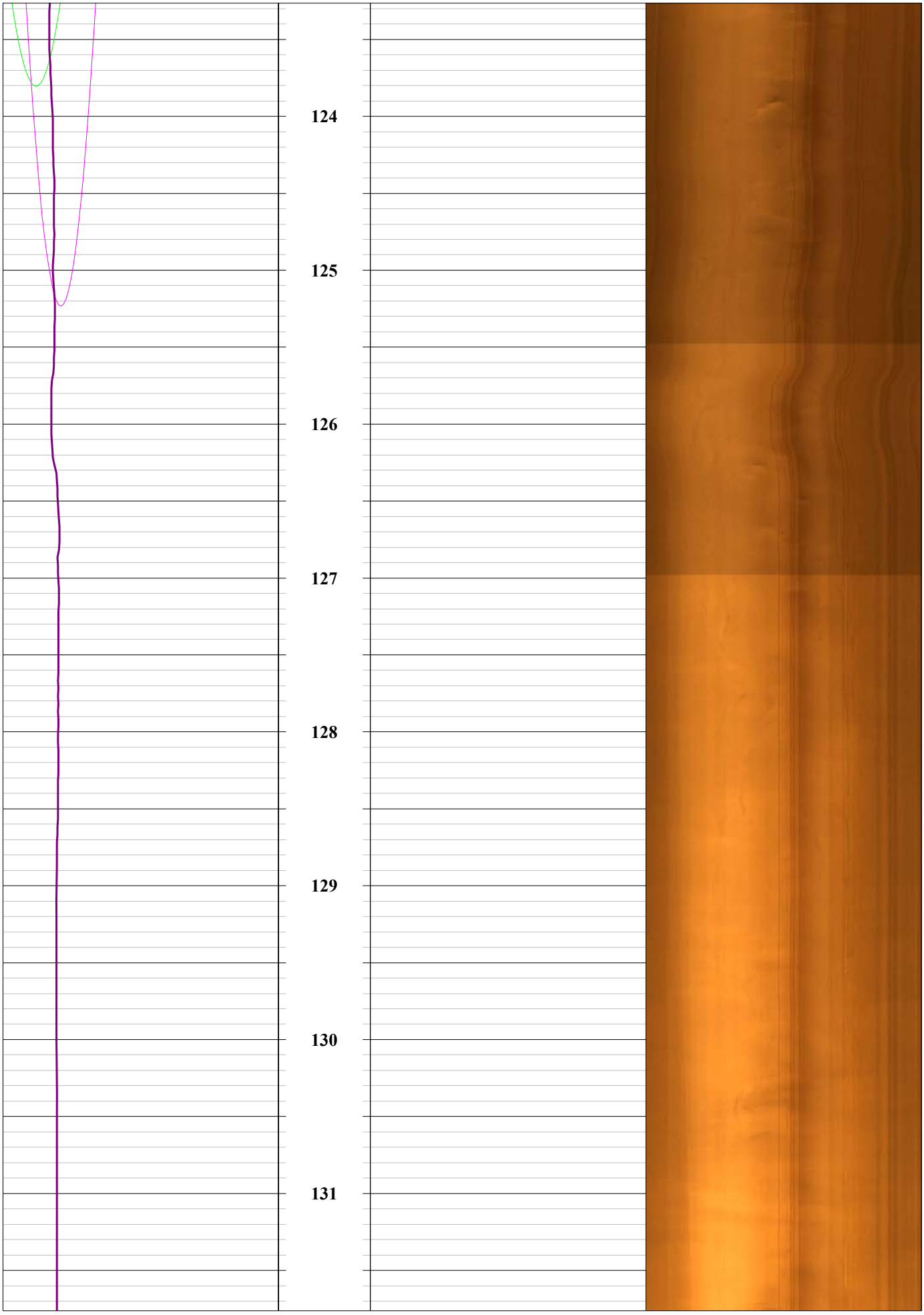

81
82
83
84
85
86
87
88
89

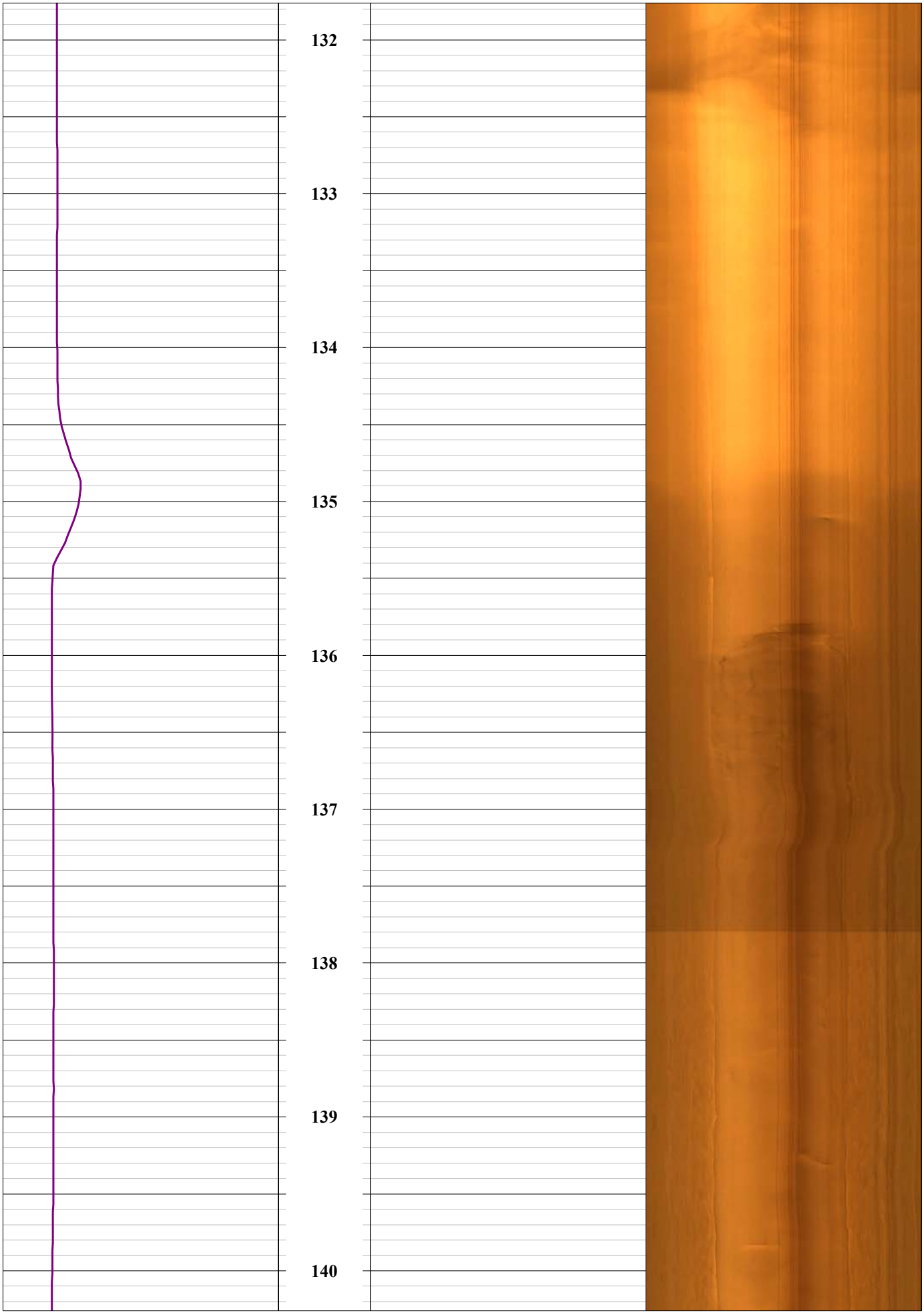

90
91
92
93
94
95
96
97


98
99
100
101
102
103
104
105
106


107
108
109
110
111
112
113
114


115
116
117
118
119
120
121
122
123


124
125
126
127
128
129
130
131


132
133
134
135
136
137
138
139
140

141

142

143

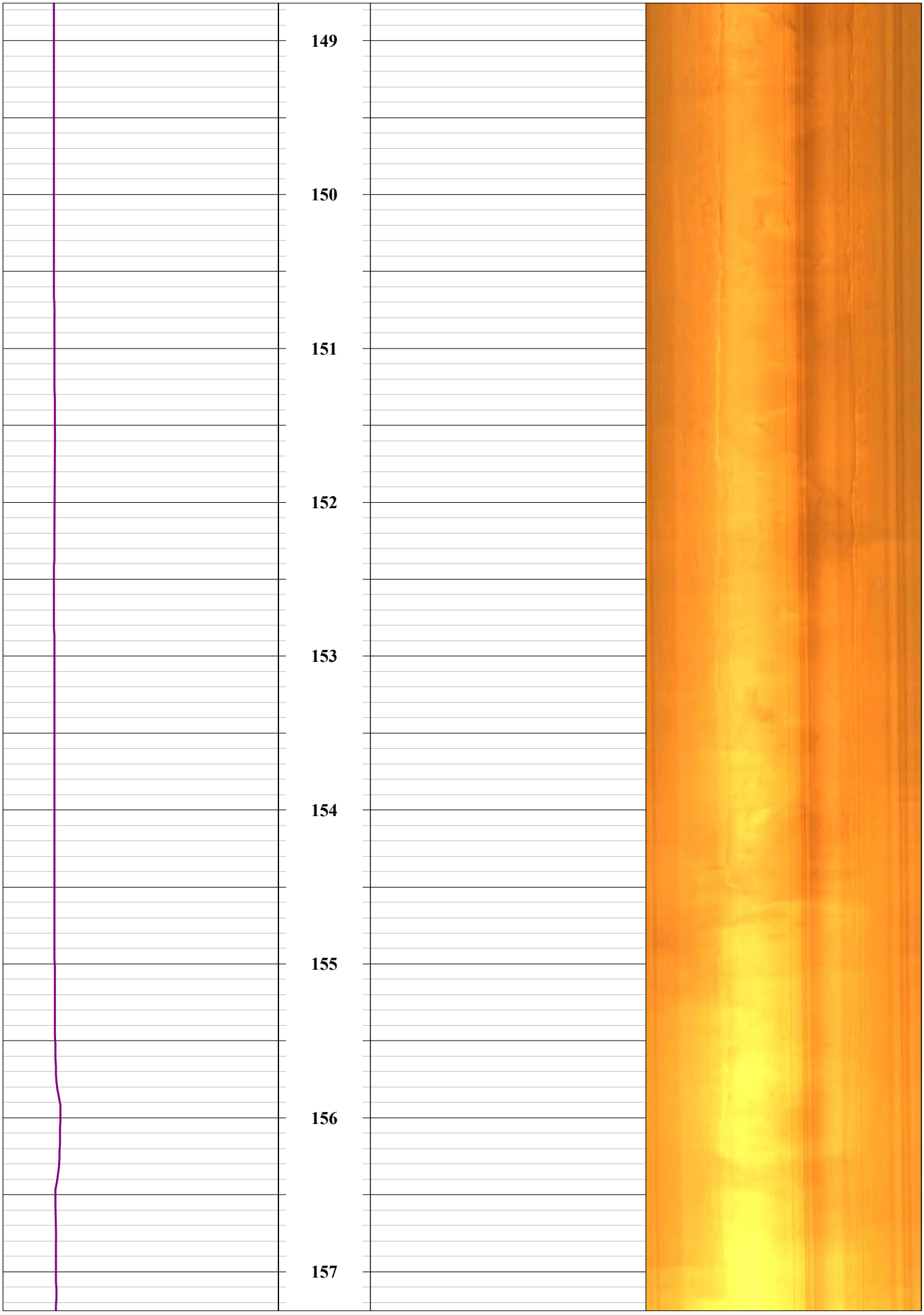
144

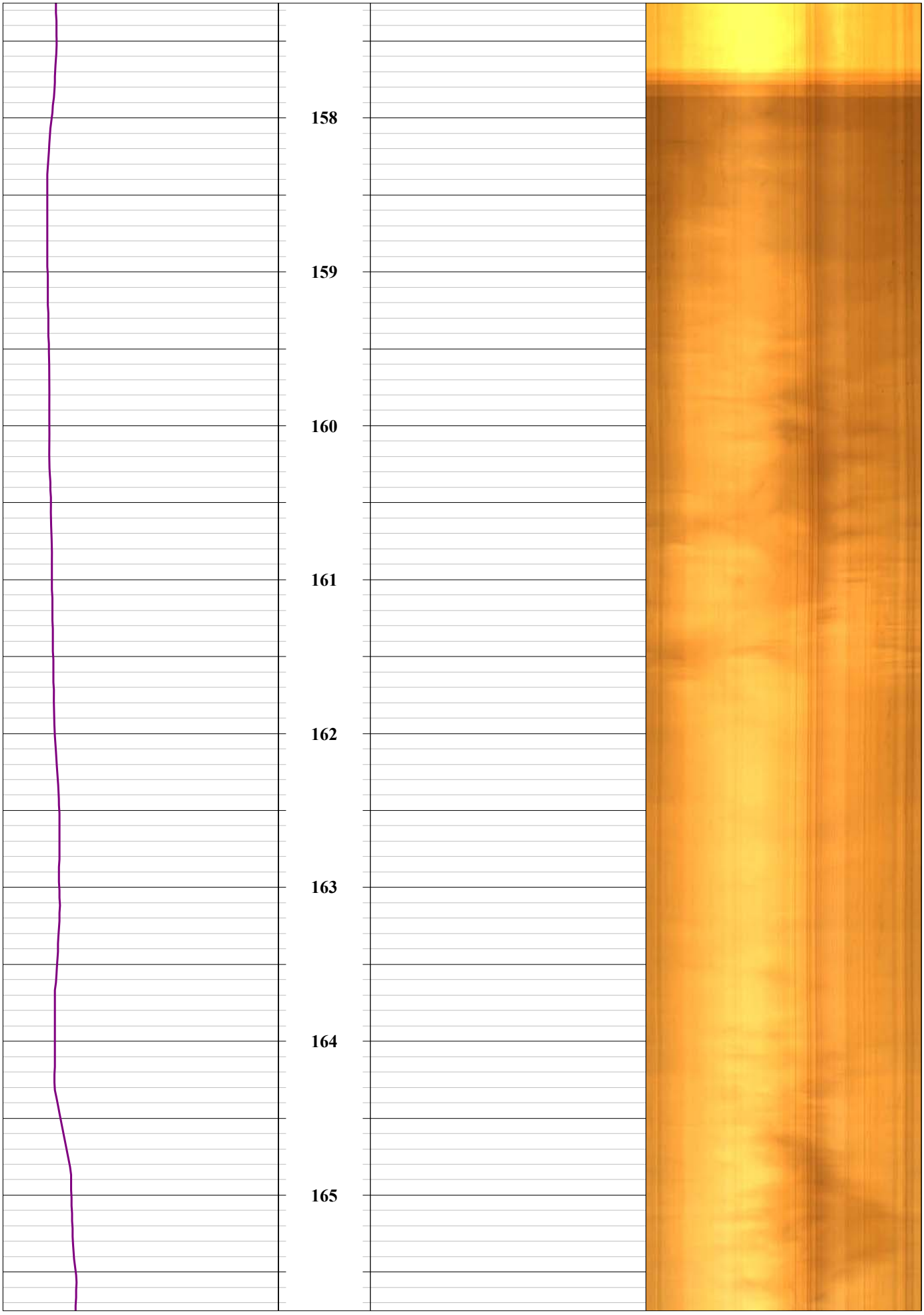
145

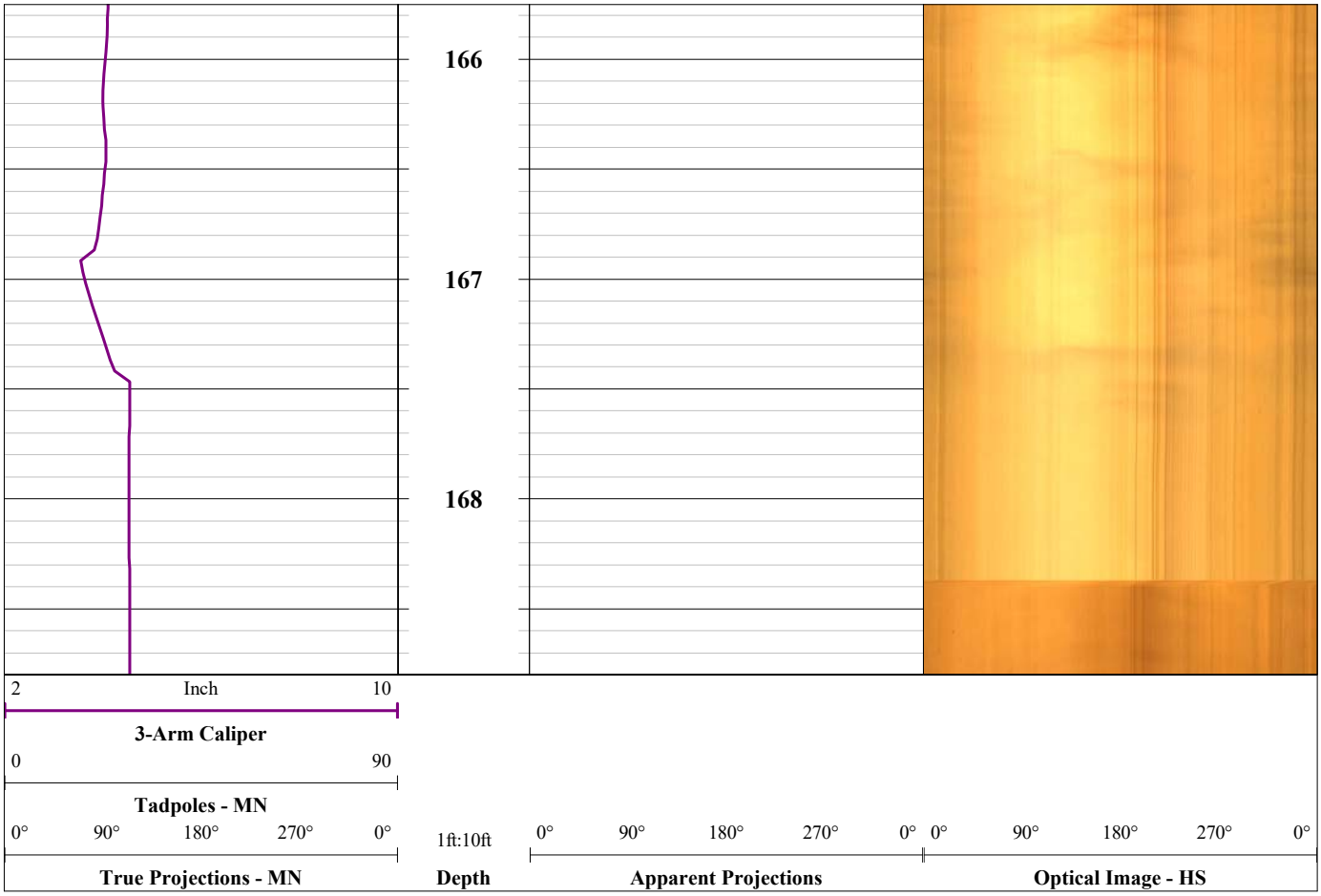
146

147

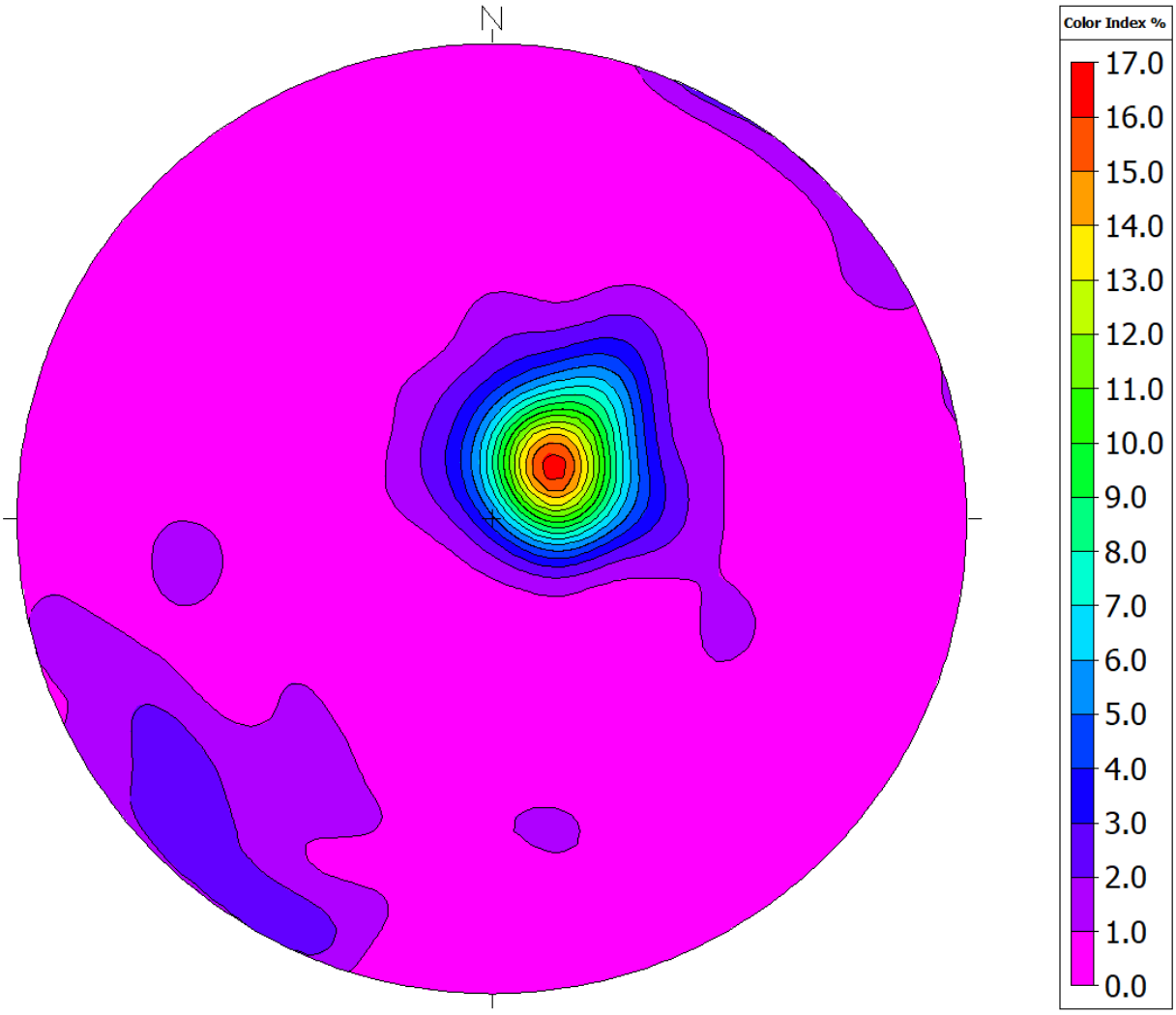
148


149
150
151
152
153
154
155
156
157


158
159
160
161
162
163
164
165

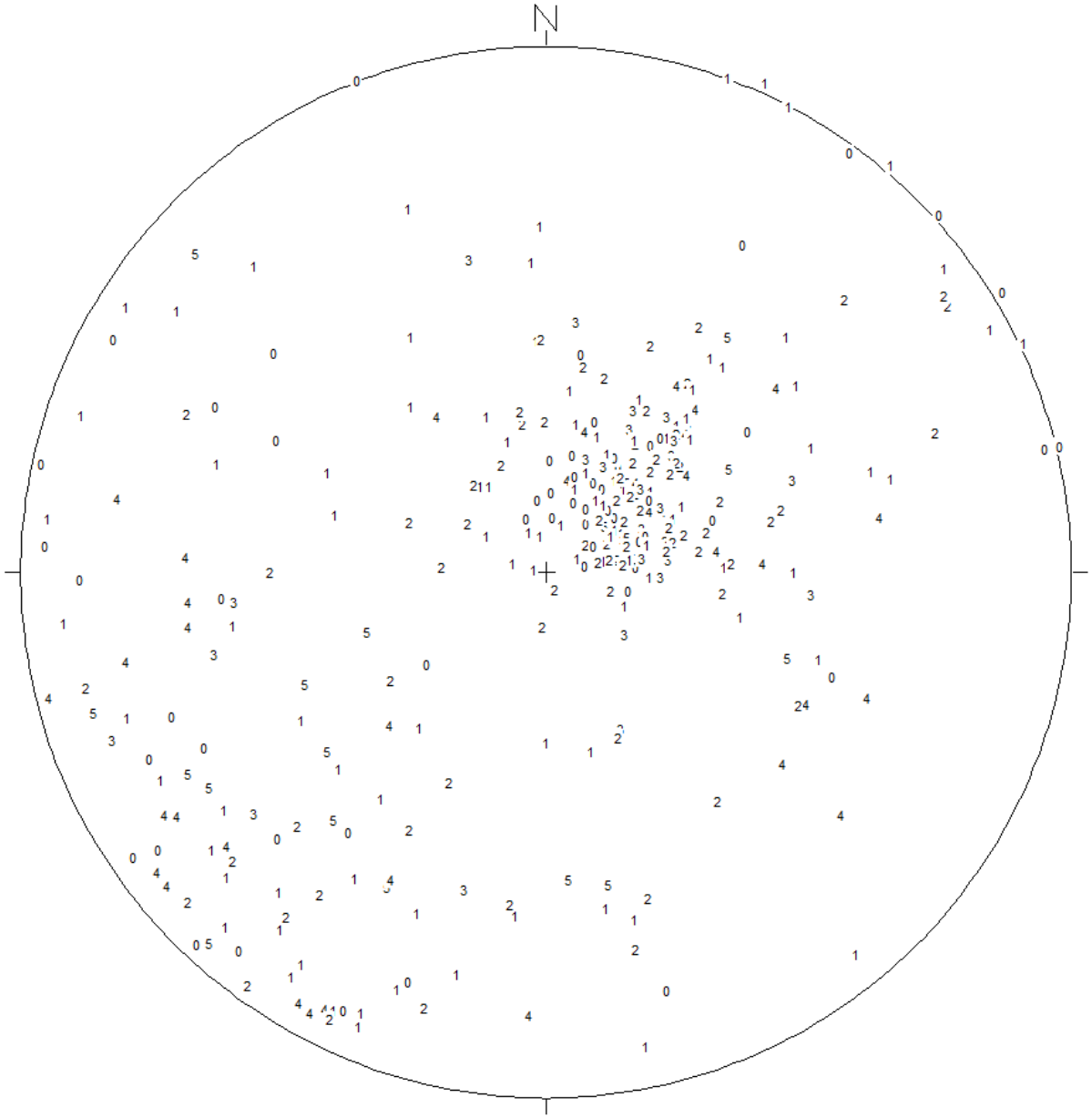

166
167
168
2
Inch
10
3-Arm Caliper
0
90
Tadpoles - MN
0°
90°
180°
270°
0°
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
True Projections - MN
Depth
Apparent Projections
Optical Image - HS

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-07
24-25 July 2019



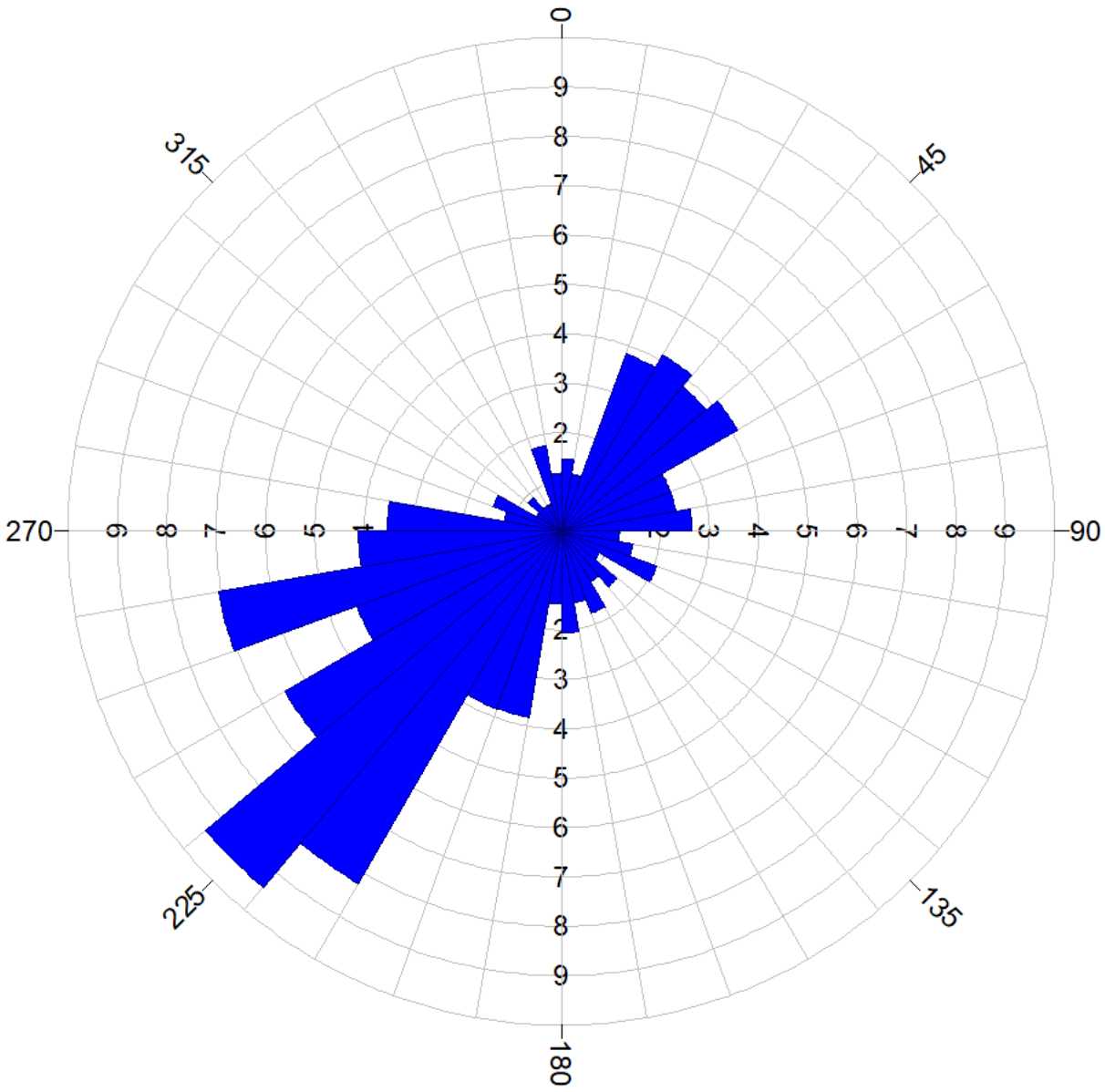
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-07
24-25 July 2019



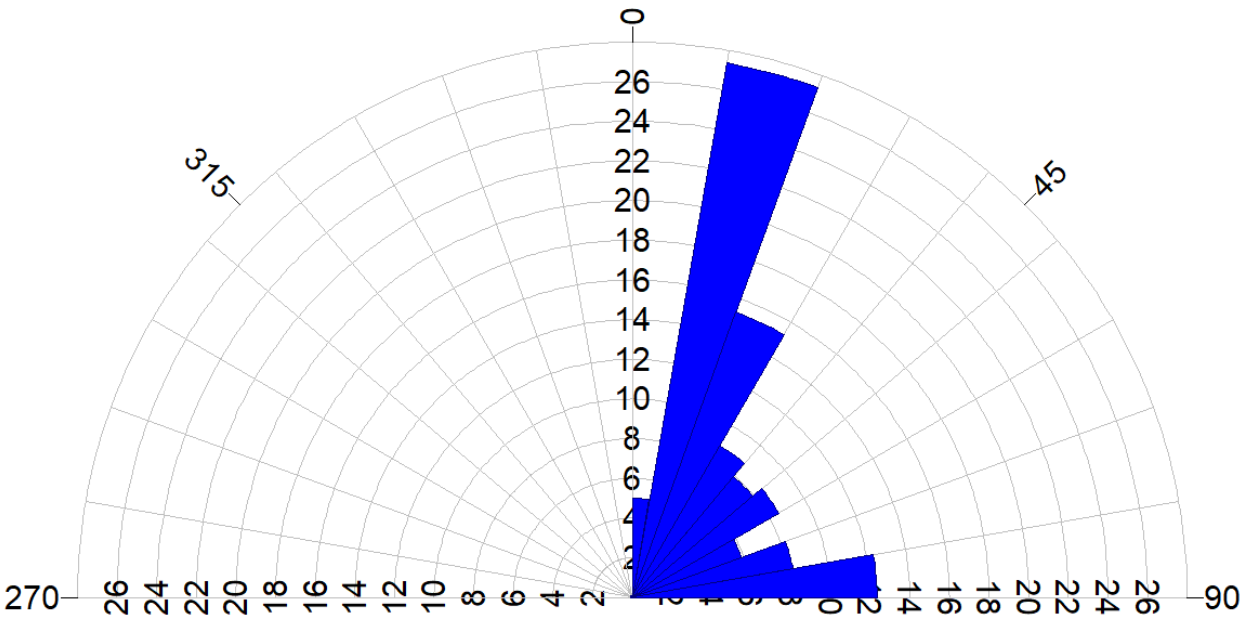
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-07
24-25 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-07
24-25 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	21.74	71.3	277	17	3
2	21.84	71.6	246	22	1
3	21.88	71.8	259	18	2
4	22.04	72.3	272	38	1
5	22.22	72.9	221	41	1
6	22.28	73.1	225	30	2
7	22.36	73.4	16	77	2
8	22.36	73.4	178	54	1
9	22.49	73.8	223	33	4
10	22.55	74.0	223	17	5
11	22.70	74.5	235	10	5
12	22.73	74.6	350	52	5
13	22.89	75.1	176	35	1
14	22.93	75.2	226	18	4
15	23.06	75.7	177	22	2
16	23.17	76.0	23	82	1
17	23.34	76.6	251	28	0
18	23.41	76.8	113	11	1
19	23.55	77.3	347	59	1
20	23.60	77.4	300	13	1
21	23.75	77.9	257	89	0
22	23.81	78.1	101	89	0
23	23.98	78.7	8	10	2
24	24.00	78.8	88	17	2
25	24.02	78.8	295	10	2
26	24.10	79.1	267	8	1
27	24.17	79.3	89	6	1
28	24.25	79.6	226	52	1
29	24.29	79.7	71	3	1
30	24.37	80.0	193	6	1
31	24.44	80.2	237	79	2
32	24.48	80.3	39	33	1
33	24.55	80.6	106	23	2
34	24.58	80.6	246	45	1
35	24.78	81.3	256	56	1
36	24.90	81.7	114	48	0
37	24.97	81.9	179	16	0
38	25.01	82.1	274	5	0
39	25.10	82.3	194	13	0
40	25.26	82.9	216	86	0
41	25.44	83.5	156	25	1
42	25.44	83.5	271	28	1
43	25.45	83.5	112	38	1
44	25.51	83.7	160	20	1
45	25.52	83.7	245	89	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	25.62	84.1	56	75	2
47	25.67	84.2	242	17	4
48	25.71	84.3	237	25	4
49	25.73	84.4	244.7	19.1	4
50	25.87	84.9	155.9	4.6	1
51	25.91	85.0	143.8	6.0	1
52	26.05	85.5	269.3	7.2	2
53	26.07	85.5	198.7	16.0	1
54	26.12	85.7	277.9	15.2	1
55	26.16	85.8	218.8	17.1	1
56	26.23	86.1	199.4	20.9	1
57	26.24	86.1	32.2	82.3	1
58	26.37	86.5	226.7	12.4	0
59	26.49	86.9	322.1	83.6	1
60	26.51	87.0	286.1	30.5	1
61	26.51	87.0	140.8	15.3	1
62	26.65	87.4	289.3	12.6	0
63	26.68	87.5	21.1	60.7	1
64	27.02	88.6	348.4	30.0	1
65	27.11	88.9	185.6	38.0	3
66	27.13	89.0	107.5	83.2	1
67	27.16	89.1	164.7	50.0	3
68	27.24	89.4	265.8	25.6	4
69	27.32	89.6	80.1	59.6	4
70	27.33	89.7	190.8	13.1	4
71	27.43	90.0	337.3	28.0	3
72	27.45	90.1	112.2	64.1	2
73	27.54	90.4	68.1	79.4	3
74	27.54	90.4	204.5	37.5	2
75	27.62	90.6	216.6	35.4	3
76	27.70	90.9	102.5	34.8	1
77	27.73	91.0	276.9	41.1	3
78	27.93	91.6	314.2	15.8	3
79	27.96	91.7	252.0	11.6	3
80	28.23	92.6	260.2	12.6	2
81	28.39	93.1	353.2	4.0	2
82	28.40	93.2	235.8	79.5	2
83	28.60	93.8	271.1	26.9	1
84	28.68	94.1	251.2	66.1	2
85	28.77	94.4	215.1	22.6	2
86	28.78	94.4	106.6	56.1	1
87	28.80	94.5	49.9	73.4	1
88	28.94	94.9	250.9	9.1	2
89	29.01	95.2	258.5	24.5	2
90	29.14	95.6	233.1	82.6	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	29.23	95.9	222.5	26.4	1
92	29.30	96.1	220.9	25.9	0
93	29.37	96.4	347.8	64.1	2
94	29.40	96.5	190.0	22.0	1
95	29.52	96.9	289.8	44.9	1
96	29.53	96.9	35.8	88.8	2
97	29.59	97.1	22.7	84.9	1
98	29.74	97.6	42.0	82.2	1
99	29.97	98.3	36.6	75.7	1
100	30.04	98.6	217.6	40.8	1
101	30.14	98.9	39.8	70.2	1
102	30.33	99.5	217.1	35.3	2
103	30.50	100.1	339.1	29.0	2
104	30.51	100.1	207.4	87.5	1
105	30.64	100.5	212.1	44.0	1
106	30.73	100.8	177.4	35.1	2
107	30.74	100.8	220.5	89.4	1
108	30.85	101.2	234.5	18.9	2
109	30.94	101.5	115.4	14.3	2
110	31.01	101.8	137.2	16.3	1
111	31.13	102.1	219.0	15.5	2
112	31.28	102.6	69.7	30.8	5
113	31.35	102.9	63.9	43.4	5
114	31.45	103.2	357.0	50.5	5
115	31.47	103.3	217.9	45.3	5
116	31.64	103.8	50.2	46.4	5
117	31.80	104.3	56.8	67.0	5
118	31.81	104.4	242.1	31.4	5
119	31.91	104.7	40.5	53.9	5
120	31.99	105.0	27.0	58.5	5
121	32.03	105.1	251.0	12.3	5
122	32.31	106.0	27.0	84.6	4
123	32.35	106.2	311.0	48.6	4
124	32.38	106.2	98.5	72.5	4
125	32.47	106.5	28.3	86.8	4
126	32.62	107.0	88.3	44.5	2
127	32.68	107.2	75.0	56.1	3
128	32.71	107.3	349	83	1
129	32.71	107.3	208	13	1
130	32.78	107.5	30	86	4
131	32.80	107.6	268	18	3
132	32.92	108.0	243	19	3
133	32.99	108.3	260	4	1
134	33.05	108.4	198	17	3
135	33.26	109.1	58	47	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	33.34	109.4	206	10	1
137	33.44	109.7	186	27	1
138	33.53	110.0	221	8	0
139	33.65	110.4	2	28	1
140	34.00	111.5	79	52	1
141	34.04	111.7	211	60	0
142	34.16	112.1	39	84	0
143	34.18	112.1	135	17	2
144	34.47	113.1	51	25	0
145	34.69	113.8	224	14	4
146	34.74	114.0	45	36	4
147	34.75	114.0	226	29	4
148	34.79	114.2	70	75	1
149	34.98	114.8	215	18	0
150	35.26	115.7	37	54	0
151	35.49	116.4	211	19	0
152	35.53	116.6	231	17	0
153	35.55	116.7	36	46	1
154	35.57	116.7	273	13	0
155	35.65	117.0	241	12	0
156	35.72	117.2	44	59	2
157	35.72	117.2	270	11	2
158	35.87	117.7	47	84	2
159	35.96	118.0	25	38	2
160	36.03	118.2	27	57	4
161	36.06	118.3	56	75	4
162	36.08	118.4	3	75	4
163	36.16	118.6	75	89	4
164	36.25	118.9	250	20	1
165	36.32	119.2	189	31	2
166	36.44	119.6	270	33	4
167	36.48	119.7	91	59	4
168	36.52	119.8	77	72	4
169	36.55	119.9	211	13	5
170	36.62	120.2	42	87	5
171	36.89	121.0	72	81	5
172	36.98	121.3	131	79	5
173	37.26	122.3	292	40	5
174	37.92	124.4	234	48	1
175	37.98	124.6	254	53	1
176	38.24	125.5	210	24	3
177	38.26	125.5	267	14	3
178	38.56	126.5	50	63	3
179	38.60	126.6	251	40	3
180	38.69	127.0	249	15	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	38.75	127.1	13	69	1
182	38.92	127.7	135	69	1
183	38.95	127.8	239	90	0
184	38.98	127.9	222	29	1
185	39.03	128.1	197	23	0
186	39.20	128.6	54	82	0
187	39.26	128.8	217	16	1
188	39.47	129.5	92	86	0
189	39.63	130.0	32	79	1
190	39.74	130.4	256	14	0
191	39.93	131.0	254	15	0
192	40.15	131.7	214	14	0
193	40.36	132.4	218	10	1
194	40.43	132.6	45	63	0
195	40.55	133.0	230	14	3
196	40.61	133.2	204	90	1
197	40.94	134.3	267	10	2
198	41.07	134.7	142	29	4
199	41.08	134.8	57	77	4
200	41.15	135.0	52	85	4
201	41.28	135.4	280	27	2
202	41.33	135.6	124	75	1
203	41.35	135.7	351	56	1
204	41.36	135.7	138	33	1
205	41.61	136.5	32	60	1
206	41.84	137.3	200	10	0
207	41.84	137.3	68	67	0
208	41.99	137.8	191	17	0
209	42.20	138.5	179	11	0
210	42.34	138.9	26	84	1
211	42.38	139.1	242	11	1
212	42.45	139.3	6	57	1
213	42.46	139.3	200	88	1
214	42.57	139.7	121	84	1
215	42.65	139.9	47	72	2
216	42.67	140.0	176	48	1
217	42.69	140.1	83	83	1
218	42.71	140.1	234	19	1
219	42.89	140.7	224	10	0
220	42.94	140.9	167	10	0
221	43.09	141.4	212	10	0
222	43.14	141.6	19	73	0
223	43.19	141.7	245	10	1
224	43.24	141.9	217	16	1
225	43.34	142.2	207	14	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	43.34	142.2	257	86	0
227	43.34	142.2	158	62	1
228	43.41	142.4	46	75	1
229	43.45	142.5	197	12	1
230	43.61	143.1	7	55	2
231	43.62	143.1	88	79	0
232	43.71	143.4	46	47	1
233	43.74	143.5	234	12	0
234	43.80	143.7	28	48	2
235	43.90	144.0	228	14	2
236	43.94	144.2	259	12	2
237	44.02	144.4	214	23	1
238	44.05	144.5	207	19	1
239	44.11	144.7	223	31	1
240	44.15	144.9	228	29	1
241	44.21	145.1	224	16	1
242	44.25	145.2	224	28	2
243	44.30	145.3	153	17	2
244	44.30	145.4	259	35	2
245	44.33	145.4	241	6	2
246	44.37	145.6	260	19	2
247	44.41	145.7	215	12	1
248	44.47	145.9	188	33	0
249	44.54	146.1	180	7	0
250	44.57	146.2	62	64	0
251	44.57	146.2	292	48	0
252	44.58	146.3	55	87	0
253	44.70	146.7	255	26	0
254	44.76	146.9	237	18	0
255	44.98	147.6	43	89	0
256	45.23	148.4	248	7	0
257	45.41	149.0	195	14	0
258	45.46	149.2	227	12	0
259	45.49	149.3	25	83	0
260	45.69	149.9	201	15	1
261	45.85	150.4	20	75	1
262	46.04	151.1	150	8	0
263	46.47	152.5	115	60	0
264	46.67	153.1	236	37	0
265	46.73	153.3	158	89	0
266	46.73	153.3	267	12	1
267	46.91	153.9	64	74	0
268	46.96	154.1	117	83	0
269	46.98	154.2	95	86	1
270	47.12	154.6	228	89	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	47.40	155.5	84	53	0
272	47.54	156.0	242	84	1
273	47.62	156.2	228	25	3
274	47.65	156.3	271	11	2
275	47.70	156.5	253	19	2
276	47.78	156.8	239	16	2
277	47.82	156.9	266	9	2
278	47.85	157.0	54	31	2
279	48.12	157.9	264	18	2
280	48.16	158.0	240	13	2
281	48.20	158.1	228	10	2
282	48.47	159.0	265	23	2
283	48.50	159.1	257	37	2
284	48.57	159.4	168	22	2
285	48.60	159.4	233	25	2
286	48.62	159.5	250	28	2
287	48.68	159.7	35	66	2
288	48.70	159.8	227	14	2
289	48.71	159.8	344	56	2
290	48.84	160.2	168	24	2
291	48.88	160.4	230	16	2
292	48.91	160.5	231	18	2
293	48.94	160.6	221	12	1
294	48.99	160.7	259	15	1
295	49.23	161.5	37	73	0
296	49.27	161.7	258	21	2
297	49.35	161.9	53	67	1
298	49.51	162.4	50	85	4
299	49.55	162.6	49	71	4
300	49.71	163.1	220	24	0
301	49.81	163.4	227	21	2
302	49.84	163.5	226	14	2
303	49.90	163.7	231	25	2
304	49.94	163.9	61	74	1
305	49.96	163.9	148	42	1
306	49.99	164.0	225	27	3
307	50.08	164.3	37	73	2
308	50.21	164.7	219	35	1
309	50.21	164.7	230	18	3
310	50.30	165.0	208	29	1
311	50.44	165.5	208	27	3
312	50.52	165.8	83	51	3
313	50.53	165.8	208	17	3
314	50.58	166.0	212	44	2
315	50.64	166.2	345	73	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-07

24-25 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
316	50.71	166.4	127	56	0
317	50.80	166.7	194	21	4
318	50.83	166.8	15	54	3
319	50.87	166.9	215	34	4
320	51.07	167.5	60	69	5
321	52.80	173.2	293	55	4
322	52.92	173.6	232	45	4
323	53.14	174.3	299	46	4
324	53.34	175.0	311	62	4
325	53.89	176.8	218	29	3
326	54.05	177.3	225	23	2
327	54.20	177.8	270	28	2
328	54.61	179.2	26	86	2
329	54.65	179.3	75	81	2
330	54.72	179.5	228	64	2
331	55.22	181.2	300	45	2
332	55.36	181.6	219	17	2
333	55.70	182.7	325	46	2
334	56.21	184.4	233	23	2
335	57.06	187.2	212	28	2
336	57.50	188.7	257	12	2
337	57.60	189.0	219	20	2
338	57.86	189.8	84	59	4
339	57.98	190.2	262	53	4
340	58.36	191.5	196	30	2

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-07
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-07
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83808 N
Longitude: 84.75731 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.4'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	24/25 July 2019	24/25 July 2019	24/25 July 2019	
RUN NUMBER	1	1	1	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	204'	204'	204'	
DEPTH-LOGGER	203'	203'	203'	
BTM LOG INTERVAL	204'	203.6'	204.4'	
TOP LOG INTERVAL	1.9'	48'	45'	
RECORDED BY	MAC/MJC	MAC/MJC	MAC/MJC	
WITNESSED BY				
PROBE TYPE, S/N	2PFA #5969	3ACS #6011	ELXG #4248	
LOGGING SPEED	7 fpm	12 fpm	15 fpm	
A.S.D.E. / Sample Interval	.0.06' / 0.10'	0.11' / 0.10'	0.05' / 0.25'	
Fluid Level / Fluid Type	19ft/water	19ft/water	19ft/water	

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	70'	204'

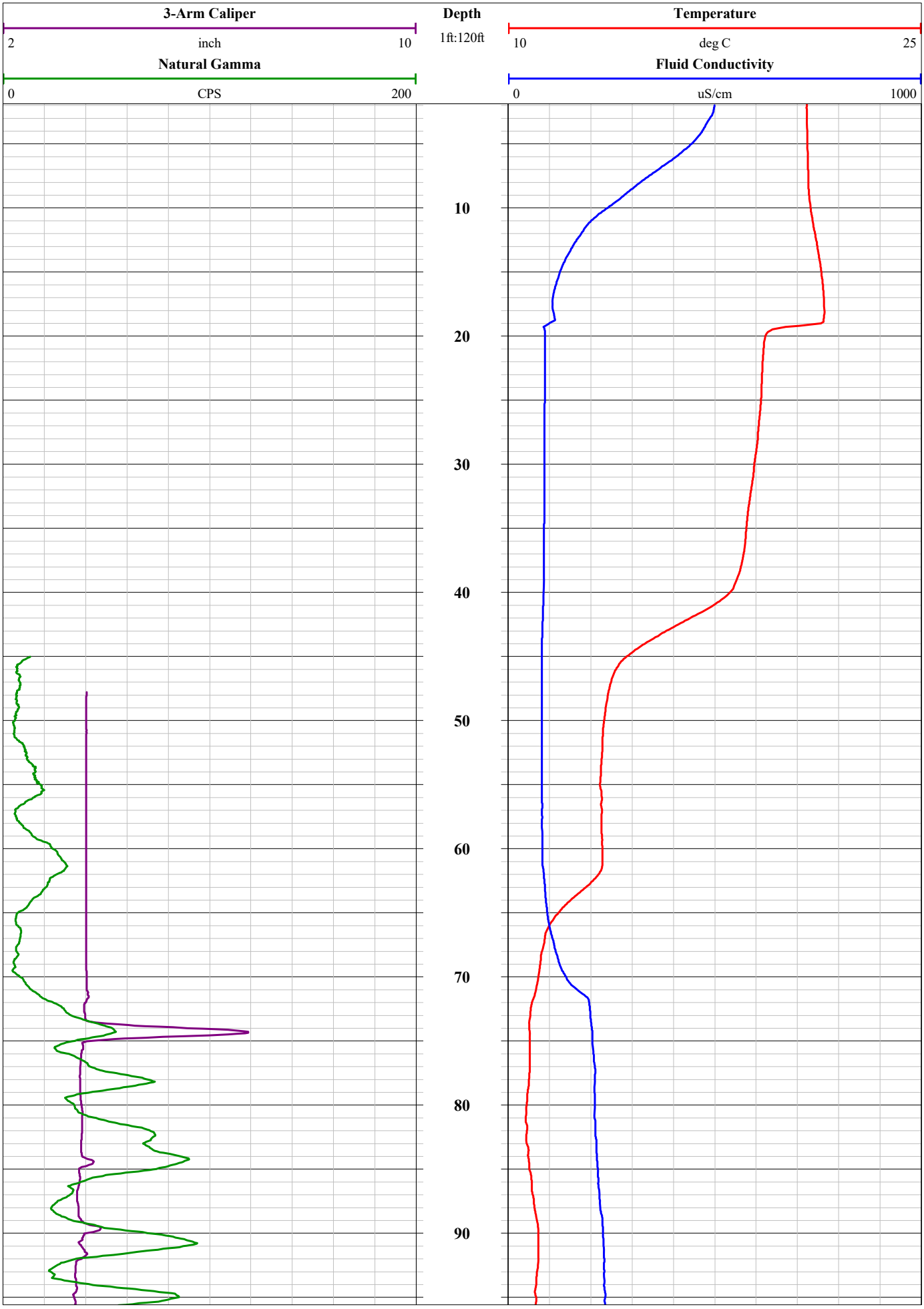
CASING RECORD

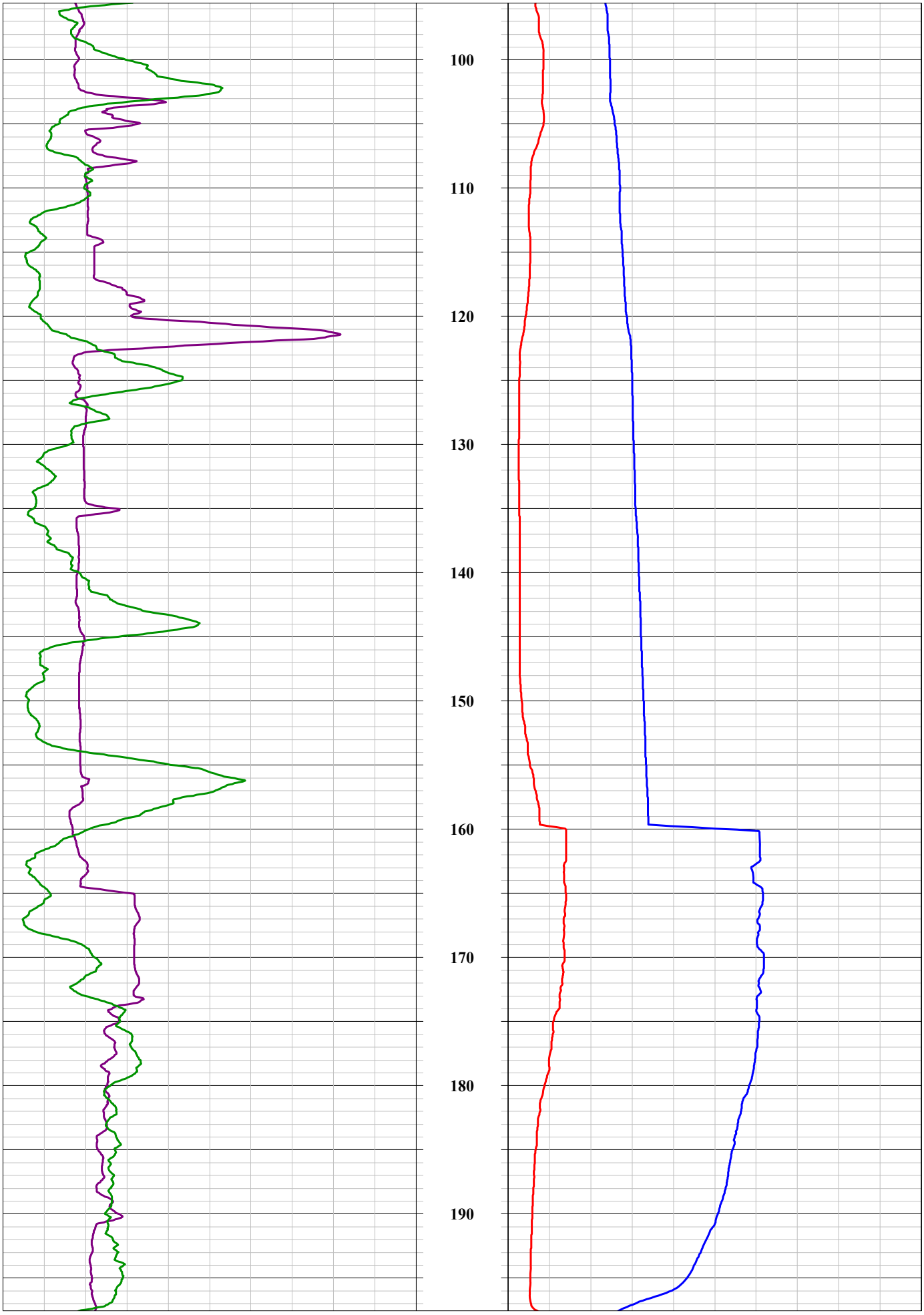
SIZE	WGT.	FROM	TO
PQ	Steel	0'	70'

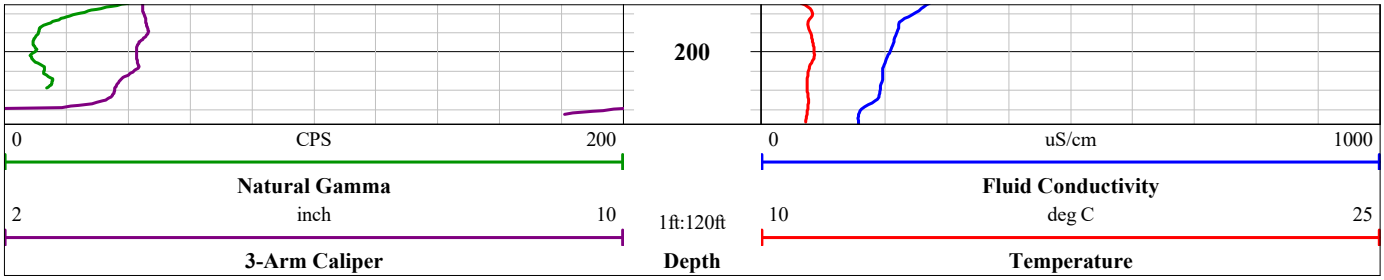
NA - Not Available, N/A - Not Applicable

COMMENTS

Logs merged at 160' hole conditions changes resulted in jump of temp/conductivity


3-Arm Caliper
2
inch
10
Natural Gamma
0
CPS
200
Depth
1ft:120ft
Temperature
10
deg C
25
Fluid Conductivity
0
uS/cm
1000
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
0
CPS
200
Natural Gamma
2
inch
10
3-Arm Caliper
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
10
deg C
25
Temperature

Borehole Deviation

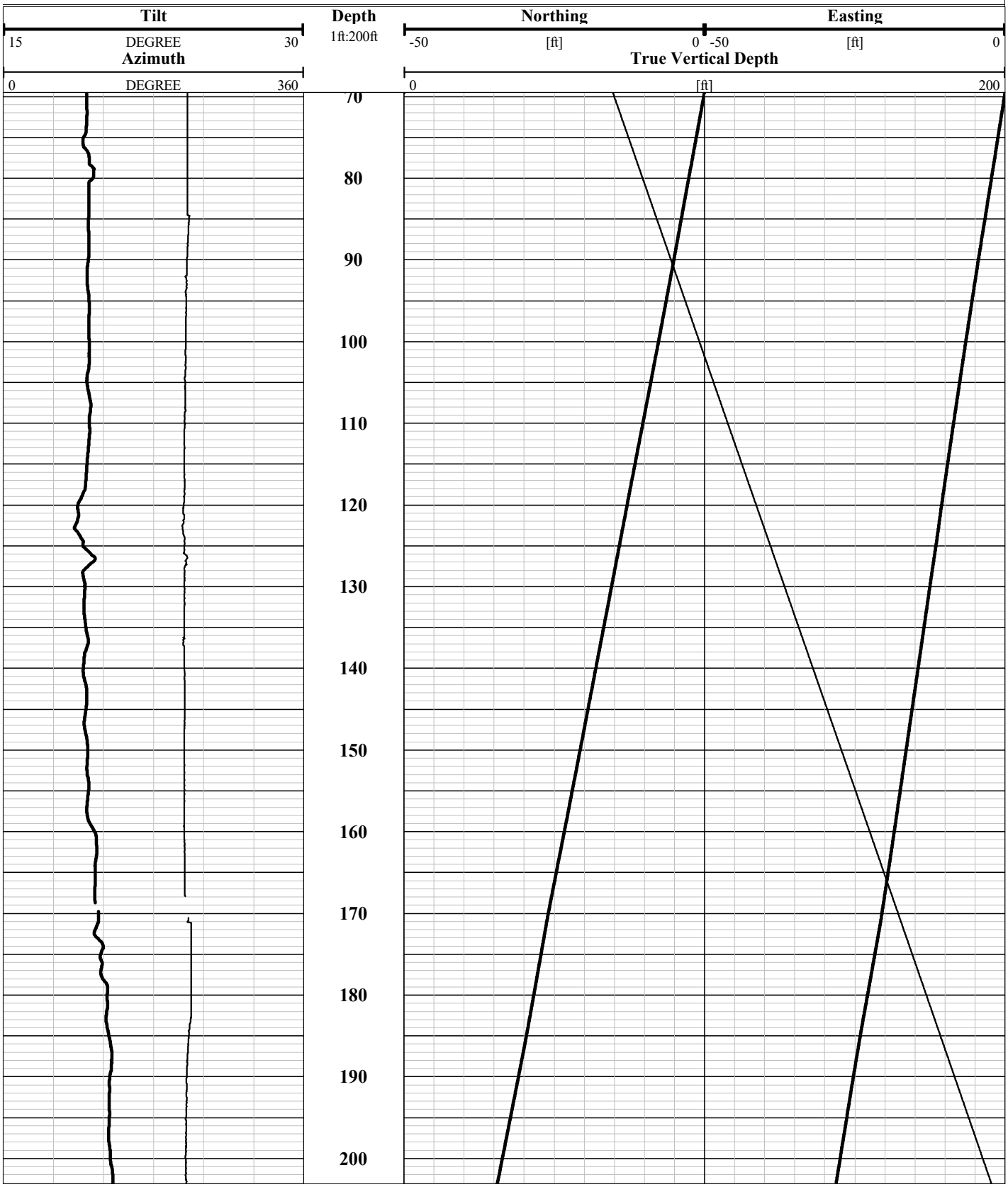
borehole geophysics / hydrophysics

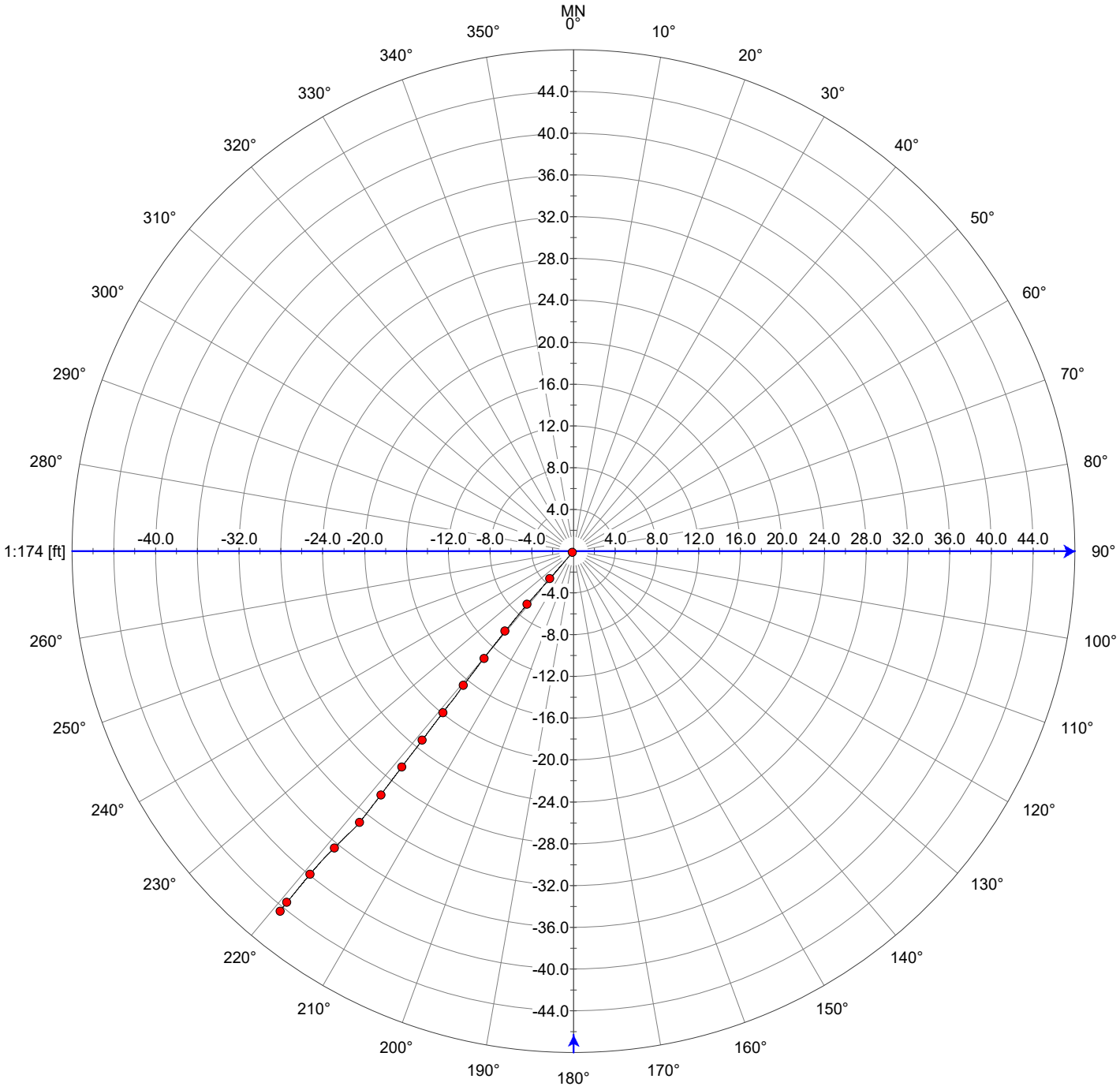
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 24-25 July 2019	WELL: BH19-07 - North Side

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 600.4'** **Latitude: 45.83808 N** **Longitude: 84.75731 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
-4.0
-8.0
-12.0
-16.0
-20.0
-24.0
-28.0
-32.0
-36.0
-40.0
-44.0
-40.0 -32.0 -24.0 -20.0 -12.0 -8.0 -4.0
4.0 8.0 12.0 16.0 20.0 24.0 28.0 32.0 36.0 40.0 44.0
1:174 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-07
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-07
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83808 N
Longitude: 84.75731 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.4'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	24/25 July 2019	24/25 July 2019		
RUN NUMBER	1	1		
LOG TYPE	Natural Gamma	Eletcric Log		
DEPTH-DRILLER	204'	204'		
DEPTH-LOGGER	204'	204'		
BTM LOG INTERVAL	202'	200'		
TOP LOG INTERVAL	57.5'	71'		
RECORDED BY	MJC/MAC	MJC/MAC		
WITNESSED BY				
PROBE TYPE, S/N	ELXG #4248	ELXG #4248		
LOGGING SPEED	15 fpm	15fpm		
A.S.D.E. / Sample Interval	0.05' / 0.25'	0.05' / 0.25'		
Fluid Level / Fluid Type	19'/water	19'/water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	70'	204'

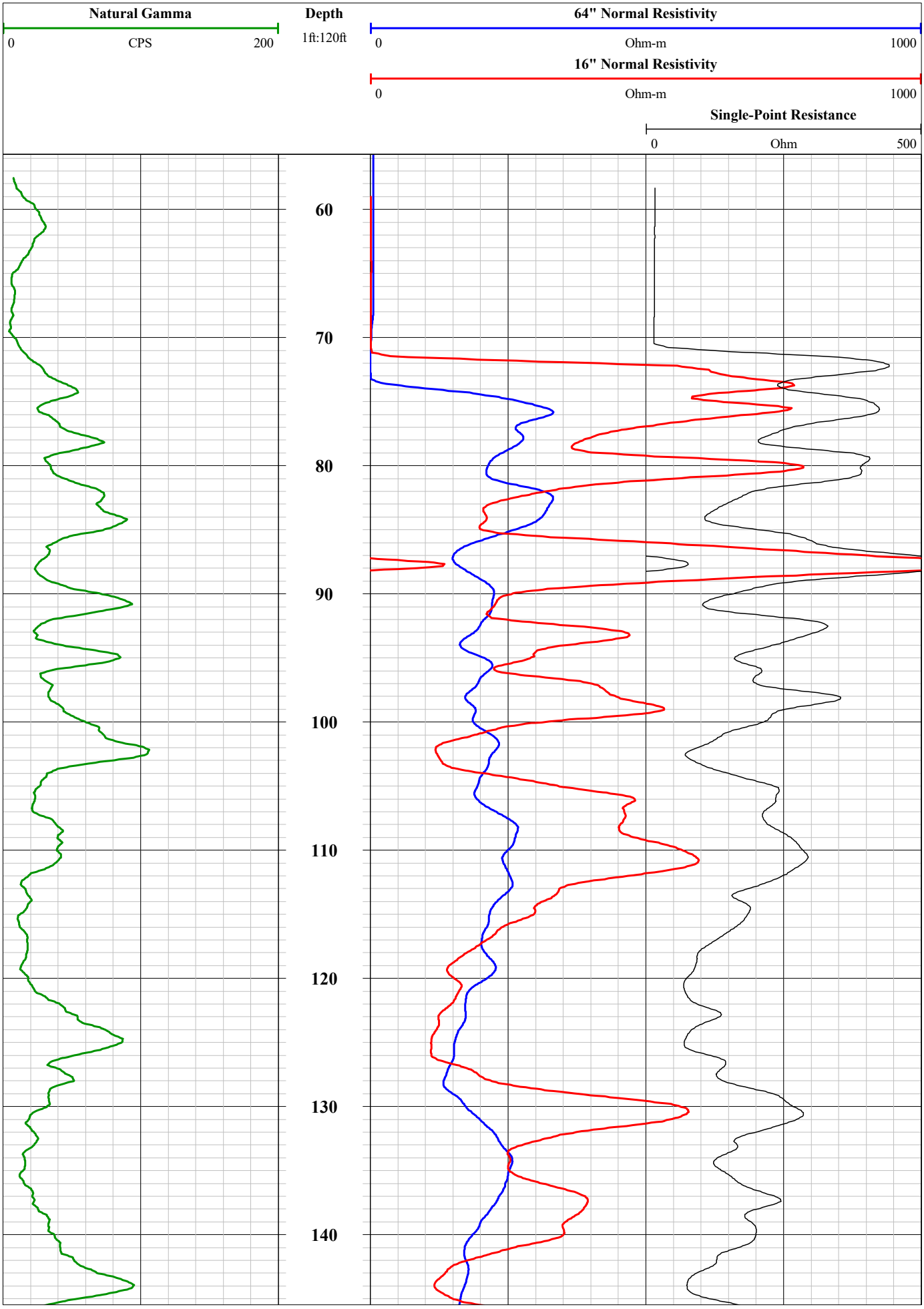
CASING RECORD

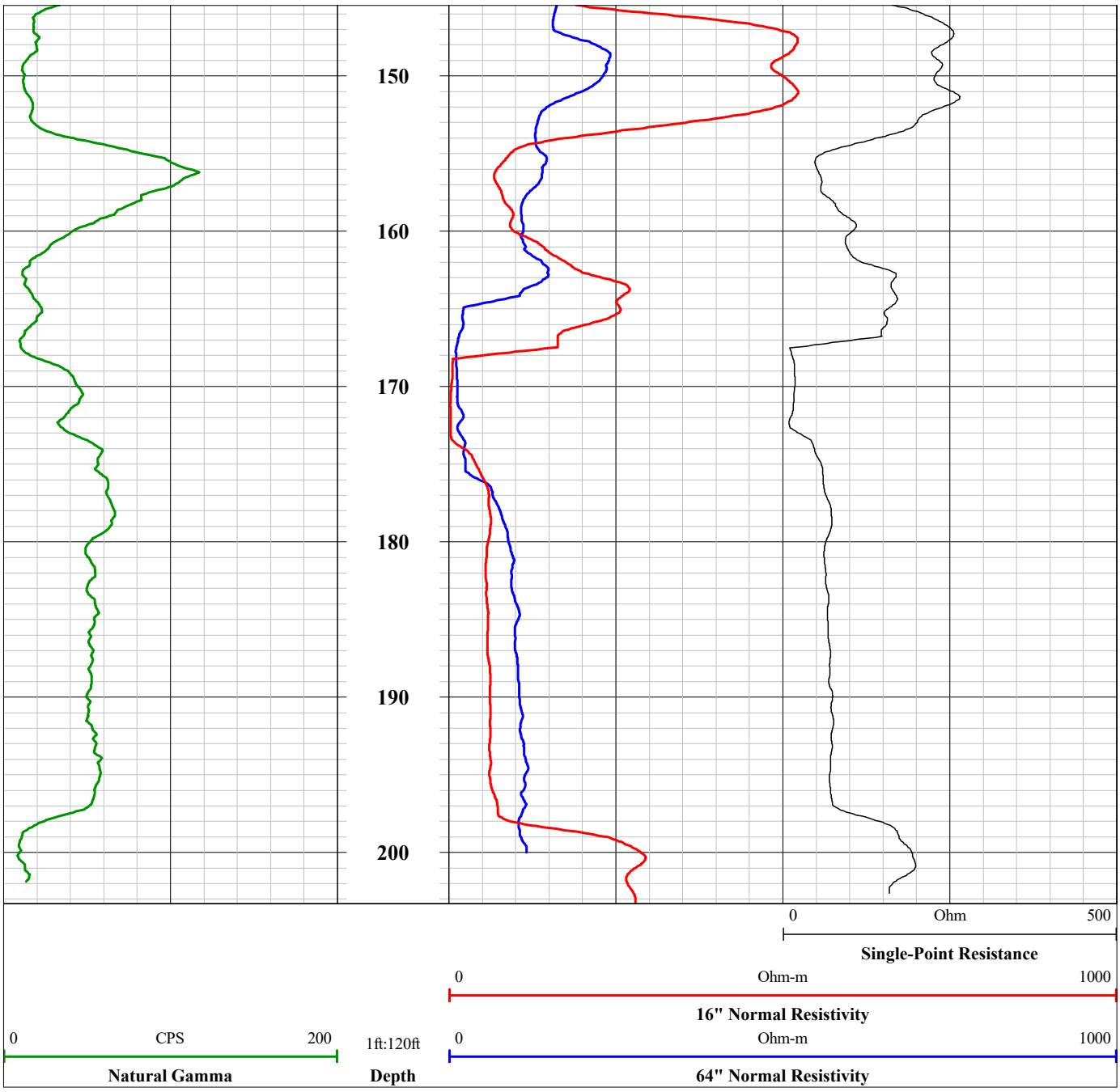
SIZE	WGT.	FROM	TO
PQ	Steel	0'	70'

NA - Not Available, N/A - Not Applicable

COMMENTS

Spontaneous Potential omitted due to configuration error


Natural Gamma
0
CPS
200
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
1000
16" Normal Resistivity
0
Ohm-m
1000
Single-Point Resistance
0
Ohm
500
60
70
80
90
100
110
120
130
140


150
160
170
180
190
200
0
Ohm
500
Single-Point Resistance
0
Ohm-m
1000
16" Normal Resistivity
0
CPS
200
1ft:120ft
0
Ohm-m
1000
Natural Gamma
Depth
64" Normal Resistivity

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-07
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-07
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83808 N
Longitude: 84.75731 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.4'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	23-24 July 2019			
RUN NUMBER	1			
LOG TYPE	P&S log			
DEPTH-DRILLER	204'			
DEPTH-LOGGER	204.5'			
BTM LOG INTERVAL	194'			
TOP LOG INTERVAL	76'			
RECORDED BY	MJC/MAC			
WITNESSED BY				
PROBE TYPE, S/N	PSlogger #10926			
LOGGING SPEED	stationary			
A.S.D.E. / Sample Interval	NA' / 2.0'			
Fluid Level / Fluid Type	19' / water			

BOREHOLE RECORD

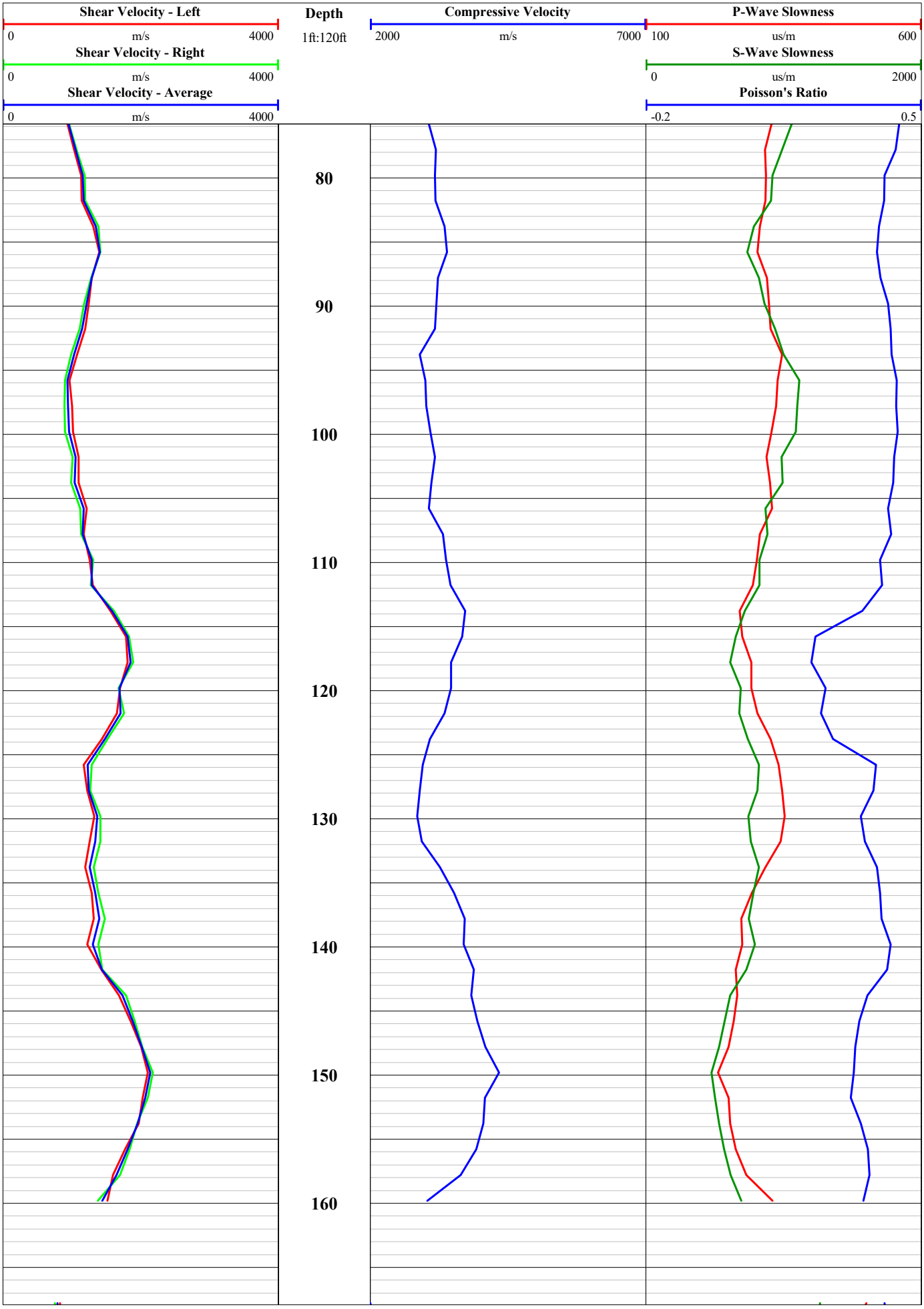
RUN No.	BIT	FROM	TO
1	HQ	70'	204'

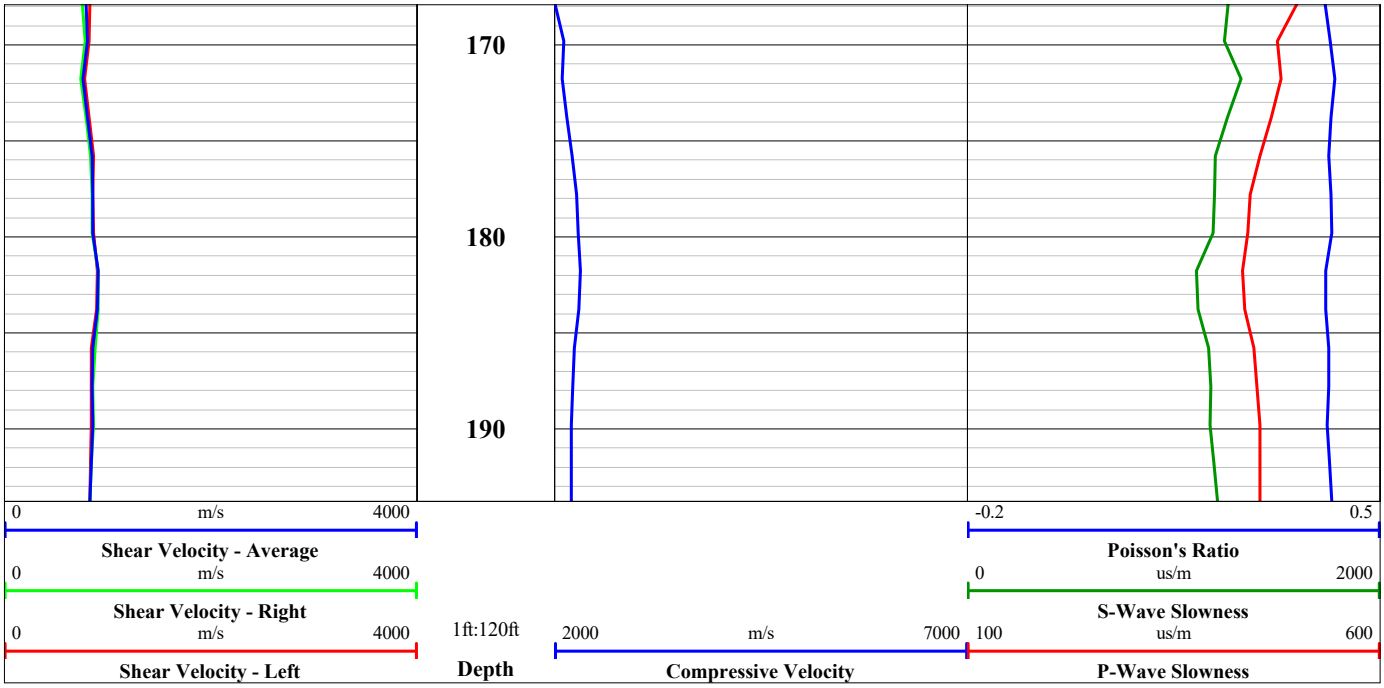
CASING RECORD

SIZE	WGT.	FROM	TO
PQ	Steel	0'	70'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Average
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
2000
m/s
7000
P-Wave Slowness
100
us/m
600
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-0.2
0.5
80
90
100
110
120
130
140
150
160


170
180
190
0
m/s
4000
Shear Velocity - Average
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
2000
m/s
7000
Compressive Velocity
-0.2
0.5
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
100
us/m
600
P-Wave Slowness

COLOG

borehole geophysics / hydrophysics

Geophysical Summary Plot

COMPANY: WSP

PROJECT: L5RT Project

DATE LOGGED: 6 June 2019

WELL: BH19-08 - South Shore

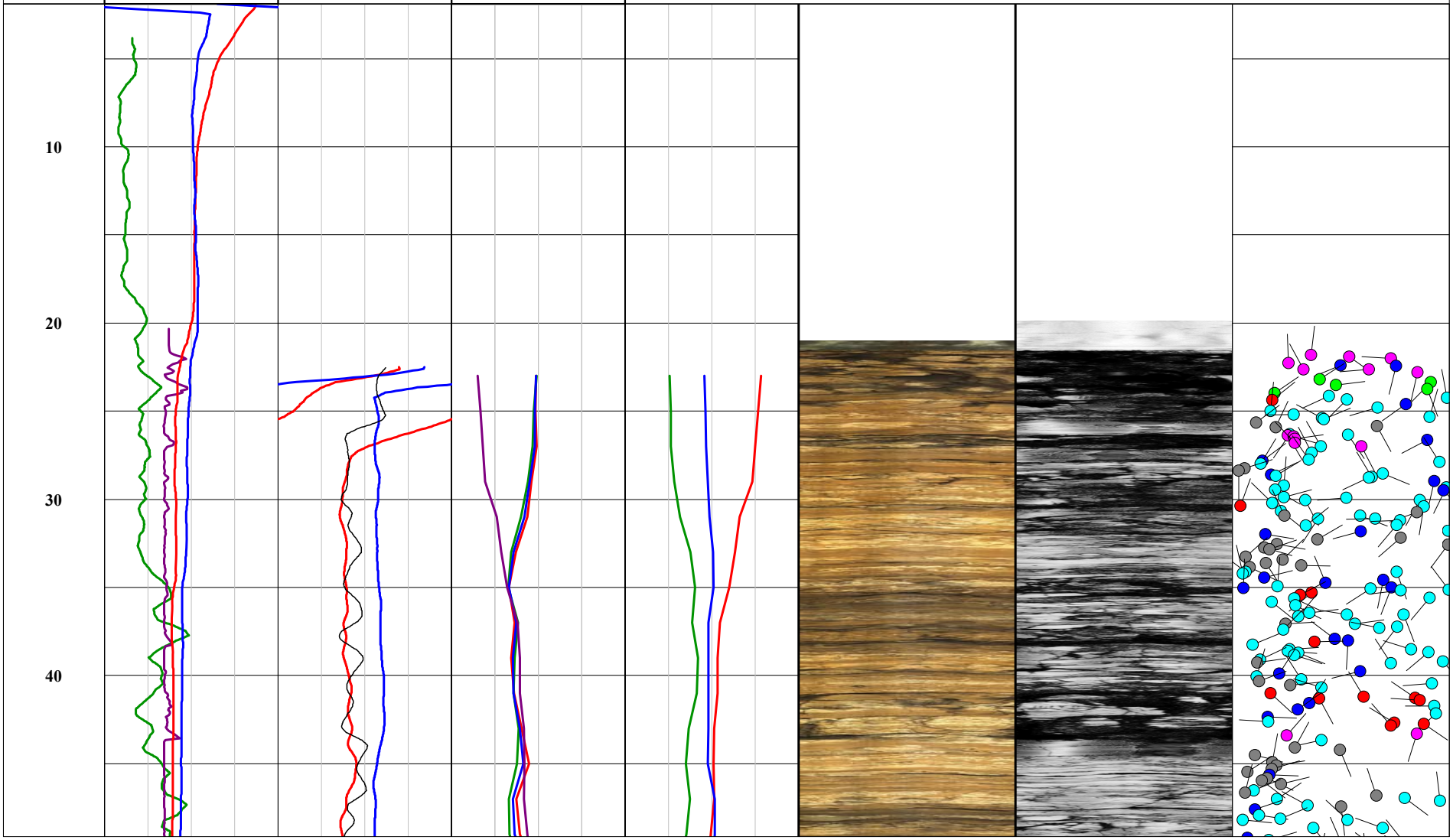
COLOG Main Office

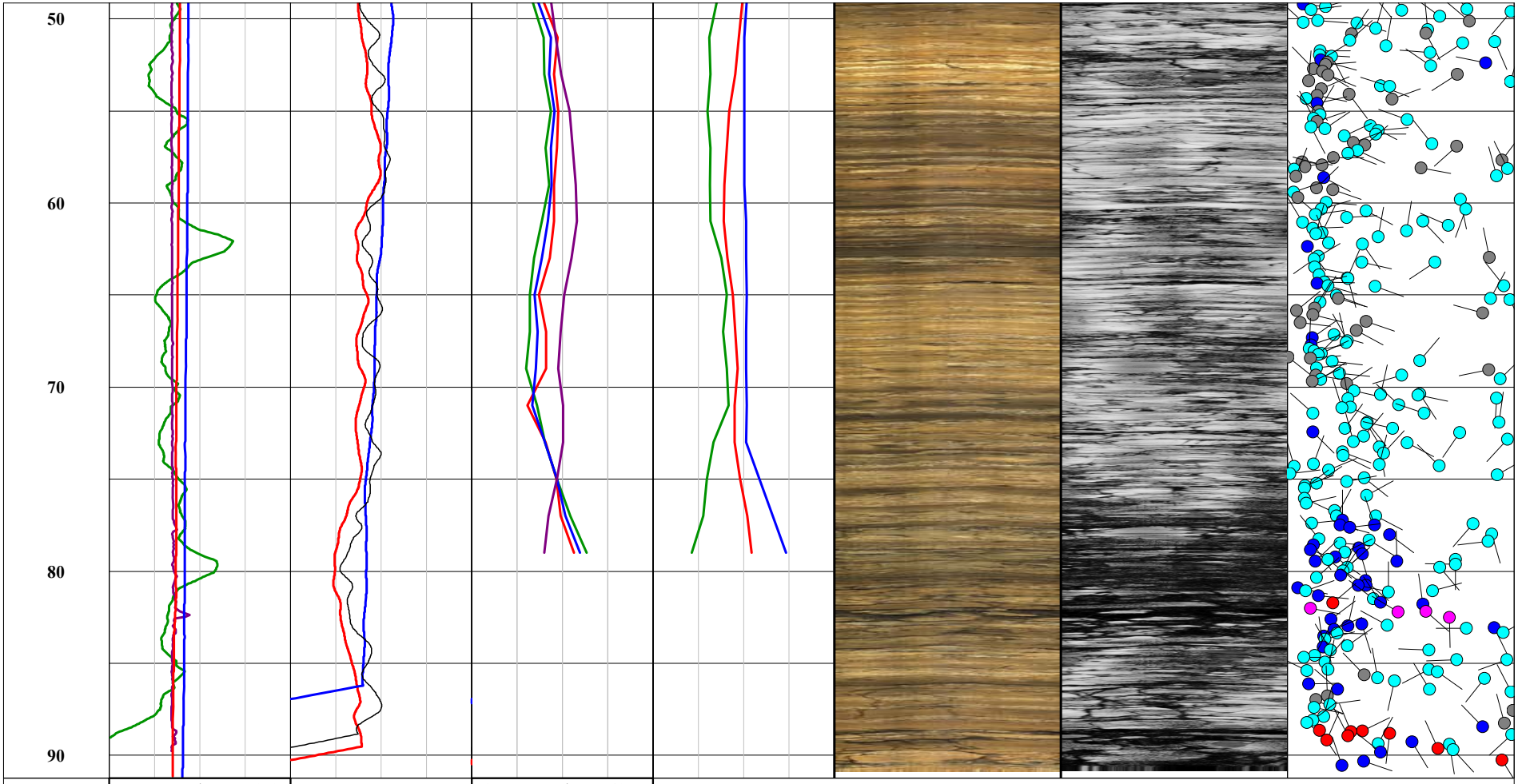
810 Quail Street, Suite E, Lakewood, CO 80215

Phone: (303) 279-0171, Fax: (303) 278-0135

www.colog.com

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - HS	Amplitude - HS	Tadpoles - MN
1ft:100ft	0 CPS 50	0 Ohm-m 1000	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper: 2 inch 7	64" Normal Resistivity: 0 Ohm-m 1000	Shear Velocity - Right: 0 m/s 4000	S-Wave Slowness: 0 us/m 2000			
	Temperature: 5 deg C 15	Single-Point Resistance: 0 Ohm 500	Shear Velocity - Avg: 0 m/s 4000	Poisson's Ratio: -10 10			
	Fluid Conductivity: 0 uS/cm 250		Compressive Velocity: 2000 m/s 4000				





	0 uS/cm 250 **Fluid Conductivity**		2000 m/s 4000 **Compressive Velocity**				
	5 deg C 15 **Temperature**	0 Ohm 500 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-10 10 **Poisson's Ratio**			
	2 inch 7 **3-Arm Caliper**	0 Ohm-m 1000 **64" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**			
1ft:100ft **Depth**	0 CPS 50 **Natural Gamma**	0 Ohm-m 1000 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Left**	200 us/m 500 **P-Wave Slowness**	0° 90° 180° 270° 0° **Optical Image - HS**	0° 90° 180° 270° 0° **Amplitude - HS**	0 90 **Tadpoles - MN**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-08
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-08
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.788830 N
Longitude: 84.77656 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 584.3'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	6 June 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	113'			
DEPTH-LOGGER	91'			
BTM LOG INTERVAL	91.0'			
TOP LOG INTERVAL	20.0'			
RECORDED BY	JBG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	ABI LIM #1729			
LOGGING SPEED	3.5 ft/min			
A.S.D.E. / Sample Interval	0.13' / 0.0024'			
Fluid Level / Fluid Type	2' / water			

BOREHOLE RECORD

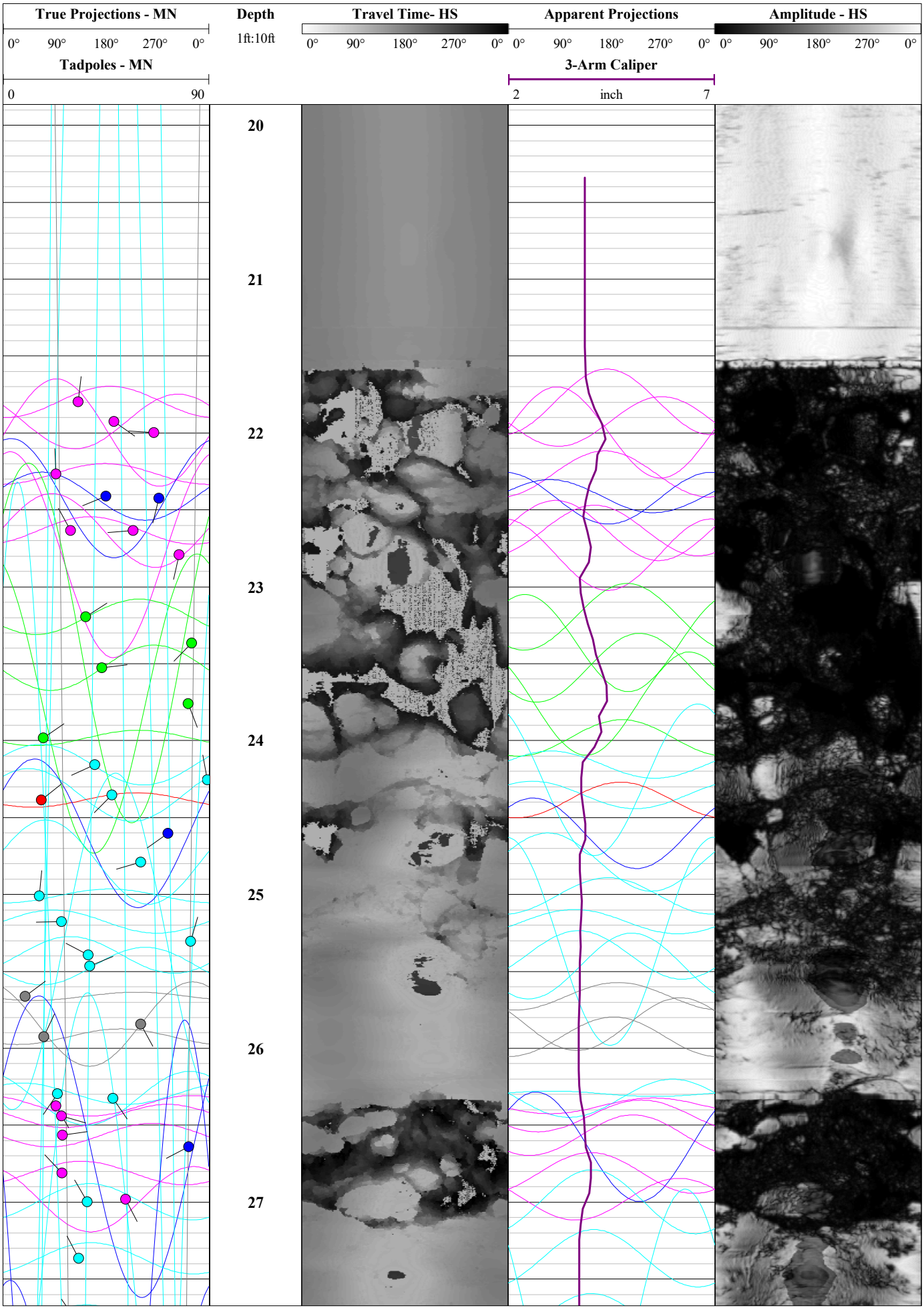
RUN No.	BIT	FROM	TO
1	HQ	22'	105'
1	NQ	105'	113'
1			

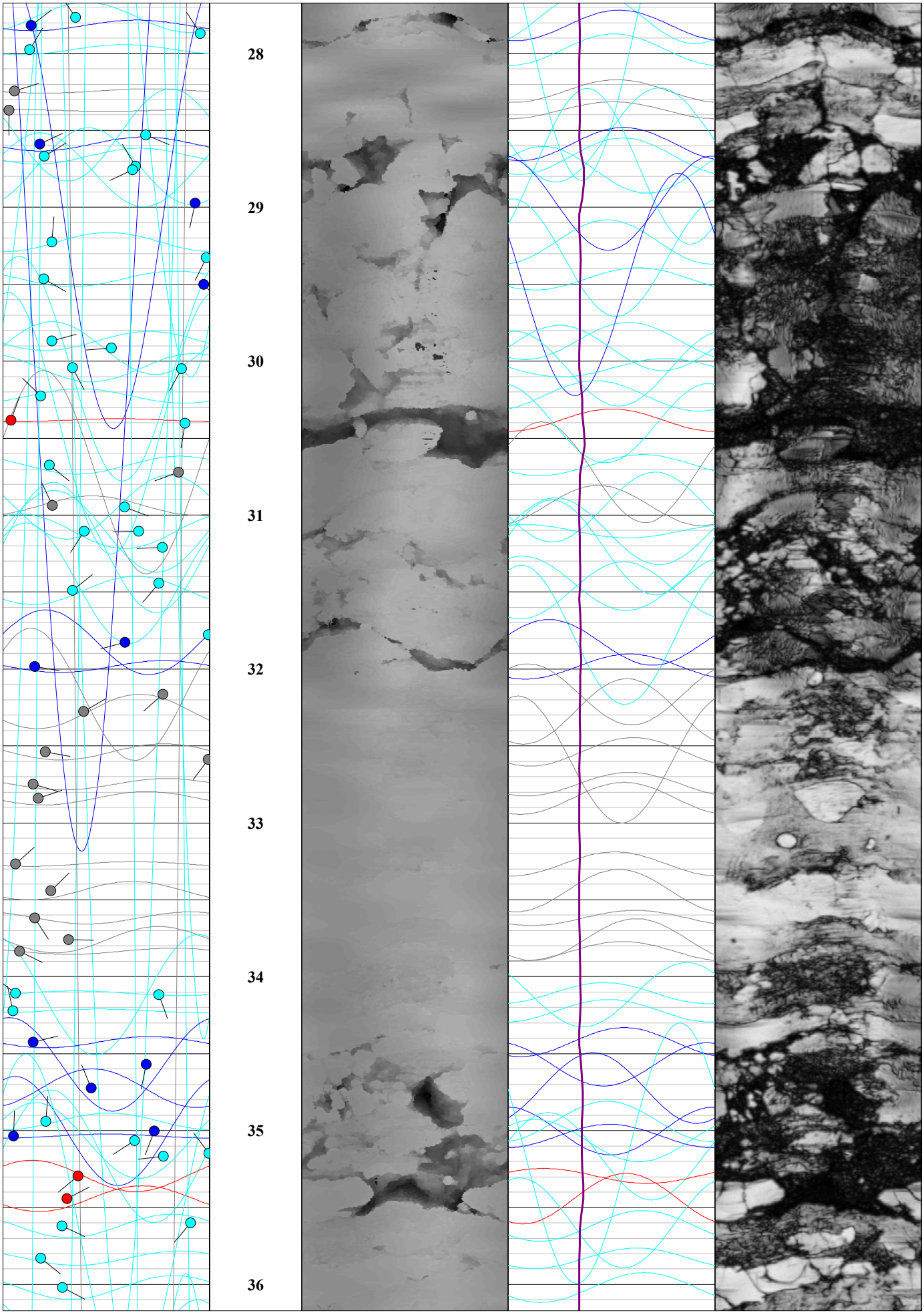
CASING RECORD

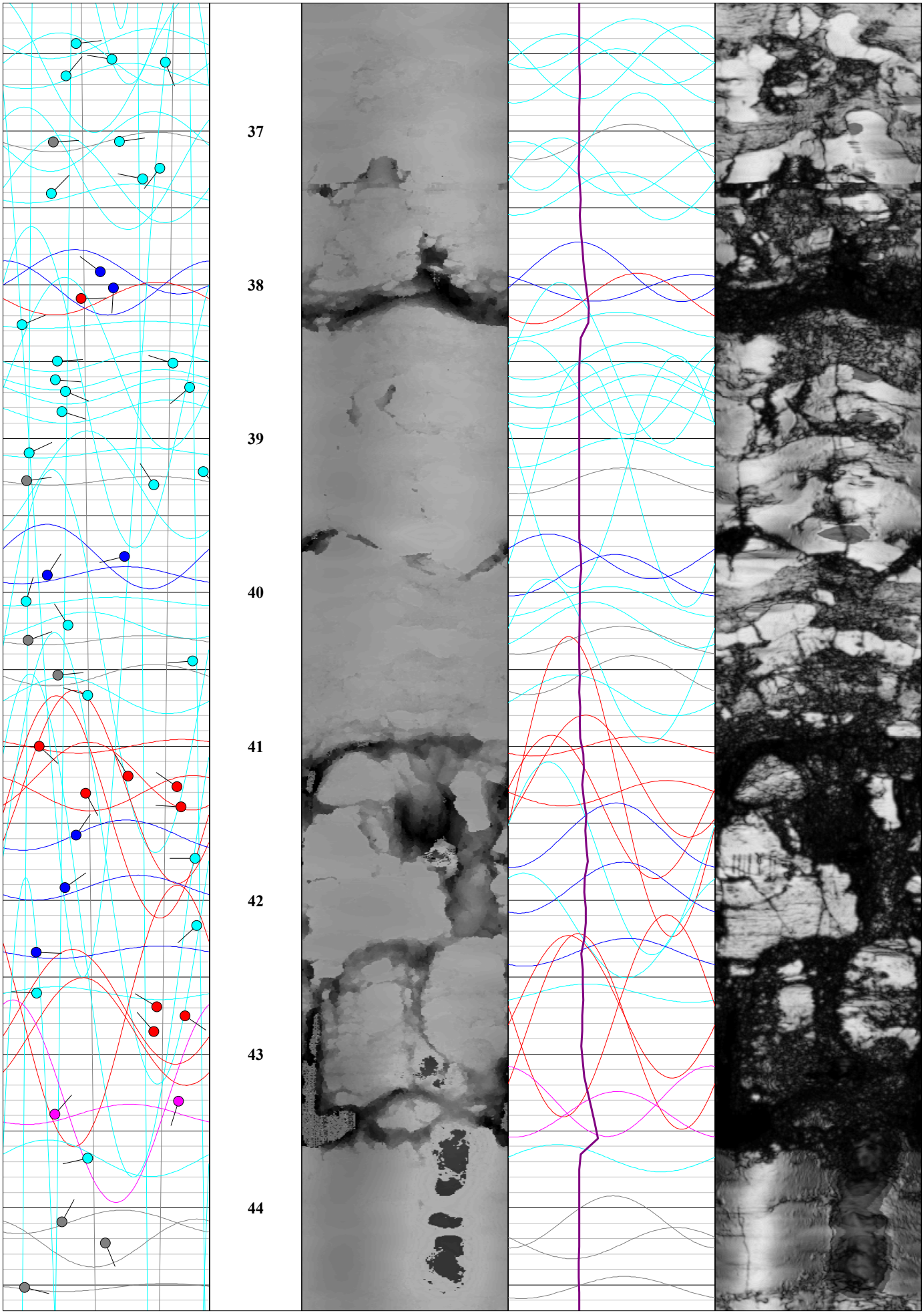
SIZE	WGT.	FROM	TO
6"	Steel	GL	20'
HWT	Steel	GL	22'

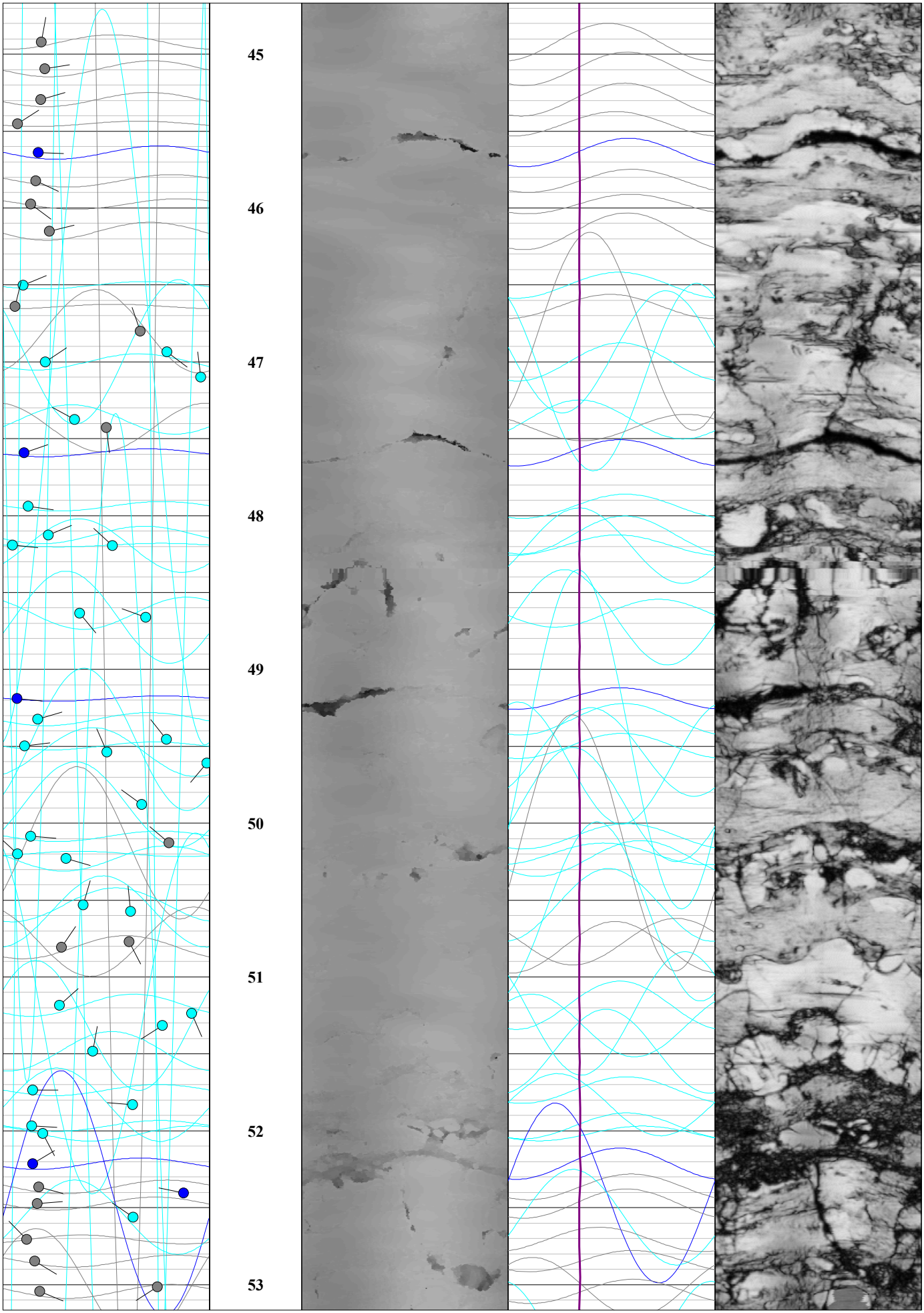
NA - Not Available, N/A - Not Applicable

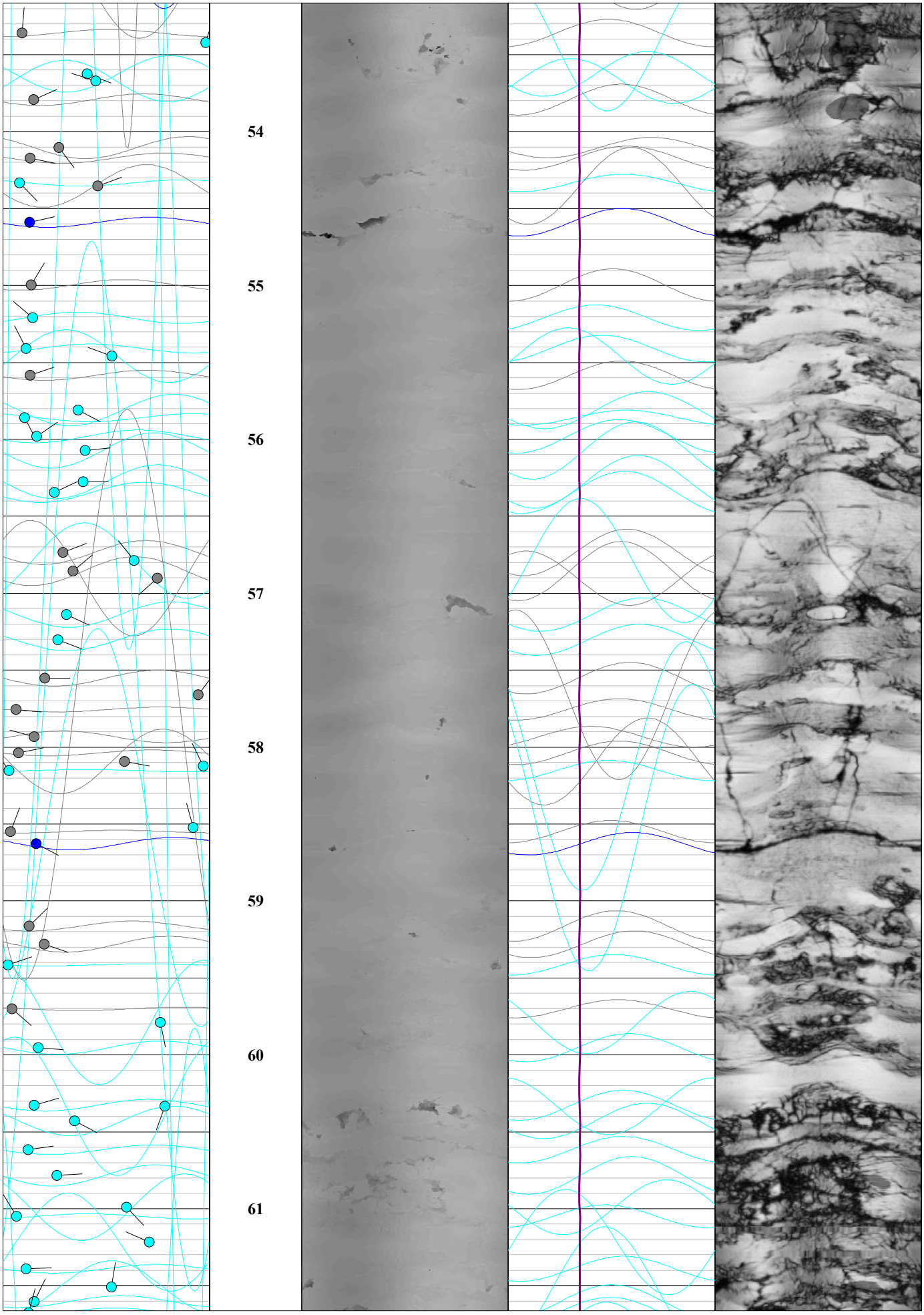
COMMENTS

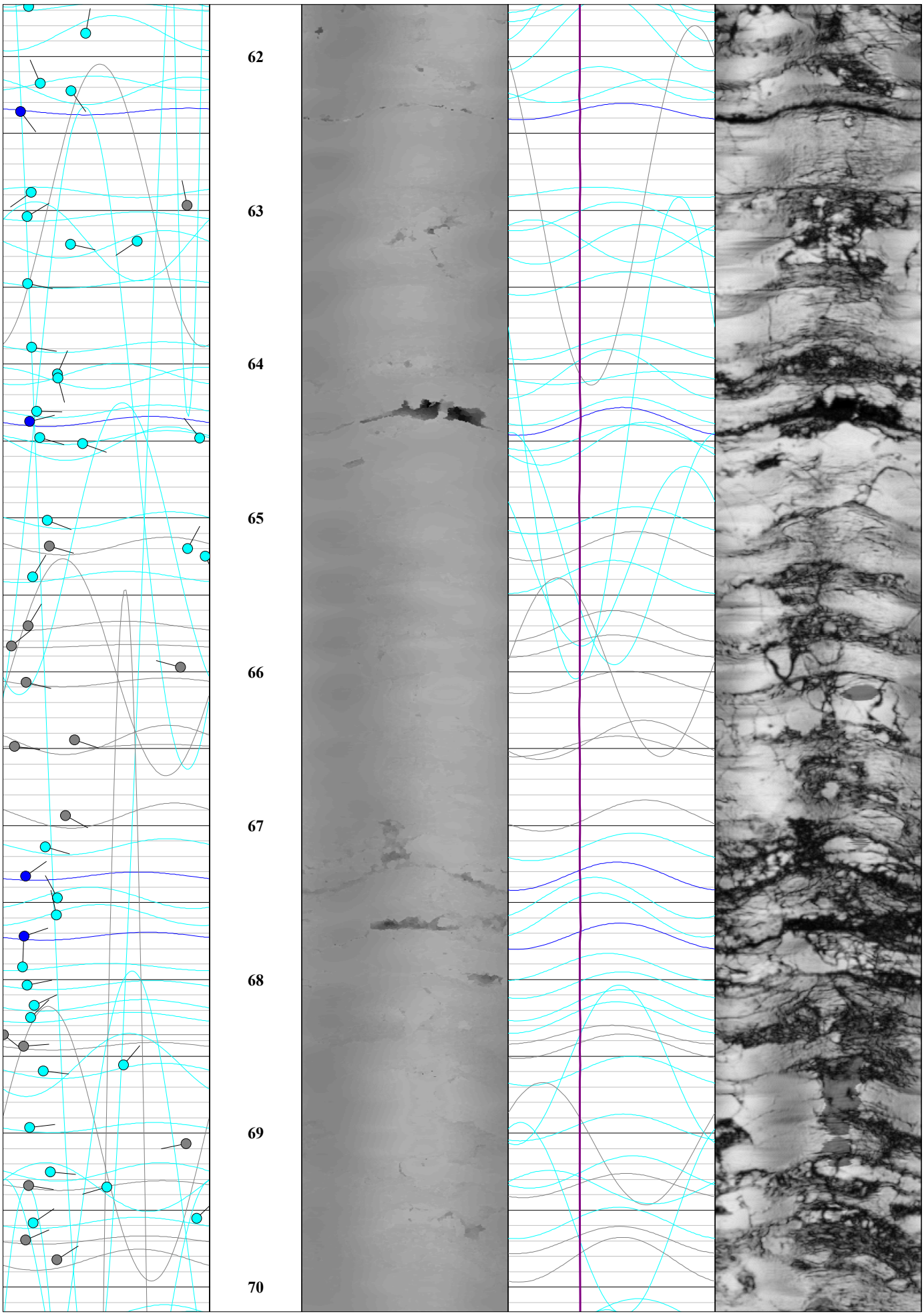

True Projections - MN
0° 90° 180° 270° 0°
Tadpoles - MN
0 90
Depth
1ft:10ft
Travel Time- HS
0° 90° 180° 270° 0°
Apparent Projections
0° 90° 180° 270° 0°
3-Arm Caliper
2 inch 7
Amplitude - HS
0° 90° 180° 270° 0°
20
21
22
23
24
25
26
27

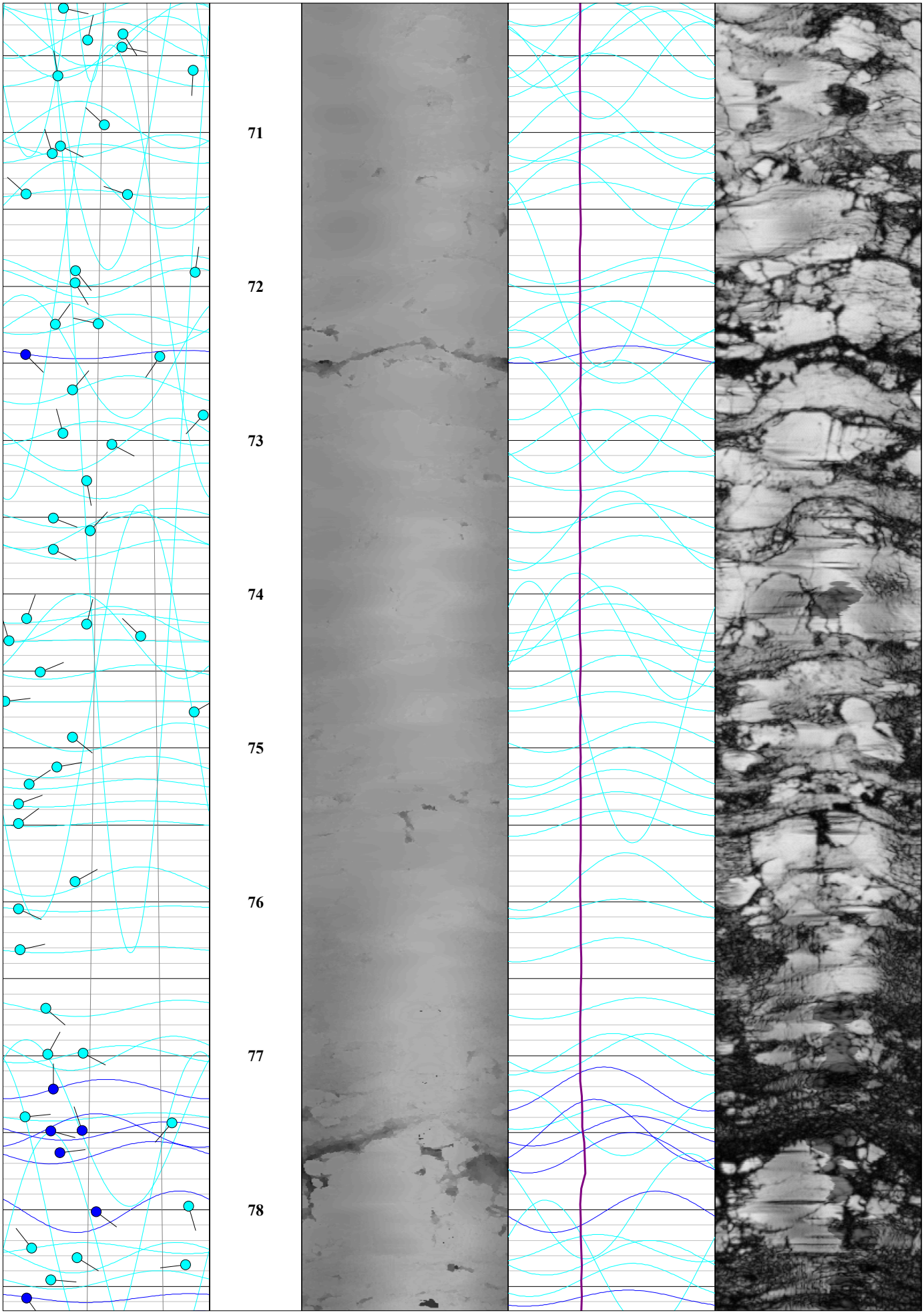

28
29
30
31
32
33
34
35
36

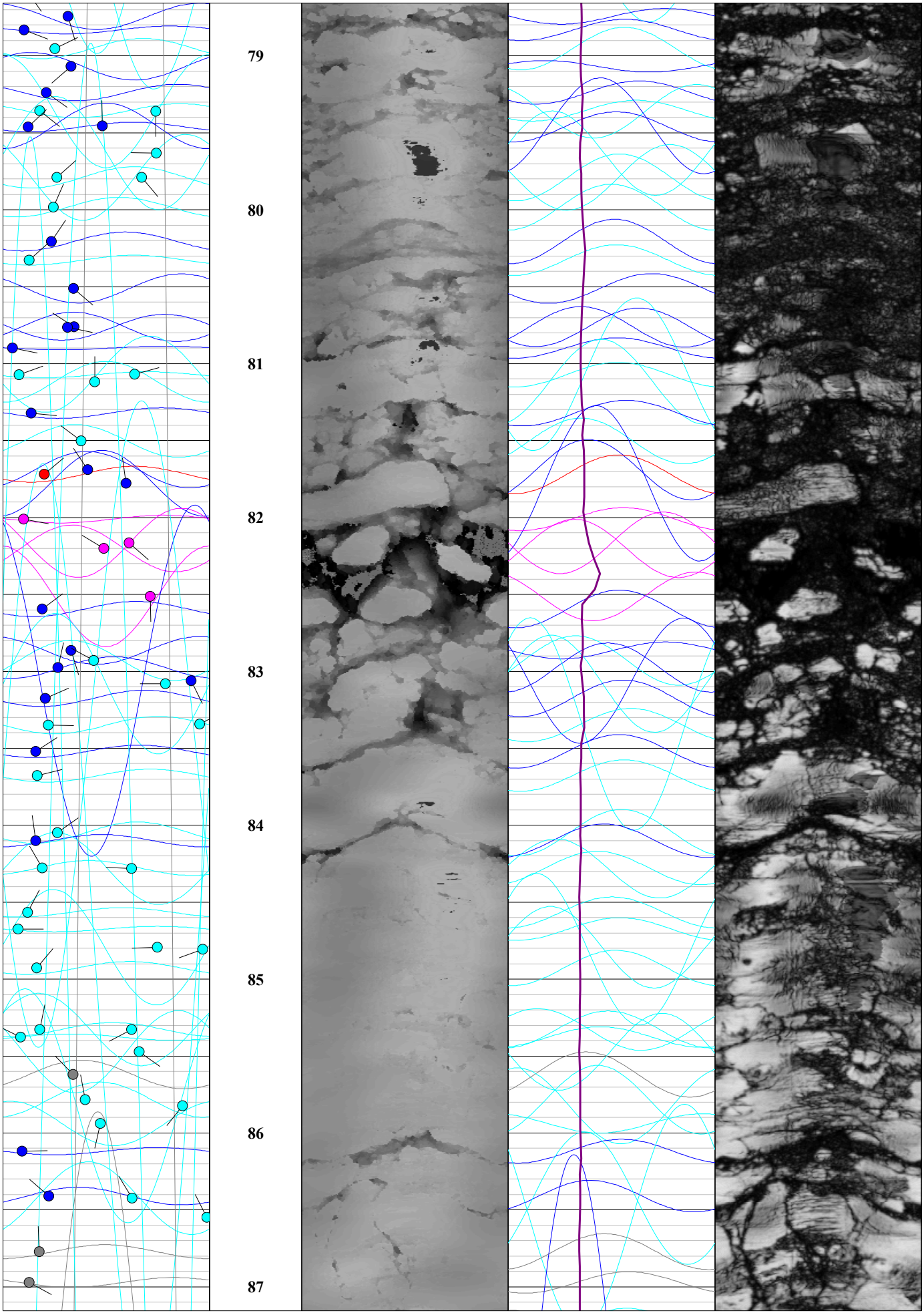

37
38
39
40
41
42
43
44

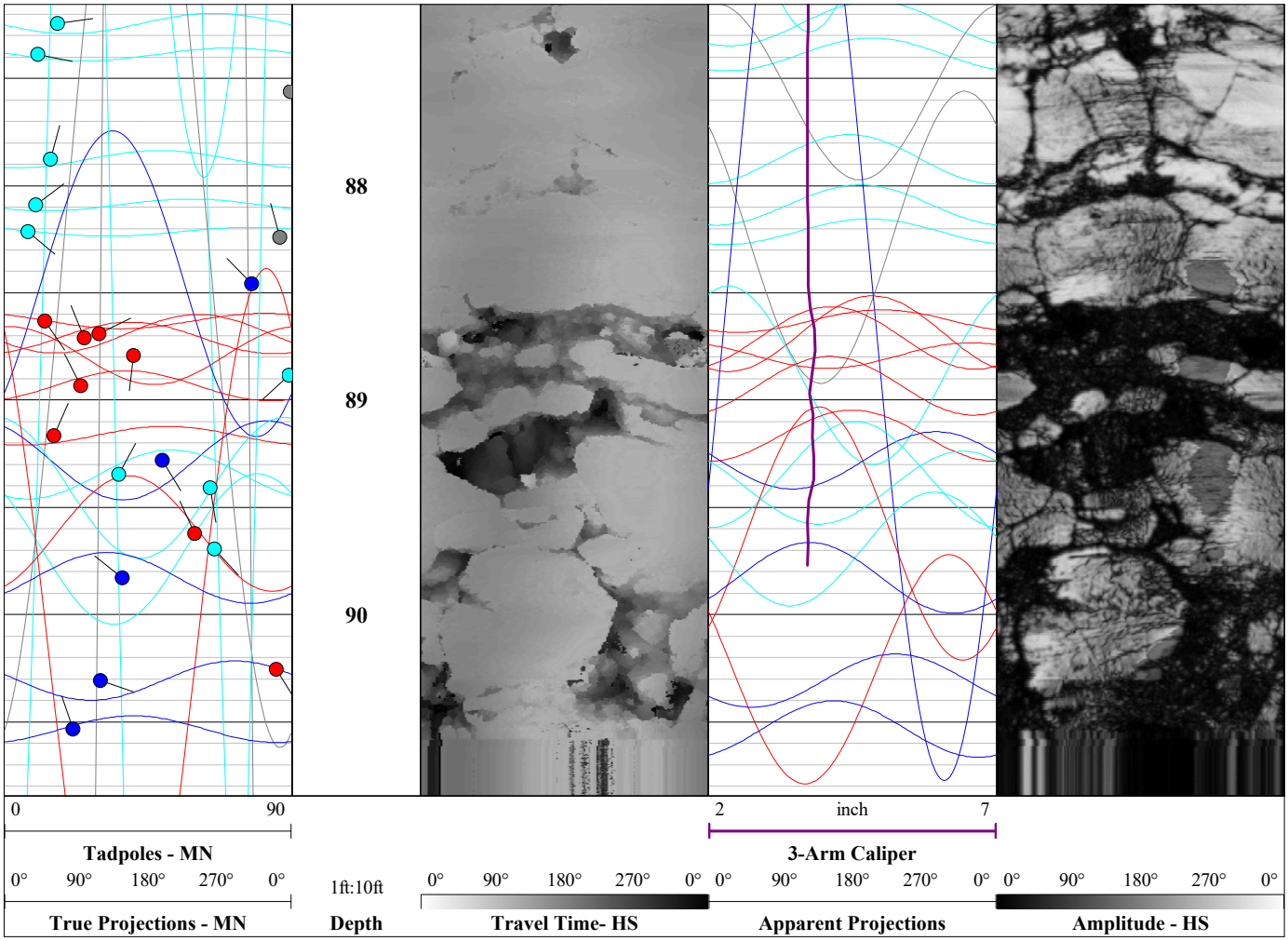

45
46
47
48
49
50
51
52
53


54
55
56
57
58
59
60
61


62
63
64
65
66
67
68
69
70


71
72
73
74
75
76
77
78


79
80
81
82
83
84
85
86
87


88
89
90
0
90
2
inch
7
Tadpoles - MN
3-Arm Caliper
0° 90° 180° 270° 0°
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
True Projections - MN
Depth
Travel Time- HS
Apparent Projections
Amplitude - HS

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-08
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-08
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.788830 N
Longitude: 84.77656 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 584.3'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	6 June 2019			
RUN NUMBER	1			
LOG TYPE	Optical Televiewer			
DEPTH-DRILLER	113'			
DEPTH-LOGGER	91'			
BTM LOG INTERVAL	90.9'			
TOP LOG INTERVAL	21.0'			
RECORDED BY	JBG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	OTV #1729			
LOGGING SPEED	4 ft/min			
A.S.D.E. / Sample Interval	0.11' / 0.003'			
Fluid Level / Fluid Type	2' / water			

BOREHOLE RECORD

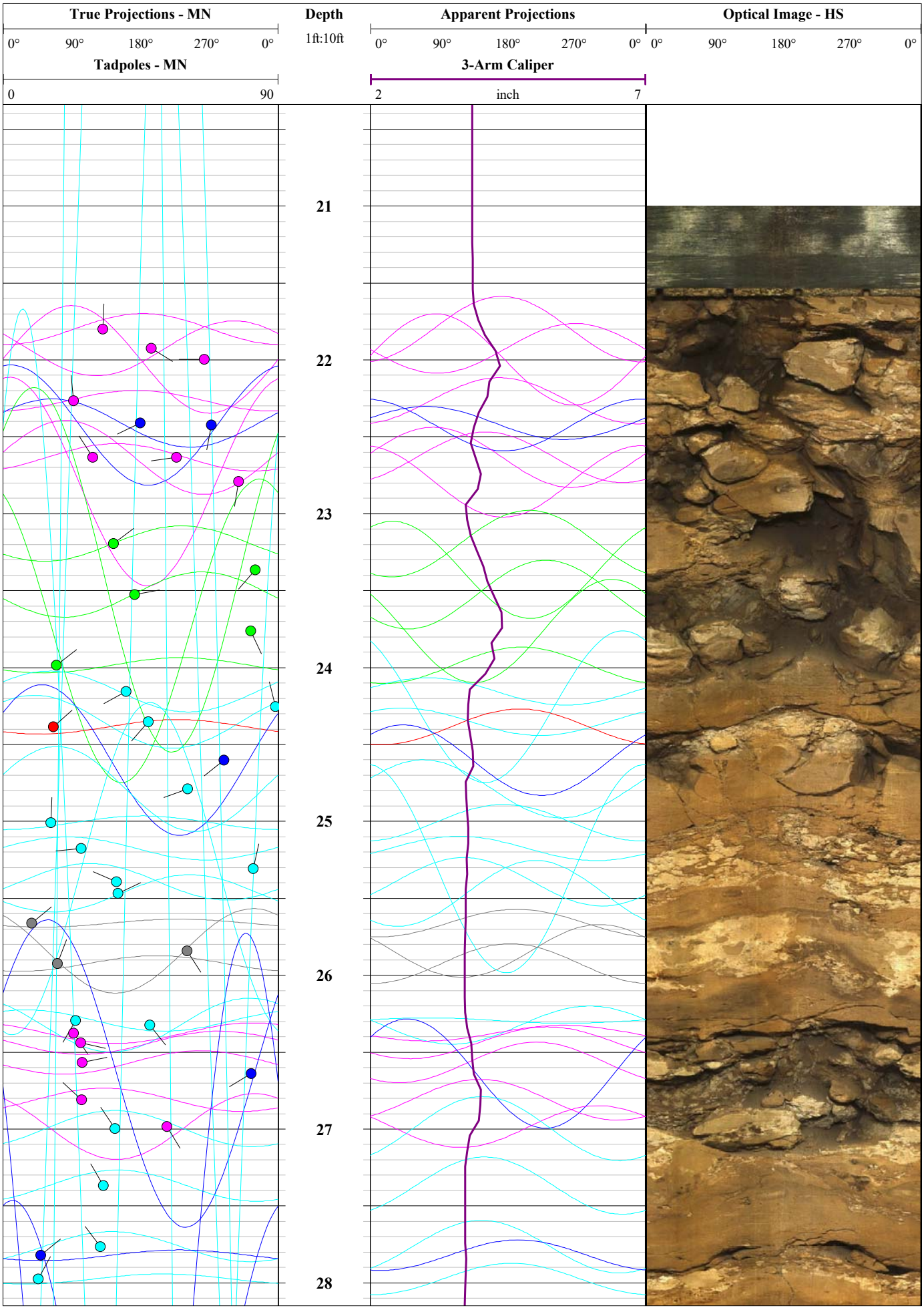
RUN No.	BIT	FROM	TO
1	HQ	22'	105'
1	NQ	105'	113'

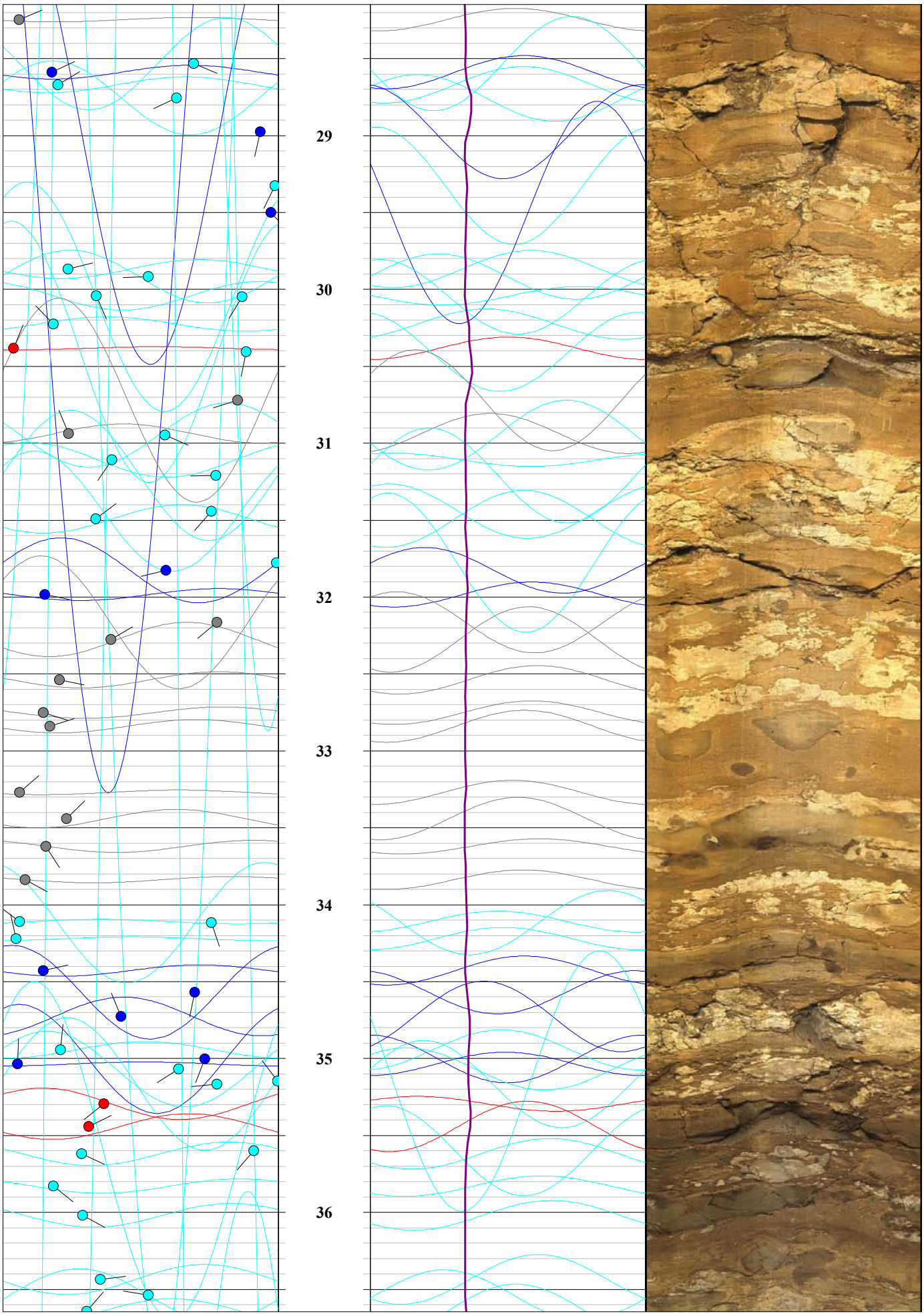
CASING RECORD

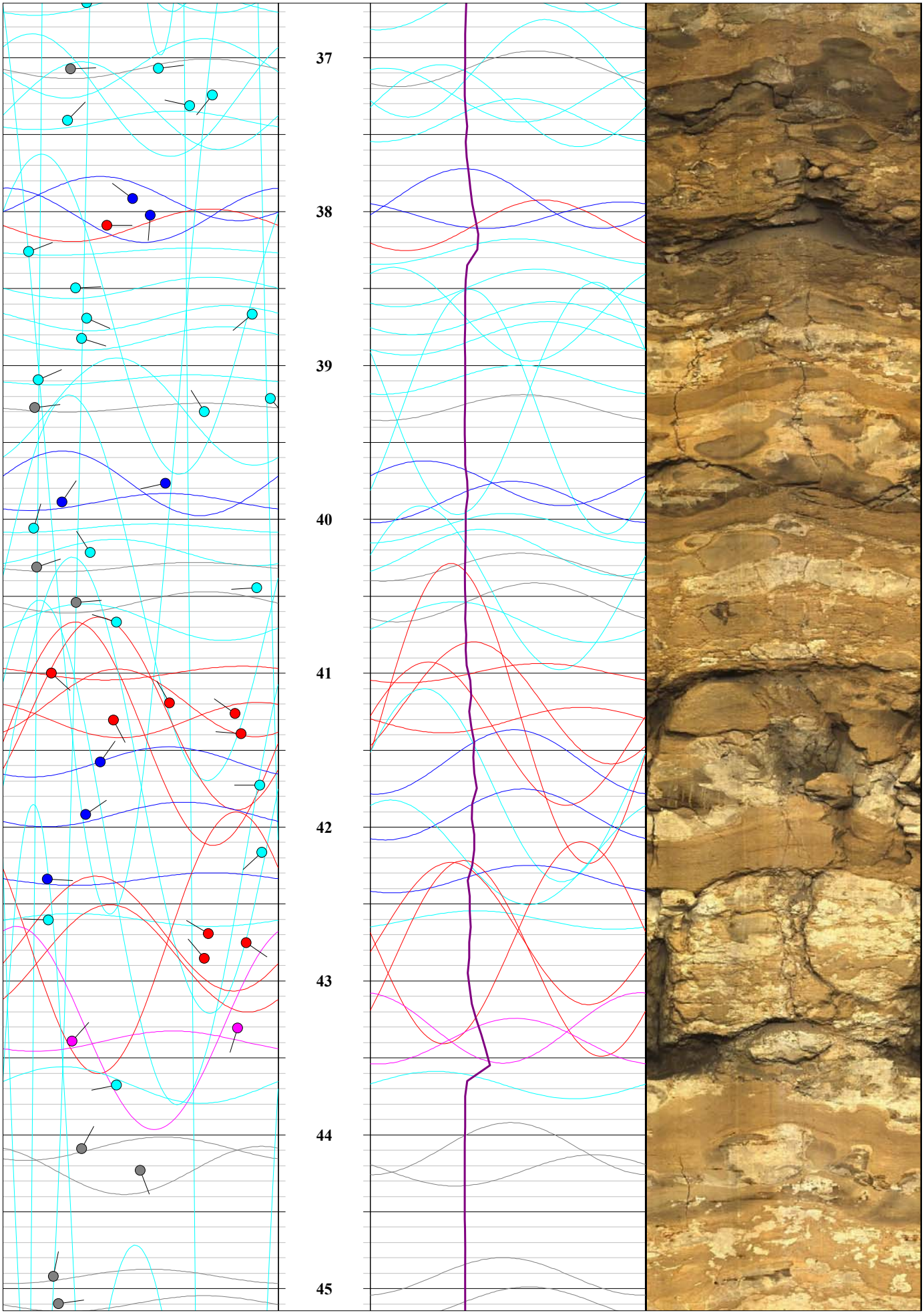
SIZE	WGT.	FROM	TO
6"	Steel	GL	20'
HWT	Steel	GL	22'

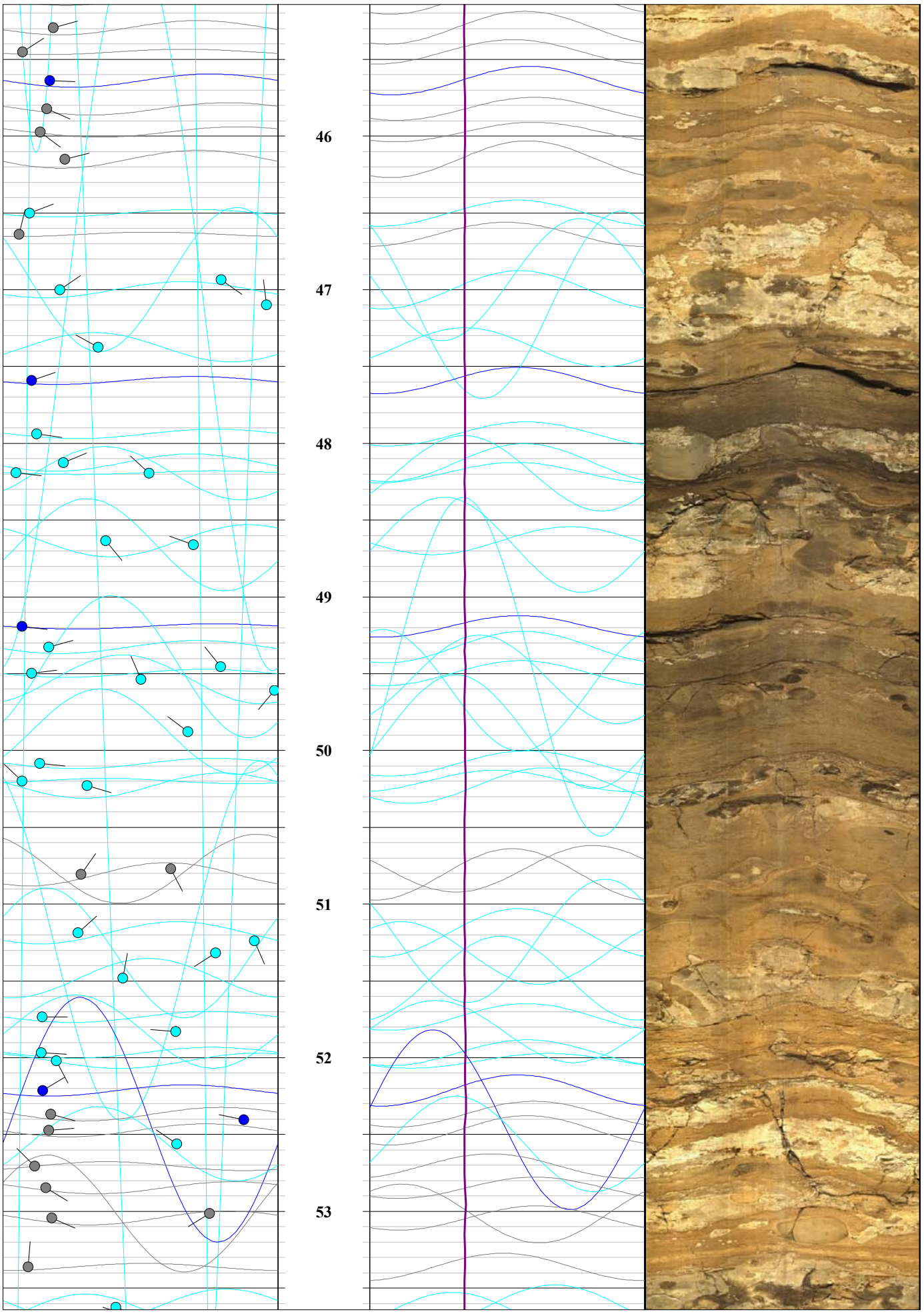
NA - Not Available, N/A - Not Applicable

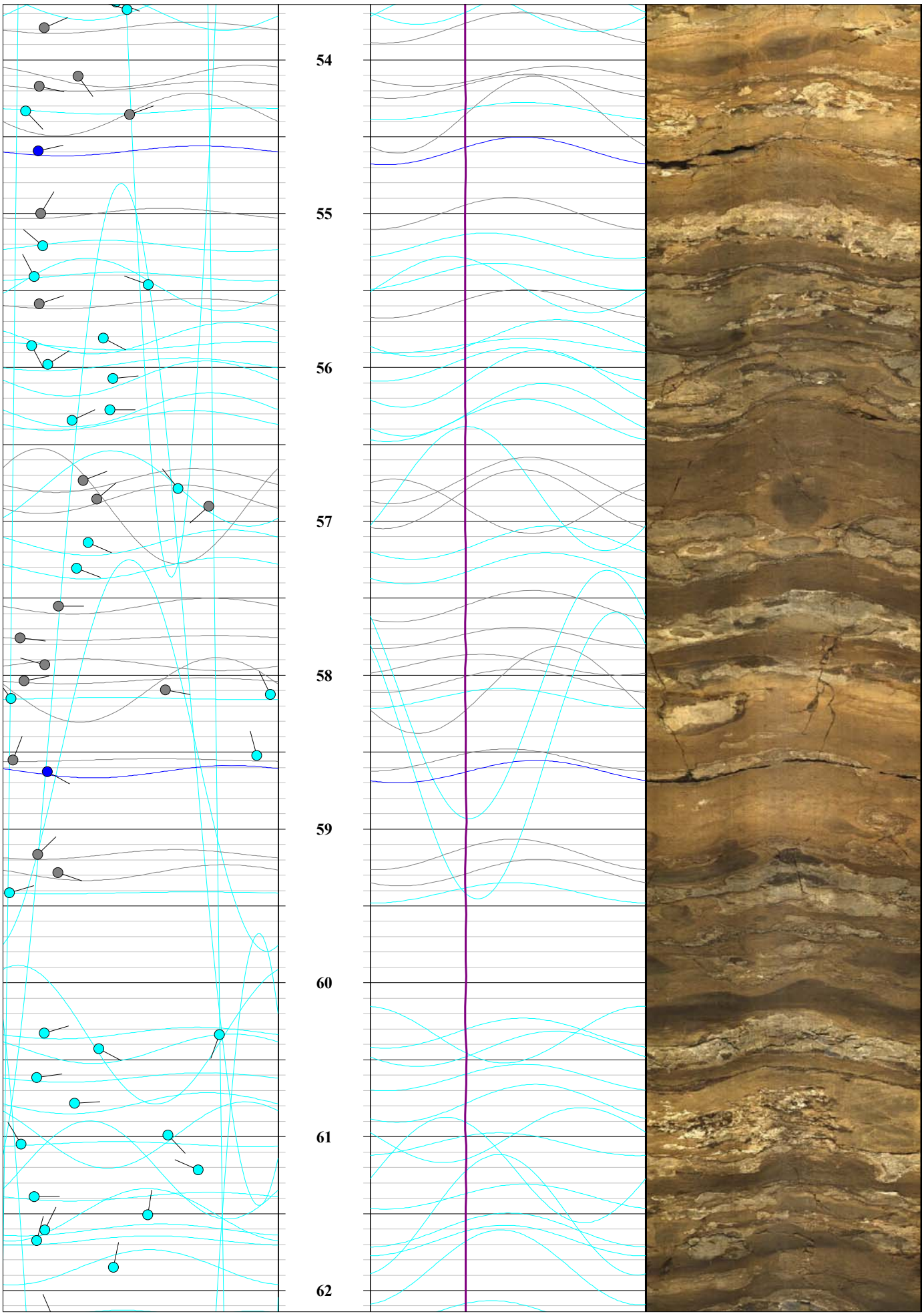
COMMENTS

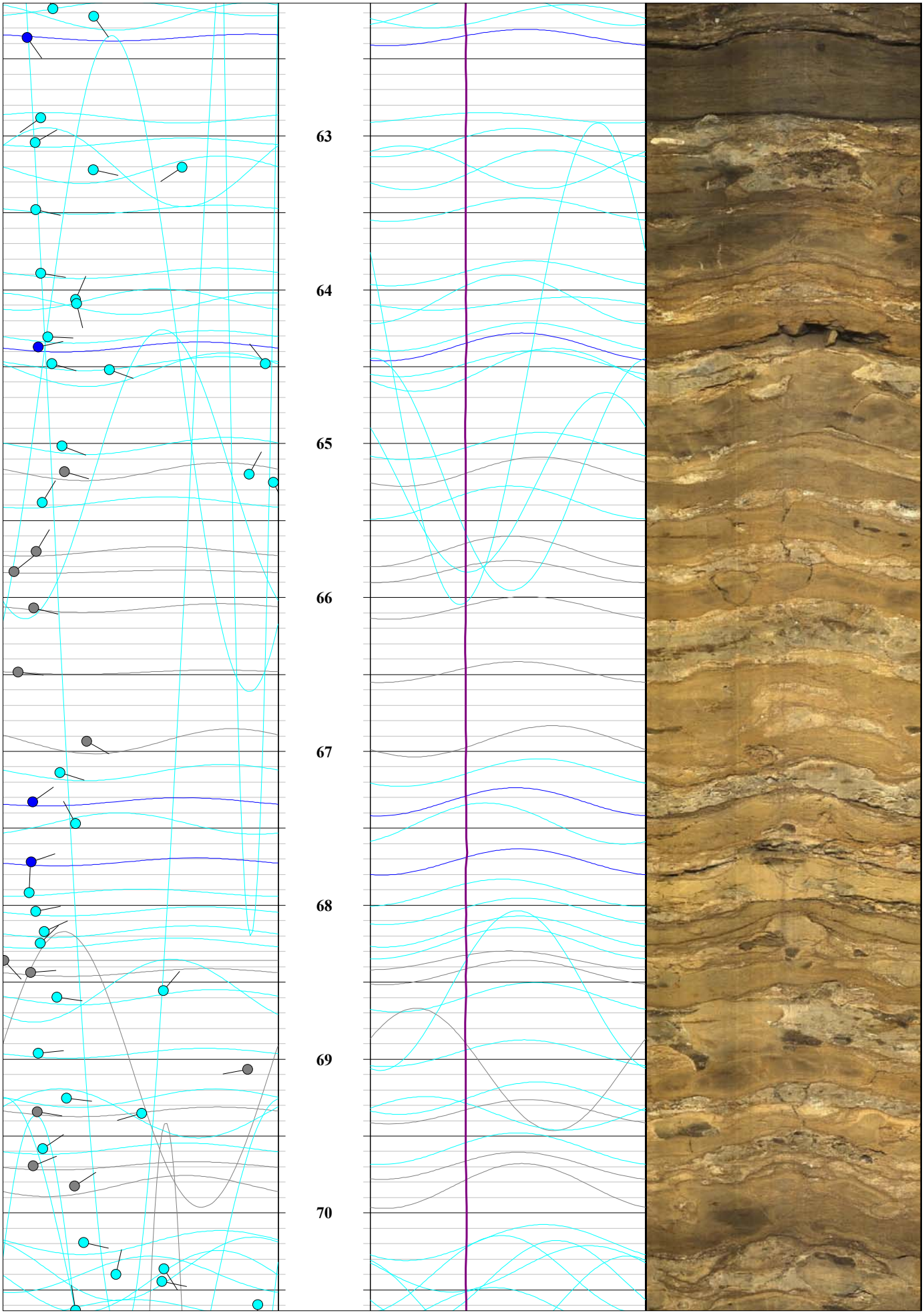

True Projections - MN
0°
90°
180°
270°
0°
Tadpoles - MN
0
90
Depth
1ft:10ft
21
22
23
24
25
26
27
28
Apparent Projections
0°
90°
180°
270°
0°
3-Arm Caliper
2
inch
7
Optical Image - HS
0°
90°
180°
270°
0°

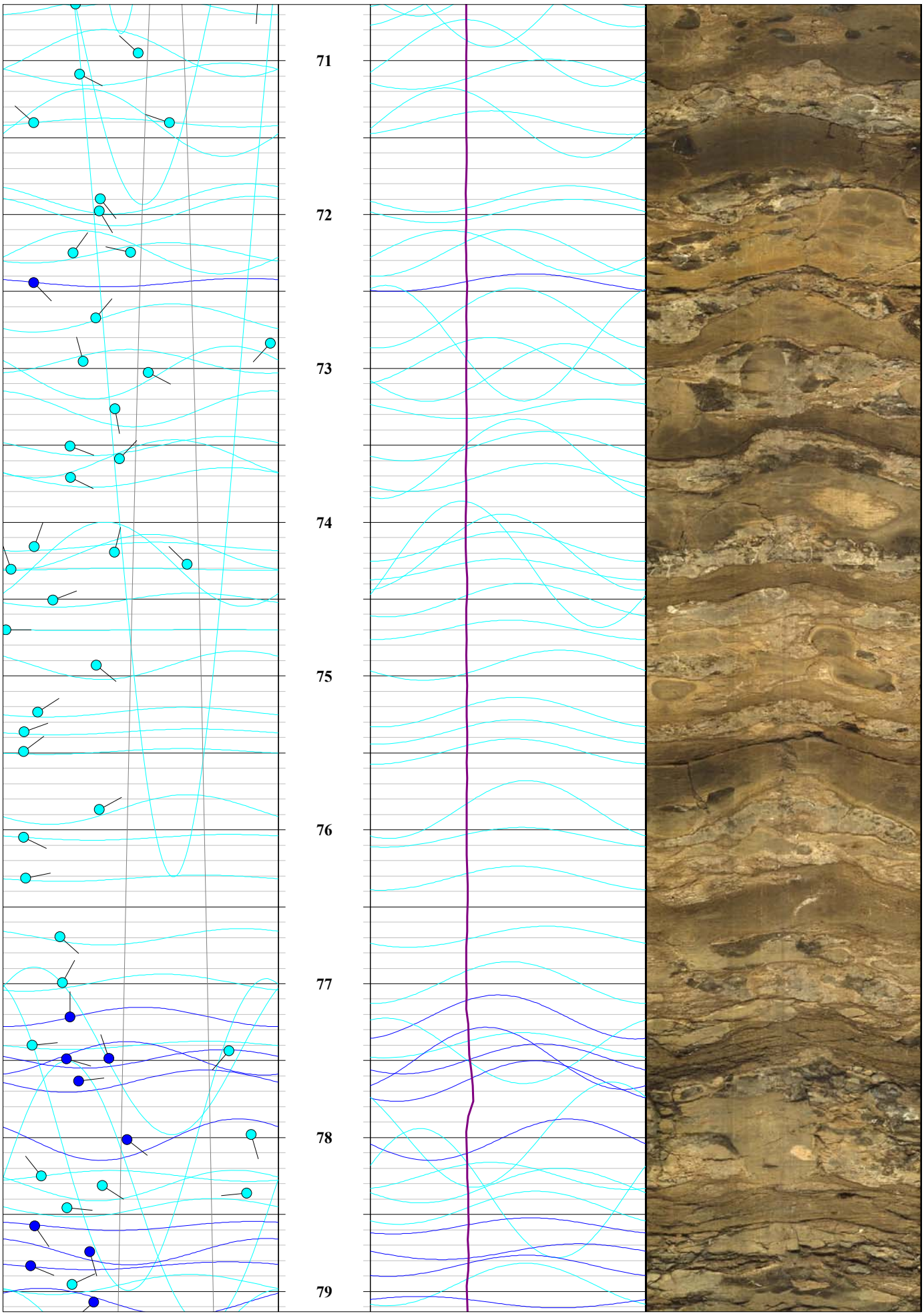

29
30
31
32
33
34
35
36

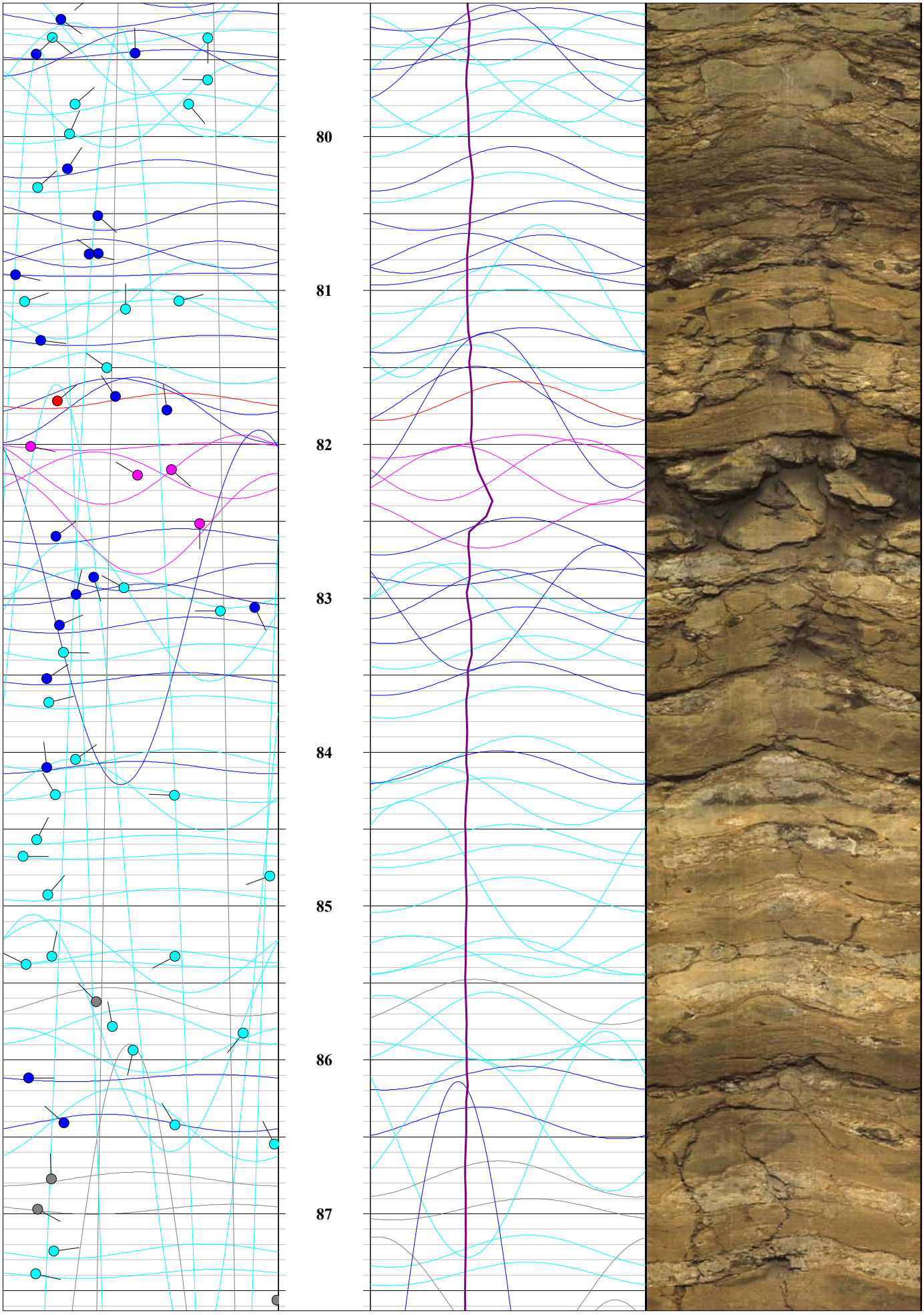

37
38
39
40
41
42
43
44
45

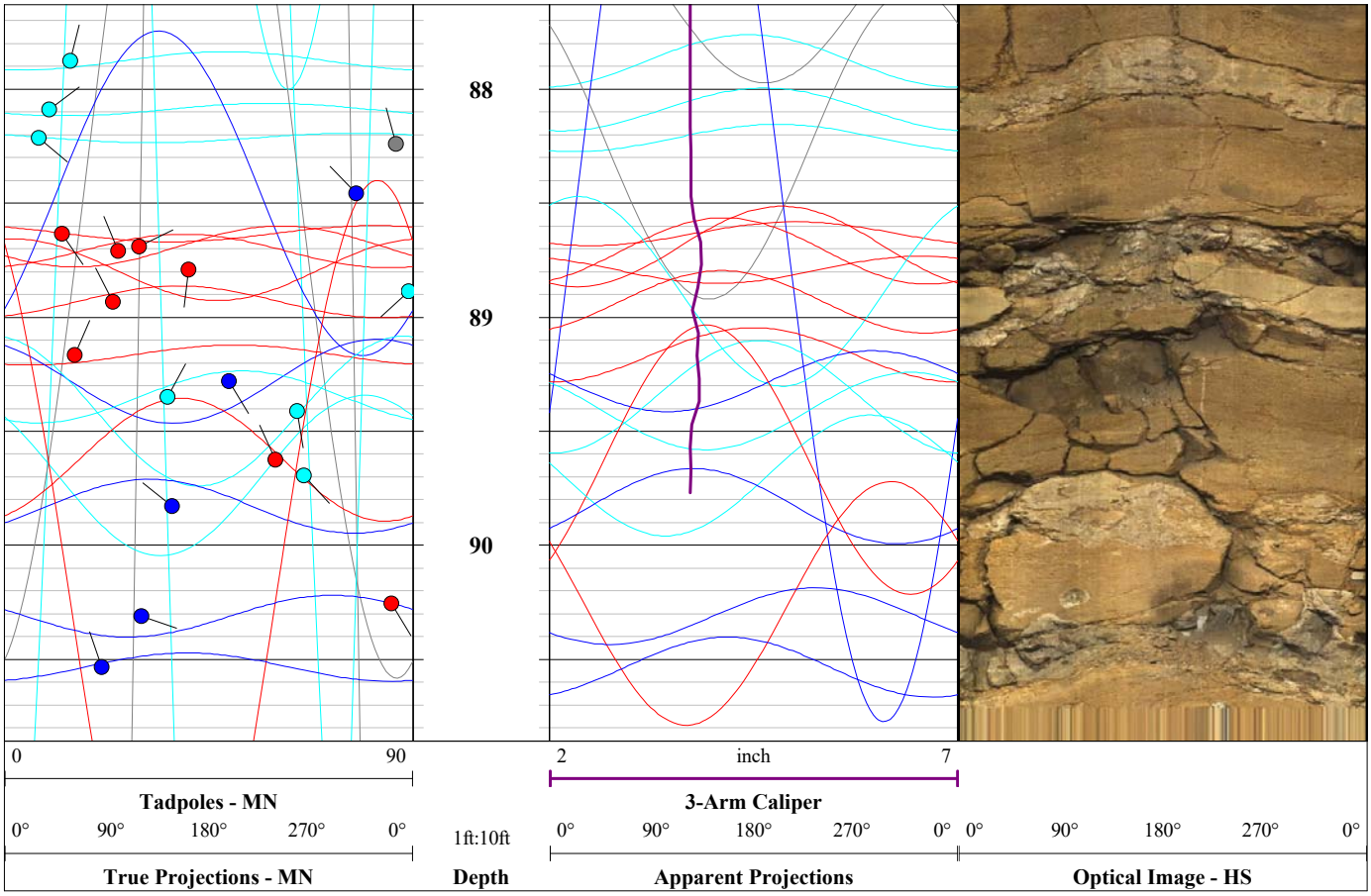

46
47
48
49
50
51
52
53


54
55
56
57
58
59
60
61
62

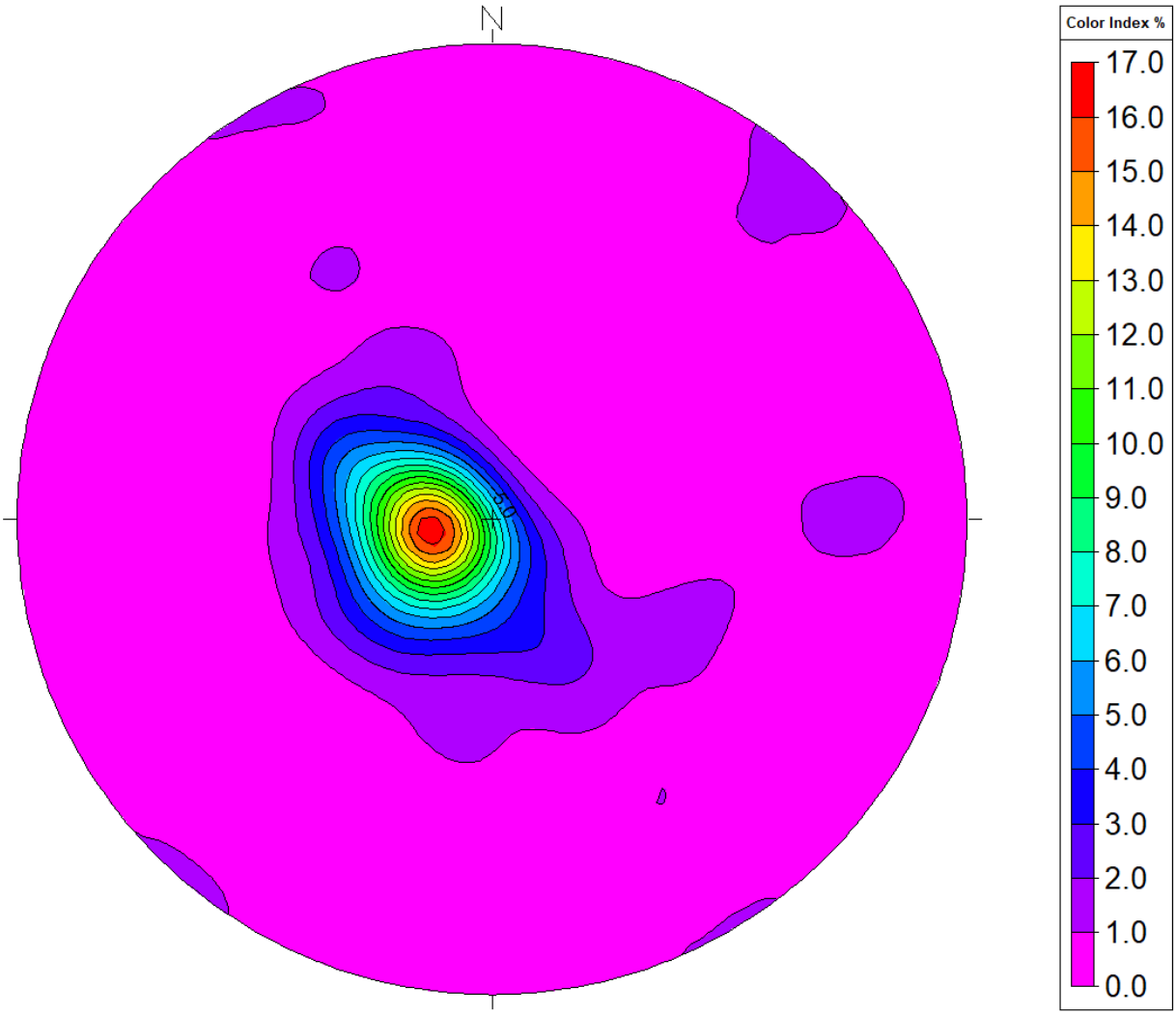

63
64
65
66
67
68
69
70


71
72
73
74
75
76
77
78
79


80
81
82
83
84
85
86
87

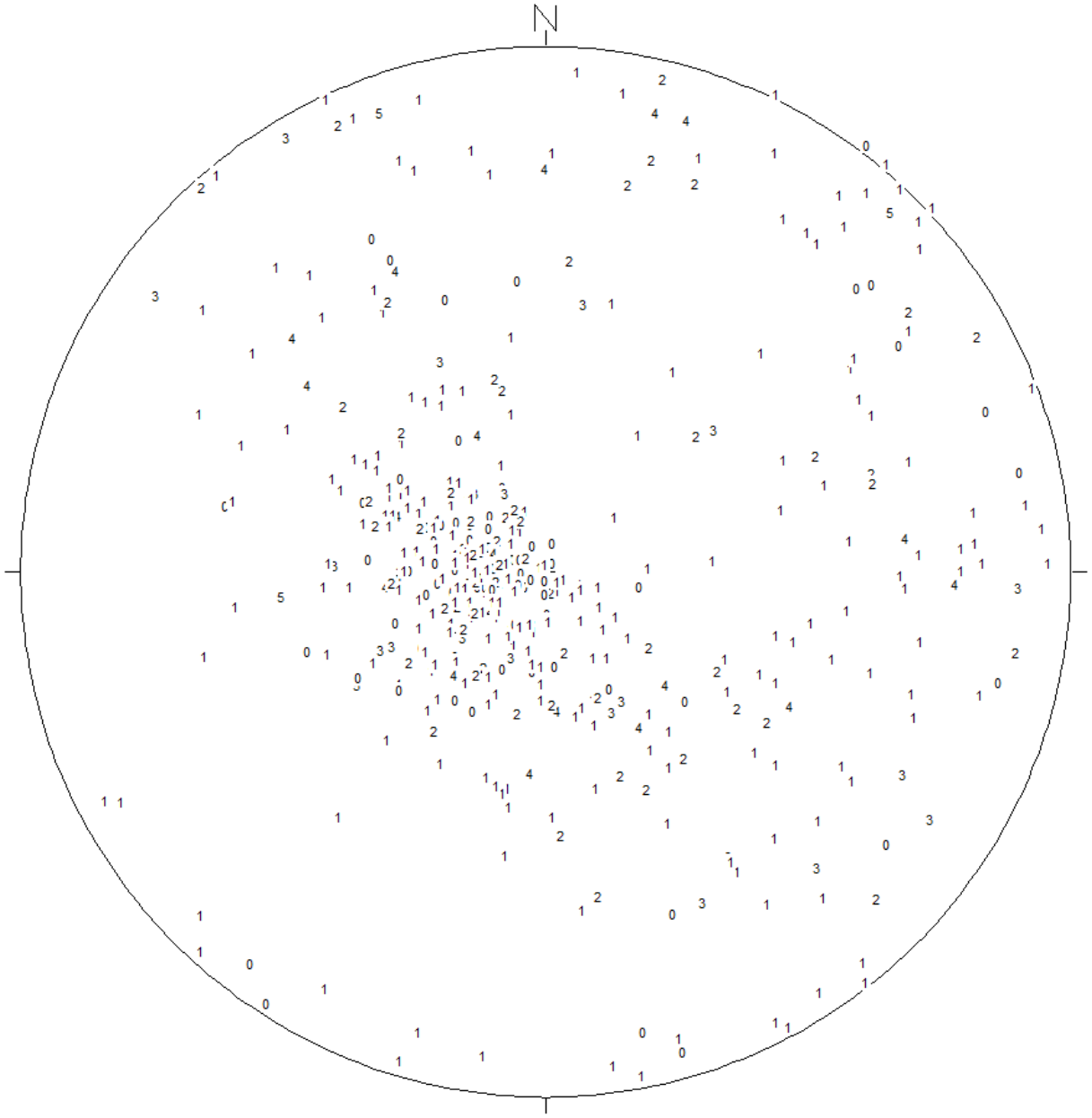

88
89
90
0
90
2
inch
7
Tadpoles - MN
3-Arm Caliper
0°
90°
180°
270°
0°
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
True Projections - MN
Depth
Apparent Projections
Optical Image - HS

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-08
6 June 2019



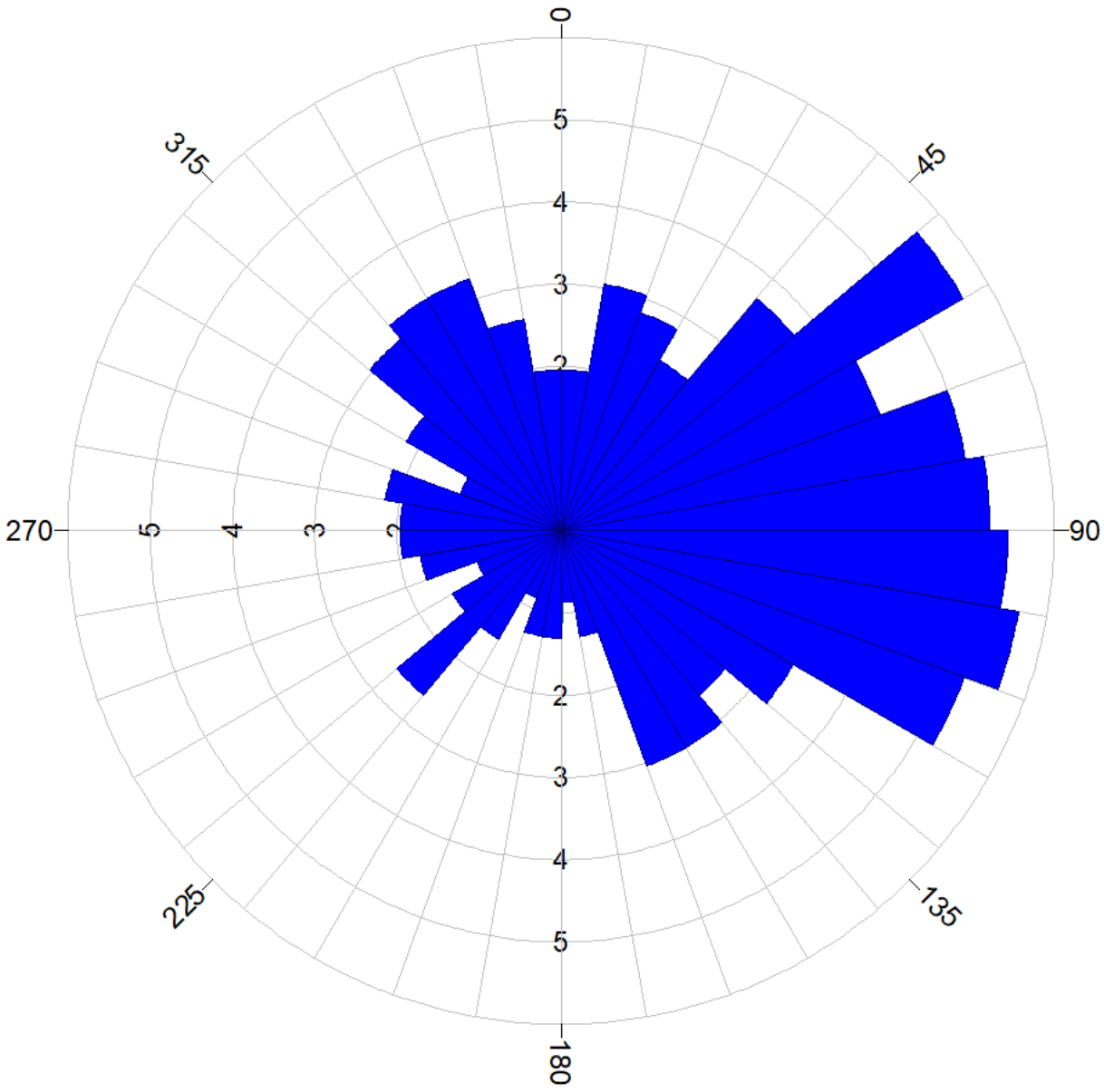
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-08
6 June 2019



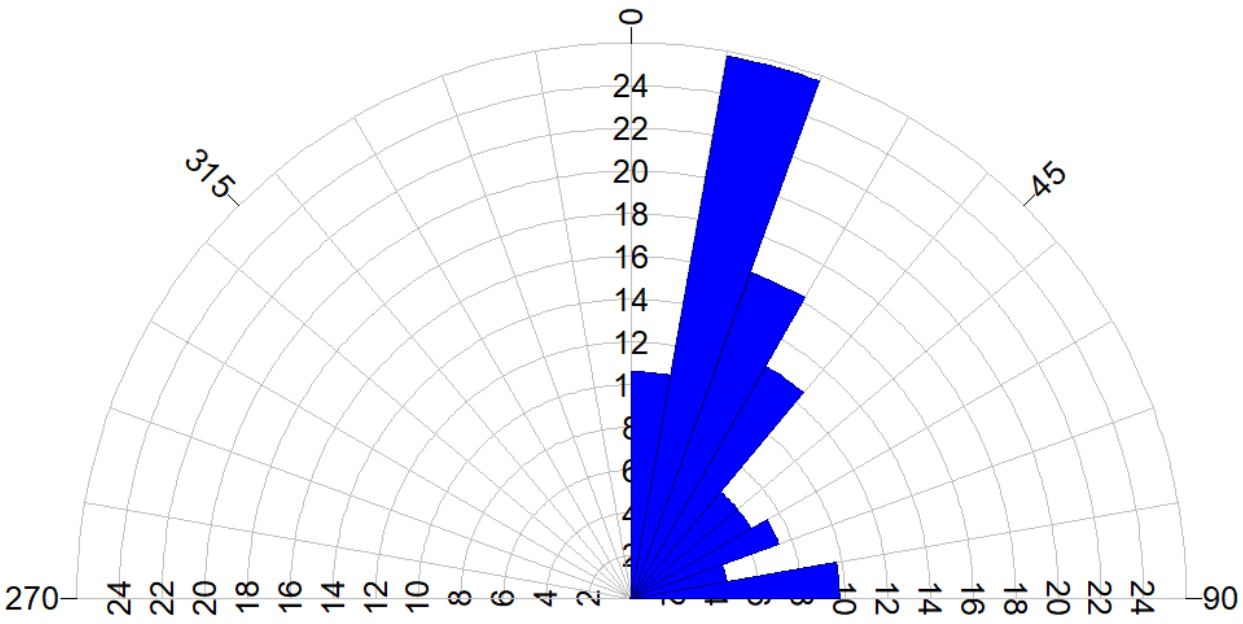
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-08
6 June 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-08
6 June 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	6.64	21.8	6	33	4
2	6.68	21.9	126	48	4
3	6.71	22.0	273	66	4
4	6.79	22.3	358	23	4
5	6.83	22.4	248	45	2
6	6.83	22.4	194	68	2
7	6.90	22.6	266	57	4
8	6.90	22.6	332	29	4
9	6.95	22.8	193	77	4
10	7.07	23.2	58	36	5
11	7.12	23.4	224	82	5
12	7.17	23.5	83	43	5
13	7.24	23.8	159	81	5
14	7.31	24.0	56	18	5
15	7.36	24.2	246	40	1
16	7.39	24.3	350	89	1
17	7.42	24.4	225	47	1
18	7.43	24.4	52	17	3
19	7.50	24.6	235	72	2
20	7.56	24.8	254	60	1
21	7.62	25.0	6	16	1
22	7.67	25.2	269	25	1
23	7.71	25.3	16	82	1
24	7.74	25.4	298	37	1
25	7.76	25.5	68	38	1
26	7.82	25.7	53	10	0
27	7.88	25.8	151	60	0
28	7.90	25.9	25	18	0
29	8.02	26.3	214	24	1
30	8.03	26.3	146	48	1
31	8.04	26.4	150	23	4
32	8.06	26.4	107	25	4
33	8.10	26.6	82	26	4
34	8.12	26.6	242	81	2
35	8.17	26.8	317	26	4
36	8.22	27.0	152	53	4
37	8.23	27.0	330	37	1
38	8.34	27.4	332	33	1
39	8.46	27.8	325	32	1
40	8.48	27.8	53	12	2
41	8.49	27.9	328	86	1
42	8.53	28.0	31	12	1
43	8.61	28.3	72	5	0
44	8.65	28.4	180	3	0
45	8.70	28.5	113	62	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	8.71	28.6	65	16	2
47	8.74	28.7	59	18	1
48	8.76	28.7	329	58	1
49	8.77	28.8	245.2	56.7	1
50	8.83	29.0	192.9	83.9	2
51	8.91	29.2	4.5	21.4	1
52	8.94	29.3	205.6	88.7	1
53	8.98	29.5	120.4	17.9	1
54	8.99	29.5	137.0	87.6	2
55	9.10	29.9	74.6	21.4	1
56	9.12	29.9	265.7	47.4	1
57	9.16	30.0	152.9	30.3	1
58	9.16	30.1	208.5	77.8	1
59	9.21	30.2	314.5	16.5	1
60	9.26	30.4	20.3	3.5	3
61	9.27	30.4	188.7	79.5	1
62	9.35	30.7	128.7	20.2	1
63	9.36	30.7	250.7	76.6	0
64	9.43	30.9	335.4	21.5	0
65	9.43	31.0	110.8	53.0	1
66	9.48	31.1	268.7	59.3	1
67	9.48	31.1	212.2	35.5	1
68	9.51	31.2	267.4	69.6	1
69	9.58	31.4	219.7	68.1	1
70	9.60	31.5	51.7	30.4	1
71	9.69	31.8	42.1	89.6	1
72	9.70	31.8	254.5	53.2	2
73	9.75	32.0	99.8	13.8	2
74	9.80	32.2	229.0	69.8	0
75	9.84	32.3	59.4	35.3	0
76	9.92	32.5	100.5	18.5	0
77	9.93	32.6	217.0	89.6	0
78	9.98	32.8	105.9	13.2	0
79	10.01	32.8	71.0	15.4	0
80	10.14	33.3	48.1	5.6	0
81	10.19	33.4	45.8	20.8	0
82	10.25	33.6	147.0	13.9	0
83	10.29	33.8	91.2	28.6	0
84	10.31	33.8	116.4	7.2	0
85	10.40	34.1	307.1	5.5	1
86	10.40	34.1	160.7	68.1	1
87	10.43	34.2	347.4	4.3	1
88	10.49	34.4	76.1	13.2	2
89	10.54	34.6	191.4	62.6	2
90	10.58	34.7	337.2	38.6	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	10.65	34.9	4.9	18.8	1
92	10.67	35.0	200.7	66.1	2
93	10.68	35.0	2.0	4.7	2
94	10.69	35.1	236.9	57.4	1
95	10.71	35.2	323.1	89.7	1
96	10.72	35.2	263.2	69.9	1
97	10.76	35.3	230.8	32.8	3
98	10.80	35.4	62.5	28.0	3
99	10.85	35.6	220.3	81.8	1
100	10.86	35.6	114.6	25.8	1
101	10.92	35.8	127.9	16.4	1
102	10.98	36.0	117.8	26.1	1
103	11.10	36.4	83.2	31.8	1
104	11.14	36.5	279.1	47.5	1
105	11.14	36.6	159.3	70.9	1
106	11.17	36.6	40.0	27.5	1
107	11.30	37.1	82.1	50.9	1
108	11.30	37.1	86.9	22.1	0
109	11.35	37.2	217.7	68.4	1
110	11.37	37.3	282.1	61.0	1
111	11.40	37.4	44.1	21.2	1
112	11.56	37.9	306.4	42.4	2
113	11.59	38.0	183.5	48.1	2
114	11.61	38.1	89.4	34.0	3
115	11.66	38.3	67.8	8.4	1
116	11.73	38.5	87.0	23.8	1
117	11.74	38.5	287.2	74.2	1
118	11.77	38.6	94.4	23.0	1
119	11.79	38.7	229.6	81.4	1
120	11.79	38.7	112.5	27.4	1
121	11.83	38.8	107.0	25.8	1
122	11.91	39.1	65.1	11.5	1
123	11.95	39.2	139.2	87.3	1
124	11.97	39.3	81.6	10.4	0
125	11.98	39.3	327.6	65.8	1
126	12.12	39.8	256.2	53.0	2
127	12.16	39.9	32.9	19.4	2
128	12.21	40.1	16	10	1
129	12.26	40.2	327	28	1
130	12.29	40.3	70	11	0
131	12.33	40.5	266	83	1
132	12.36	40.5	84	24	0
133	12.40	40.7	288	37	1
134	12.50	41.0	132	16	3
135	12.55	41.2	329	55	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	12.58	41.3	304	76	3
137	12.59	41.3	151	36	3
138	12.62	41.4	273	78	3
139	12.67	41.6	35	32	2
140	12.72	41.7	270	84	1
141	12.78	41.9	55	27	2
142	12.85	42.2	227	85	1
143	12.91	42.3	93	15	2
144	12.98	42.6	273	15	1
145	13.01	42.7	301	67	3
146	13.03	42.8	124	80	3
147	13.06	42.9	319	66	3
148	13.20	43.3	197	77	4
149	13.23	43.4	41	23	4
150	13.31	43.7	257	37	1
151	13.44	44.1	28	26	0
152	13.48	44.2	158	45	0
153	13.57	44.5	104	9	0
154	13.69	44.9	10	17	0
155	13.75	45.1	80	18	0
156	13.80	45.3	74	16	0
157	13.85	45.5	57	6	0
158	13.91	45.6	92	15	2
159	13.97	45.8	115	14	0
160	14.01	46.0	127	12	0
161	14.07	46.2	76	20	0
162	14.17	46.5	68	9	1
163	14.22	46.6	13	5	0
164	14.26	46.8	341	60	0
165	14.31	46.9	126	71	1
166	14.33	47.0	56	19	1
167	14.36	47.1	353	86	1
168	14.44	47.4	299	31	1
169	14.46	47.4	173	45	0
170	14.51	47.6	71	9	2
171	14.61	47.9	97	11	1
172	14.67	48.1	67	20	1
173	14.69	48.2	96	4	1
174	14.69	48.2	312	48	1
175	14.82	48.6	140	34	1
176	14.83	48.7	290	62	1
177	14.99	49.2	96	6	2
178	15.04	49.3	74	15	1
179	15.07	49.5	321	71	1
180	15.09	49.5	83	9	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	15.10	49.5	336	45	1
182	15.12	49.6	220	89	1
183	15.20	49.9	306	60	1
184	15.27	50.1	95	12	1
185	15.28	50.1	310	72	0
186	15.30	50.2	312	6	1
187	15.31	50.2	106	27	1
188	15.40	50.5	17	35	1
189	15.41	50.6	355	56	1
190	15.47	50.8	152	55	0
191	15.49	50.8	35	26	0
192	15.60	51.2	48	25	1
193	15.62	51.2	156	82	1
194	15.64	51.3	237	70	1
195	15.69	51.5	10	39	1
196	15.77	51.7	90	13	1
197	15.80	51.8	274	57	1
198	15.84	52.0	94	13	1
199	15.86	52.0	153	17	1
200	15.91	52.2	59	13	2
201	15.96	52.4	106	16	0
202	15.97	52.4	281	79	2
203	15.99	52.5	86	15	0
204	16.02	52.6	305	57	1
205	16.07	52.7	315	10	0
206	16.11	52.9	121	14	0
207	16.16	53.0	238	67	0
208	16.17	53.0	113	16	0
209	16.26	53.4	5	8	0
210	16.28	53.4	17	89	1
211	16.34	53.6	111	37	1
212	16.36	53.7	288	40	1
213	16.40	53.8	66	14	0
214	16.49	54.1	143	24	0
215	16.51	54.2	102	12	0
216	16.56	54.3	136	7	1
217	16.57	54.4	70	41	0
218	16.64	54.6	77	12	2
219	16.76	55.0	31	12	0
220	16.83	55.2	310	13	1
221	16.89	55.4	333	10	1
222	16.90	55.5	289	47	1
223	16.94	55.6	72	12	0
224	17.01	55.8	118	33	1
225	17.03	55.9	152	9	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	17.06	56.0	56	15	1
227	17.09	56.1	84	36	1
228	17.15	56.3	90	35	1
229	17.17	56.3	65	23	1
230	17.29	56.7	69	26	0
231	17.31	56.8	321	57	1
232	17.33	56.9	50	31	0
233	17.34	56.9	228	67	0
234	17.42	57.1	115	28	1
235	17.47	57.3	111	24	1
236	17.54	57.6	90	18	0
237	17.57	57.7	37	85	0
238	17.61	57.8	95	6	0
239	17.66	57.9	285	14	0
240	17.69	58.0	79	7	0
241	17.71	58.1	100	53	0
242	17.71	58.1	334	87	1
243	17.72	58.2	324	3	1
244	17.84	58.5	345	83	1
245	17.85	58.6	21	3	0
246	17.87	58.6	118	14	2
247	18.03	59.2	46	11	0
248	18.07	59.3	109	18	0
249	18.11	59.4	71	2	1
250	18.20	59.7	131	4	0
251	18.22	59.8	169	69	1
252	18.27	60.0	95	15	1
253	18.39	60.3	74	14	1
254	18.39	60.3	200	71	1
255	18.42	60.4	118	31	1
256	18.48	60.6	82	11	1
257	18.53	60.8	87	23	1
258	18.59	61.0	137	54	1
259	18.61	61.1	329	6	1
260	18.66	61.2	293	64	1
261	18.71	61.4	88	10	1
262	18.75	61.5	9	47	1
263	18.78	61.6	25	14	1
264	18.80	61.7	15	11	1
265	18.85	61.9	11	36	1
266	18.95	62.2	336	16	1
267	18.96	62.2	145	30	1
268	19.01	62.4	144	8	2
269	19.17	62.9	234	12	1
270	19.19	63.0	349	80	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	19.21	63.0	59	11	1
272	19.26	63.2	236	59	1
273	19.27	63.2	102	30	1
274	19.35	63.5	102	11	1
275	19.47	63.9	99	12	1
276	19.53	64.1	24	24	1
277	19.53	64.1	165	24	1
278	19.60	64.3	91	15	1
279	19.62	64.4	76	12	2
280	19.65	64.5	106	16	1
281	19.65	64.5	322	86	1
282	19.67	64.5	109	35	1
283	19.82	65.0	111	19	1
284	19.87	65.2	106	20	0
285	19.87	65.2	28	81	1
286	19.89	65.3	154	88	1
287	19.93	65.4	31	13	1
288	20.03	65.7	31	11	0
289	20.06	65.8	51	4	0
290	20.11	66.0	285	77	0
291	20.14	66.1	104	10	0
292	20.25	66.4	108	31	0
293	20.26	66.5	97	5	0
294	20.40	66.9	119	27	0
295	20.46	67.1	107	19	1
296	20.52	67.3	55	10	2
297	20.56	67.5	332	24	1
298	20.60	67.6	348	23	1
299	20.64	67.7	71	9	2
300	20.70	67.9	3	9	1
301	20.74	68.0	79	11	1
302	20.78	68.2	65	14	1
303	20.80	68.3	46	12	1
304	20.84	68.4	128	0	0
305	20.86	68.4	85	9	0
306	20.90	68.6	40	53	1
307	20.91	68.6	97	18	1
308	21.02	69.0	83	12	1
309	21.05	69.1	259	80	0
310	21.11	69.3	96	21	1
311	21.13	69.3	99	11	0
312	21.14	69.4	254	45	1
313	21.20	69.6	45	84	1
314	21.21	69.6	55	13	1
315	21.24	69.7	66	10	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
316	21.28	69.8	57	24	0
317	21.39	70.2	103	26	1
318	21.45	70.4	147	52	1
319	21.46	70.4	12	37	1
320	21.47	70.5	101	52	1
321	21.52	70.6	183	83	1
322	21.53	70.6	351	24	1
323	21.63	71.0	313	44	1
324	21.67	71.1	117	25	1
325	21.68	71.1	343	22	1
326	21.76	71.4	312	10	1
327	21.76	71.4	289	54	1
328	21.92	71.9	142	32	1
329	21.92	71.9	8	84	1
330	21.94	72.0	148	32	1
331	22.02	72.2	283	42	1
332	22.02	72.3	36	23	1
333	22.08	72.4	135	10	2
334	22.09	72.5	214	68	1
335	22.15	72.7	40	30	1
336	22.20	72.8	223	87	1
337	22.24	73.0	345	26	1
338	22.26	73.0	117	47	1
339	22.33	73.3	170	36	1
340	22.41	73.5	111	22	1
341	22.43	73.6	43	38	1
342	22.47	73.7	116	22	1
343	22.60	74.2	20	10	1
344	22.62	74.2	14	36	1
345	22.64	74.3	314	60	1
346	22.65	74.3	344	3	1
347	22.71	74.5	68	16	1
348	22.77	74.7	83	1	1
349	22.79	74.8	61	83	1
350	22.84	74.9	129	30	1
351	22.90	75.1	80	24	1
352	22.93	75.2	57	11	1
353	22.97	75.4	70	7	1
354	23.01	75.5	53	7	1
355	23.13	75.9	61	32	1
356	23.18	76.1	115	7	1
357	23.26	76.3	78	7	1
358	23.38	76.7	131	19	1
359	23.47	77.0	118	35	1
360	23.47	77.0	29	20	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
361	23.54	77.2	360	22	2
362	23.59	77.4	84	10	1
363	23.60	77.4	221	74	1
364	23.62	77.5	342	35	2
365	23.62	77.5	105	21	2
366	23.66	77.6	83	25	2
367	23.77	78.0	164	81	1
368	23.78	78.0	127	41	2
369	23.85	78.3	322	13	1
370	23.87	78.3	122	32	1
371	23.88	78.4	263	80	1
372	23.91	78.5	95	21	1
373	23.95	78.6	145	10	2
374	24.00	78.7	164	28	2
375	24.03	78.8	112	9	2
376	24.06	79.0	64	23	1
377	24.10	79.1	229	30	2
378	24.15	79.2	125	19	2
379	24.19	79.4	129	16	1
380	24.19	79.4	180	67	1
381	24.22	79.5	358	43	2
382	24.22	79.5	47	11	2
383	24.27	79.6	271	67	1
384	24.32	79.8	49	24	1
385	24.32	79.8	140	61	1
386	24.38	80.0	23	22	1
387	24.45	80.2	34	21	2
388	24.48	80.3	48	11	1
389	24.54	80.5	131	31	2
390	24.62	80.8	303	31	2
391	24.62	80.8	102	28	2
392	24.66	80.9	101	4	2
393	24.71	81.1	75	58	1
394	24.71	81.1	70	7	1
395	24.73	81.1	360	40	1
396	24.79	81.3	96	12	2
397	24.84	81.5	306	34	1
398	24.90	81.7	326	37	2
399	24.91	81.7	50	18	3
400	24.93	81.8	352	54	2
401	25.00	82.0	100	9	4
402	25.04	82.2	131	55	4
403	25.05	82.2	301	44	4
404	25.15	82.5	179	64	4
405	25.18	82.6	53	17	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
406	25.26	82.9	163	30	2
407	25.28	82.9	298	40	1
408	25.29	83.0	13	24	2
409	25.32	83.1	154	82	2
410	25.32	83.1	270	71	1
411	25.35	83.2	67	18	2
412	25.40	83.3	62	86	1
413	25.41	83.4	91	20	1
414	25.46	83.5	57	14	2
415	25.51	83.7	76	15	1
416	25.62	84.1	55	24	1
417	25.63	84.1	352	14	2
418	25.69	84.3	330	17	1
419	25.69	84.3	272	56	1
420	25.78	84.6	27	11	1
421	25.81	84.7	90	7	1
422	25.84	84.8	268	67	1
423	25.85	84.8	250	87	1
424	25.89	84.9	40	15	1
425	26.01	85.3	11	16	1
426	26.01	85.3	242	56	1
427	26.02	85.4	297	8	1
428	26.05	85.5	125	59	1
429	26.10	85.6	316	30	0
430	26.15	85.8	349	36	1
431	26.16	85.8	218	78	1
432	26.19	85.9	193	42	1
433	26.25	86.1	89	8	2
434	26.34	86.4	311	20	2
435	26.34	86.4	329	56	1
436	26.38	86.6	333	89	1
437	26.45	86.8	358	16	0
438	26.51	87.0	119	11	0
439	26.59	87.2	82	17	1
440	26.64	87.4	102	11	1
441	26.69	87.6	33	90	0
442	26.79	87.9	15	14	1
443	26.85	88.1	53	10	1
444	26.89	88.2	130	8	1
445	26.90	88.2	345	86	0
446	26.96	88.5	316	78	2
447	27.01	88.6	146	13	3
448	27.03	88.7	63	30	3
449	27.04	88.7	338	25	3
450	27.06	88.8	187	41	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-08

6 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
451	27.09	88.9	227	89	1
452	27.11	88.9	333	24	3
453	27.18	89.2	23	16	3
454	27.21	89.3	148	49	2
455	27.23	89.4	29	36	1
456	27.25	89.4	171	64	1
457	27.32	89.6	336	60	3
458	27.34	89.7	137	66	1
459	27.38	89.8	308	37	2
460	27.51	90.3	148	85	3
461	27.53	90.3	109	30	2
462	27.59	90.5	341	22	2

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-08
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-08
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.788830 N
Longitude: 84.77656 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 584.3'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	6 June 2019	6 June 2019	6 June 2019	
RUN NUMBER	1	1	1	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	113'	113'	113'	
DEPTH-LOGGER	91'	91'	91'	
BTM LOG INTERVAL	91.2'	89.5'	88.4'	
TOP LOG INTERVAL	0.0'	15.7'	3.8'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP	
PROBE TYPE, S/N	2PFA #5969	Comprobe #5238	ELXG #4248	
LOGGING SPEED	10 ft/min	10 ft/min	10 ft/min	
A.S.D.E. / Sample Interval	.0.06' / 0.10'	0.11' / 0.10'	0.05' / 0.25'	
Fluid Level / Fluid Type	2' / water	2' / water	2' / water	

BOREHOLE RECORD

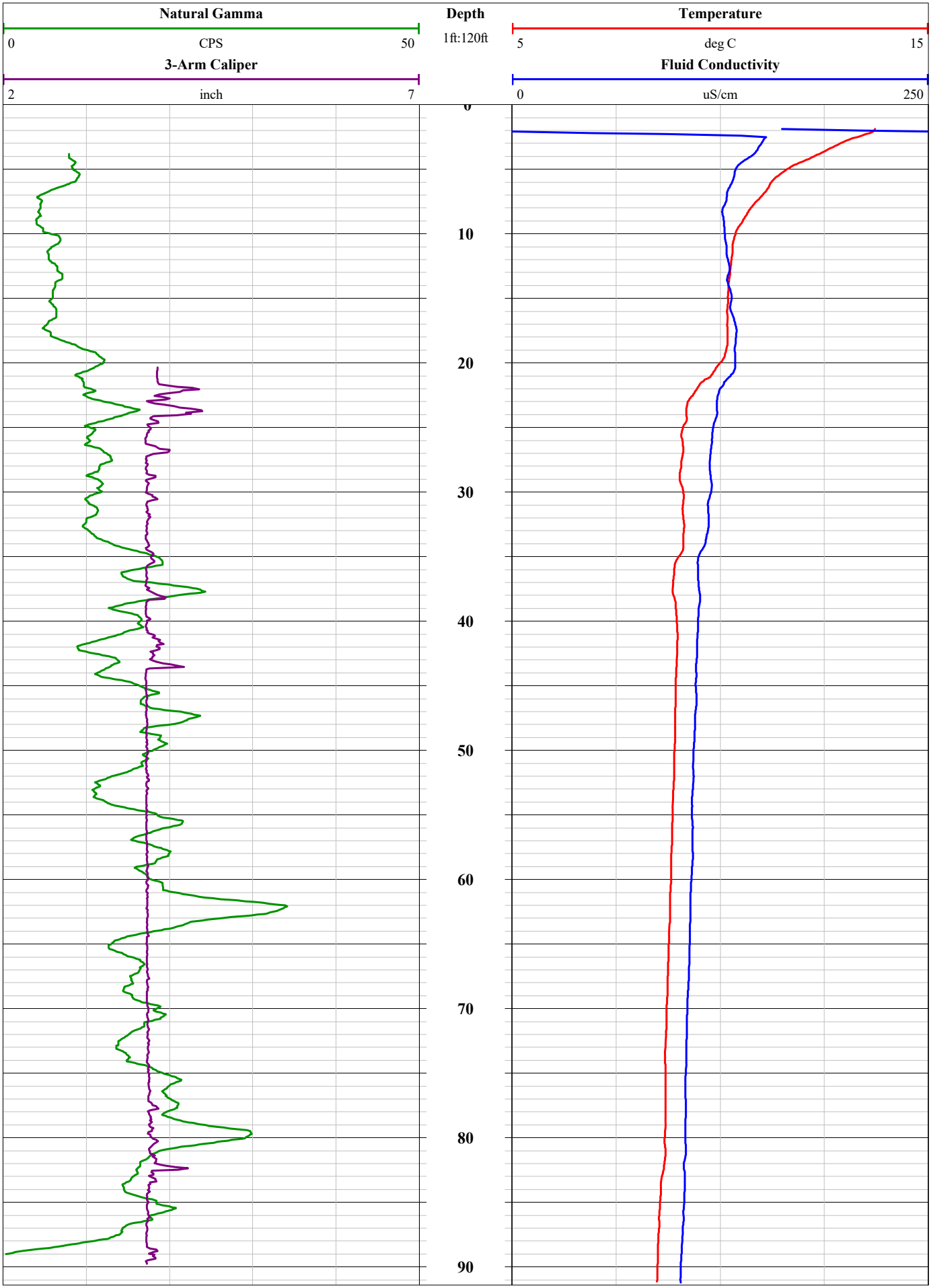
RUN No.	BIT	FROM	TO
1	HQ	22'	105'
1	NQ	105'	113'

CASING RECORD

SIZE	WGT.	FROM	TO
6"	Steel	GL	20'
HWT	Steel	GL	22'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
50
3-Arm Caliper
2
inch
7
Depth
1ft:120ft
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
250
0
10
20
30
40
50
60
70
80
90

Borehole Deviation

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

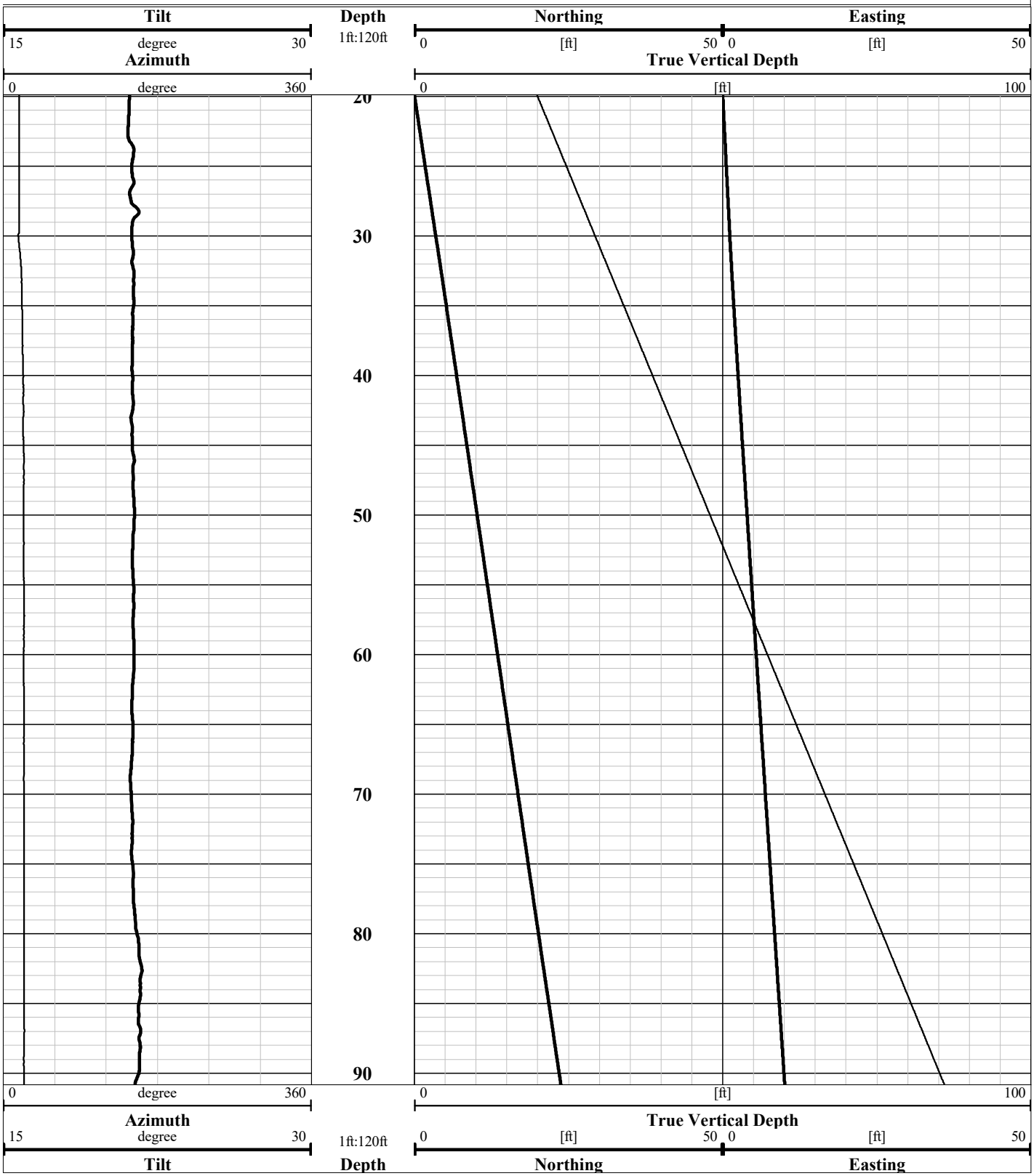
COLOG
borehole geophysics / hydrophysics

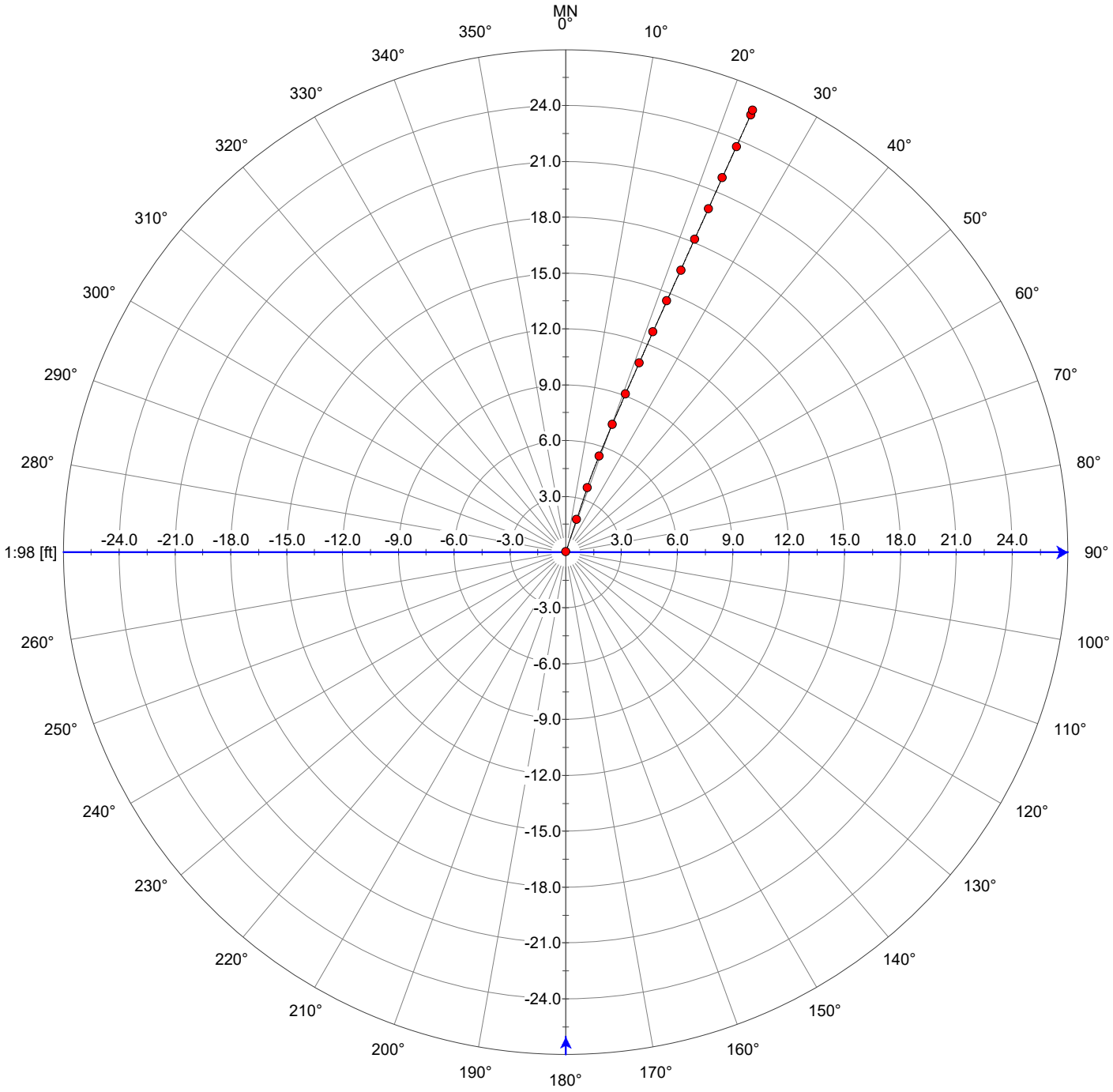
COMPANY: WSP | **PROJECT:** L5RT Project

DATE LOGGED: 6 June 2019 | **WELL:** BH19-08 - South Shore

COMMENTS:

Straits of Mackinac Elevation: 584.3' Latitude: 45.78830 N Longitude: 84.77656 W




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
-3.0
-6.0
-9.0
-12.0
-15.0
-18.0
-21.0
-24.0
1:98 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-08
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-08
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.788830 N
Longitude: 84.77656 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM GL **ELEVATION** 584.3'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	6 June 2019	6 June 2019		
RUN NUMBER	1	1		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	113'	113'		
DEPTH-LOGGER	91'	91'		
BTM LOG INTERVAL	88.4'	89.9'		
TOP LOG INTERVAL	3.8'	22.8'		
RECORDED BY	JBG	JBG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	ELXG #4248	ELXG #4248		
LOGGING SPEED	10 ft/min	10 ft/min		
A.S.D.E. / Sample Interval	0.05' / 0.25'	0.05' / 0.25'		
Fluid Level / Fluid Type	2' / water	2' / water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	22'	105'
1	NQ	105'	113'

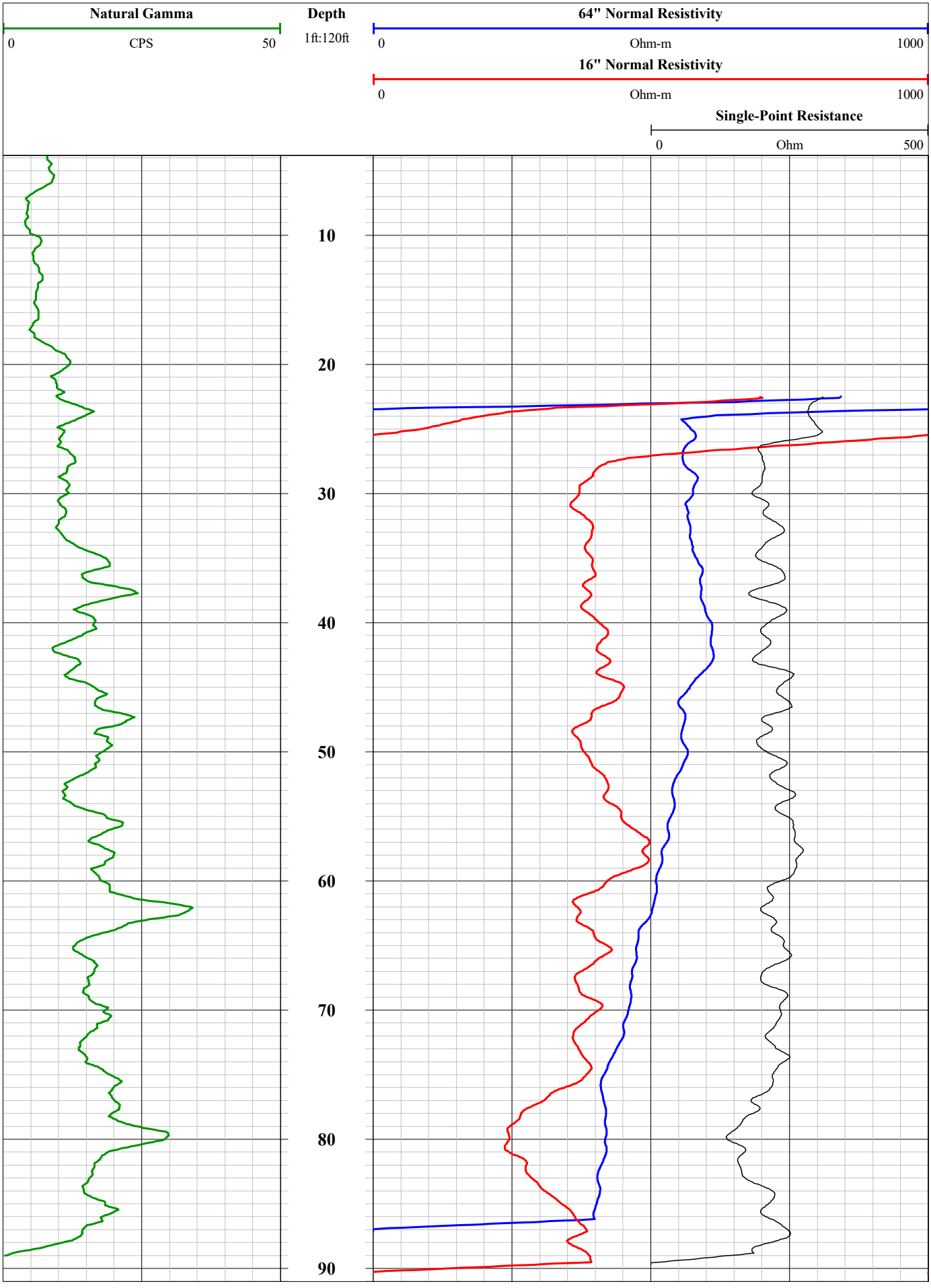
CASING RECORD

SIZE	WGT.	FROM	TO
6"	Steel	GL	20'
HWT	Steel	GL	22'

NA - Not Available, N/A - Not Applicable

COMMENTS

Spontaneous Potential omitted due to configuration error


Natural Gamma
0
CPS
50
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
1000
16" Normal Resistivity
0
Ohm-m
1000
Single-Point Resistance
0
Ohm
500
10
20
30
40
50
60
70
80
90

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-08
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-08
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.788830 N
Longitude: 84.77656 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond
Electrical Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 584.3'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	6 June 2019			
RUN NUMBER	1			
LOG TYPE	P&S log			
DEPTH-DRILLER	113'			
DEPTH-LOGGER	91'			
BTM LOG INTERVAL	79'			
TOP LOG INTERVAL	23'			
RECORDED BY	JBG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	PSlogger #10926			
LOGGING SPEED	stationary			
A.S.D.E. / Sample Interval	?' / 2.0'			
Fluid Level / Fluid Type	2' / water			

BOREHOLE RECORD

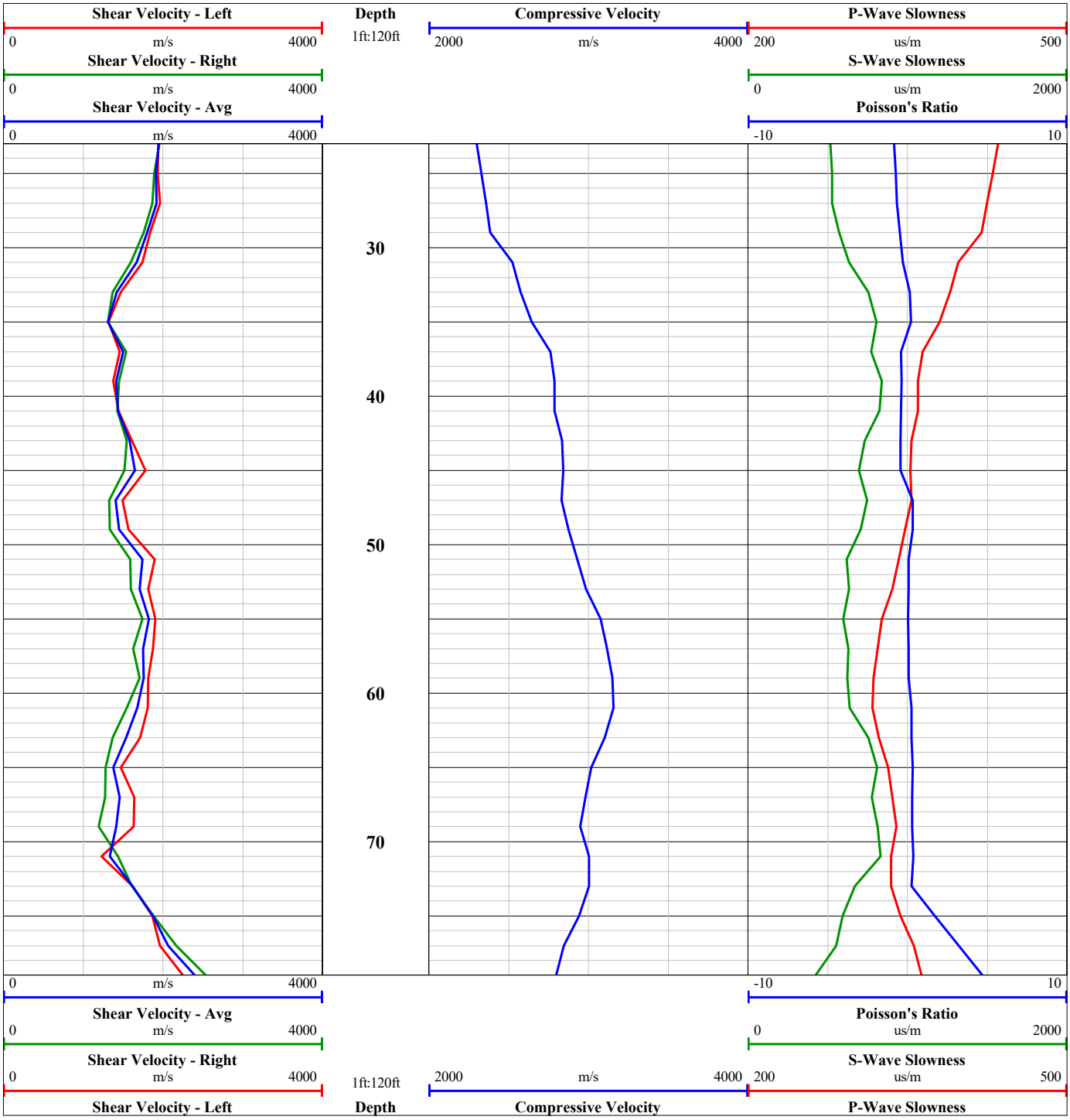
RUN No.	BIT	FROM	TO
1	HQ	22'	105'
1	NQ	105'	113'

CASING RECORD

SIZE	WGT.	FROM	TO
6"	Steel	GL	20'
HWT	Steel	GL	22'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
30
40
50
60
70
Compressive Velocity
2000
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-10
10
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
Depth
1ft:120ft
2000
m/s
4000
Compressive Velocity
-10
10
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness

PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-08**	Test depth:	**38.00 ft**
Test date: (mm/dd/yyyy)	**6/6/2019**	C :	1.0011 cc/MPa
Test number:	1	Poisson's coefficient	0.20

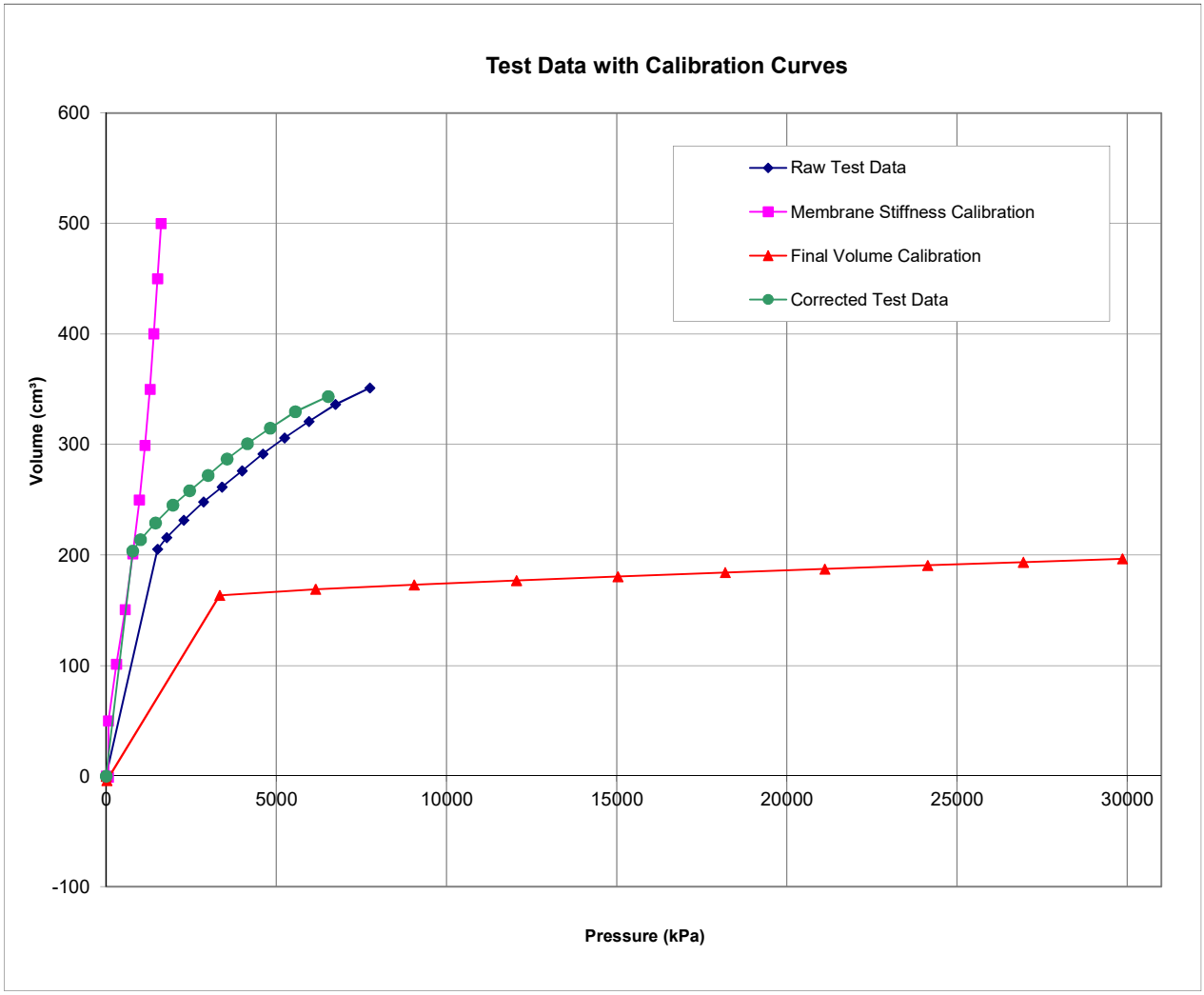
Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	$\Delta R/R_{0\ Probe}$ %
0	0.00	0	0.00	0.00
1511	205.19	781	203.67	5.18
1781	215.77	1007	213.99	5.44
2286	231.42	1450	229.13	5.81
2865	248.05	1961	245.18	6.21
3403	261.50	2454	258.10	6.53
3995	276.11	2996	272.11	6.87
4606	291.57	3556	286.96	7.23
5243	306.04	4148	300.79	7.57
5959	320.90	4822	314.93	7.91
6741	336.41	5560	329.66	8.26
7746	351.20	6524	343.44	8.60

Test Results

PROBEX Modulus E:	**206,308 kPa**
Ultimate Pressure P_L:	**n.a.**
Ratio E / P_L:	**n.a.**

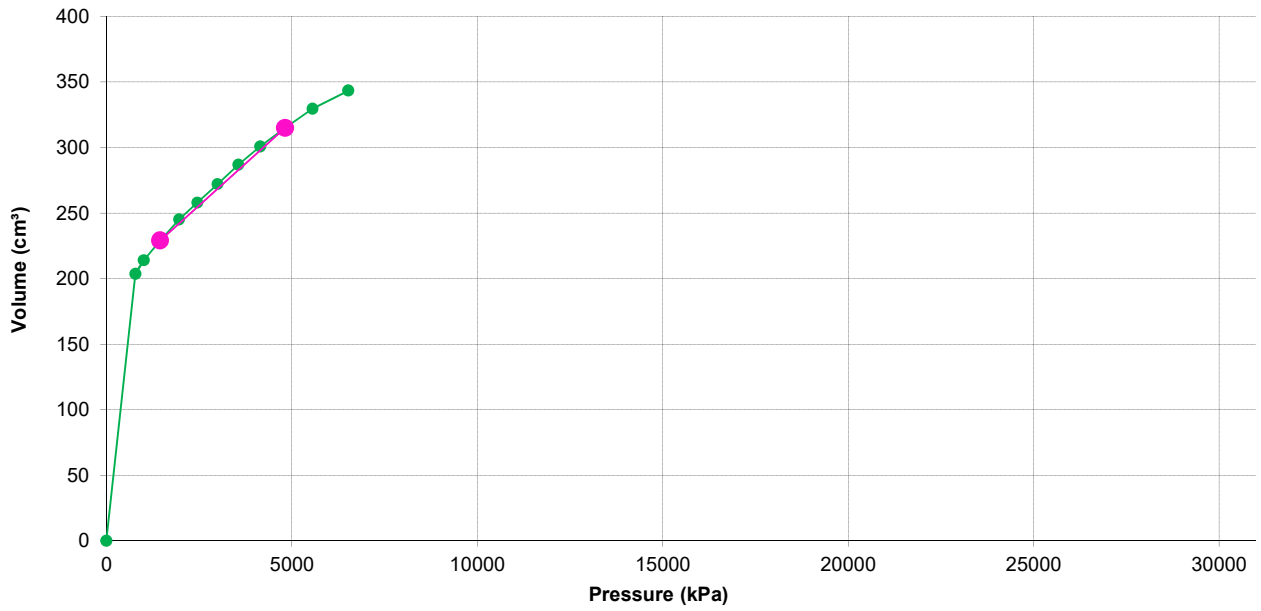
Volume & Pressure Calibrations ID

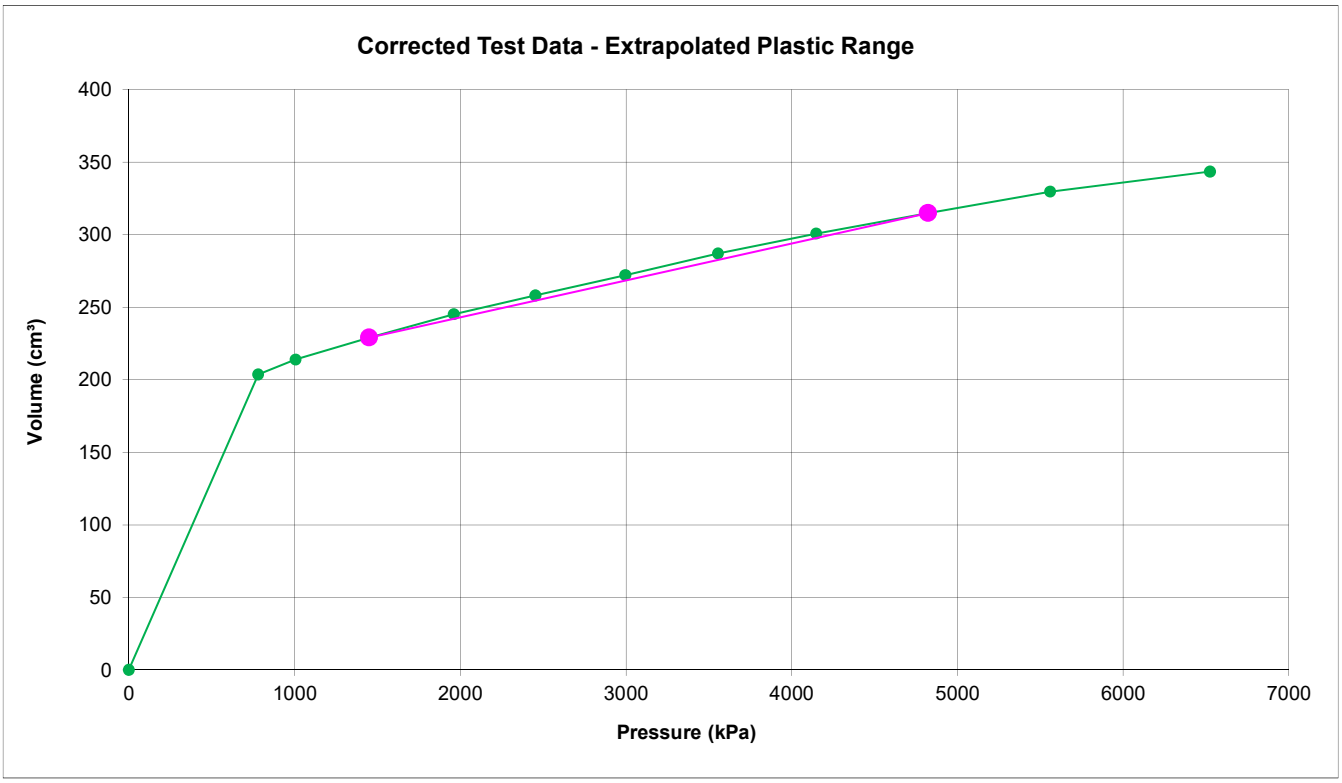
CalV3	CalP1



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-08**	Test depth:	**38.00 ft**
Test date: (mm/dd/yyyy)	**6/6/2019**	C :	1.0011 cc/MPa
Test number:	1	Poisson's coefficient	0.20





PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-08**	Test depth:	**110.00 ft**
Test date: (mm/dd/yyyy)	**6/6/2019**	C :	1.0011 cc/MPa
Test number:	1	Poisson's coefficient	0.20

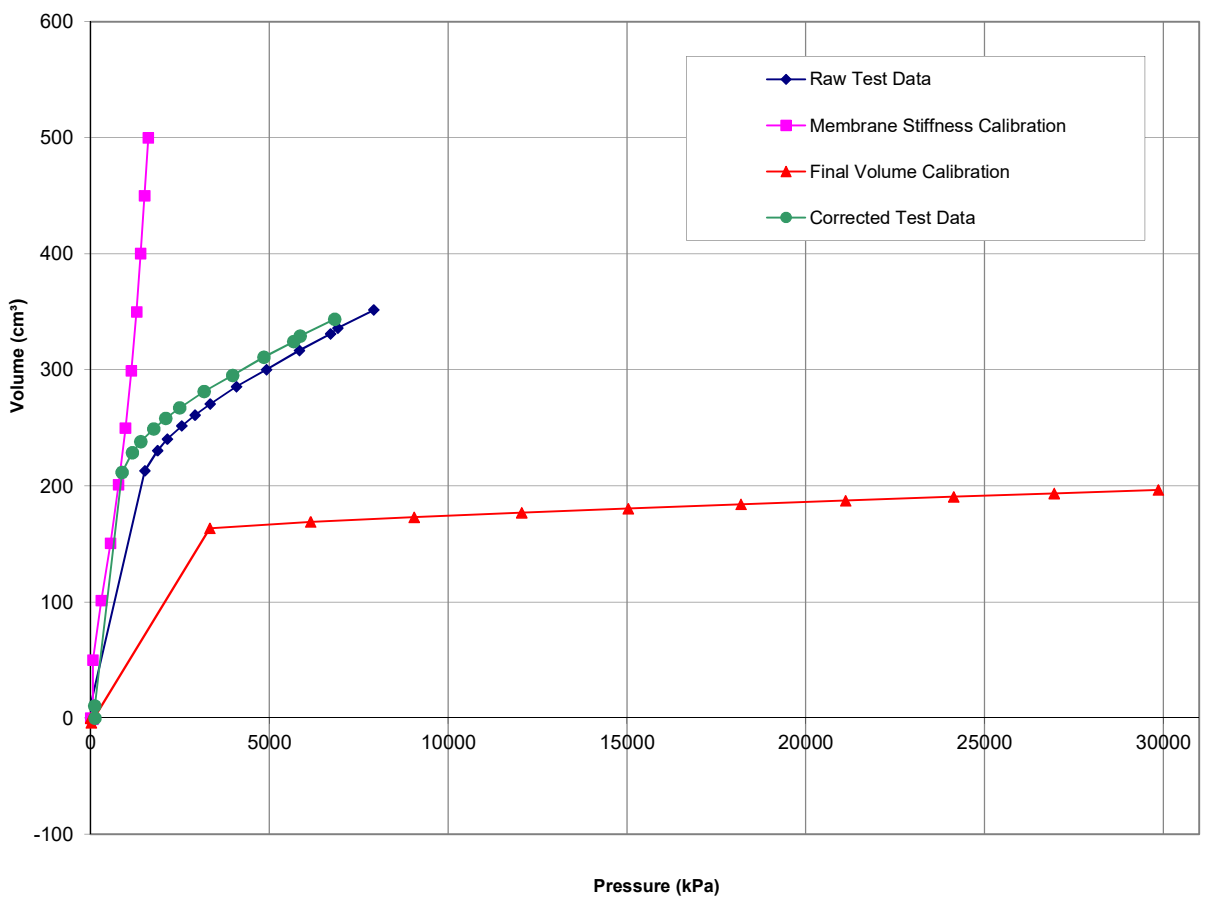
Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	$\Delta R/R_{0\ Probe}$ %
0	0.00	125	0.00	0.00
-7	10.41	118	10.42	0.27
1518	213.18	884	211.66	5.38
1873	230.58	1169	228.70	5.80
2149	240.37	1405	238.22	6.04
2556	251.69	1768	249.13	6.31
2924	261.15	2105	258.22	6.53
3344	270.56	2494	267.21	6.75
4080	285.50	3180	281.41	7.10
4921	300.11	3972	295.19	7.43
5841	316.78	4845	310.93	7.81
6715	331.01	5678	324.29	8.14
6912	336.04	5861	329.12	8.25
7924	351.59	6830	343.66	8.60

Test Results

PROBEX Modulus E:	**296,060 kPa**
Ultimate Pressure P_L:	**n.a.**
Ratio E / P_L:	**n.a.**

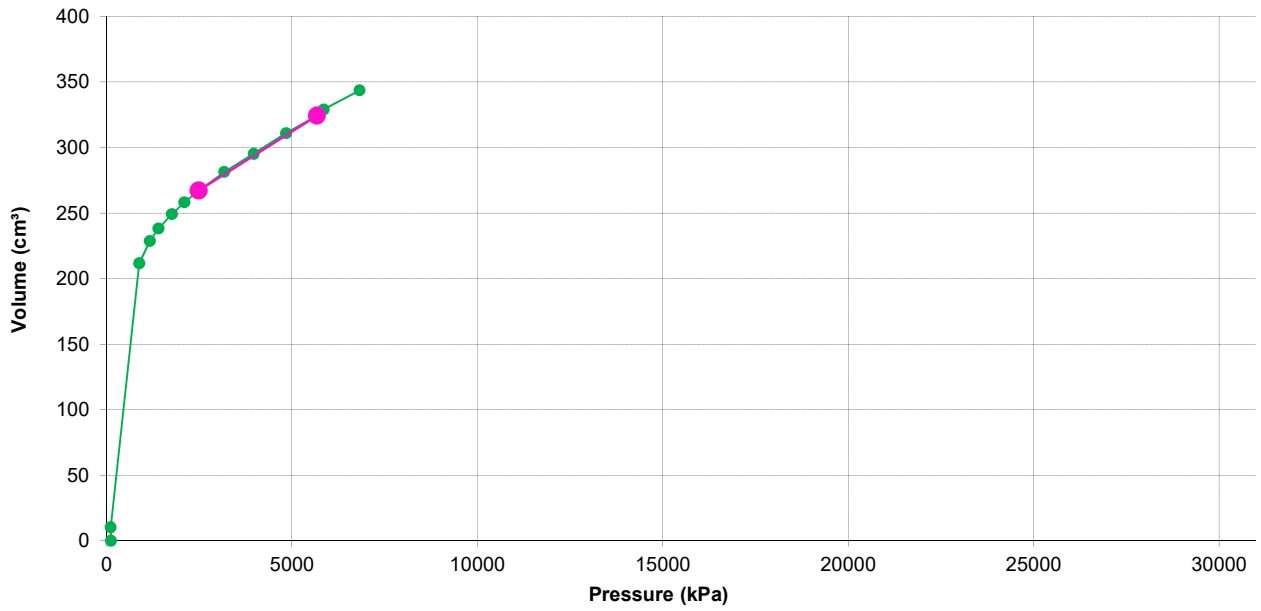
Volume & Pressure Calibrations ID

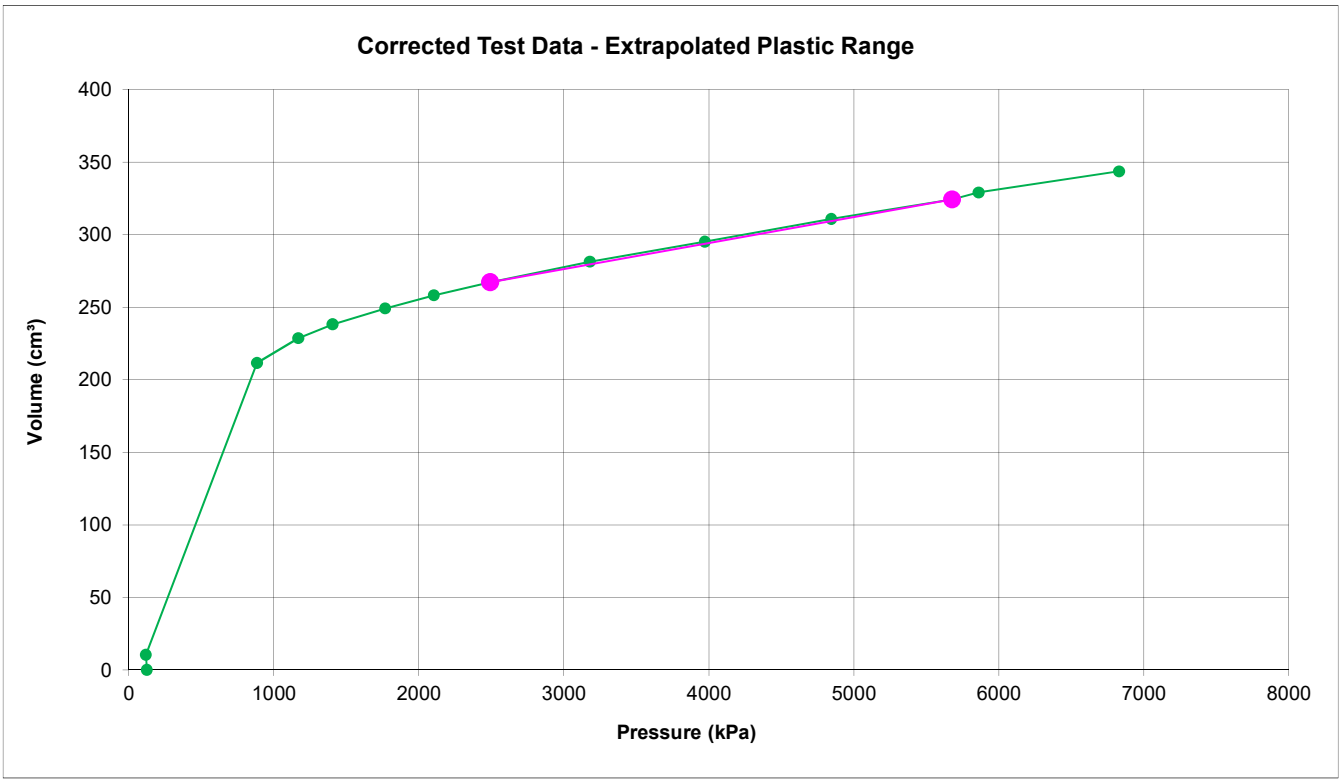
CalV3	CalP1



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-08**	Test depth:	**110.00 ft**
Test date: (mm/dd/yyyy)	**6/6/2019**	C :	1.0011 cc/MPa
Test number:	1	Poisson's coefficient	0.20





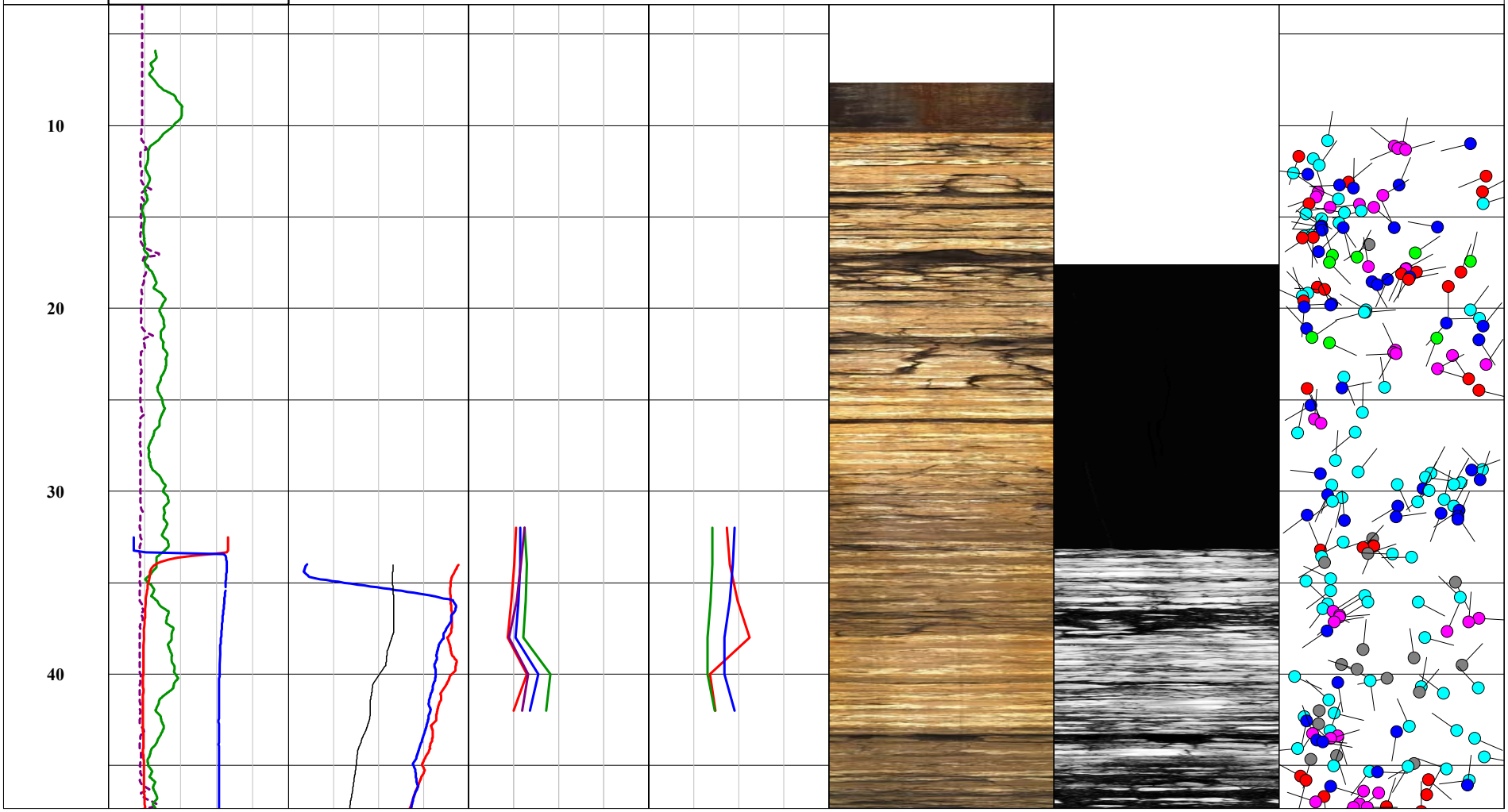
Geophysical Summary Plot

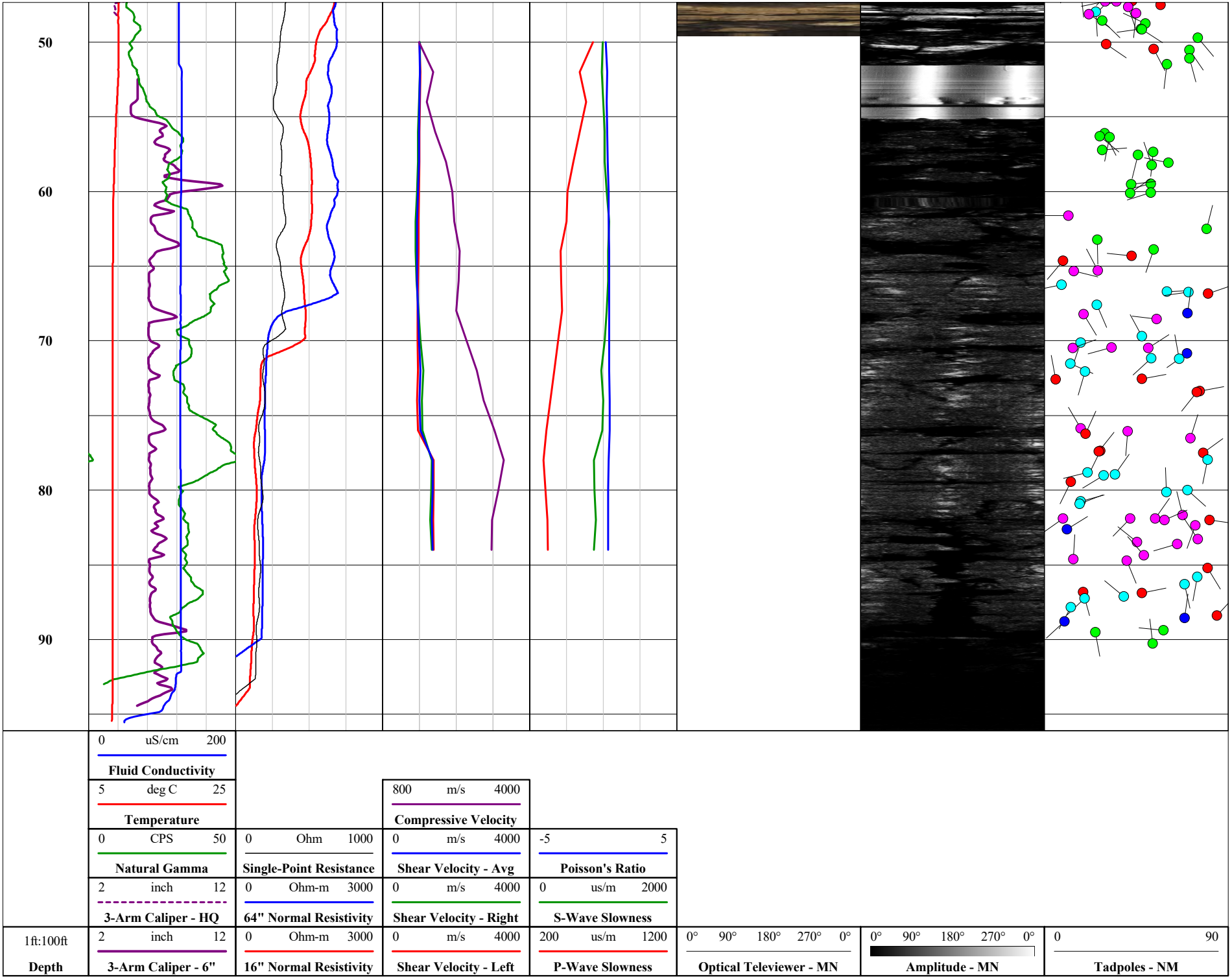
COLOG
borehole geophysics / hydrophysics

COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 7, 8, 19 June 2019
WELL: BH19-09 - South Shore

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	3-Arm Caliper - 6"	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Televiewer - MN	Amplitude - MN	Tadpoles - NM
1ft:100ft	2 inch 12	0 Ohm-m 3000	0 m/s 4000	200 us/m 1200	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper - HQ	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 inch 12	0 Ohm-m 3000	0 m/s 4000	0 us/m 2000			
	Natural Gamma	Single-Point Resistance	Shear Velocity - Avg	Poisson's Ratio			
	0 CPS 50	0 Ohm 1000	0 m/s 4000	-5 5			
	Temperature		Compressive Velocity				
	5 deg C 25		800 m/s 4000				
	Fluid Conductivity						
	0 uS/cm 200						




50
60
70
80
90
0 uS/cm 200
Fluid Conductivity
5 deg C 25
Temperature
0 CPS 50
Natural Gamma
2 inch 12
3-Arm Caliper - HQ
2 inch 12
3-Arm Caliper - 6"
0 Ohm 1000
Single-Point Resistance
0 Ohm-m 3000
64" Normal Resistivity
0 Ohm-m 3000
16" Normal Resistivity
800 m/s 4000
Compressive Velocity
0 m/s 4000
Shear Velocity - Avg
0 m/s 4000
Shear Velocity - Right
0 m/s 4000
Shear Velocity - Left
-5 5
Poisson's Ratio
0 us/m 2000
S-Wave Slowness
200 us/m 1200
P-Wave Slowness
0° 90° 180° 270° 0°
Optical Televiewer - MN
0° 90° 180° 270° 0°
Amplitude - MN
0 90
Tadpoles - NM
1ft:100ft
Depth

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-09
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-09
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78736 N
Longitude: 84.77692 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 619.2'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	7 June 2019	19 June 2019		
RUN NUMBER	1	1		
LOG TYPE	Acoustic Televiewer	Acoustic Televiewer		
DEPTH-DRILLER	103'	95'		
DEPTH-LOGGER	49'	95'		
BTM LOG INTERVAL	51.8'	96.9'		
TOP LOG INTERVAL	32.0'			
RECORDED BY	JBG	JBG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	ATV LIM #1729	ATV LIM #1729		
LOGGING SPEED	3 ft/min	3 ft/min		
A.S.D.E. / Sample Interval	0.00' / 0.25'	0.26' / 0.0024'		
Fluid Level / Fluid Type	33' / water	33' / water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	10'	95'
1	NQ	95'	103'
2	6"	GL	95'

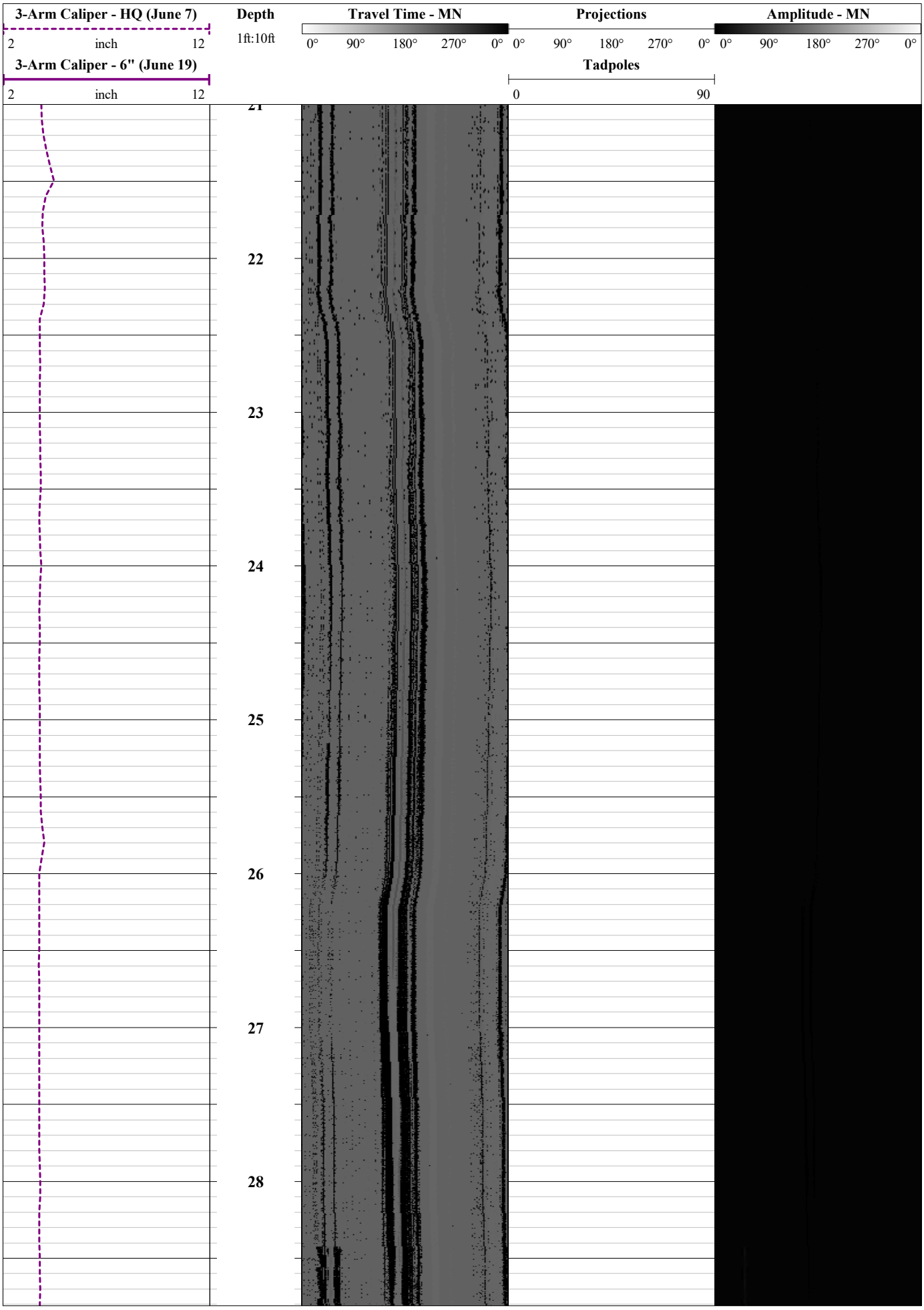
CASING RECORD

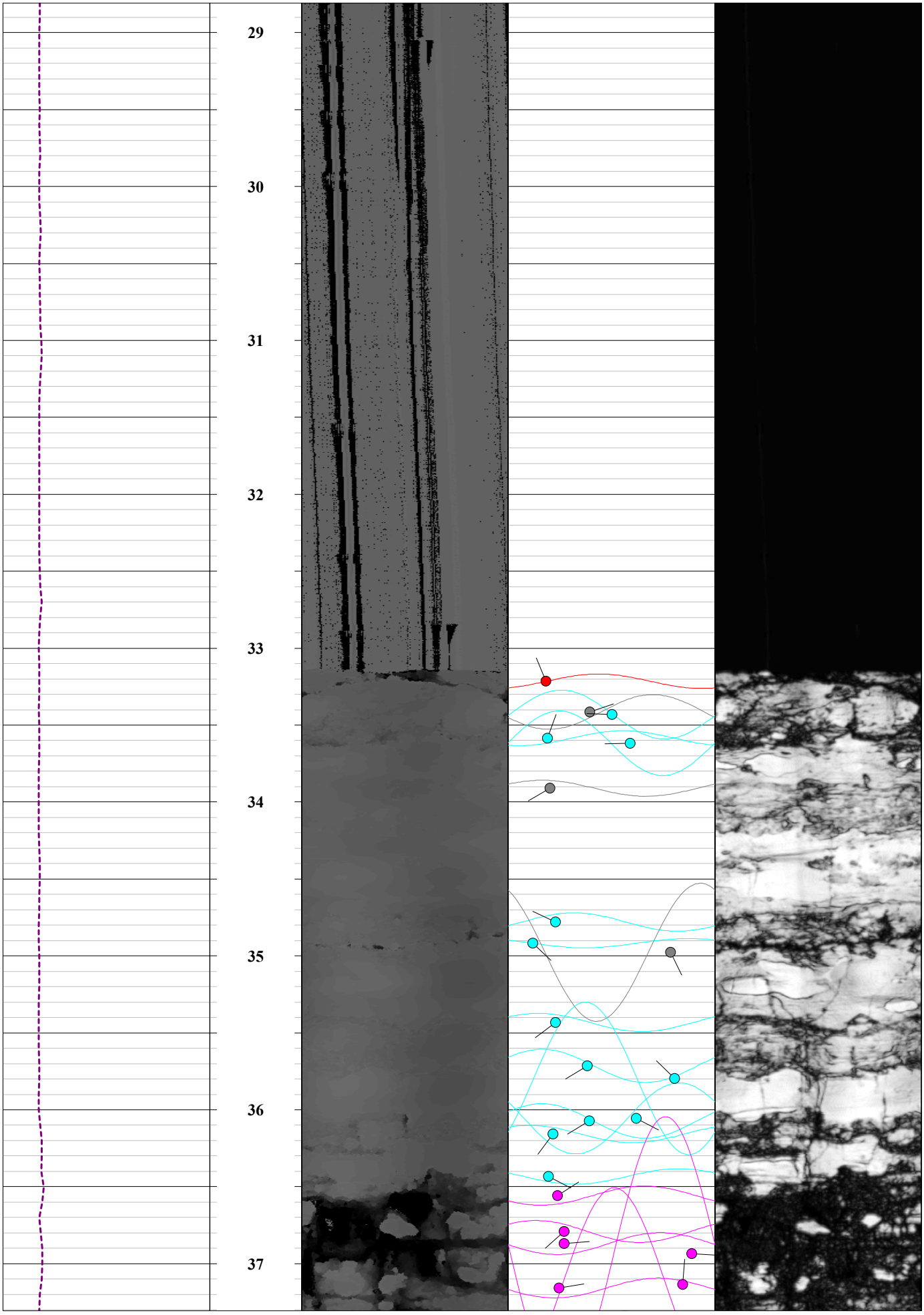
SIZE	WGT.	FROM	TO
6"	Steel	GL	10'
6"	Steel	GL	55'

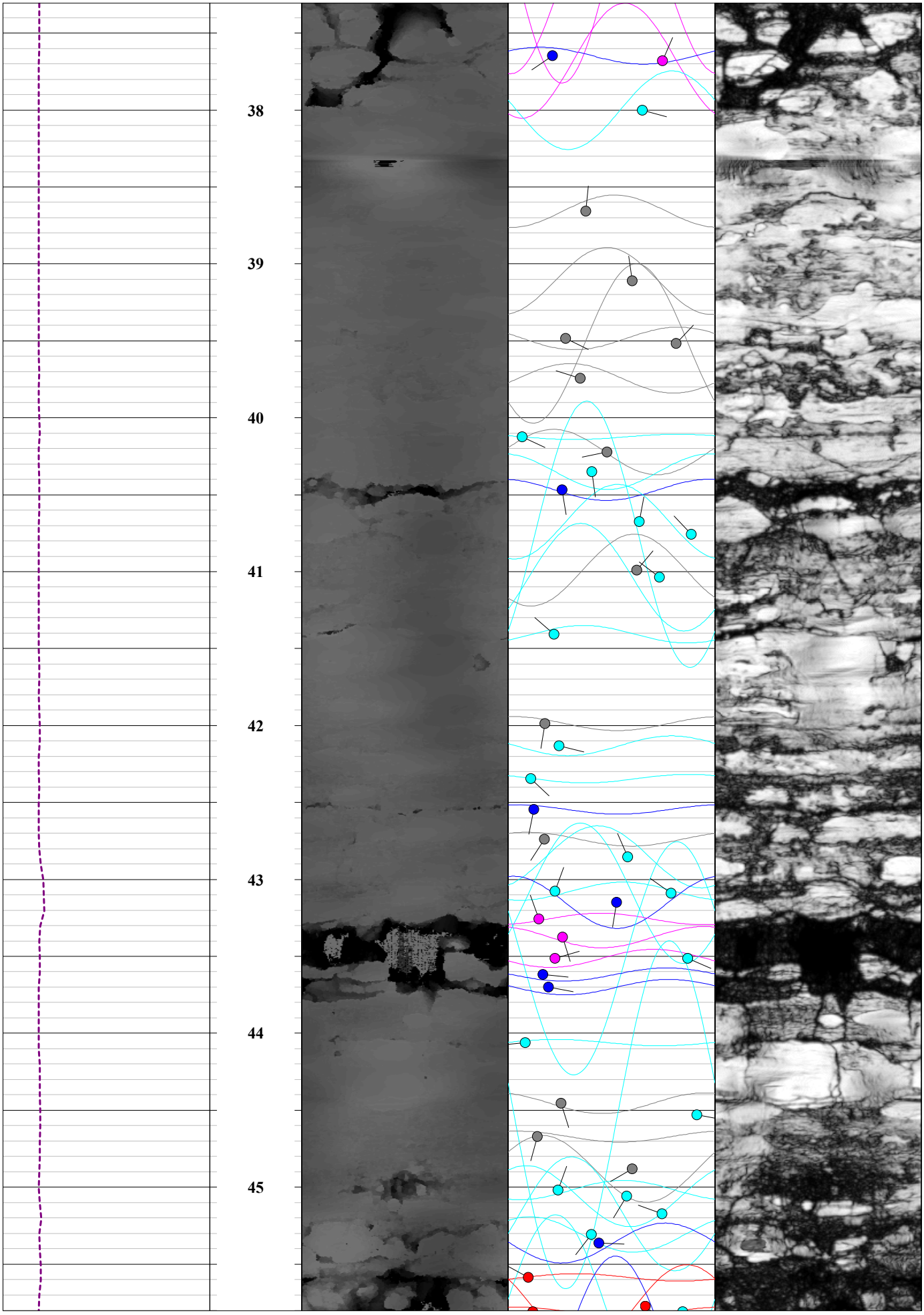
NA - Not Available, N/A - Not Applicable

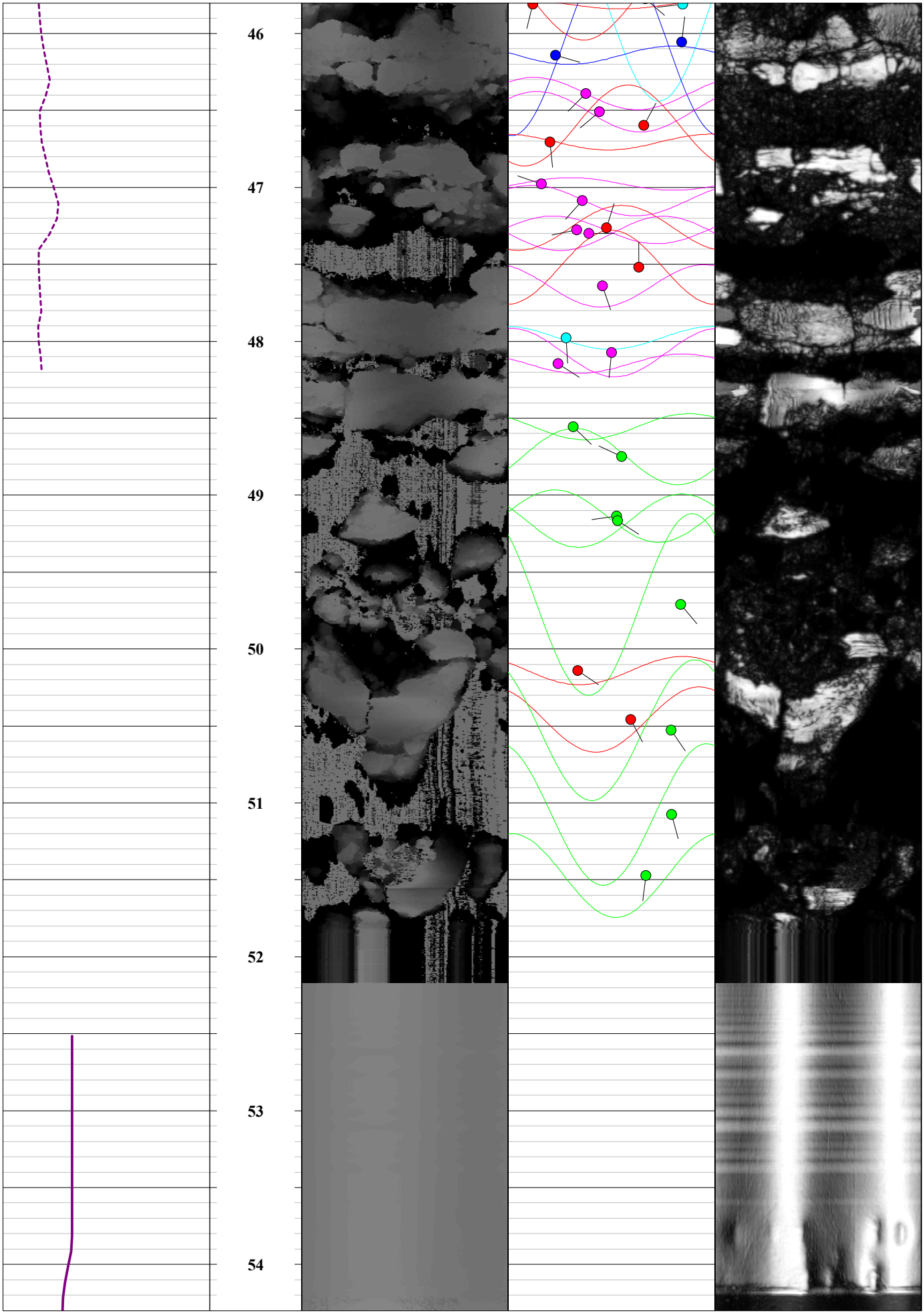
COMMENTS

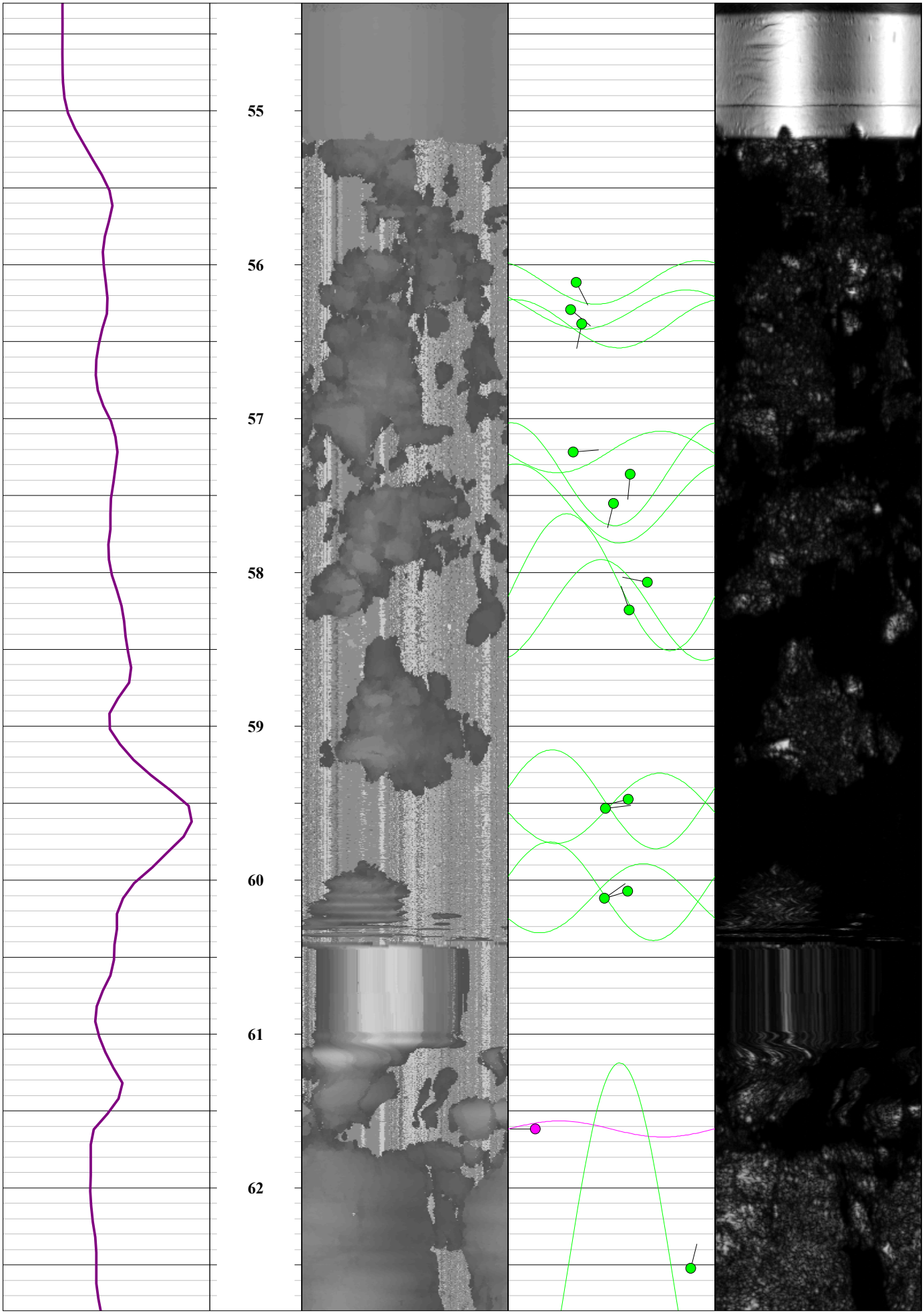
Due to the hole collapsing, the data collection occurred at two separate times. Casing was advanced deeper, causing a blank zone between 52' to 55'.

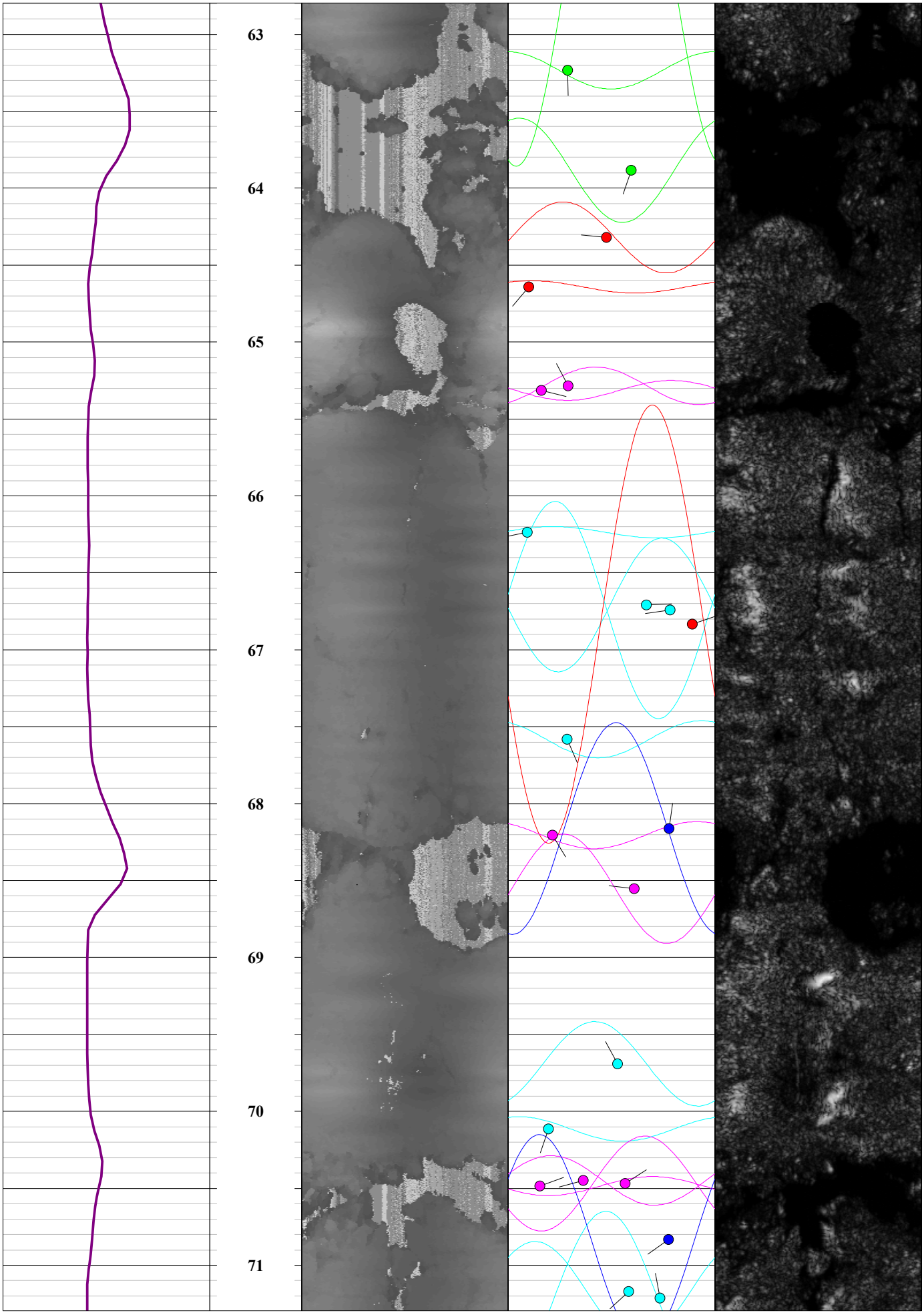

3-Arm Caliper - HQ (June 7)
2
inch
12
3-Arm Caliper - 6" (June 19)
2
inch
12
Depth
1ft:10ft
Travel Time - MN
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude - MN
0°
90°
180°
270°
0°
21
22
23
24
25
26
27
28

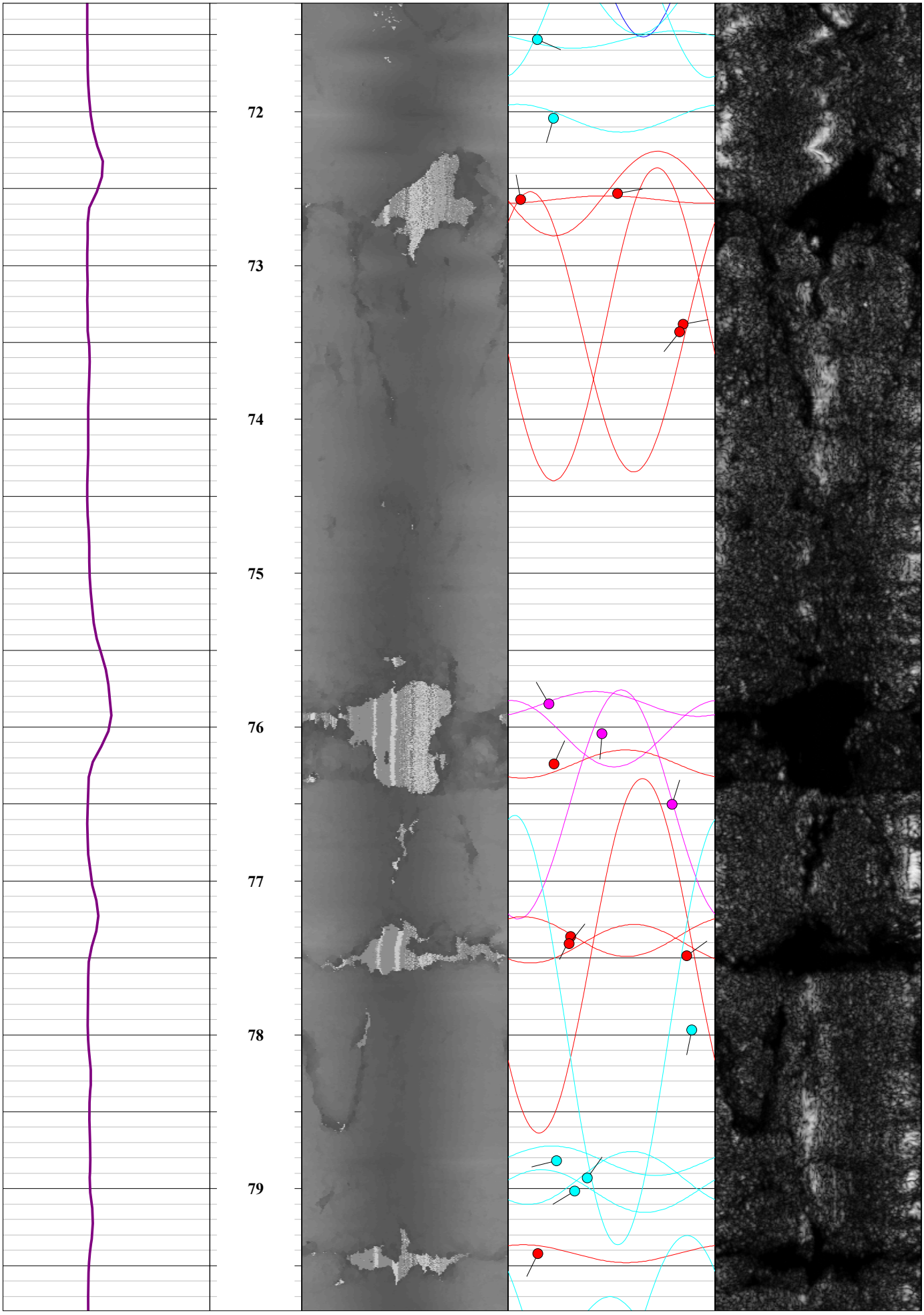

29
30
31
32
33
34
35
36
37

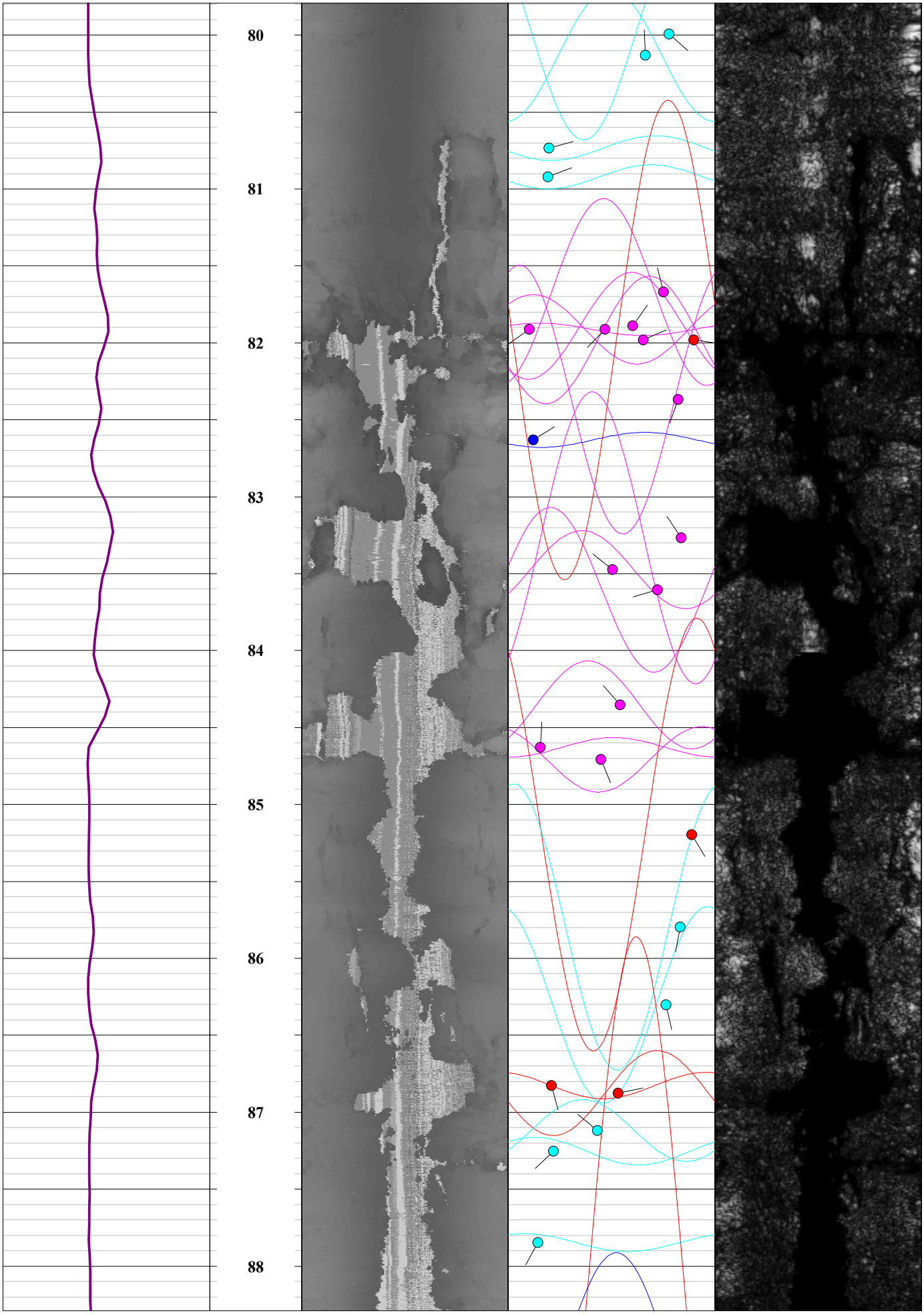

38
39
40
41
42
43
44
45

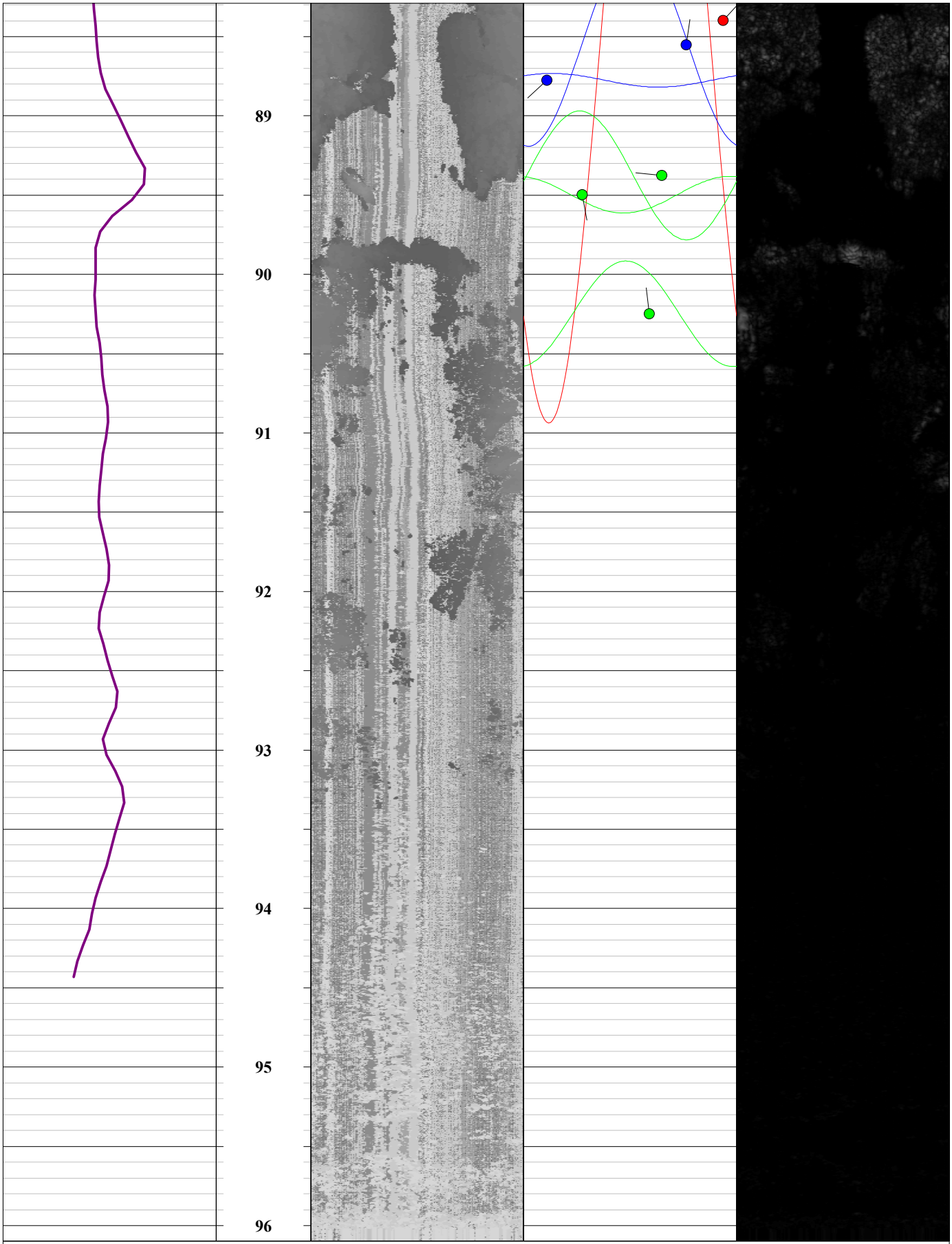

46
47
48
49
50
51
52
53
54


55
56
57
58
59
60
61
62


63
64
65
66
67
68
69
70
71


72
73
74
75
76
77
78
79


80
81
82
83
84
85
86
87
88


89
90
91
92
93
94
95
96
2
inch
12
0
90
3-Arm Caliper - 6" (June 19)
Tadpoles
2
inch
12
1ft:10ft
0° 90° 180° 270° 0° 0° 90° 180° 270° 0° 0° 90° 180° 270° 0°
3-Arm Caliper - HQ (June 7)
Depth
Travel Time - MN
Projections
Amplitude - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-09
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-09
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78736 N
Longitude: 84.77692 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 619.2'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	June 8, 2019	June 19, 2019		
RUN NUMBER	1	2 Drill run 4		
LOG TYPE	OTV	OTV		
DEPTH-DRILLER	103'	95'		
DEPTH-LOGGER	49.74'	89.9'		
BTM LOG INTERVAL	49.74'	89.9'		
TOP LOG INTERVAL	8'	54.75		
RECORDED BY	JBG	JBG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	OTV LIM 1729	OTV LIM 1729		
LOGGING SPEED	4.5 ft/min	4.5 ft/min		
A.S.D.E. / Sample Interval	38 mil	38 mil		
Fluid Level / Fluid Type	33' / water	33' / water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	10'	95'
1	NQ	95'	103'
2	6"	GL	95'

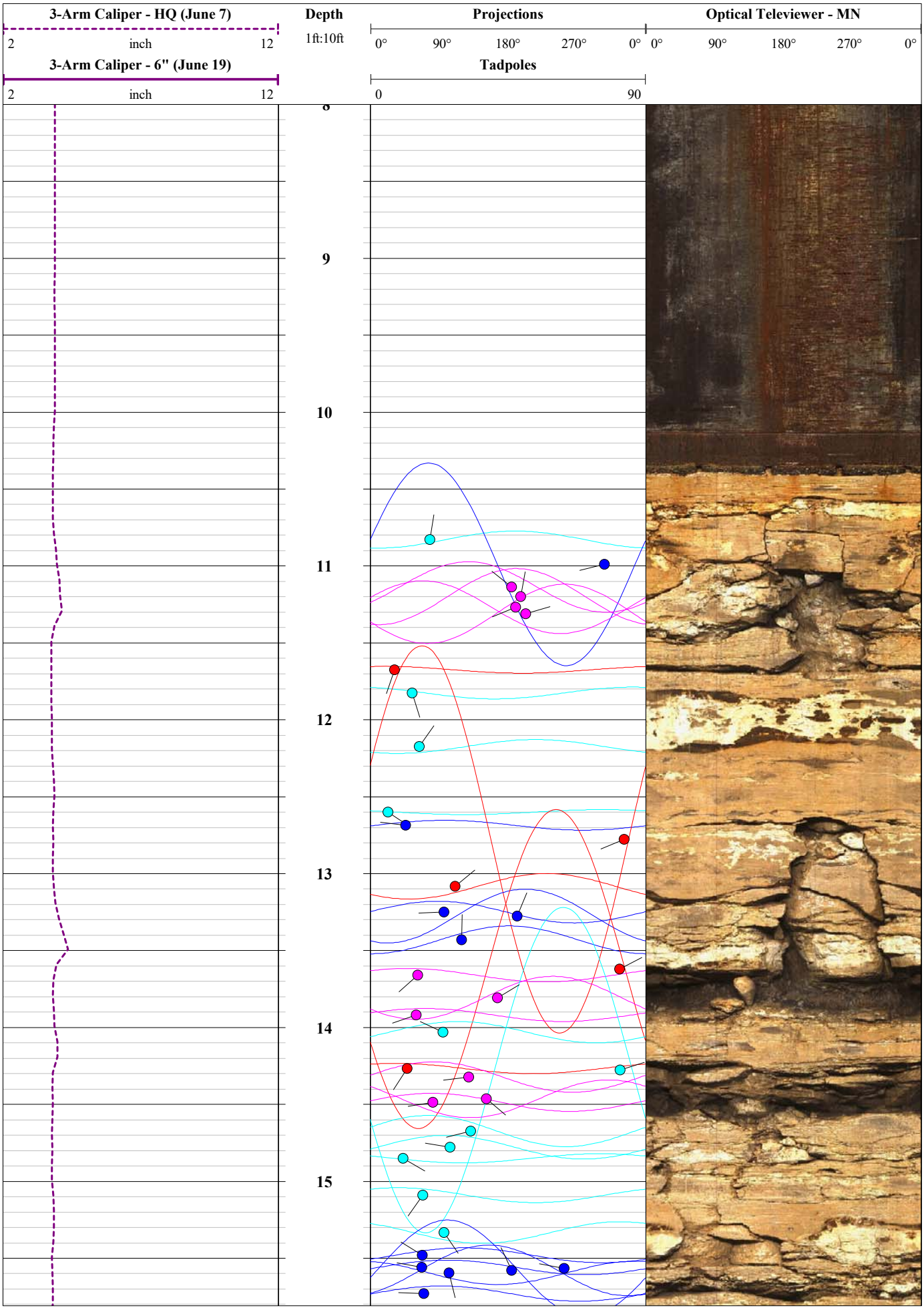
CASING RECORD

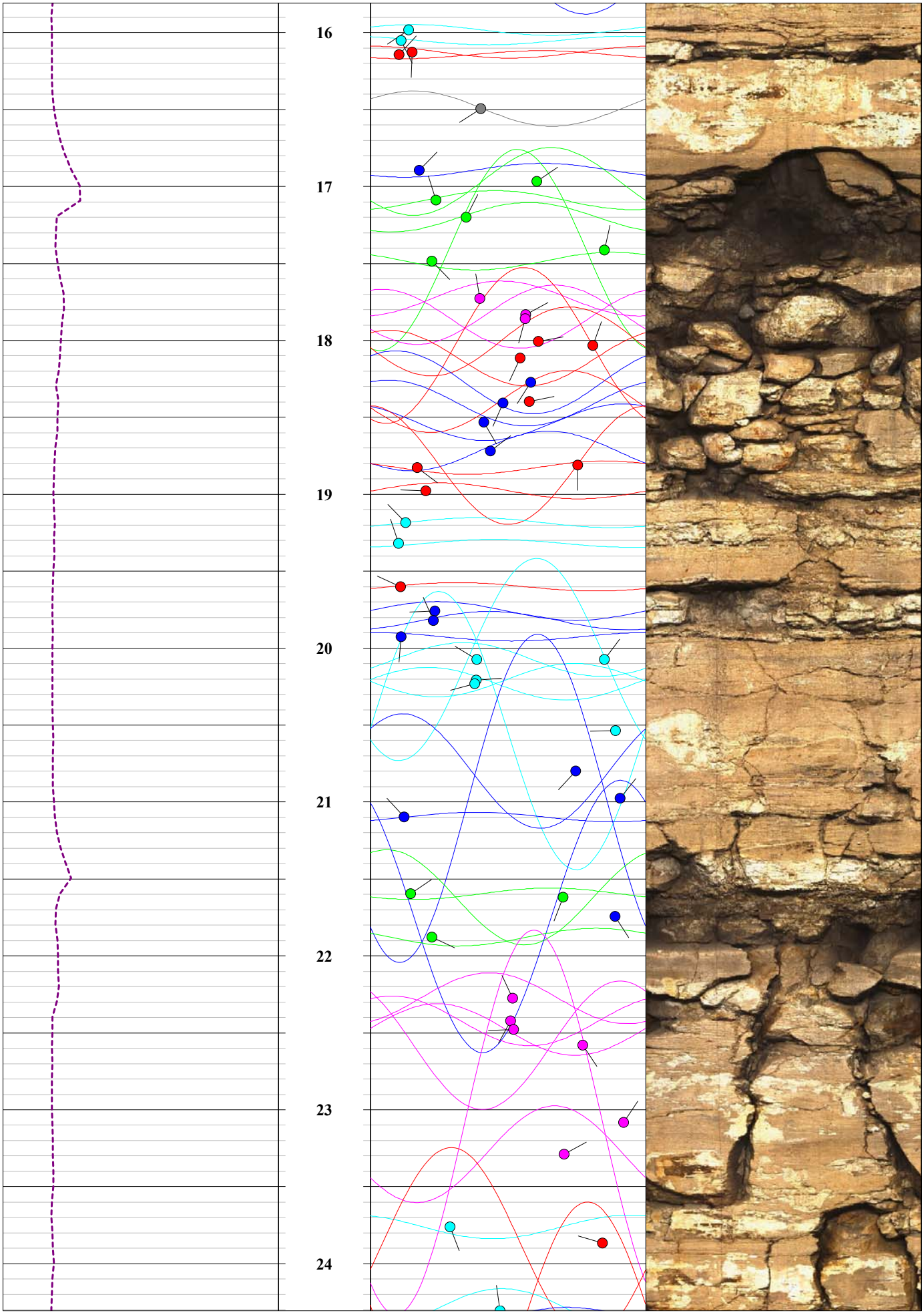
SIZE	WGT.	FROM	TO
6"	Steel	GL	10'
6"	Steel	GL	55"

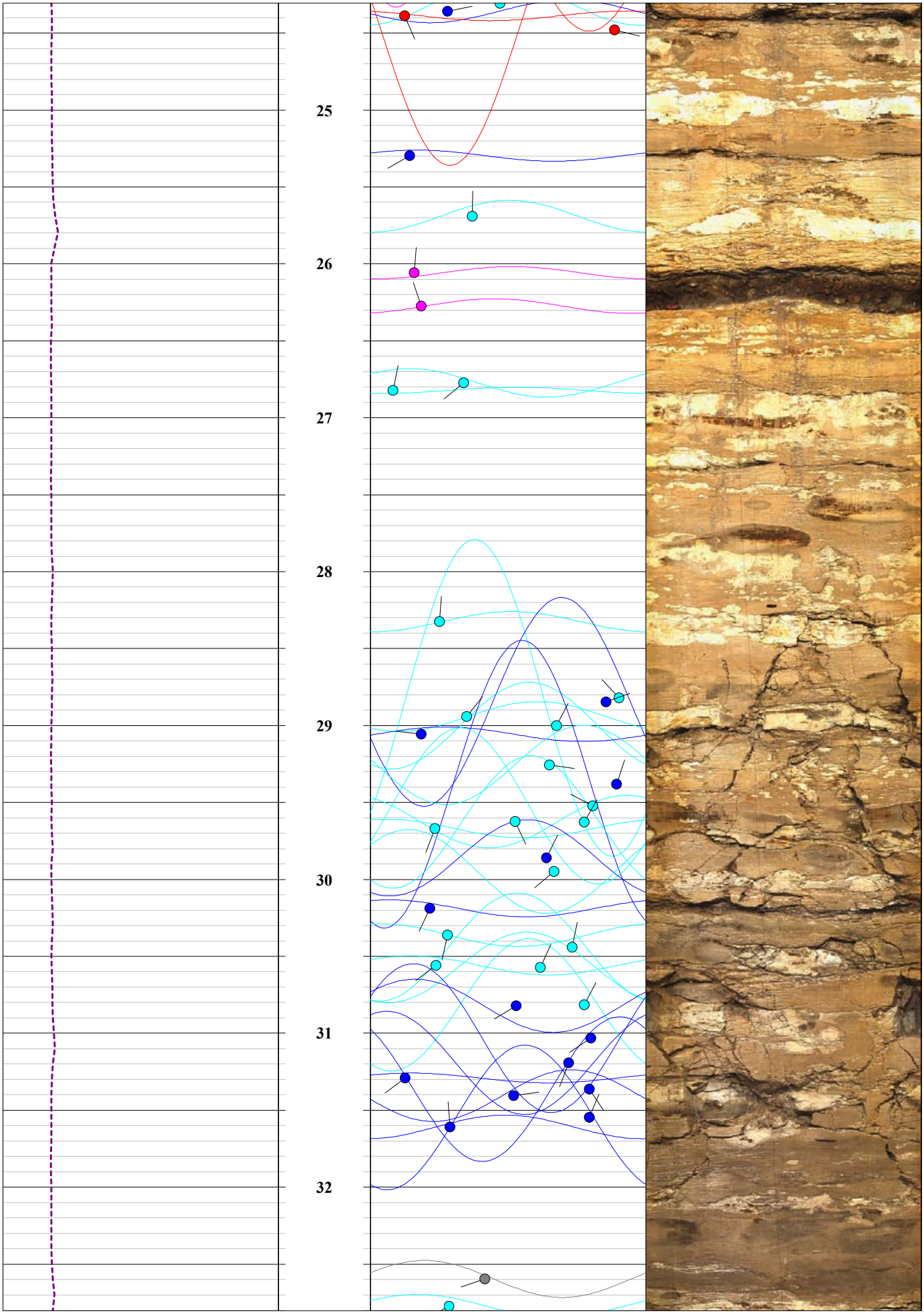
NA - Not Available, N/A - Not Applicable

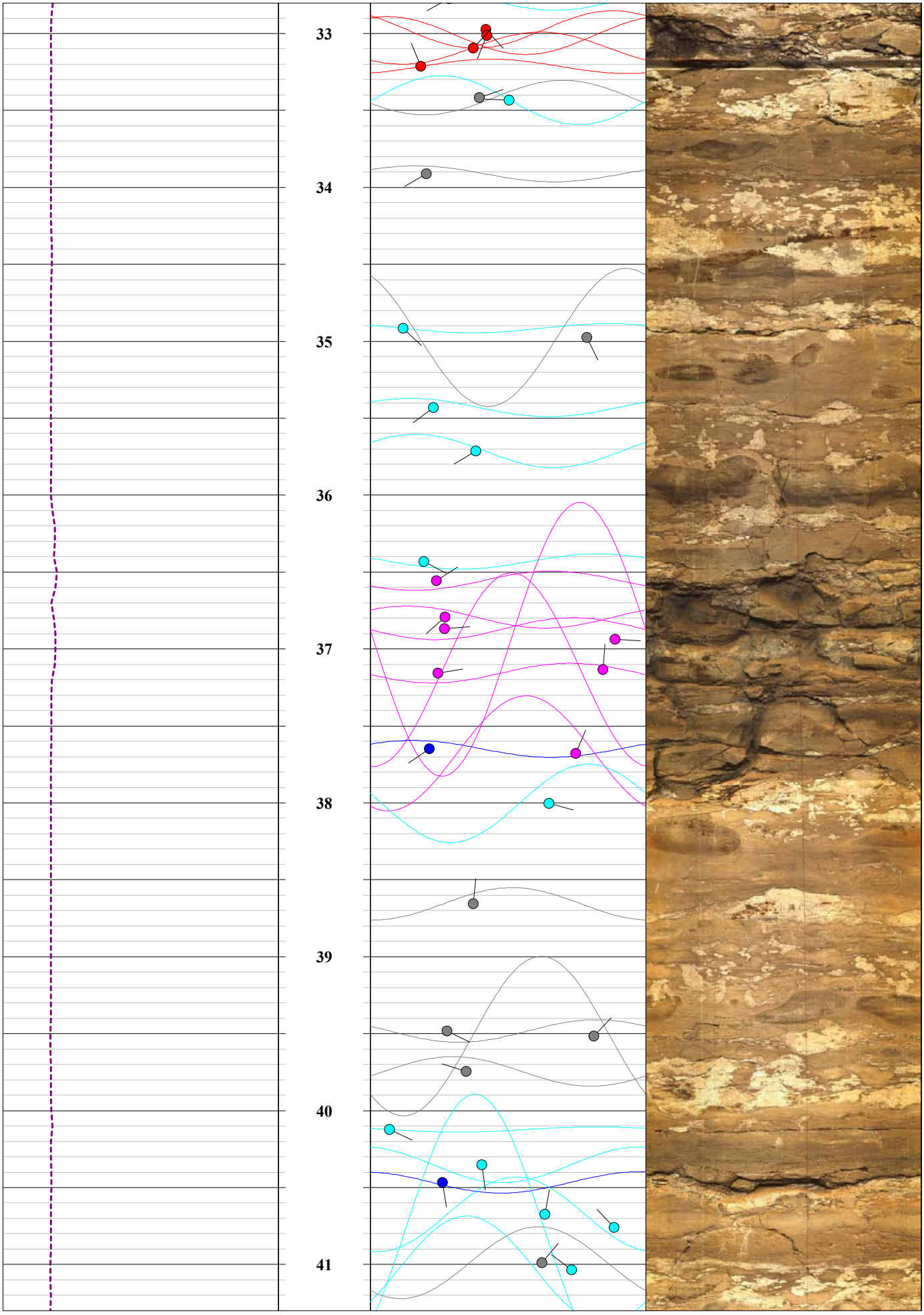
COMMENTS

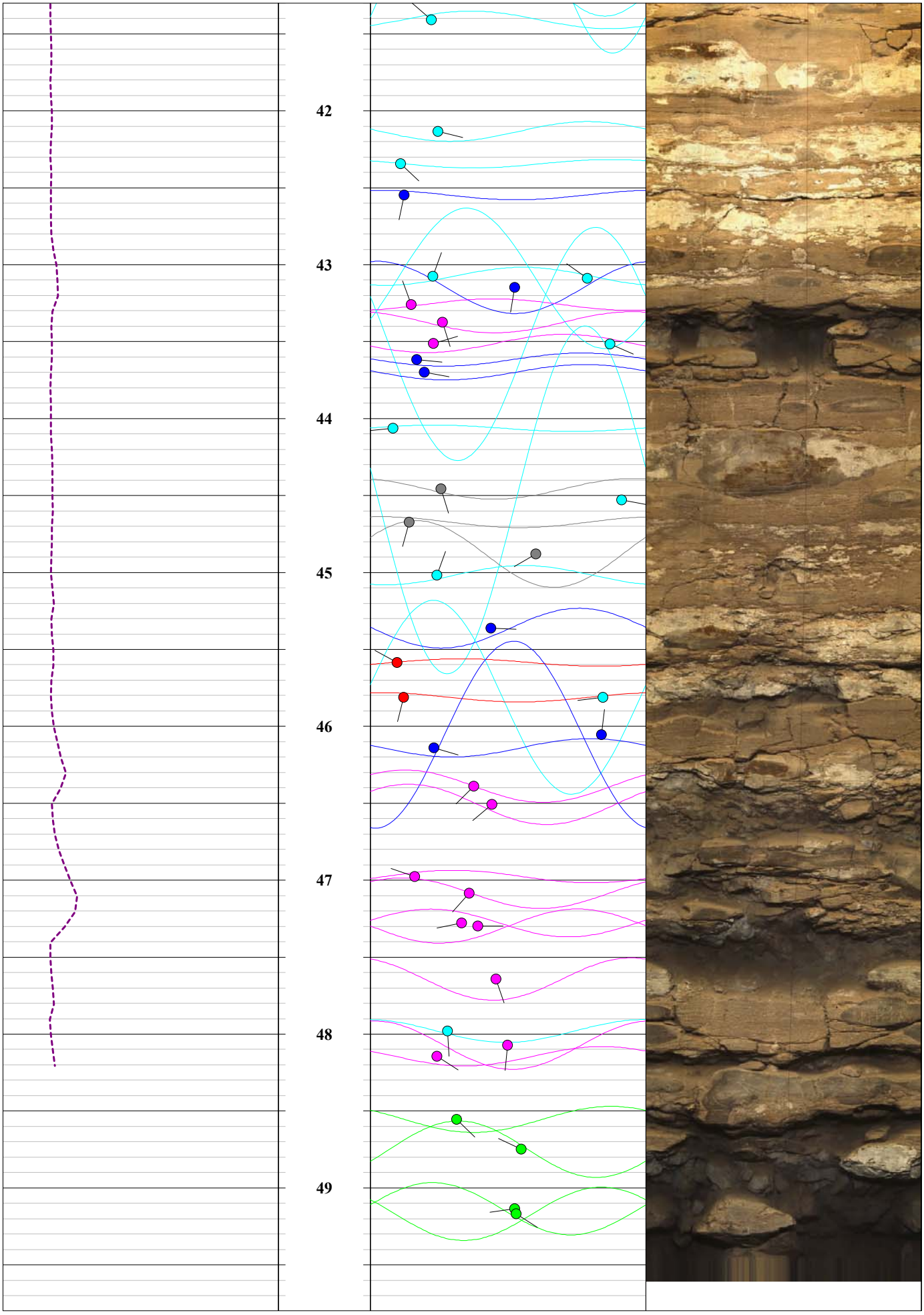
Due to the hole collapsing, the data collection occurred at two separate times. Casing was advanced deeper, causing a blank zone between 49.5' to 55'.

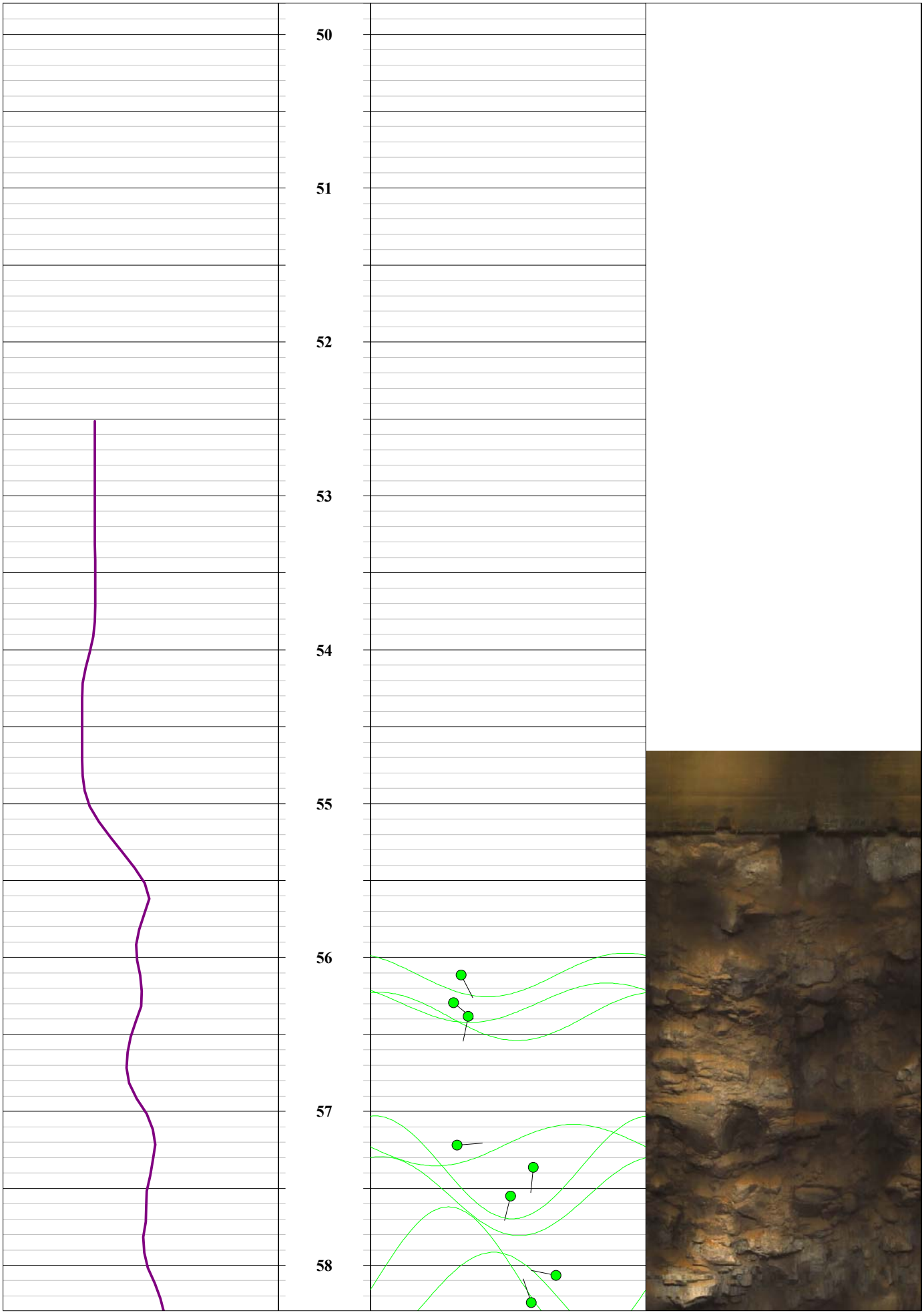

3-Arm Caliper - HQ (June 7)
2
inch
12
3-Arm Caliper - 6" (June 19)
2
inch
12
Depth
1ft:10ft
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Optical Televiewer - MN
0°
90°
180°
270°
0°
8
9
10
11
12
13
14
15

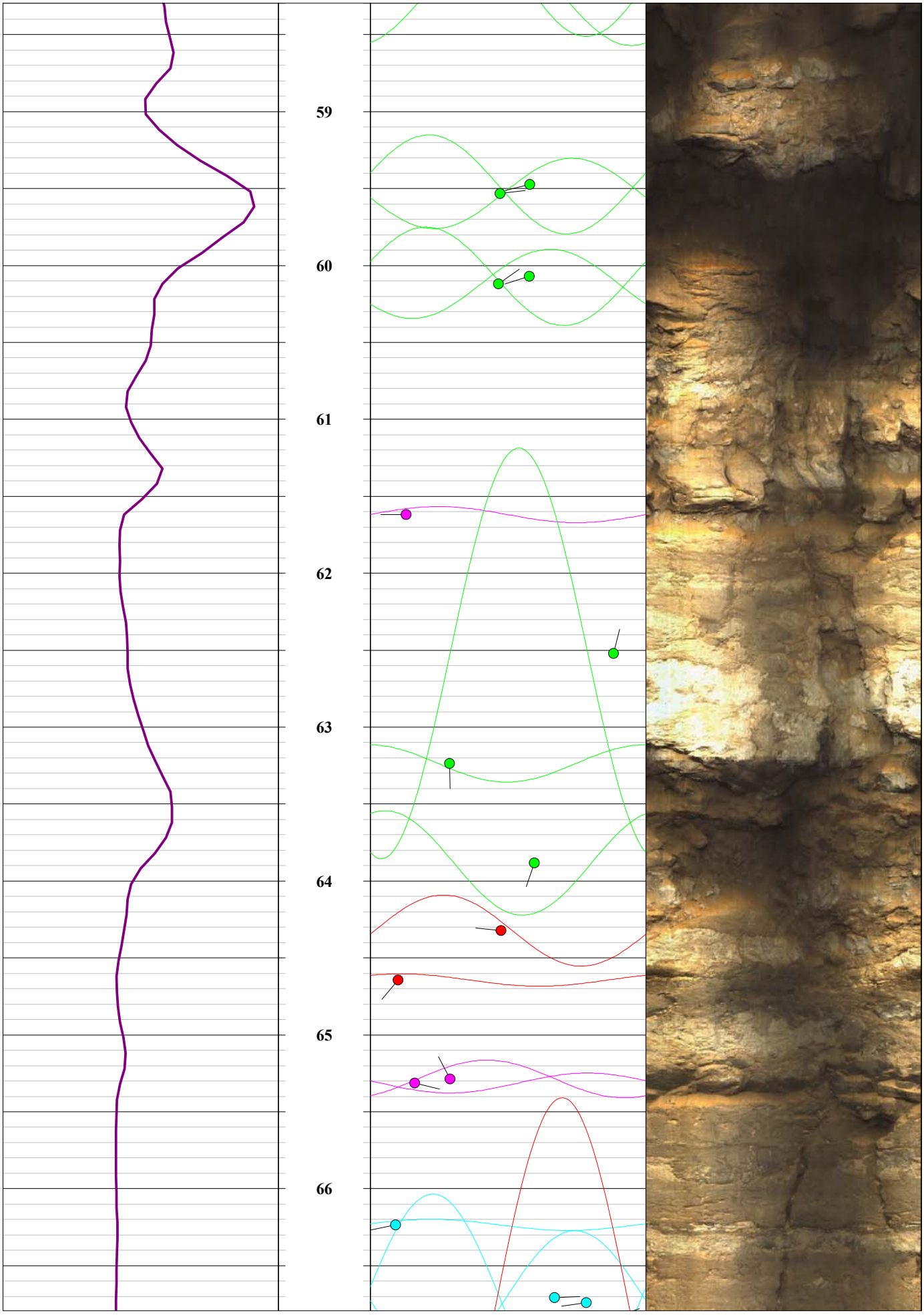

16
17
18
19
20
21
22
23
24

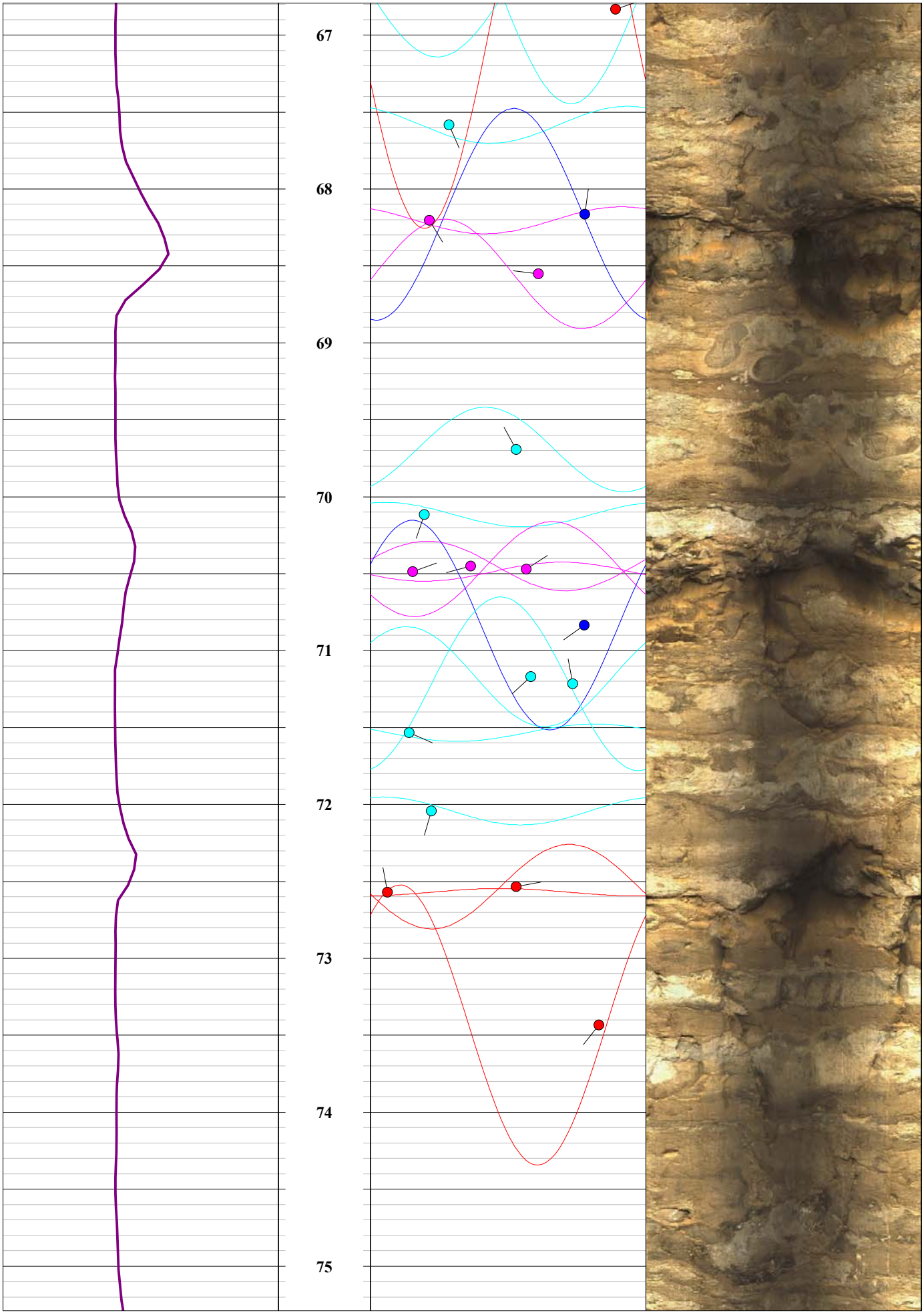

25
26
27
28
29
30
31
32

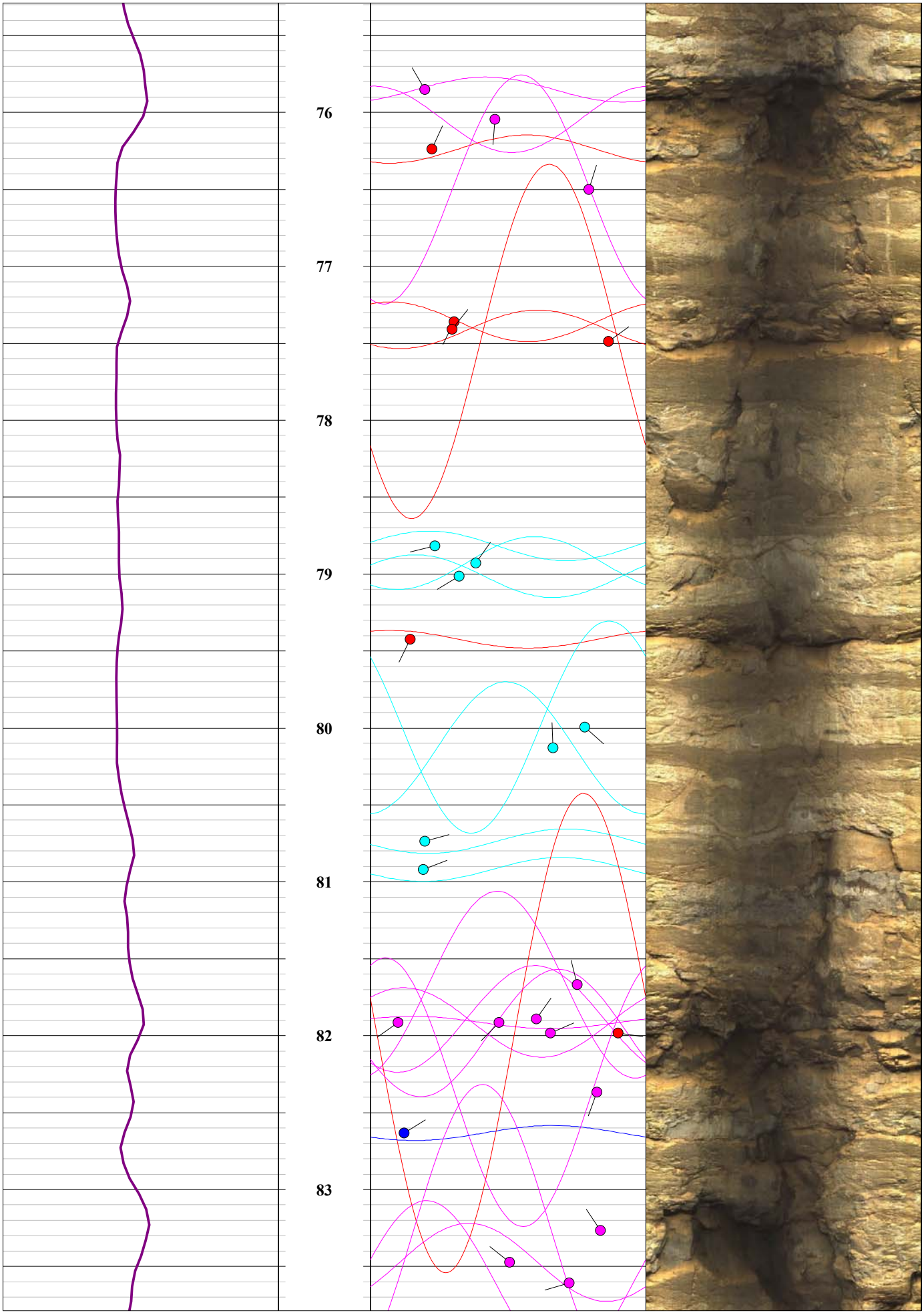

33
34
35
36
37
38
39
40
41

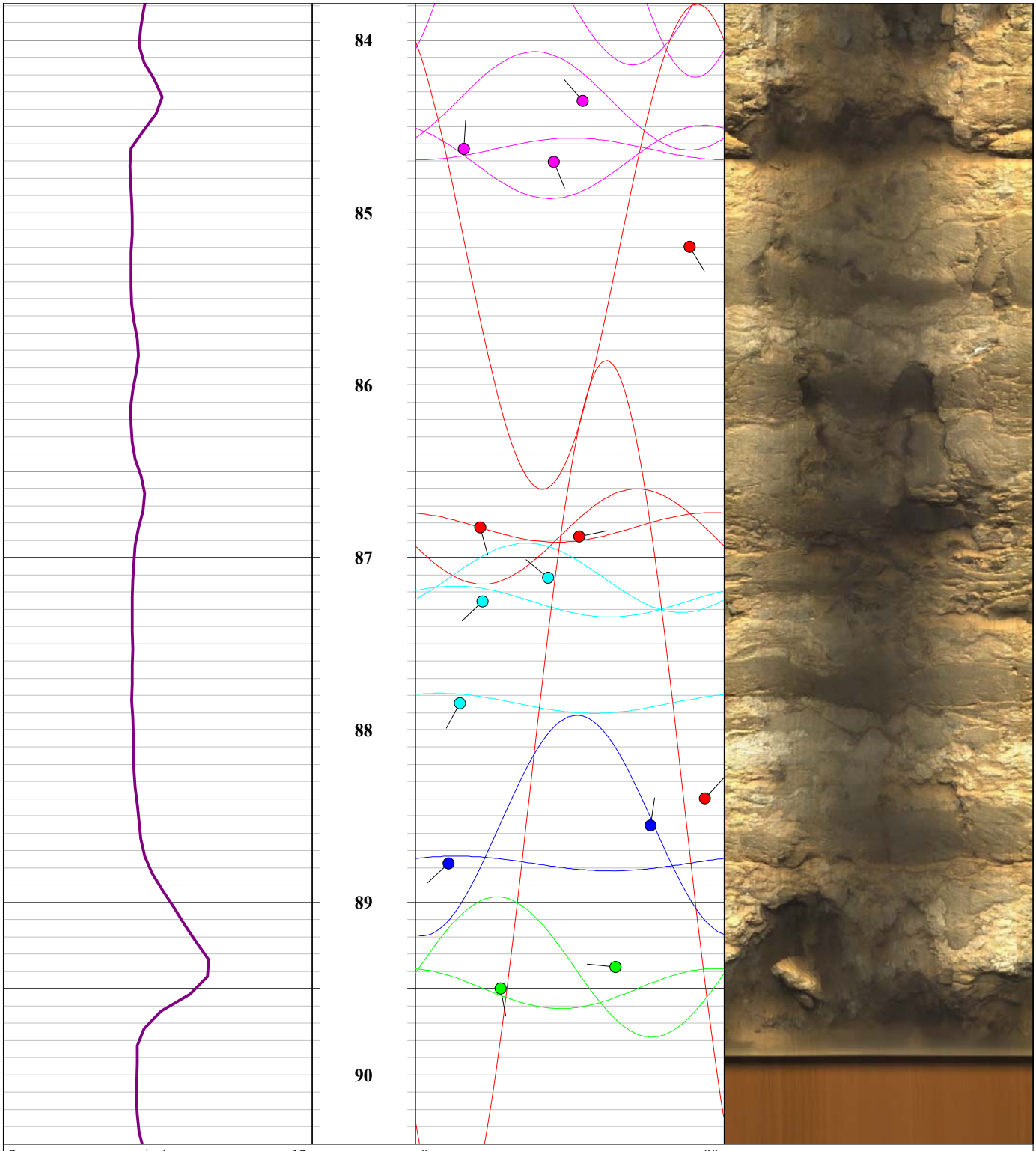

42
43
44
45
46
47
48
49


50
51
52
53
54
55
56
57
58

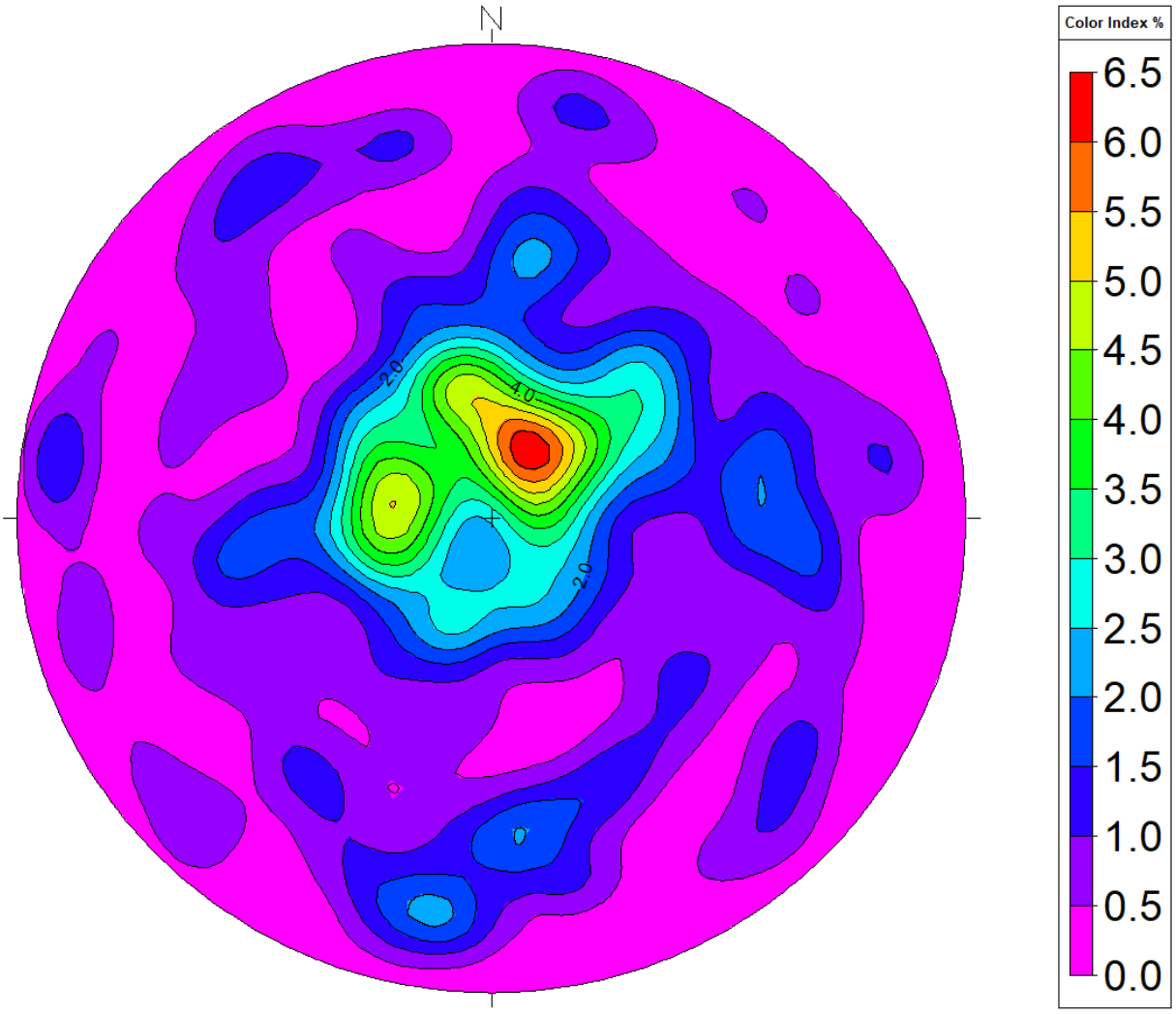

59
60
61
62
63
64
65
66


67
68
69
70
71
72
73
74
75


76
77
78
79
80
81
82
83

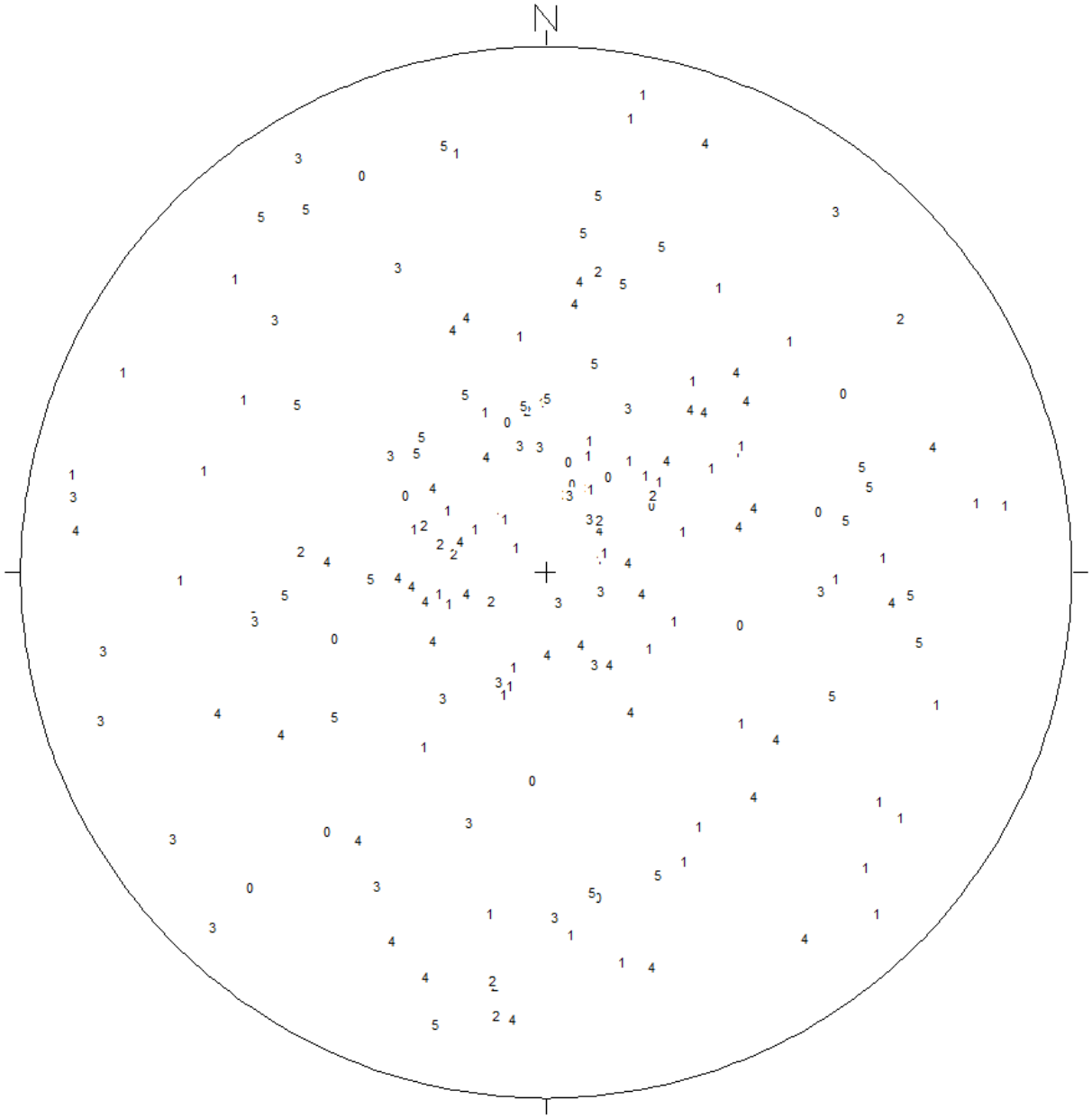

84
85
86
87
88
89
90
2
inch
12
0
90
3-Arm Caliper - 6" (June 19)
Tadpoles
2
inch
12
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper - HQ (June 7)
Depth
Projections
Optical Televiewer - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-09
7 & 19 June 2019



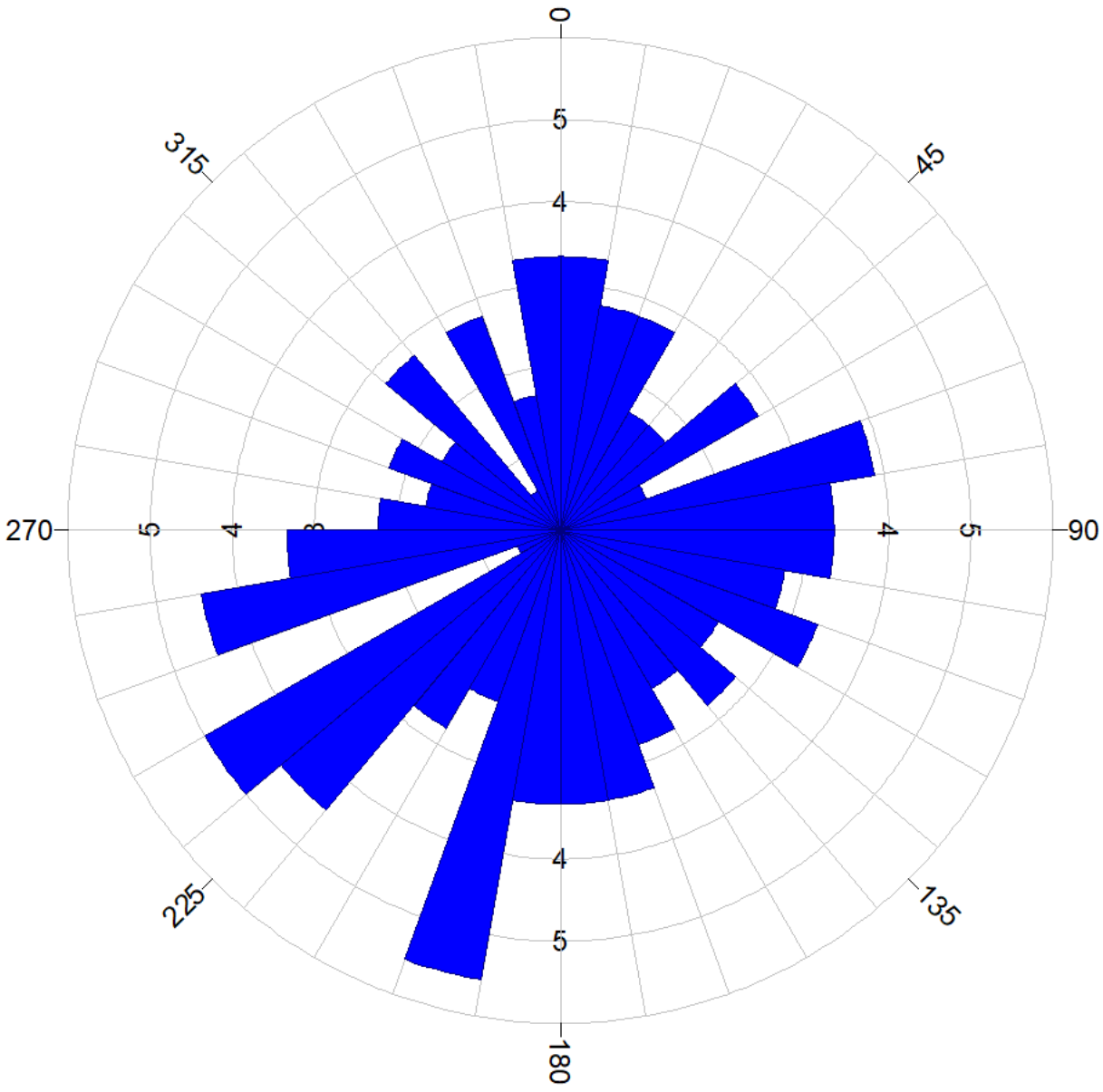
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-09
7 & 19 June 2019



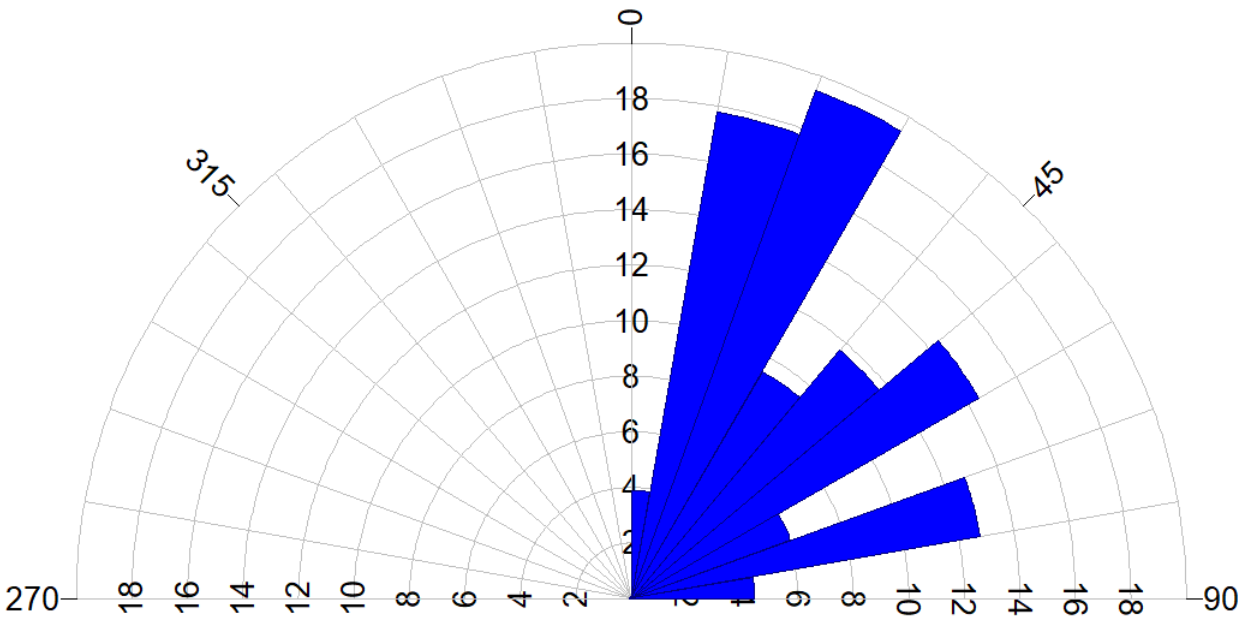
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-09
7 & 19 June 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-09
7 & 19 June 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-09

7 and 19 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	10.12	33.2	337	17	3
2	10.19	33.4	71	36	0
3	10.19	33.4	273	45	1
4	10.24	33.6	20	17	1
5	10.25	33.6	269	53	1
6	10.34	33.9	240	18	0
7	10.60	34.8	295	21	1
8	10.64	34.9	133	11	1
9	10.66	35.0	154	71	0
10	10.80	35.4	233	21	1
11	10.88	35.7	239	34	1
12	10.91	35.8	314	72	1
13	10.99	36.1	118	56	1
14	10.99	36.1	238	35	1
15	11.02	36.2	217	20	1
16	11.10	36.4	117	18	1
17	11.14	36.6	57	22	4
18	11.21	36.8	228	24	4
19	11.24	36.9	85	24	4
20	11.26	36.9	94	80	4
21	11.32	37.1	5	76	4
22	11.33	37.2	81	22	4
23	11.48	37.7	236	19	2
24	11.48	37.7	23	67	4
25	11.58	38.0	105	58	1
26	11.78	38.7	5	34	0
27	11.92	39.1	352	54	0
28	12.03	39.5	115	25	0
29	12.05	39.5	43	73	0
30	12.11	39.7	288	31	0
31	12.23	40.1	115	6	1
32	12.26	40.2	259	43	0
33	12.30	40.4	172	36	1
34	12.34	40.5	171	24	2
35	12.40	40.7	10	57	1
36	12.42	40.8	317	80	1
37	12.49	41.0	40	56	0
38	12.51	41.0	306	66	1
39	12.62	41.4	311	20	1
40	12.80	42.0	189	16	0
41	12.84	42.1	104	22	1
42	12.91	42.3	134	10	1
43	12.97	42.6	192	11	2
44	13.03	42.7	213	16	0
45	13.06	42.9	336	52	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-09

7 and 19 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	13.13	43.1	19	20	1
47	13.13	43.1	306	71	1
48	13.15	43.2	189	47	2
49	13.19	43.3	340.2	13.4	4
50	13.22	43.4	162.2	23.6	4
51	13.26	43.5	73.3	20.5	4
52	13.26	43.5	114.1	78.3	1
53	13.30	43.6	95.7	15.2	2
54	13.32	43.7	99.9	17.6	2
55	13.43	44.1	263.8	7.5	1
56	13.55	44.5	162.5	23.1	0
57	13.57	44.5	100.5	82.1	1
58	13.62	44.7	194.7	12.7	0
59	13.68	44.9	239.8	54.0	0
60	13.72	45.0	20.2	21.7	1
61	13.73	45.1	211.3	51.5	1
62	13.77	45.2	290.1	67.0	1
63	13.81	45.3	217.7	36.2	1
64	13.83	45.4	92.8	39.5	2
65	13.90	45.6	298.9	8.7	3
66	13.95	45.8	131.3	59.6	3
67	13.96	45.8	262.6	76.0	1
68	13.96	45.8	194.4	10.9	3
69	14.04	46.1	7.0	75.5	2
70	14.06	46.1	106.5	20.7	2
71	14.14	46.4	225.2	33.7	4
72	14.18	46.5	230.1	39.8	4
73	14.20	46.6	28.6	59.1	3
74	14.23	46.7	174.0	18.1	3
75	14.32	47.0	288.5	14.6	4
76	14.35	47.1	222.0	32.3	4
77	14.40	47.3	17.7	42.9	3
78	14.41	47.3	258.7	29.8	4
79	14.42	47.3	90.5	35.2	4
80	14.48	47.5	359.5	56.8	3
81	14.52	47.6	160.9	41.1	4
82	14.62	48.0	176.8	25.2	1
83	14.65	48.1	185.7	44.9	4
84	14.68	48.2	122.6	21.8	4
85	14.80	48.6	134.5	28.3	5
86	14.86	48.8	295.3	49.3	5
87	14.98	49.1	261.5	47.2	5
88	14.99	49.2	122.0	47.7	5
89	15.15	49.7	140.0	75.1	5
90	15.28	50.1	124.0	30.3	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-09

7 and 19 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	15.38	50.5	152.5	53.4	3
92	15.40	50.5	145.3	71.0	5
93	15.57	51.1	165.5	71.1	5
94	15.69	51.5	187.3	59.9	5
95	17.10	56.1	153.0	29.6	5
96	17.16	56.3	129.5	27.2	5
97	17.18	56.4	192.0	32.0	5
98	17.44	57.2	85.4	28.3	5
99	17.48	57.4	185.4	53.2	5
100	17.54	57.6	194.4	45.8	5
101	17.70	58.1	282.0	60.7	5
102	17.75	58.2	341.1	52.6	5
103	18.13	59.5	256.4	52.2	5
104	18.14	59.5	83.4	42.4	5
105	18.31	60.1	252.6	52.0	5
106	18.32	60.1	54.7	41.9	5
107	18.78	61.6	269.4	11.8	4
108	19.06	62.5	14.2	79.4	5
109	19.27	63.2	178.6	25.8	5
110	19.47	63.9	199.1	53.6	5
111	19.60	64.3	275.7	42.8	3
112	19.70	64.6	220.2	9.1	3
113	19.90	65.3	332.0	26.1	4
114	19.91	65.3	103.4	14.5	4
115	20.19	66.2	258.7	8.3	1
116	20.33	66.7	87.5	60.1	1
117	20.34	66.7	261.8	70.5	1
118	20.37	66.8	70.8	80.0	3
119	20.60	67.6	156.1	25.7	1
120	20.78	68.2	7.6	70.0	2
121	20.79	68.2	148.6	19.3	4
122	20.89	68.6	276.4	54.9	4
123	21.24	69.7	330.7	47.7	1
124	21.37	70.1	198.9	17.7	1
125	21.47	70.5	254.6	32.8	4
126	21.48	70.5	57.7	51.0	4
127	21.49	70.5	70.4	13.9	4
128	21.59	70.8	235	70	2
129	21.69	71.2	227	52	1
130	21.70	71.2	350	66	1
131	21.80	71.5	114	13	1
132	21.96	72.0	197	20	1
133	22.11	72.5	80	48	3
134	22.12	72.6	350	6	3
135	22.37	73.4	79	76	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-09

7 and 19 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	22.38	73.4	219	75	3
137	23.12	75.9	330	18	4
138	23.18	76.0	185	41	4
139	23.24	76.2	24	20	3
140	23.32	76.5	17	71	4
141	23.58	77.4	206	27	3
142	23.59	77.4	39	27	3
143	23.62	77.5	54	78	3
144	23.77	78.0	191	80	1
145	24.02	78.8	256	21	1
146	24.06	78.9	35	35	1
147	24.08	79.0	239	29	1
148	24.21	79.4	206	13	3
149	24.38	80.0	132	70	1
150	24.42	80.1	357	60	1
151	24.61	80.7	75	18	1
152	24.66	80.9	69	17	1
153	24.89	81.7	346	68	4
154	24.96	81.9	35	54	4
155	24.97	81.9	224	42	4
156	24.97	81.9	235	9	4
157	24.99	82.0	98	81	3
158	24.99	82.0	66	59	4
159	25.11	82.4	200	74	4
160	25.19	82.6	58	11	2
161	25.38	83.3	326	75	4
162	25.44	83.5	308	45	4
163	25.48	83.6	253	65	4
164	25.71	84.4	319	49	4
165	25.80	84.6	3	14	4
166	25.82	84.7	157	40	4
167	25.97	85.2	148	80	3
168	26.15	85.8	190	75	1
169	26.30	86.3	167	69	1
170	26.47	86.8	165	19	3
171	26.48	86.9	79	48	3
172	26.55	87.1	310	39	1
173	26.59	87.3	227	20	1
174	26.78	87.9	208	13	1
175	26.94	88.4	43	84	3
176	26.99	88.6	8	69	2
177	27.06	88.8	228	10	2
178	27.24	89.4	275	58	5
179	27.28	89.5	170	25	5
180	27.51	90.3	353	53	5

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-09
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-09
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78736 N
Longitude: 84.77692 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 619.2'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	7 June 2019	7 June 2019	20 June 2019	19 June 2019
RUN NUMBER	1	1	2	2
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Fluid Temp & Cond	3-armed Caliper
DEPTH-DRILLER	103'	103'	95'	95'
DEPTH-LOGGER	49'	49'	95'	95'
BTM LOG INTERVAL	95.6'	94.4'	95.6'	94.4'
TOP LOG INTERVAL	25.0'	43.8'	25.0'	43.8'
RECORDED BY	JBG	JBG	JBG / CKL	JBG / CKL
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP
PROBE TYPE, S/N	2PFA #5969	Comprobe #5238	2PFA #5969	Comprobe #5238
LOGGING SPEED	10 ft/min	10 ft/min	10 ft/min	10 ft/min
A.S.D.E. / Sample Interval	.0.12' / 0.10'	0.01' / 0.10'	0.20' / 0.10'	0.01' / 0.10'
Fluid Level / Fluid Type	33' / water	33' / water	33 / water	33 / water

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	10'	95'
1	NQ	95'	103'
2	6"	GL	95'

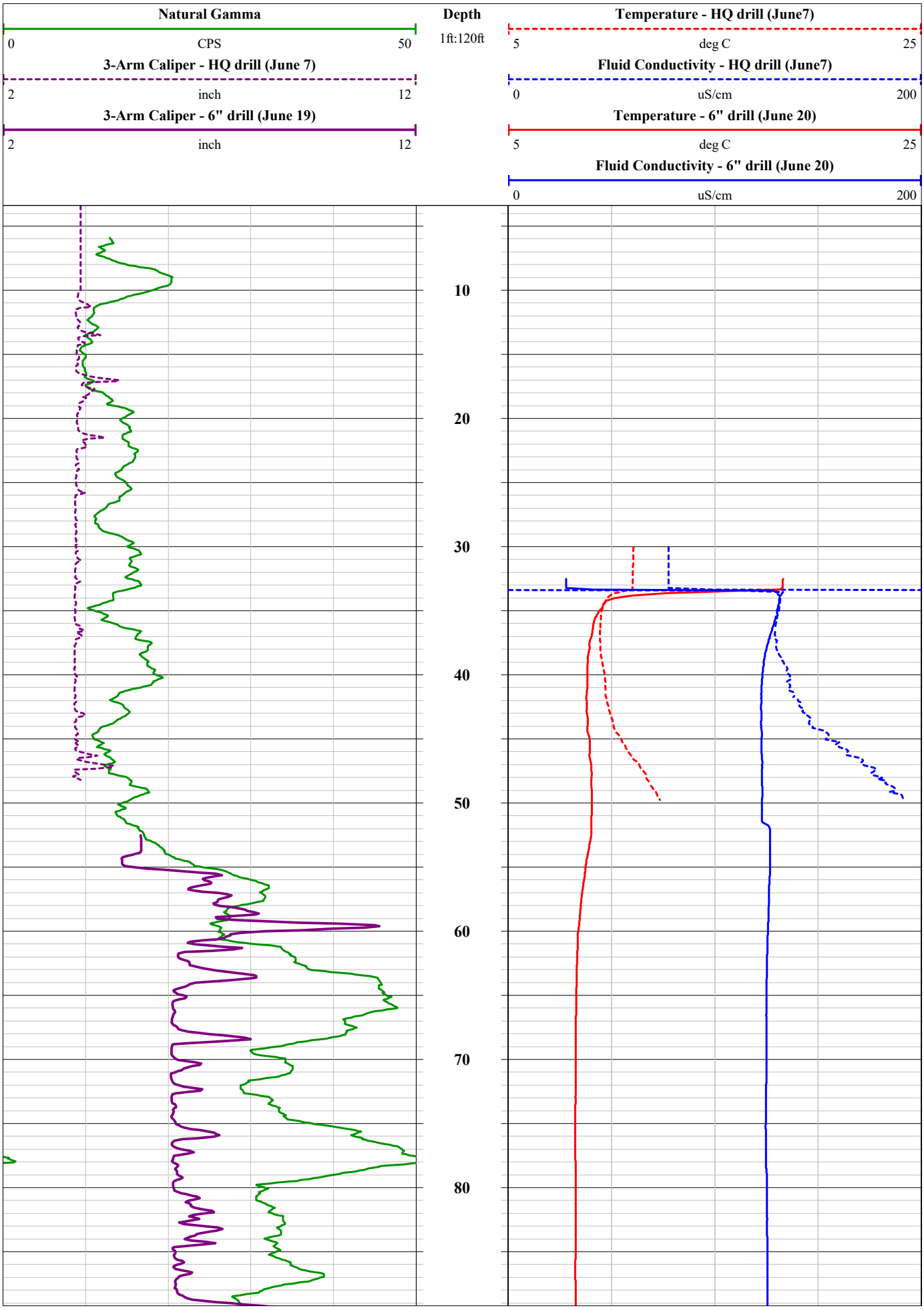
CASING RECORD

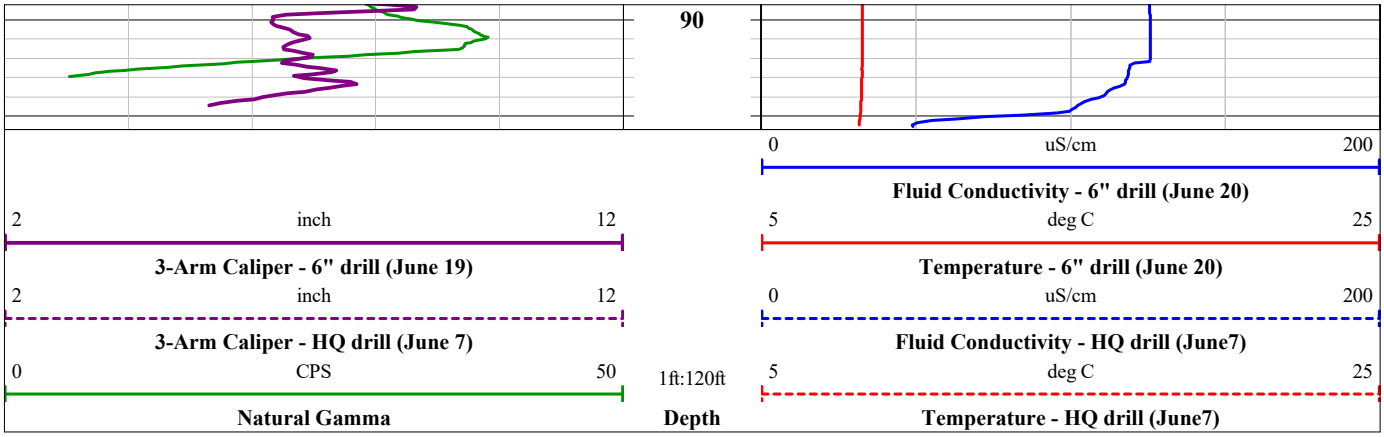
SIZE	WGT.	FROM	TO
6"	Steel	GL	10'
6"	Steel	GL	55'

NA - Not Available, N/A - Not Applicable

COMMENTS

BH19-09 hole collapsed at 49' on June 7 - came back June 19 & 20 to complete bottom portion of hole.
The following data discrepancies noted:
1) The first drilling operation used an HQ bit and the second drilling operation used a 6" bit - the caliper logs verify size difference
2) The Fluid Temperature and Conductivity from the first drilling operation was logged after disturbing the water column with multiple probes for previous tests that morning. In the 2nd drilling operation the hole was logged the next day.


Natural Gamma
0
CPS
50
3-Arm Caliper - HQ drill (June 7)
2
inch
12
3-Arm Caliper - 6" drill (June 19)
2
inch
12
Depth
1ft:120ft
Temperature - HQ drill (June7)
5
deg C
25
Fluid Conductivity - HQ drill (June7)
0
uS/cm
200
Temperature - 6" drill (June 20)
5
deg C
25
Fluid Conductivity - 6" drill (June 20)
0
uS/cm
200
10
20
30
40
50
60
70
80


90
0
uS/cm
200
Fluid Conductivity - 6" drill (June 20)
2
inch
12
5
deg C
25
3-Arm Caliper - 6" drill (June 19)
Temperature - 6" drill (June 20)
2
inch
12
0
uS/cm
200
3-Arm Caliper - HQ drill (June 7)
Fluid Conductivity - HQ drill (June7)
0
CPS
50
1ft:120ft
5
deg C
25
Natural Gamma
Depth
Temperature - HQ drill (June7)

borehole geophysics / hydrophysics

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

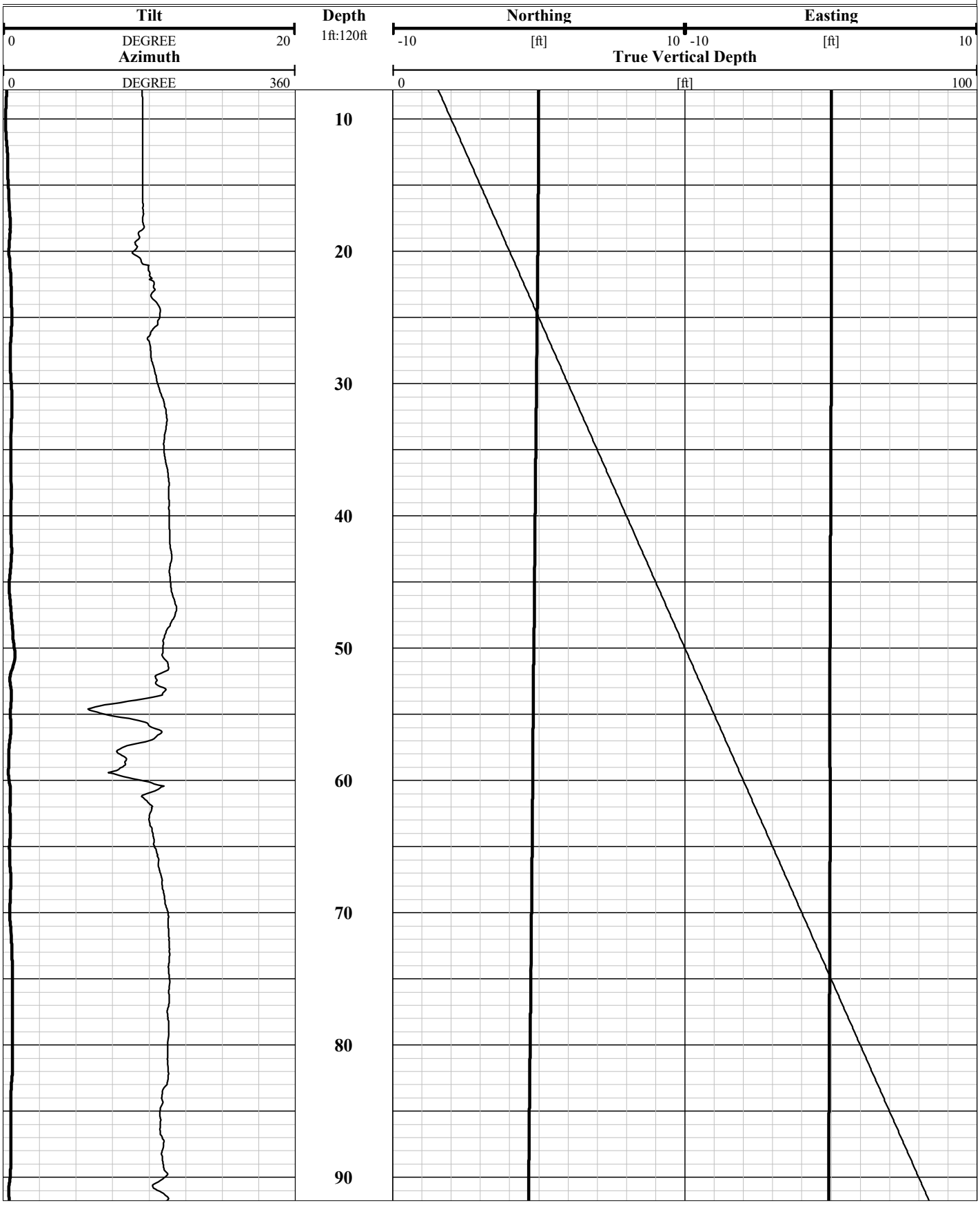
Borehole Deviation

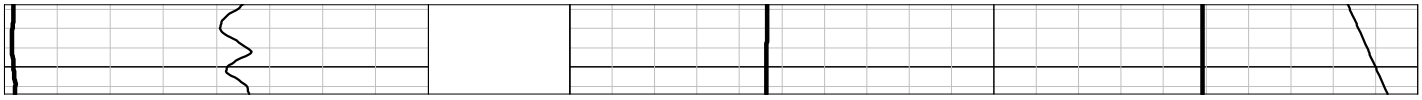
COMPANY: WSP | PROJECT: L5RT Project

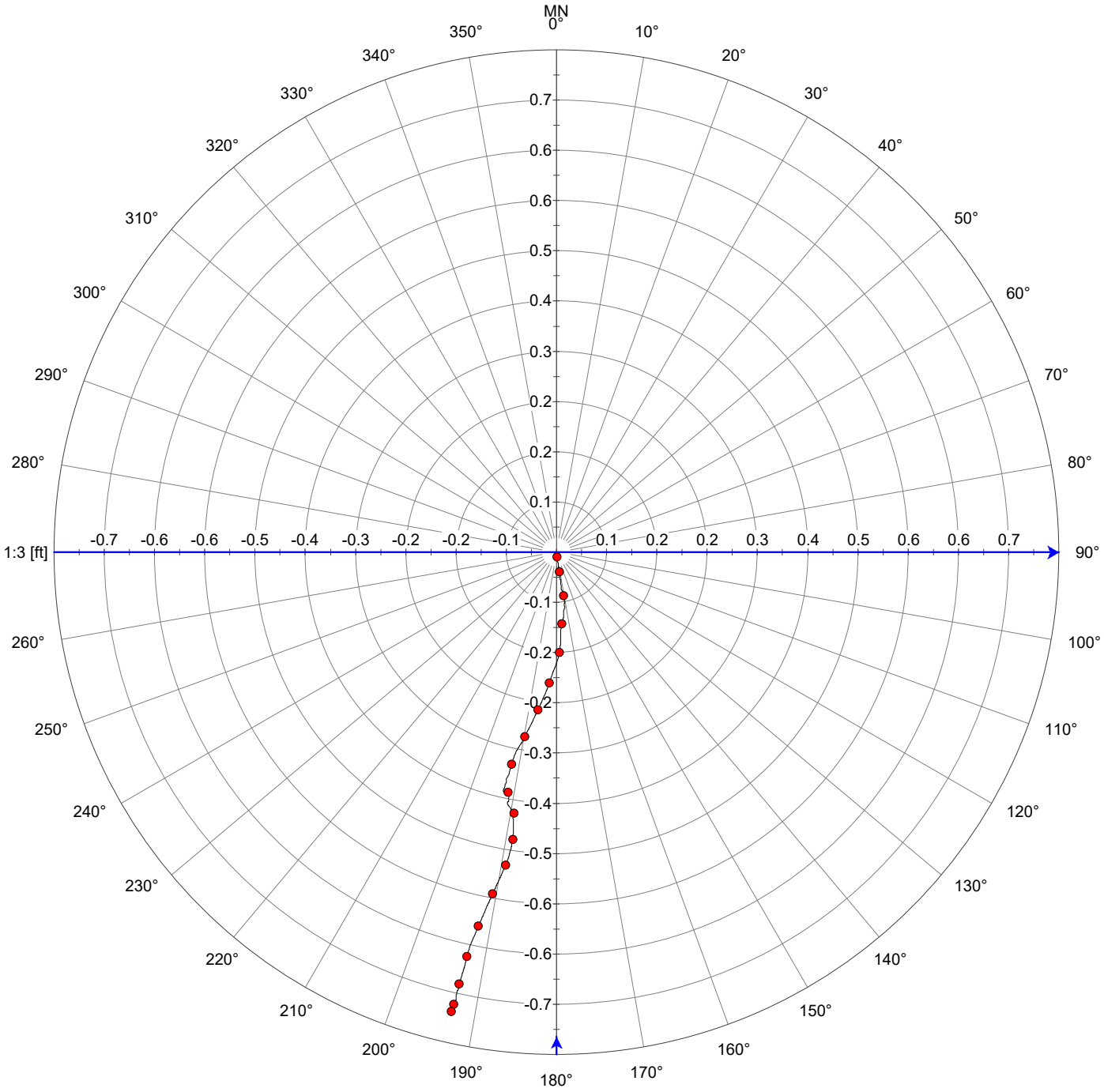
DATE LOGGED: 7-8 & 19 June '19 | WELL: BH19-09 - South Shore

COMMENTS:

Straits of Mackinac **Elevation: 619.2'** **Latitude: 45.78736 N** **Longitude: 84.77692 W**






MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
0.7
0.6
0.6
0.5
0.4
0.3
0.2
0.2
0.1
-0.1
-0.2
-0.2
-0.3
-0.4
-0.5
-0.6
-0.6
-0.7
-0.7 -0.6 -0.6 -0.5 -0.4 -0.3 -0.2 -0.2 -0.1
0.1 0.2 0.2 0.3 0.4 0.5 0.6 0.6 0.7
1:3 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point Resistance

Company WSP
Well BH19-09
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-09
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78736 N
Longitude: 84.77692 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM GL **ELEVATION** 619.2'
LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**
DRILLING MEAS. FROM GL

DATE ACQUIRED	7 June 2019	20 June 2019	20 June 2019	
RUN NUMBER	1	2	2	
LOG TYPE	Electric log	Electric log	Natural Gamma	
DEPTH-DRILLER	49'	95'	95'	
DEPTH-LOGGER	49'	95'	95'	
BTM LOG INTERVAL	49'	93.8'	93.0'	
TOP LOG INTERVAL	7'	33.2'	5.9'	
RECORDED BY	JBG	JBG / CKL	JBG / CKL	
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP	
PROBE TYPE, S/N	ELXG #4248	ELXG #4248	ELXG #4248	
LOGGING SPEED	8 ft/min	10 ft/min	10 ft/min	
A.S.D.E. / Sample Interval	0.00' / 0.25'	0.3' / 0.25'	0.3' / 0.25'	
Fluid Level / Fluid Type	33' / water	33' / water	33' / water	

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	10'	95'
1	NQ	95'	103'
2	6"	GL	95'

CASING RECORD

SIZE	WGT.	FROM	TO
6"	Steel	GL	10'
6"	Steel	GL	55"

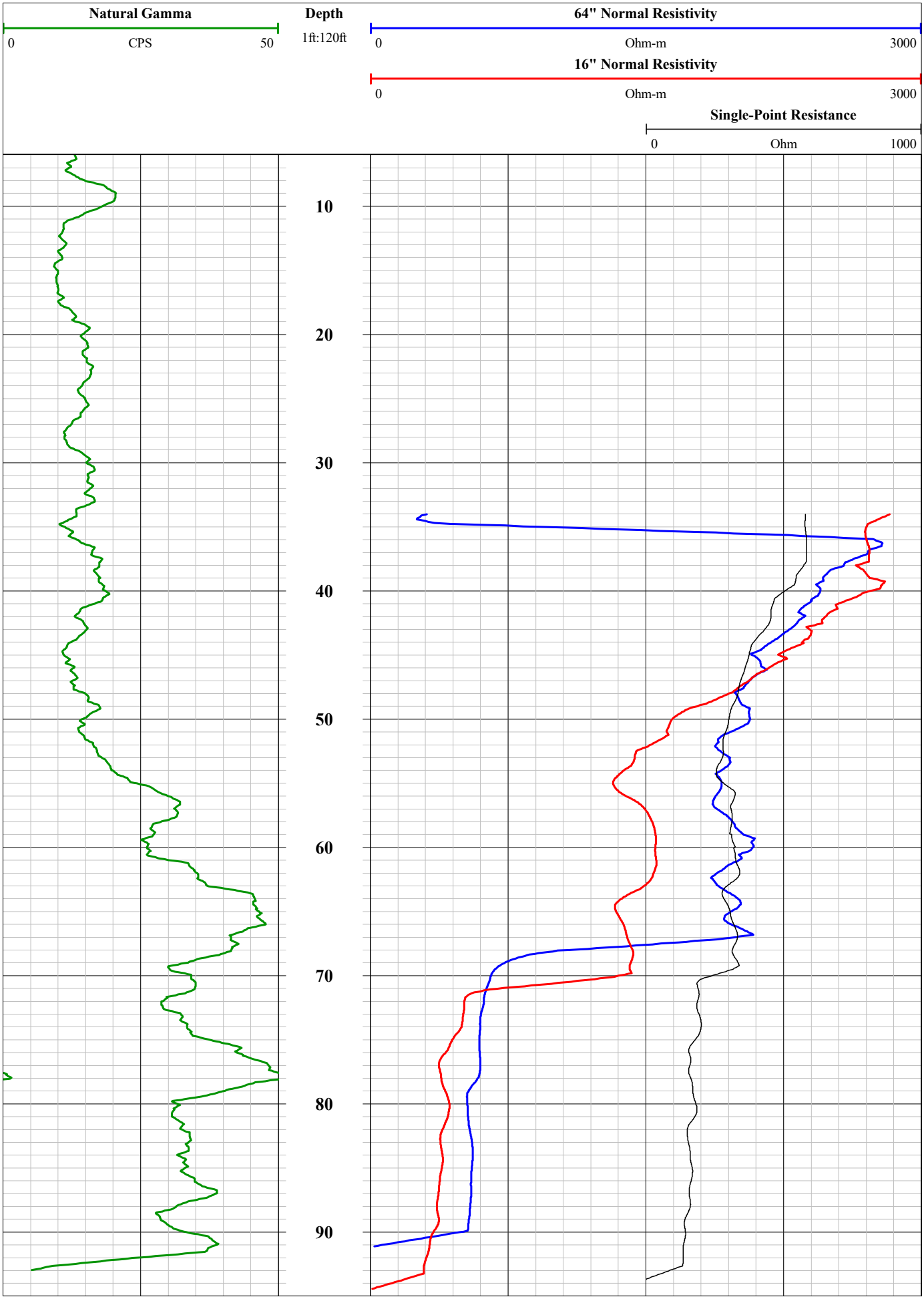
NA - Not Available, N/A - Not Applicable

COMMENTS

BH19-09 hole collapsed at 49' on June 7 - came back June19 & 20 to complete bottom portion of hole

Spontaneous Potential omitted due to configuration error

Run 1 Electric log omitted due to unusable data created by the borehole collapse at 49', water level at 33' and the length of the bridal.


Natural Gamma
0
CPS
50
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
3000
16" Normal Resistivity
0
Ohm-m
3000
Single-Point Resistance
0
Ohm
1000
10
20
30
40
50
60
70
80
90

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-09
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-09
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78736 N
Longitude: 84.77692 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond
Electrical Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 619.2'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	7 June 2019	20 June 2019		
RUN NUMBER	1	2		
LOG TYPE	P&S log	P&S log		
DEPTH-DRILLER	103'	95'		
DEPTH-LOGGER	49'	95'		
BTM LOG INTERVAL	38'	84'		
TOP LOG INTERVAL	32'	54'		
RECORDED BY	JBG	JBG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	PSlogger #10926	PSlogger #10926		
LOGGING SPEED	stationary	stationary		
A.S.D.E. / Sample Interval	?' / 2.0'	0.28' / 2.0'		
Fluid Level / Fluid Type	33' / water	33' / water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	10'	95'
1	NQ	95'	103'
2	6"	GL	95'

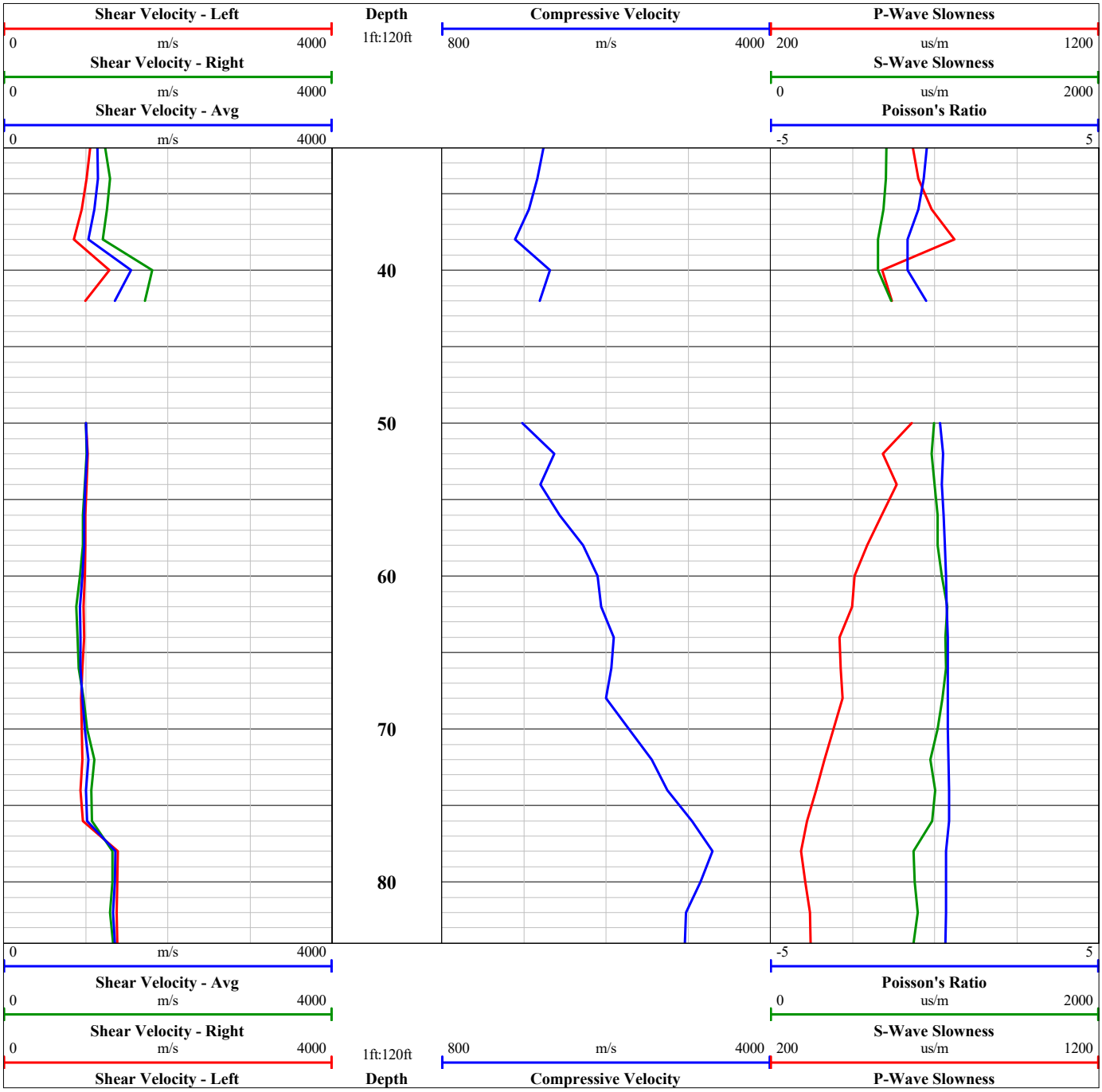
CASING RECORD

SIZE	WGT.	FROM	TO
6"	Steel	GL	10'
6"	Steel	GL	55'

NA - Not Available, N/A - Not Applicable

COMMENTS

Due to the hole collapsing, the data collection occurred at two separate times. Casing was advanced deeper, causing a blank zone between 40' to 52'.


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
40
50
60
70
80
Compressive Velocity
800
m/s
4000
P-Wave Slowness
200
us/m
1200
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-5
5

PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-09**	Test depth:	**43.70 ft**
Test date: (mm/dd/yyyy)	**6/7/2019**	C :	0.9265 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	$\Delta R/R_{0\ Probe}$ %
0	0.00	76	0.00	0.00
53	-0.40	130	-0.45	-0.01
1662	204.19	1018	202.65	5.18
2083	215.40	1393	213.48	5.45
2641	230.86	1890	228.41	5.82
3252	245.41	2442	242.39	6.16
3844	259.75	2980	256.19	6.50
4586	275.97	3667	271.72	6.89
5105	290.52	4136	285.79	7.23
5821	305.57	4802	300.18	7.58
6649	322.51	5578	316.35	7.97
7135	336.38	6021	329.77	8.30
7602	349.93	6445	342.89	8.62

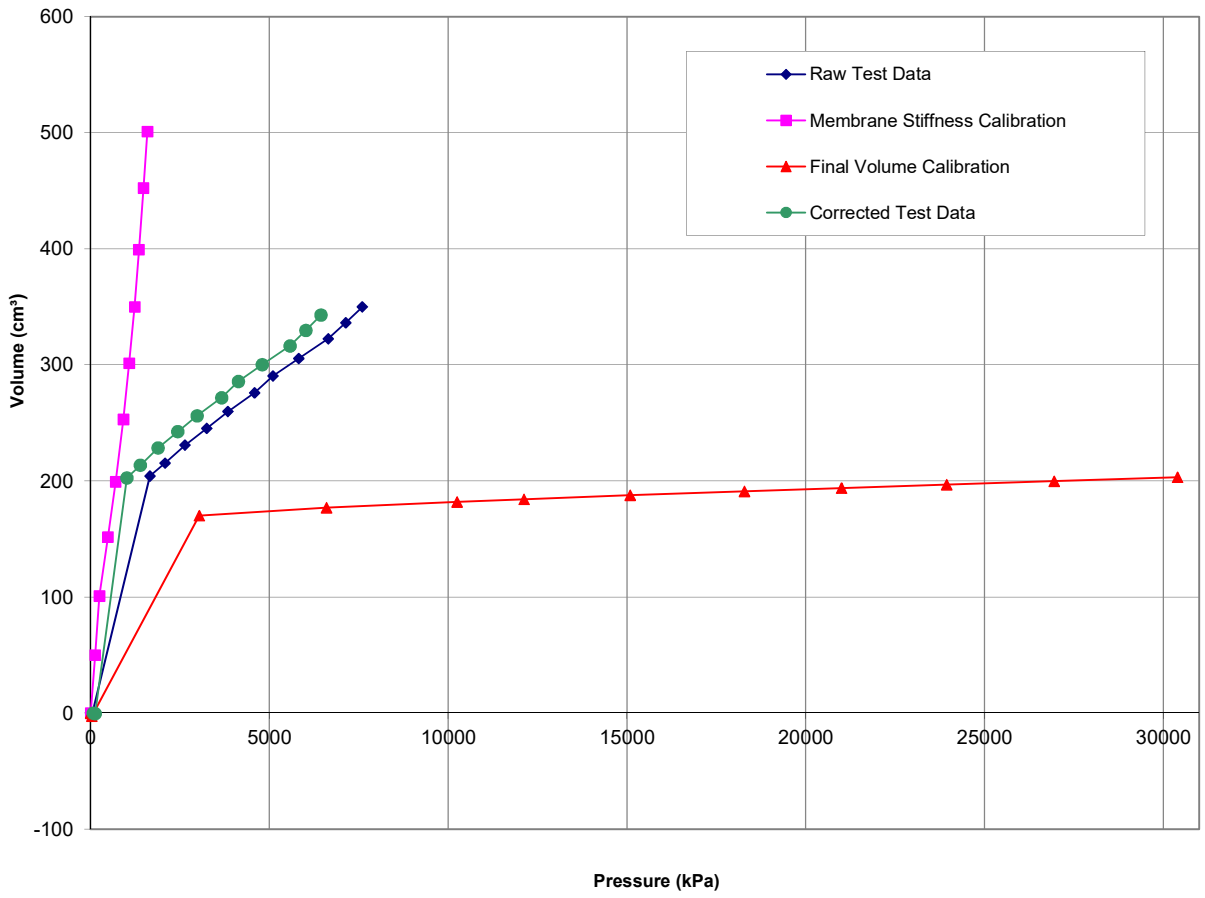
Test Results

PROBEX Modulus E:	**197,361 kPa**
Ultimate Pressure P_L:	**16,697**
Ratio E / P_L:	**11.82**

Volume & Pressure Calibrations ID

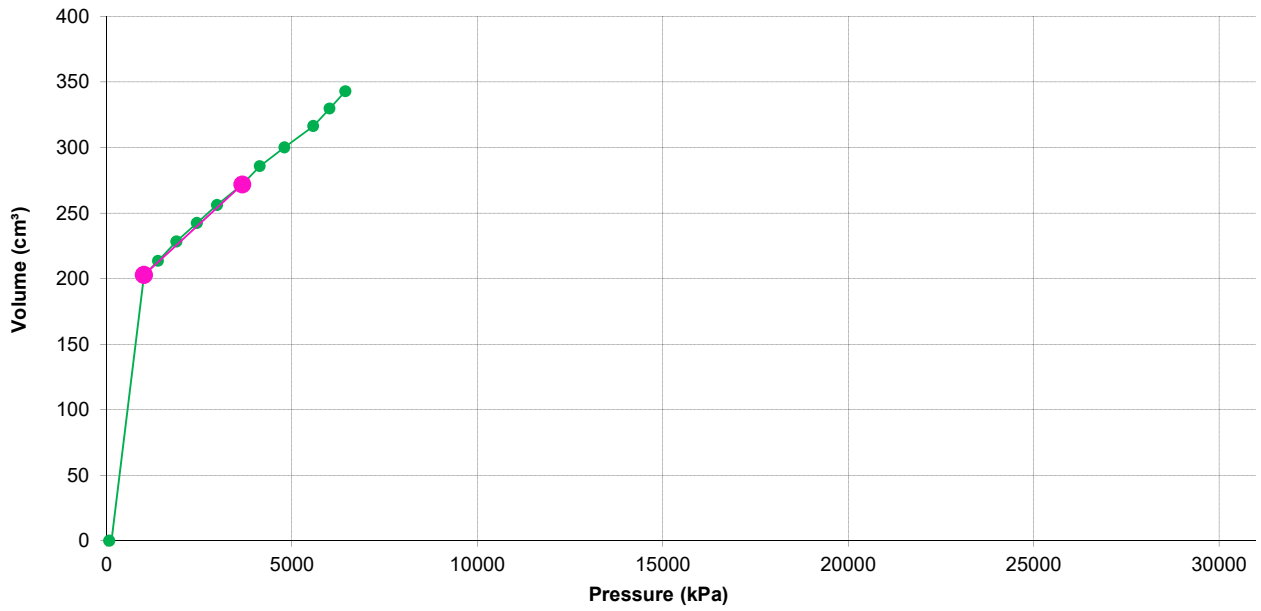
CalV4	CalP1

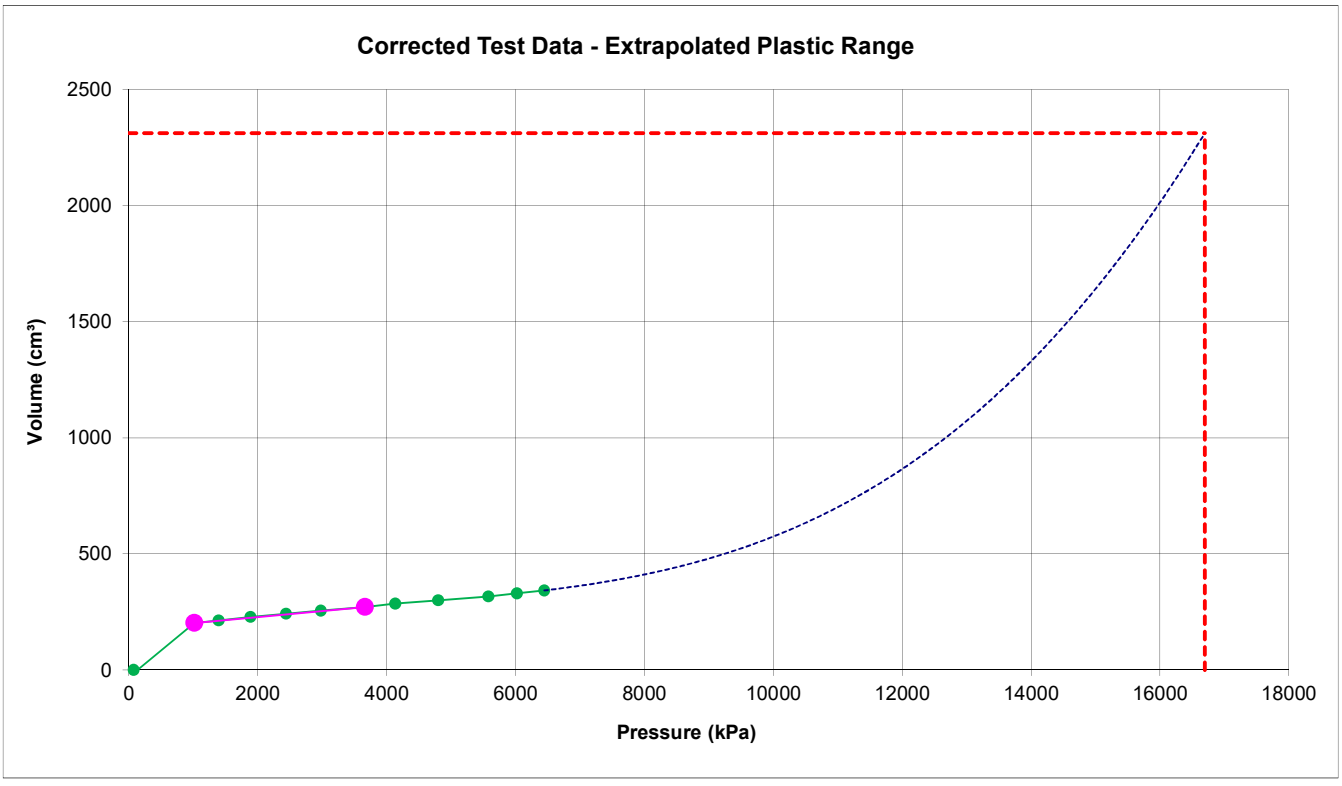
Test Data with Calibration Curves



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-09**	Test depth:	**43.70 ft**
Test date: (mm/dd/yyyy)	**6/7/2019**	C :	0.9265 cc/MPa
Test number:	1	Poisson's coefficient	0.20





PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-09**	Test depth:	**102.00 ft**
Test date: (mm/dd/yyyy)	**6/8/2019**	C :	0.9401 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	$\Delta R/R_{0\ Probe}$ %
0	0.00	175	0.00	0.00
-7	5.25	156	5.26	0.14
2641	192.05	2168	189.57	4.87
4343	206.03	3805	201.95	5.18
6216	220.72	5616	214.88	5.50
8239	235.43	7578	227.69	5.82
10729	250.65	10004	240.56	6.14
13206	265.37	12435	252.96	6.45
15821	280.40	15003	265.53	6.76
18449	295.38	17584	278.04	7.06
21058	309.73	20149	289.93	7.36
23949	325.38	22995	302.87	7.67
26597	340.39	25599	315.39	7.98
28298	350.79	27271	324.18	8.19

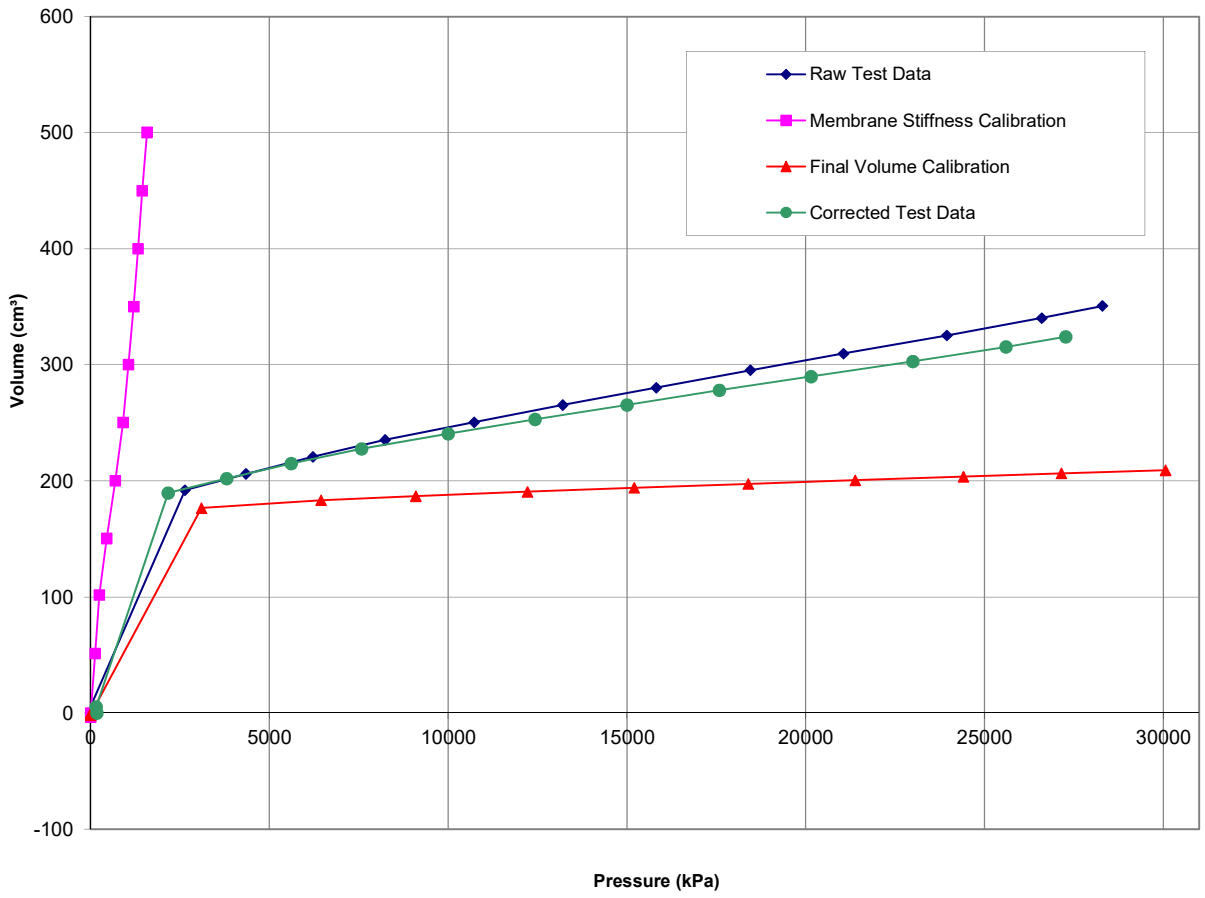
Test Results

PROBEX Modulus E:	**1,106,223 kPa**
Ultimate Pressure P_L:	**81,926**
Ratio E / P_L:	**13.50**

Volume & Pressure Calibrations ID

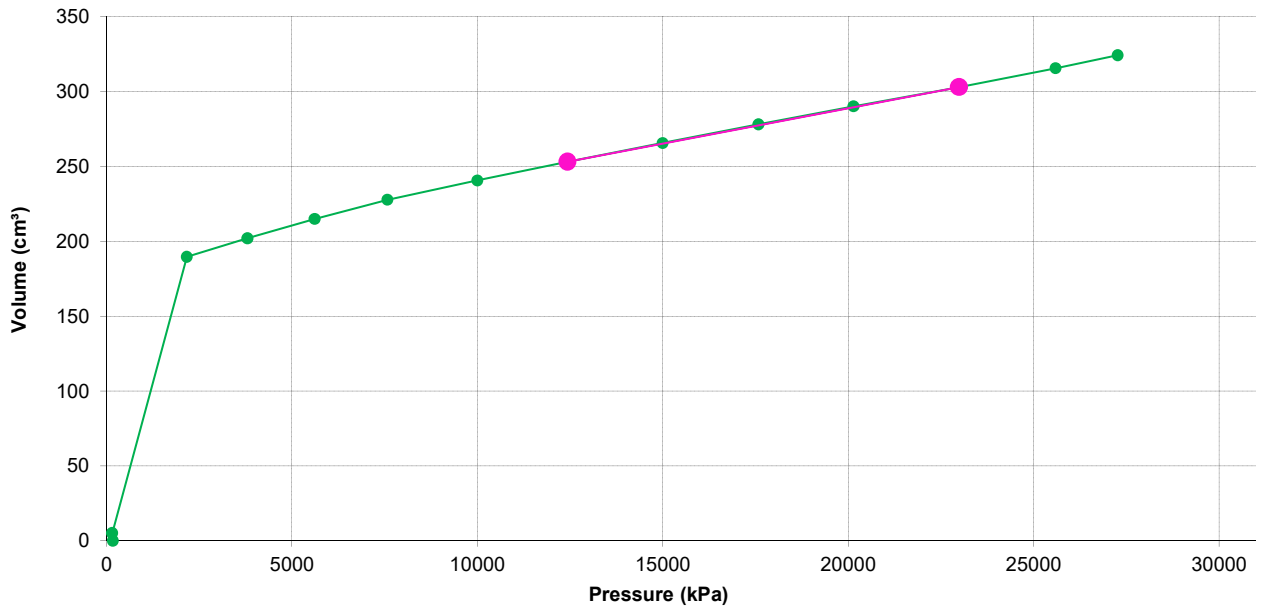
CalV4	CalP1

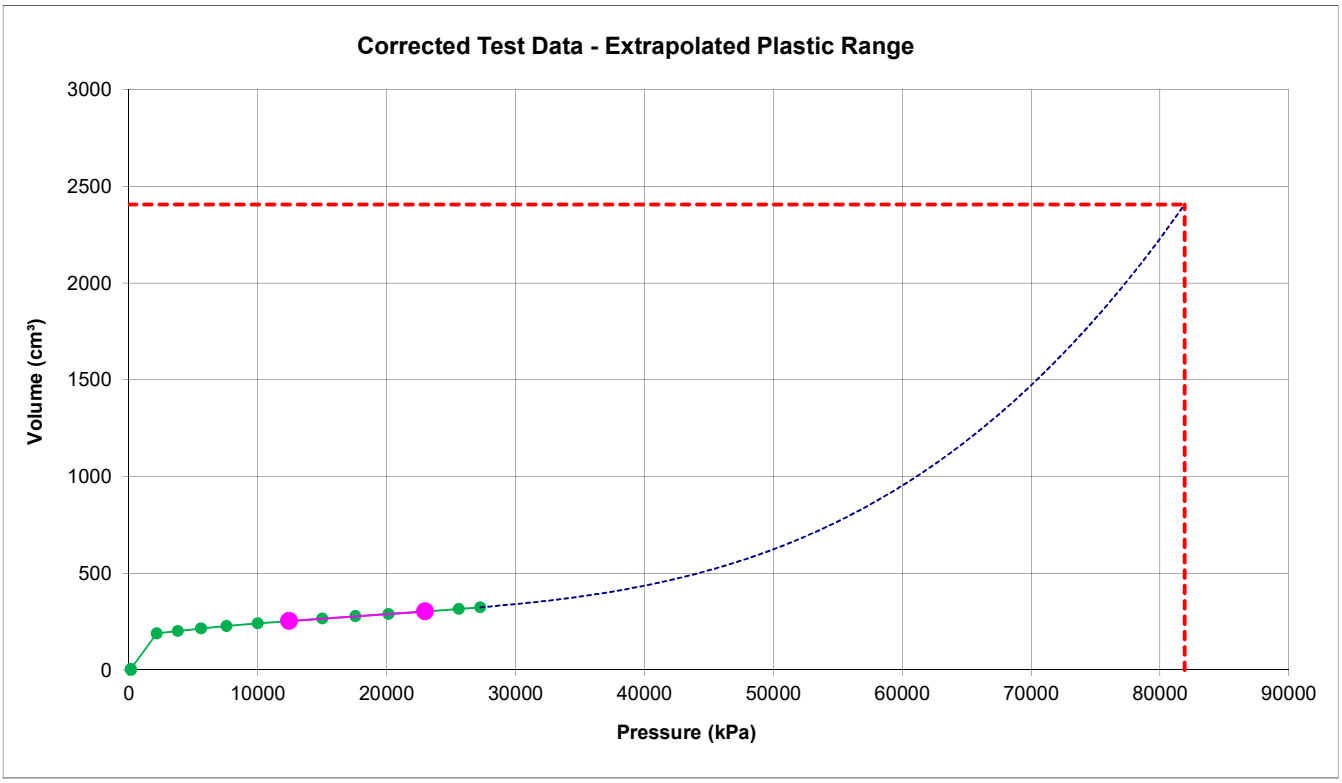
Test Data with Calibration Curves



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-09**	Test depth:	**102.00 ft**
Test date: (mm/dd/yyyy)	**6/8/2019**	C :	0.9401 cc/MPa
Test number:	1	Poisson's coefficient	0.20





Geophysical Summary Plot

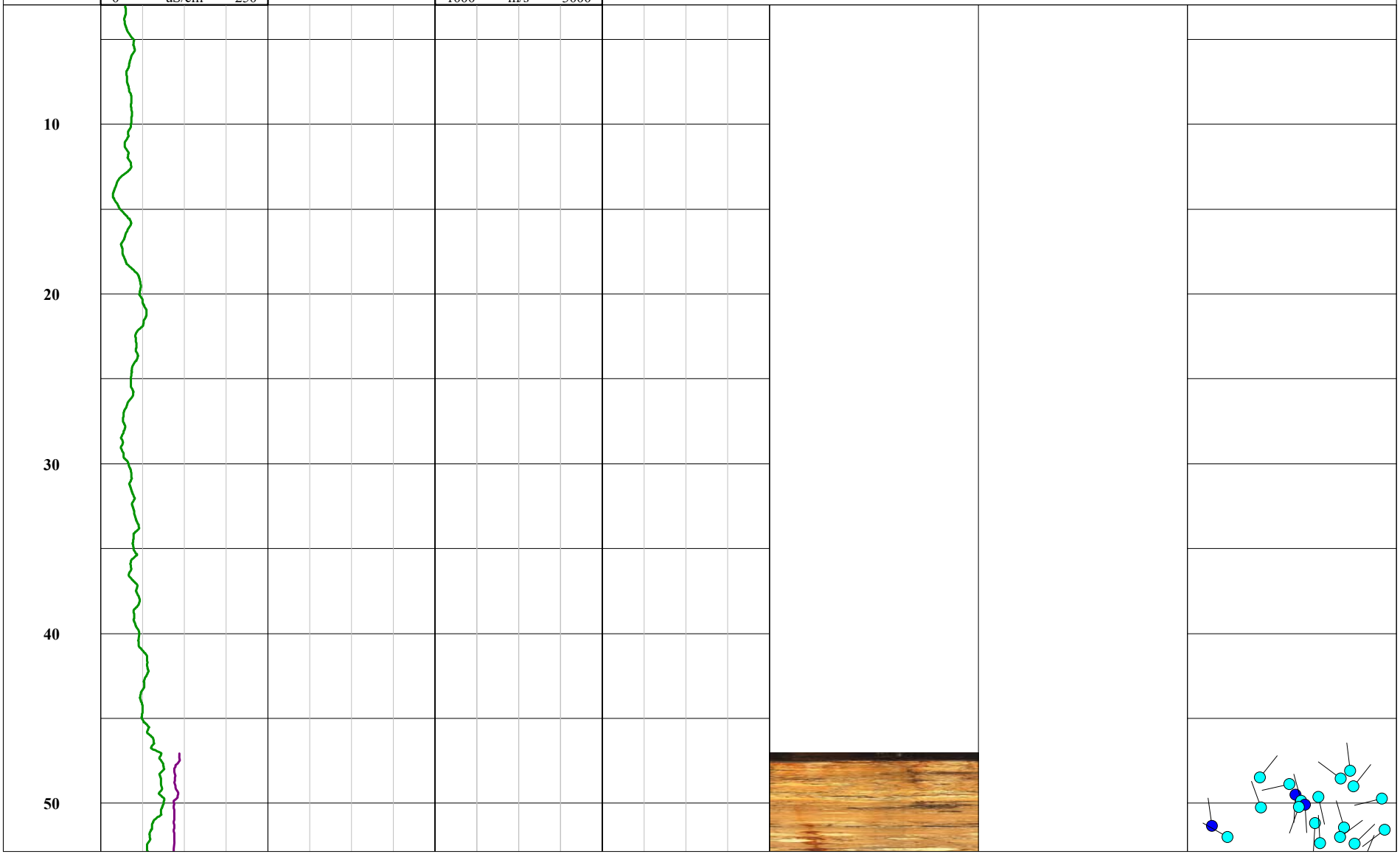
COLOG
borehole geophysics / hydrophysics

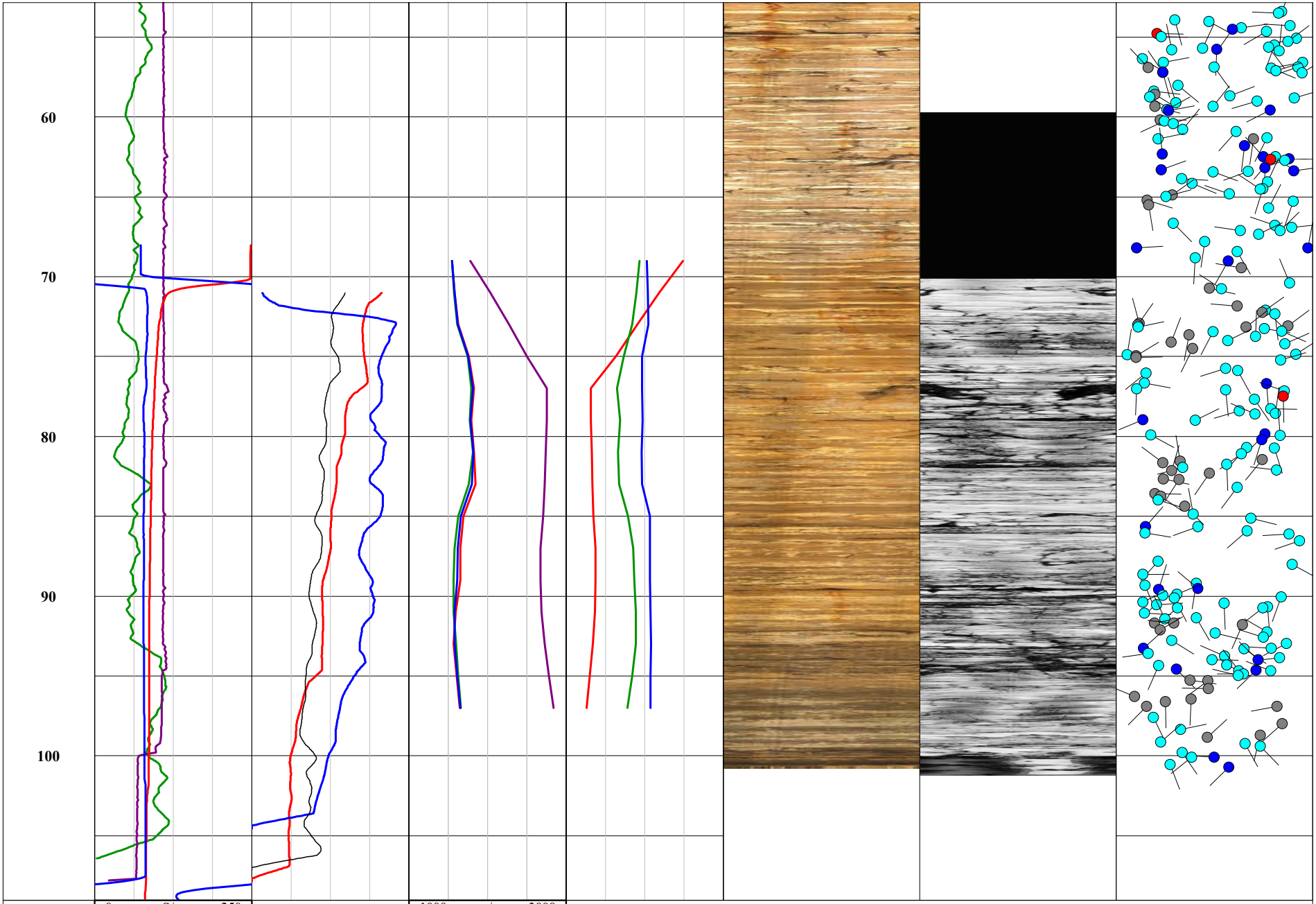
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMPANY: WSP | **PROJECT:** L5RT Project

DATE LOGGED: 8 June 2019 | **WELL:** BH19-10 - South Shore

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN	Tadpoles - MN
1ft:100ft	0 CPS 50	0 Ohm-m 3000	0 m/s 4000	300 us/m 700	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 inch 6	0 Ohm-m 3000	0 m/s 4000	0 us/m 2000			
	Temperature	Single-Point Resistance	Shear Velocity - Avg	Poisson's Ratio			
	5 deg C 15	0 Ohm 1000	0 m/s 4000	-5 5			
	Fluid Conductivity		Compressive velocity				
	0 uS/cm 250		1000 m/s 3000				





Depth						
1ft:100ft	0 uS/cm 250		1000 m/s 3000			
	Fluid Conductivity		Compressive velocity			
	5 deg C 15	0 Ohm 1000	0 m/s 4000	-5 5		
	Temperature	Single-Point Resistance	Shear Velocity - Avg	Poisson's Ratio		
	2 inch 6	0 Ohm-m 3000	0 m/s 4000	0 us/m 2000		
	3-Arm Caliper	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness		
	0 CPS 50	0 Ohm-m 3000	0 m/s 4000	300 us/m 700	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°
	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN

0 90

Tadpoles - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer
3-Armed Caliper

Company WSP
Well BH19-10
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-10
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78545 N
Longitude: 84.77588 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 662.6'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	8 June 2019		8 June 2019	
RUN NUMBER	1		1	
LOG TYPE	Acoustic Televiewer		3-armed caliper	
DEPTH-DRILLER	109'		109'	
DEPTH-LOGGER	109'		109'	
BTM LOG INTERVAL	100.2'		107.8'	
TOP LOG INTERVAL	69.3'		47.1'	
RECORDED BY	JBG / KMG		JBG / KMG	
WITNESSED BY	Conrad Fischer-WSP		Conrad Fischer	
PROBE TYPE, S/N	BHTV LIM #1729		Comprobe #5238	
LOGGING SPEED	3 ft/min		10 ft/min	
A.S.D.E. / Sample Interval	0.0031' / 0.12'		0.08' / 0.10'	
Fluid Level / Fluid Type	70' / water		70' / water	

BOREHOLE RECORD

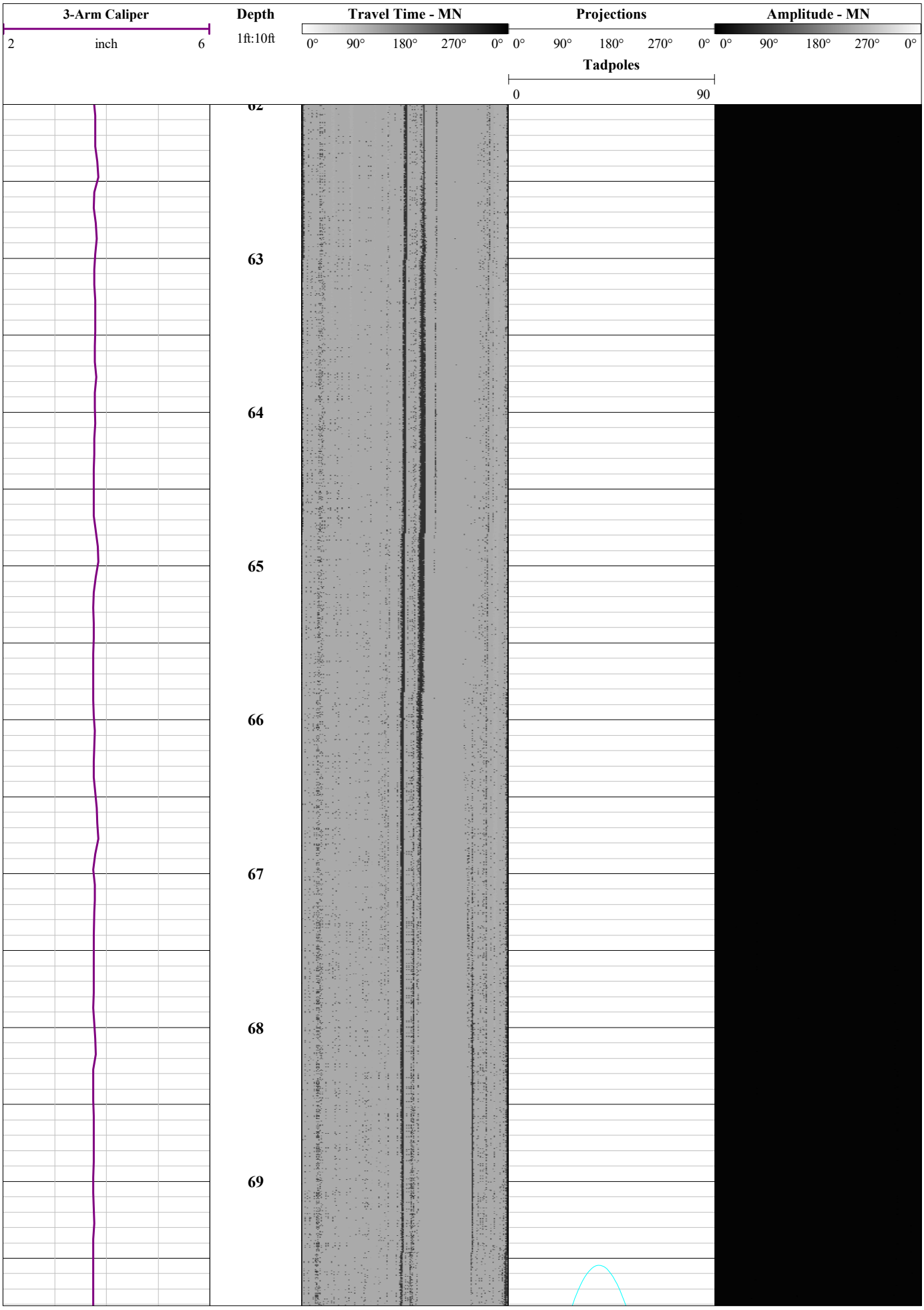
RUN No.	BIT	FROM	TO
1	HQ	47'	100'
1	NQ	100'	109'

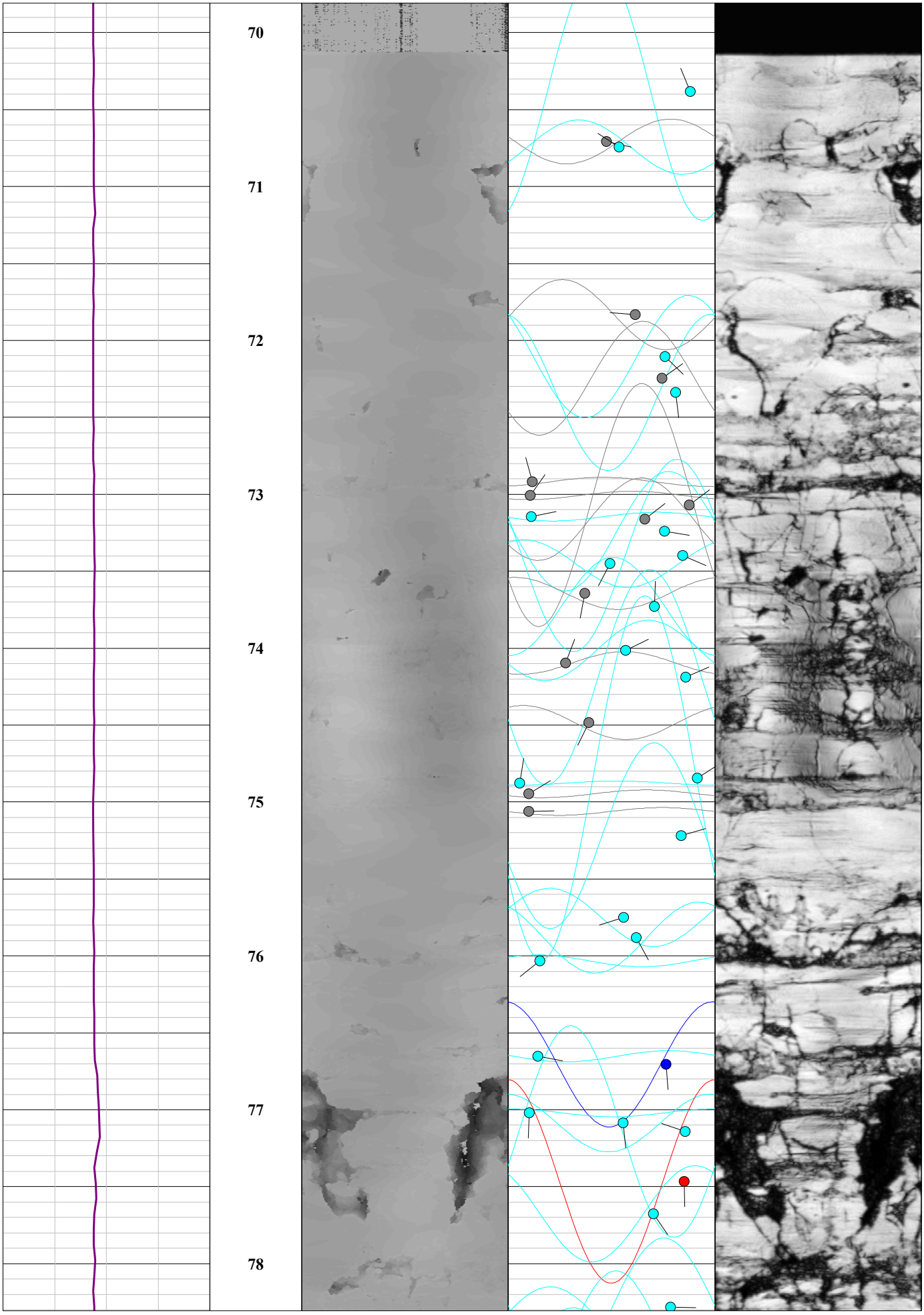
CASING RECORD

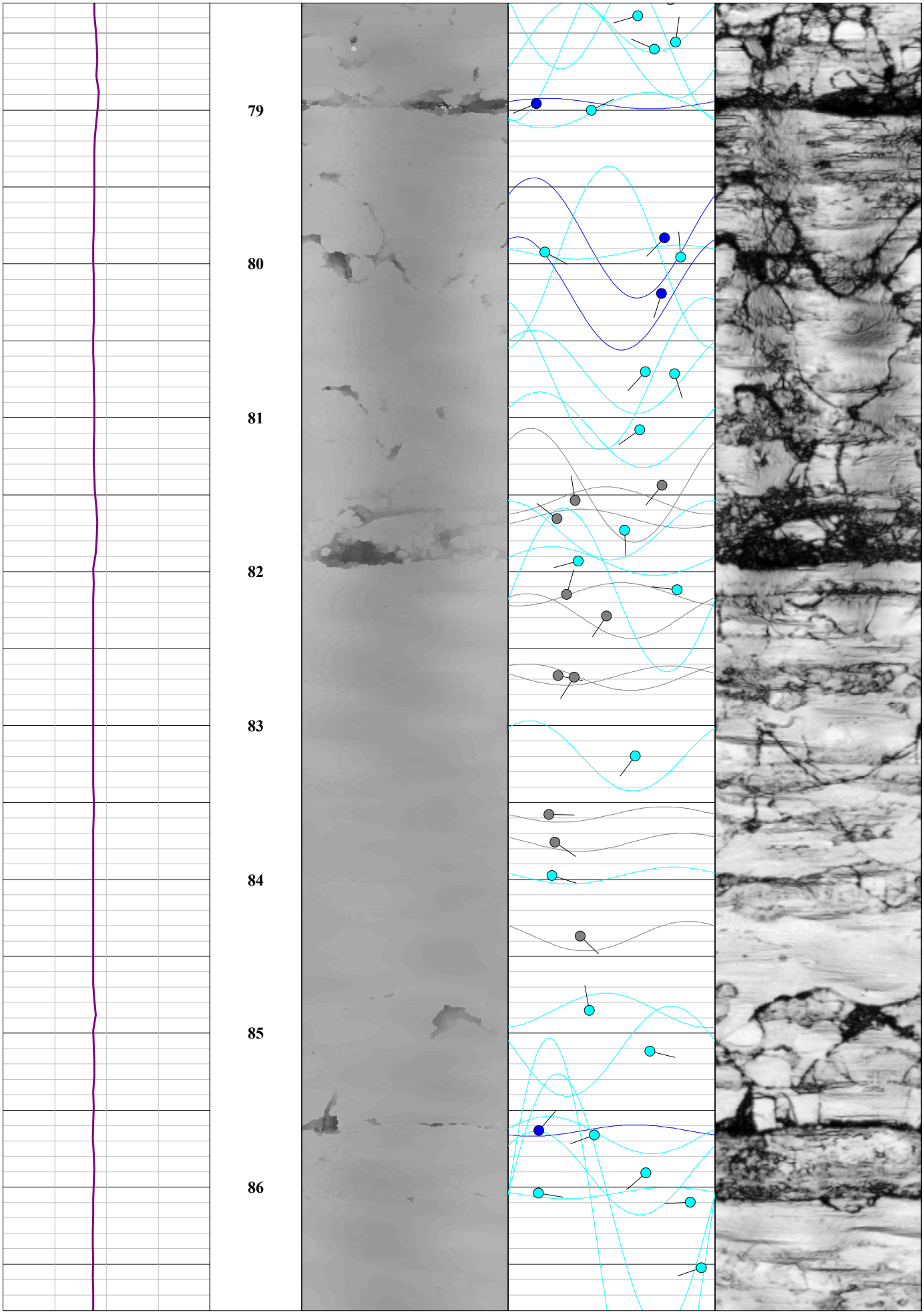
SIZE	WGT.	FROM	TO
HWT	Steel	GL	47'

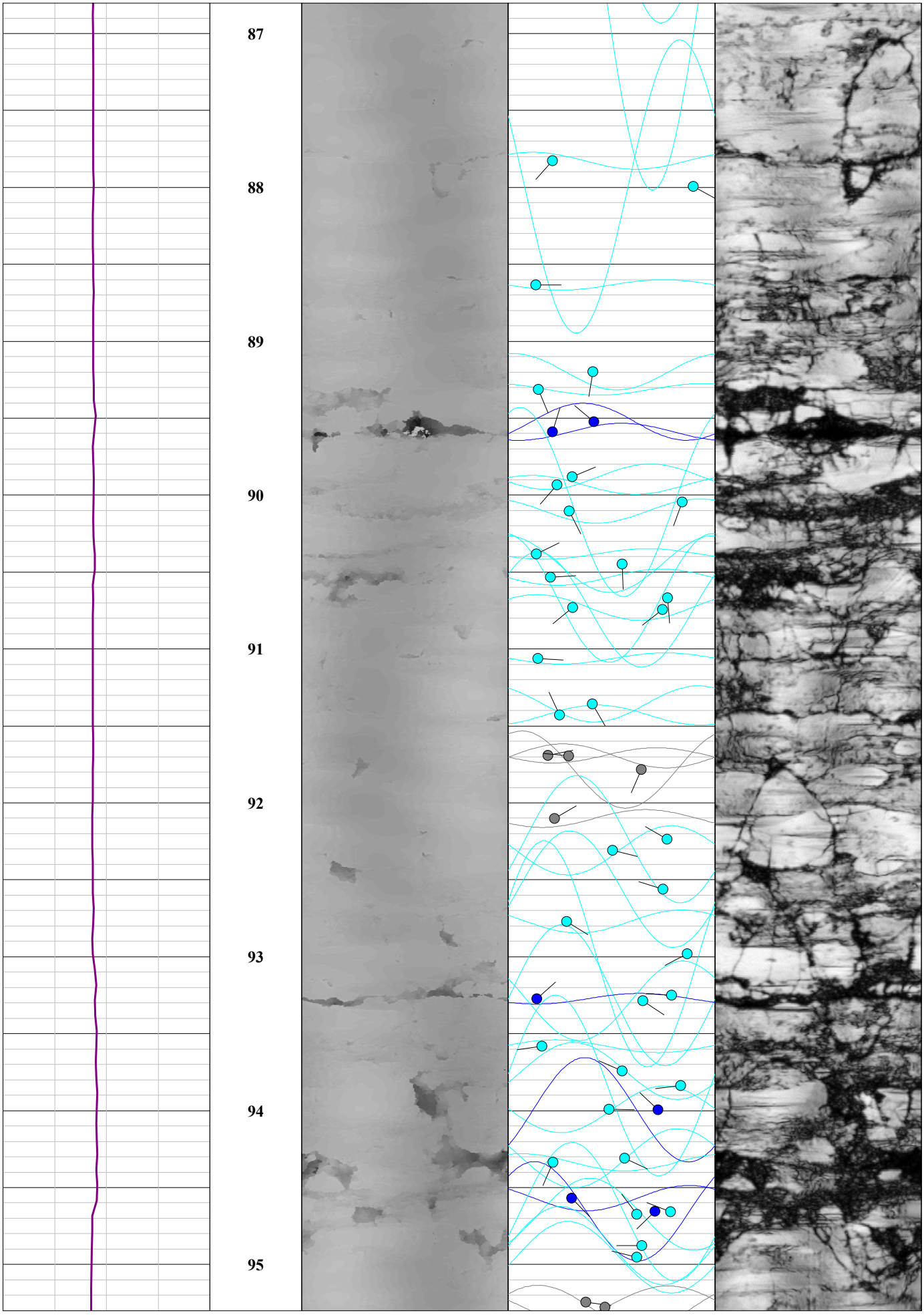
NA - Not Available, N/A - Not Applicable

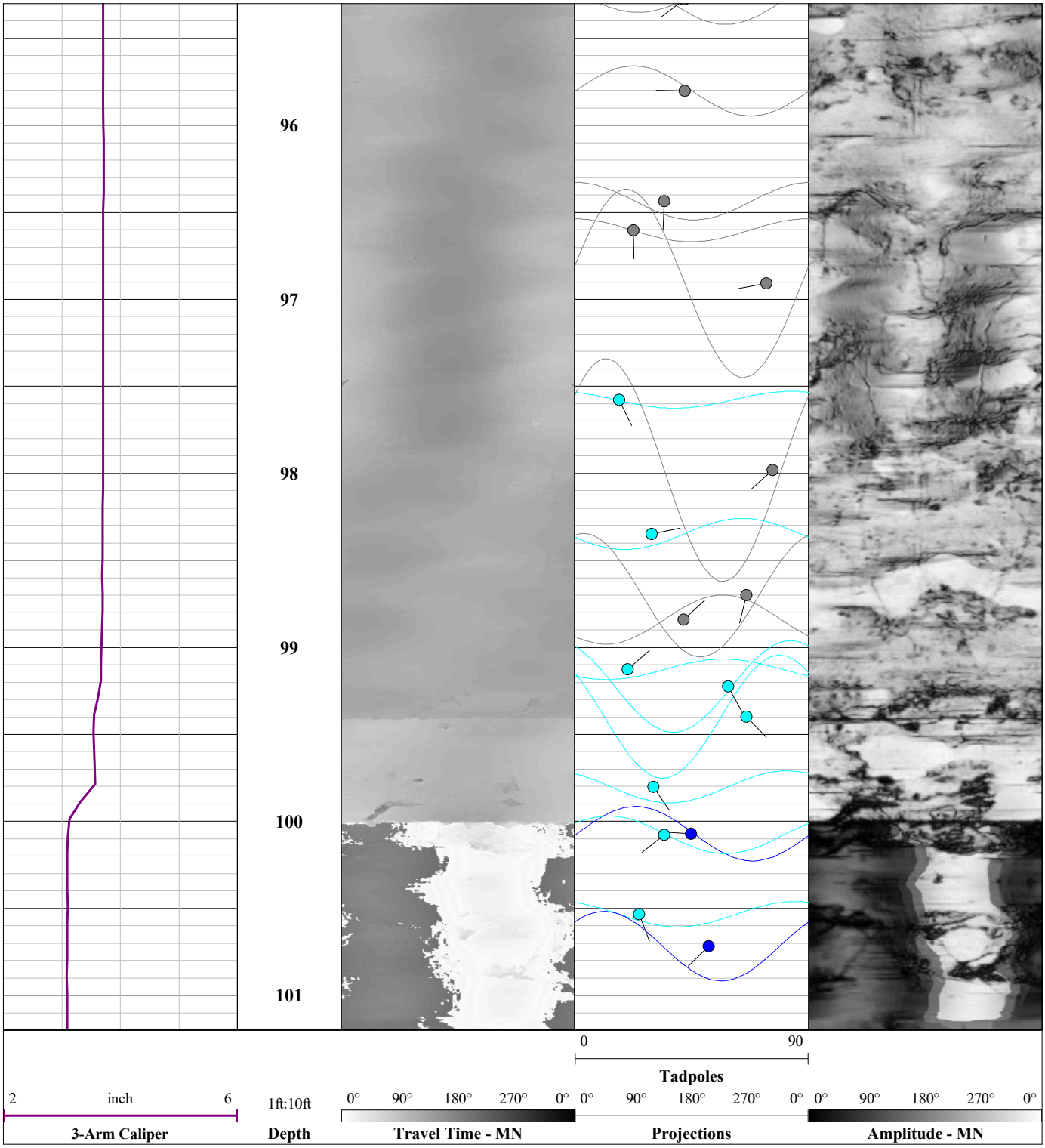
COMMENTS


3-Arm Caliper
2
inch
6
Depth
1ft:10ft
Travel Time - MN
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude - MN
0°
90°
180°
270°
0°
62
63
64
65
66
67
68
69


70
71
72
73
74
75
76
77
78


79
80
81
82
83
84
85
86


87
88
89
90
91
92
93
94
95


96
97
98
99
100
101
0
90
Tadpoles
2
inch
6
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
Travel Time - MN
Projections
Amplitude - MN

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer
3-Armed Caliper

Company WSP
Well BH19-10
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-10
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78545 N
Longitude: 84.77588 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 662.6'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	8 June 2019		8 June 2019	
RUN NUMBER	1		1	
LOG TYPE	Optical Televiewer		3-Armed Caliper	
DEPTH-DRILLER	109'		109'	
DEPTH-LOGGER	109'		109'	
BTM LOG INTERVAL	100.8'		107.8'	
TOP LOG INTERVAL	47.0'		47.1'	
RECORDED BY	JBG / KMG		JBG / KMG	
WITNESSED BY	Conrad Fischer-WSP		Conrad Fischer	
PROBE TYPE, S/N	OPTV LIM #1730		Comprobe #5238	
LOGGING SPEED	3 ft/min		10 ft/min	
A.S.D.E. / Sample Interval	0.0024' / 0.05'		0.08' / 0.10'	
Fluid Level / Fluid Type	70' / water		70' / water	

BOREHOLE RECORD

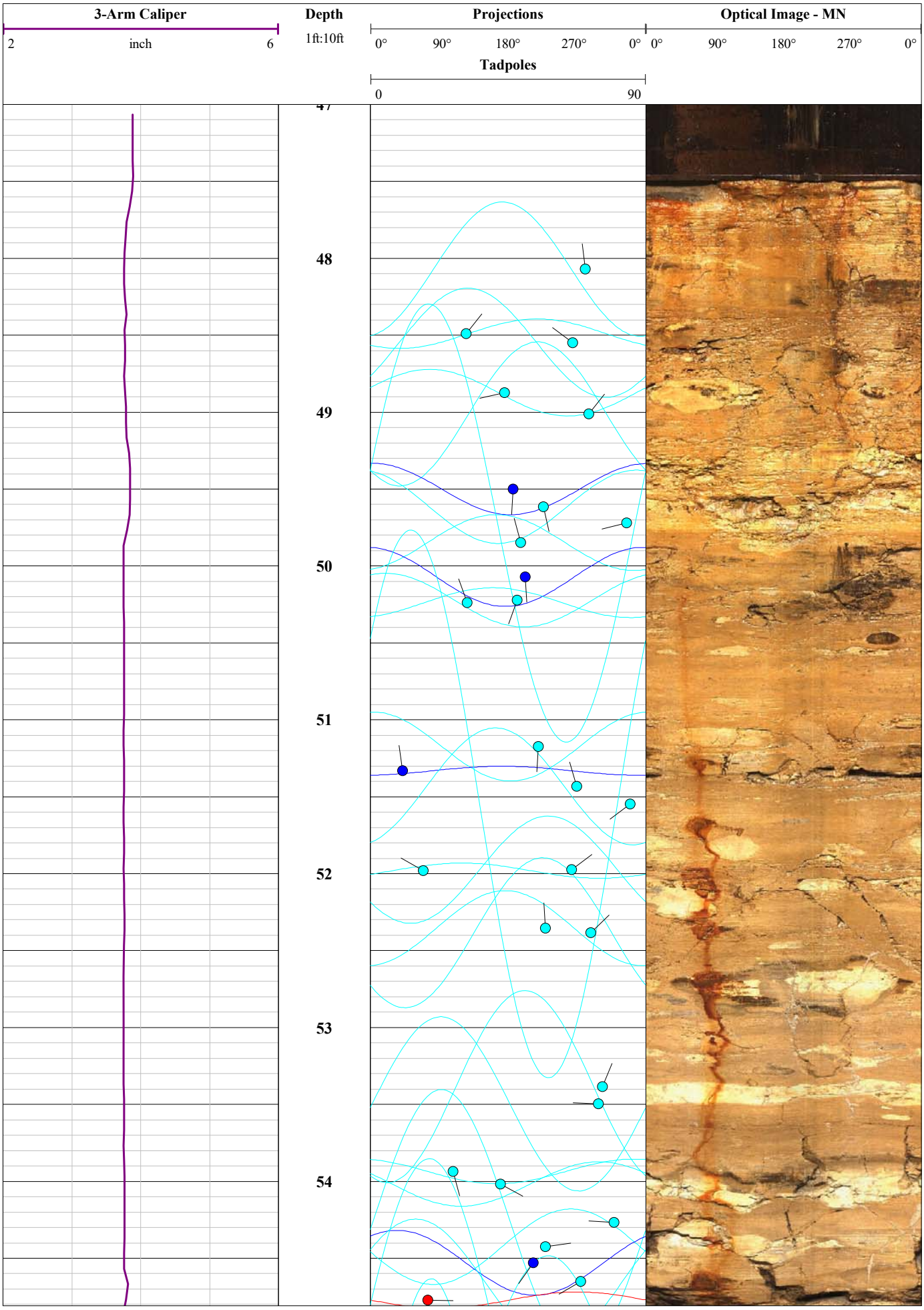
RUN No.	BIT	FROM	TO
1	HQ	47'	100'
1	NQ	100'	109'

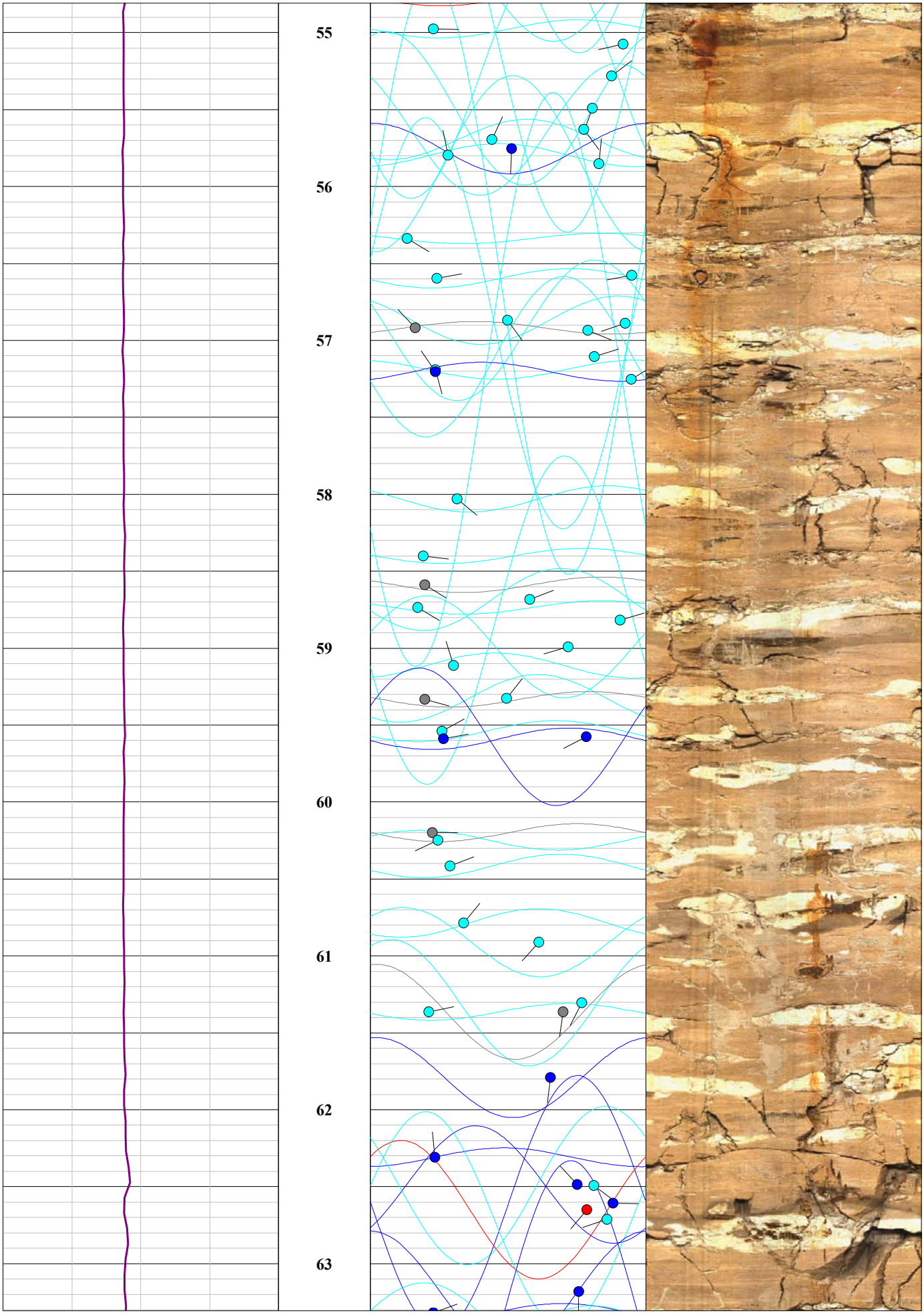
CASING RECORD

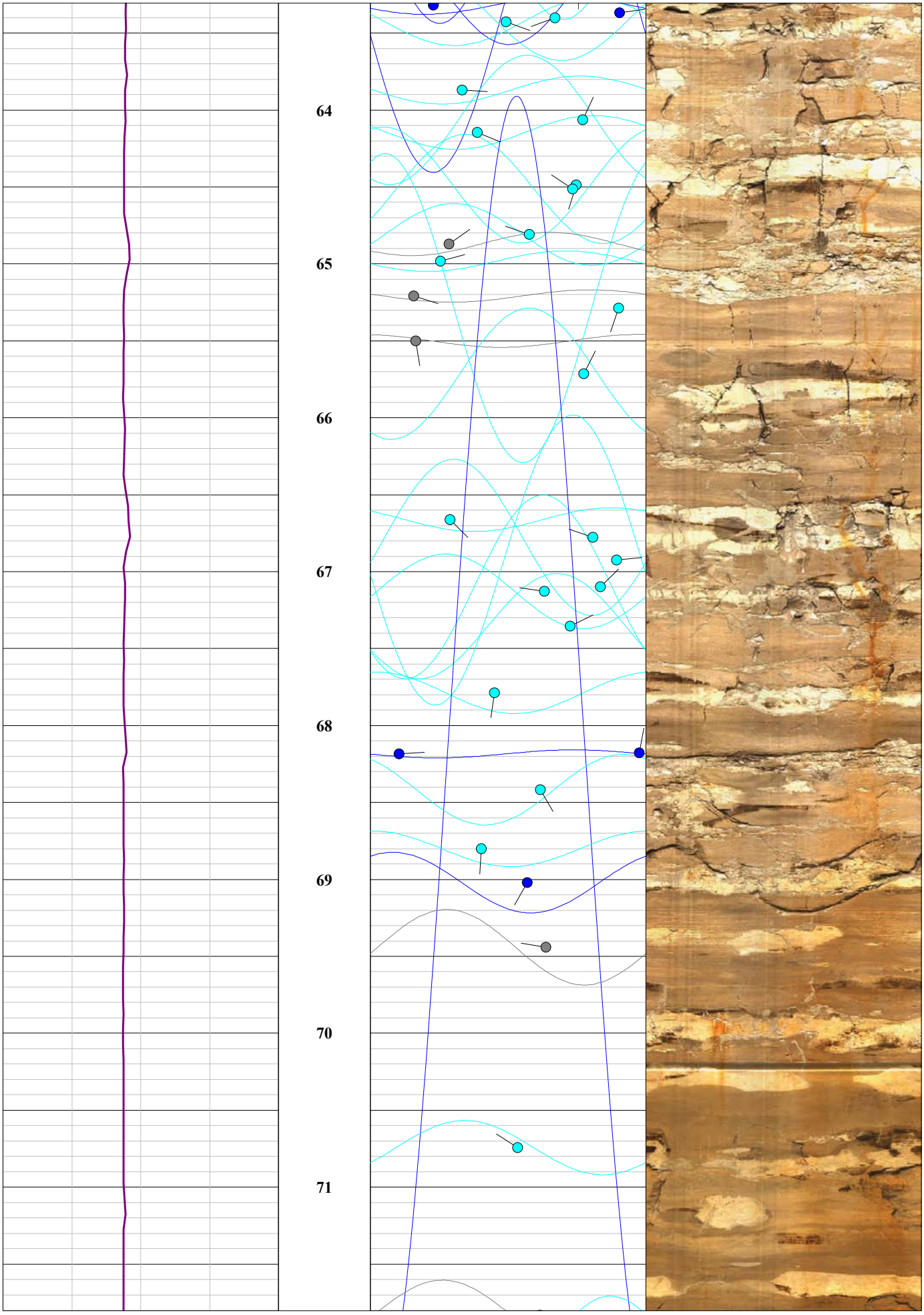
SIZE	WGT.	FROM	TO
HWT	Steel	GL	47'

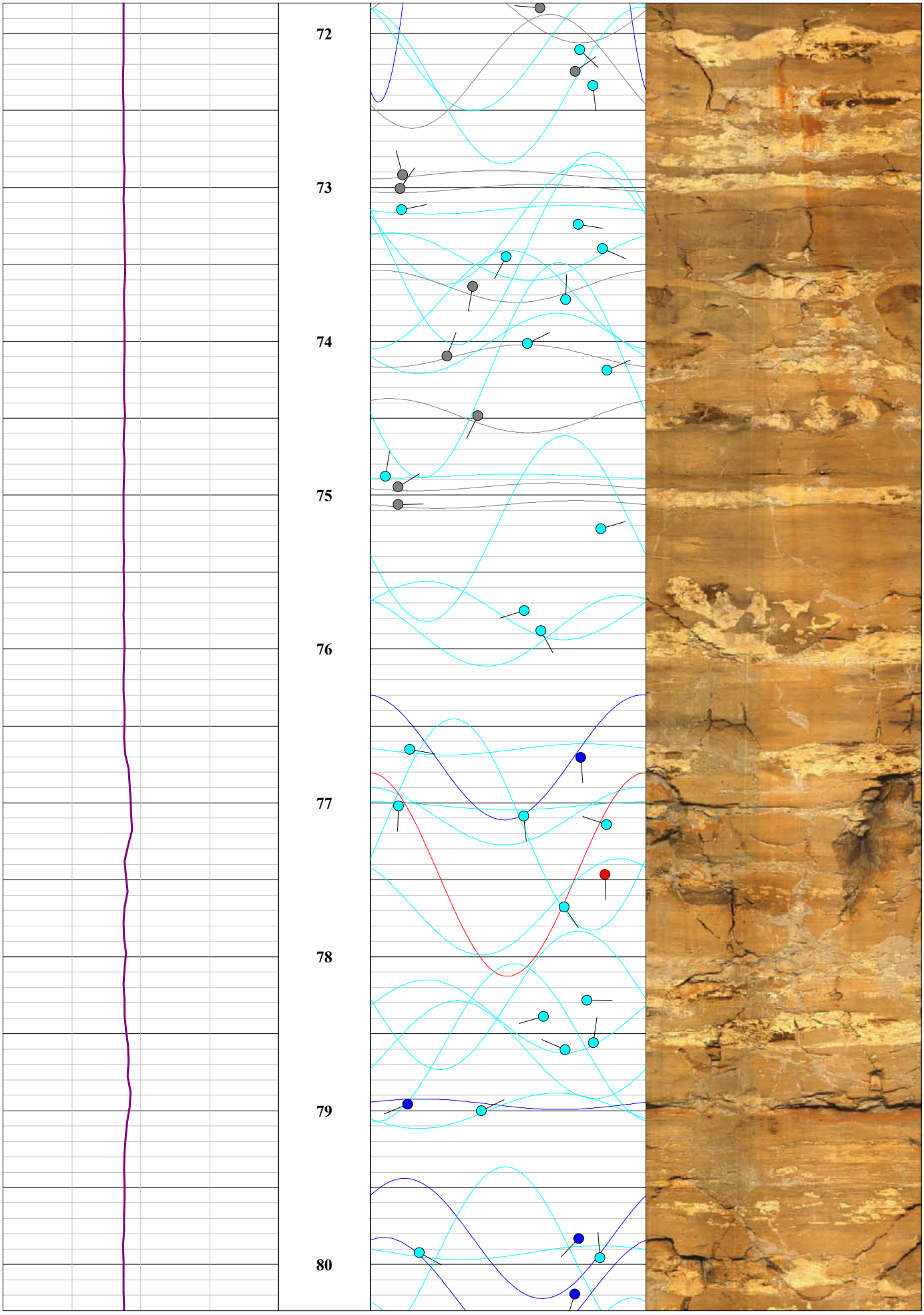
NA - Not Available, N/A - Not Applicable

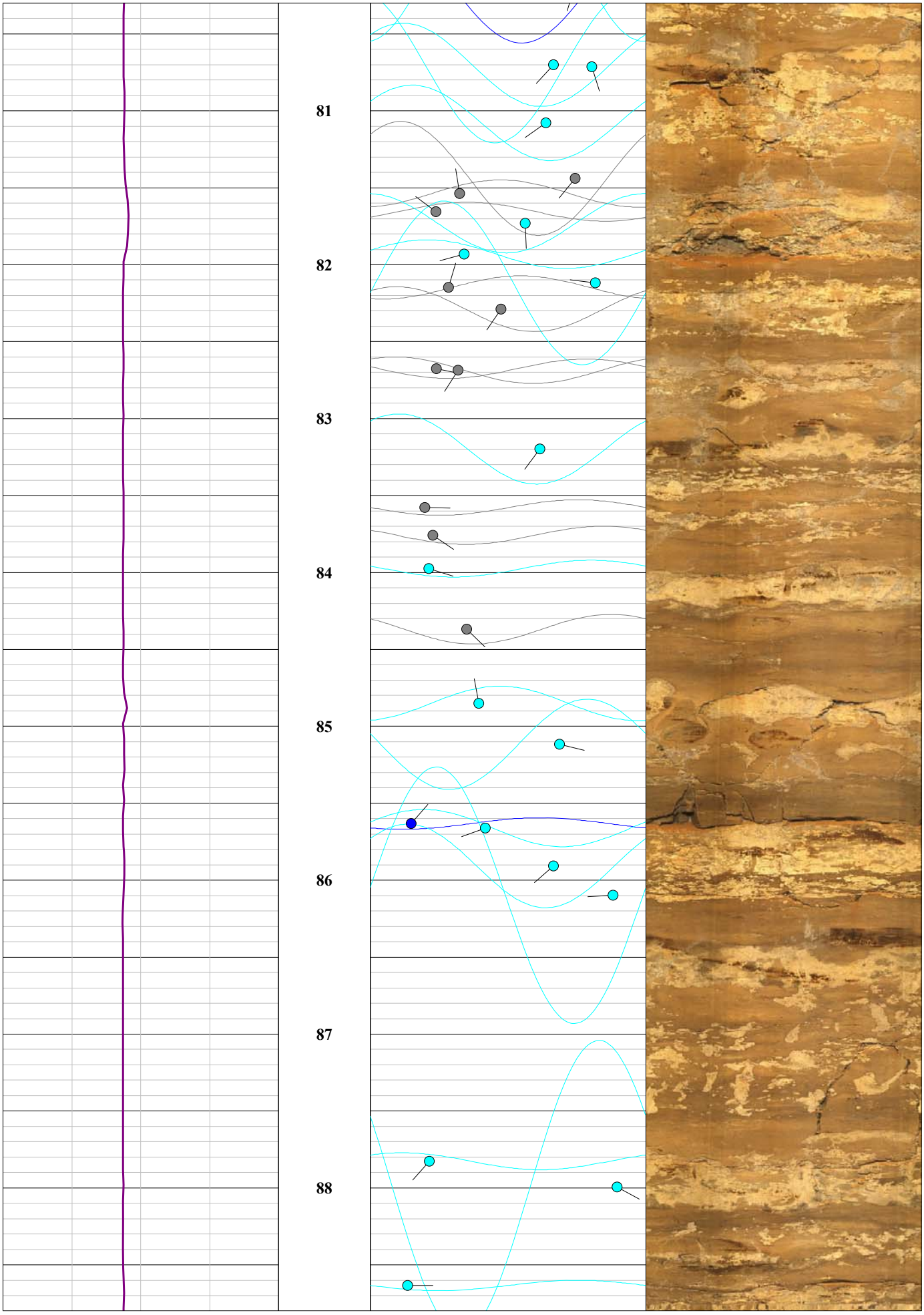
COMMENTS

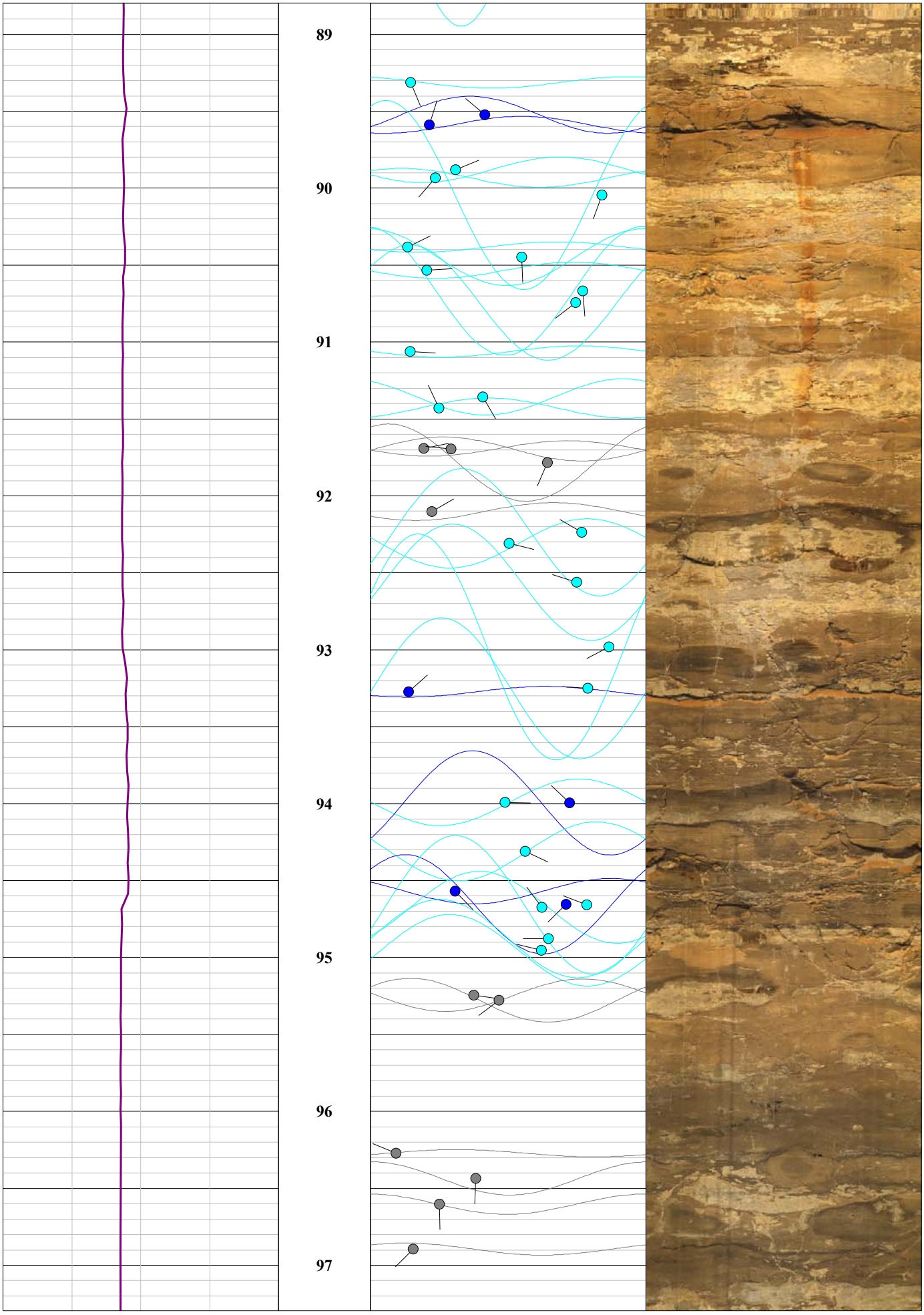

3-Arm Caliper
2
inch
6
Depth
1ft:10ft
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Optical Image - MN
0°
90°
180°
270°
0°
48
49
50
51
52
53
54

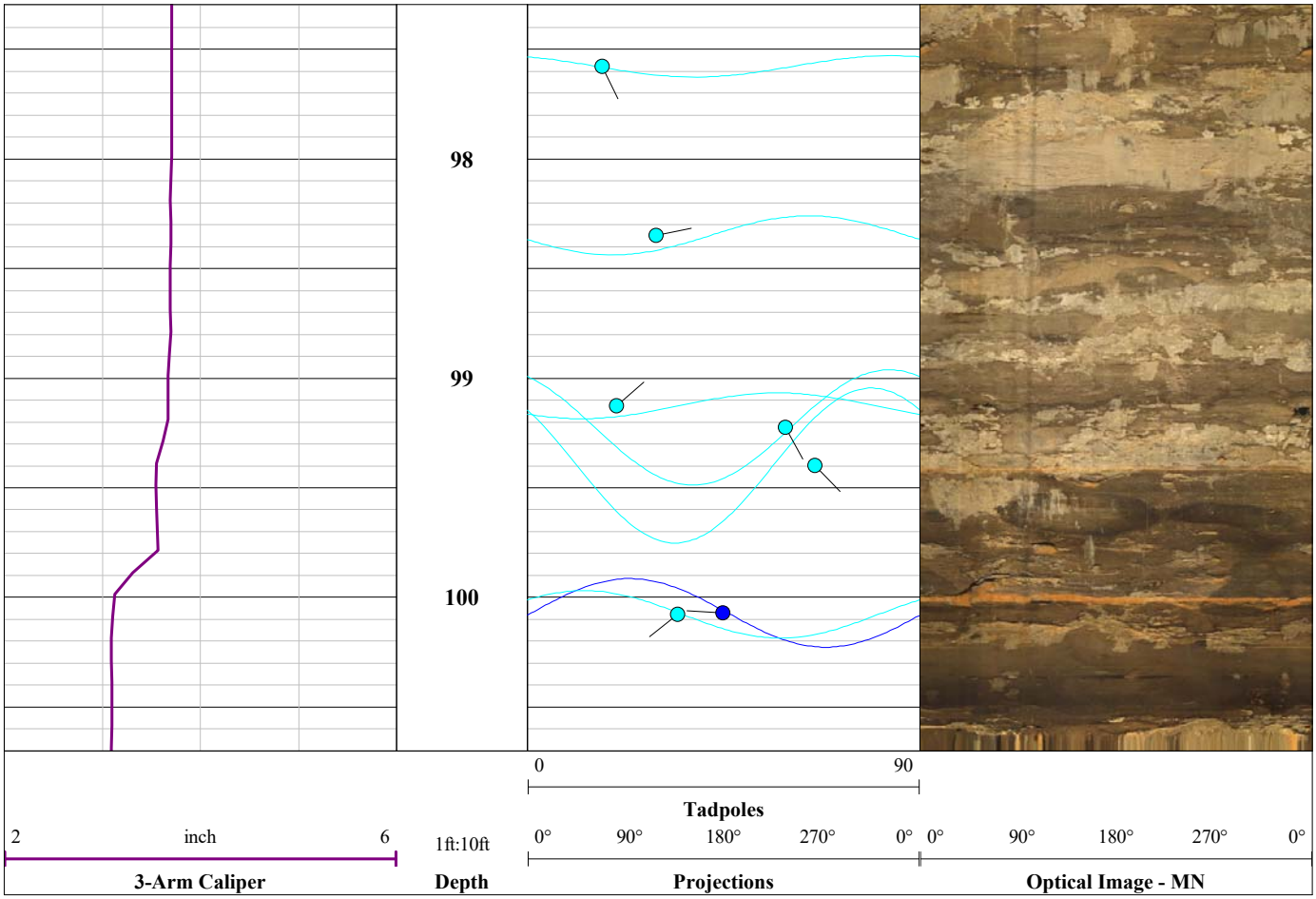

55
56
57
58
59
60
61
62
63


64
65
66
67
68
69
70
71

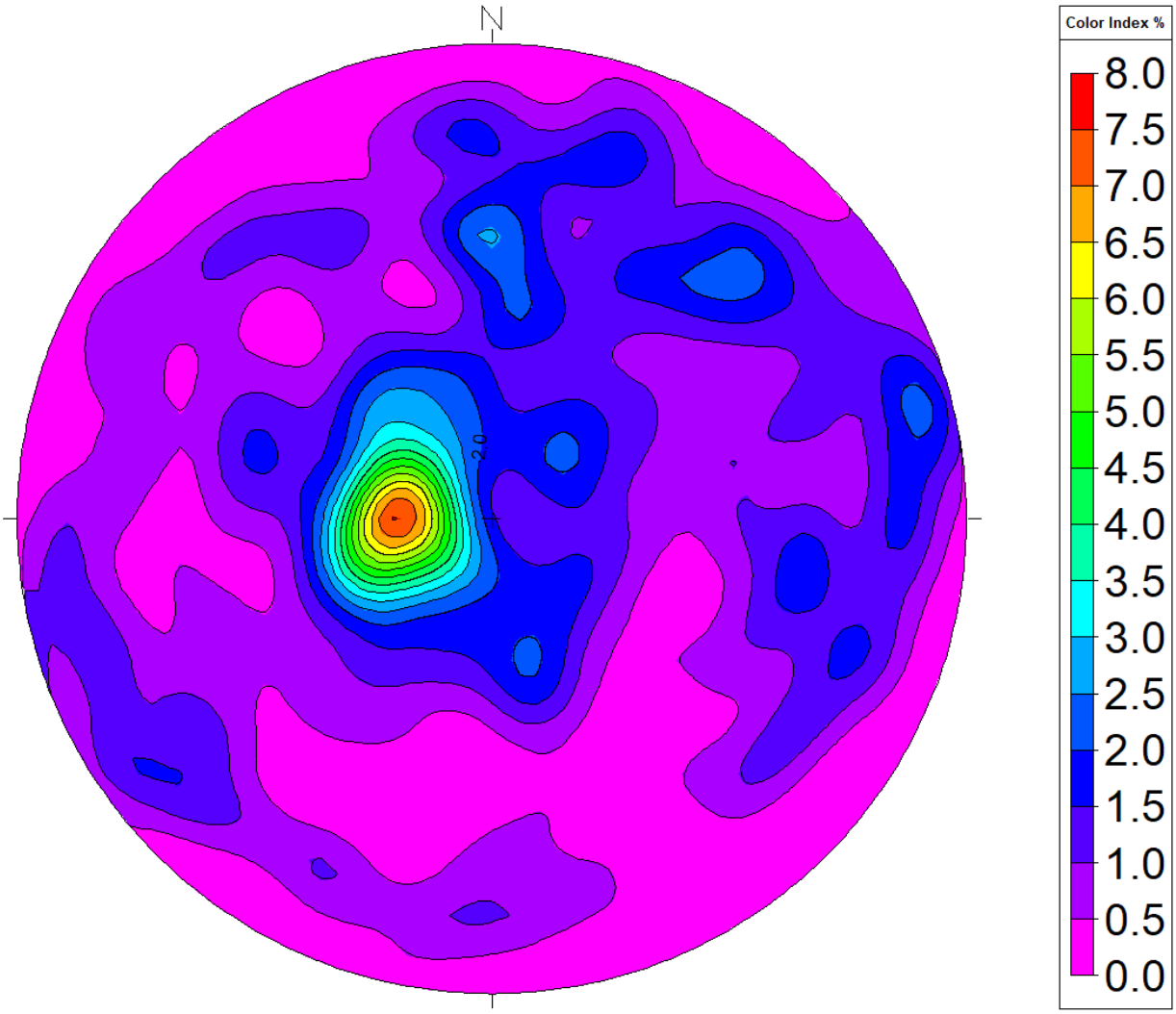

72
73
74
75
76
77
78
79
80


81
82
83
84
85
86
87
88


89
90
91
92
93
94
95
96
97

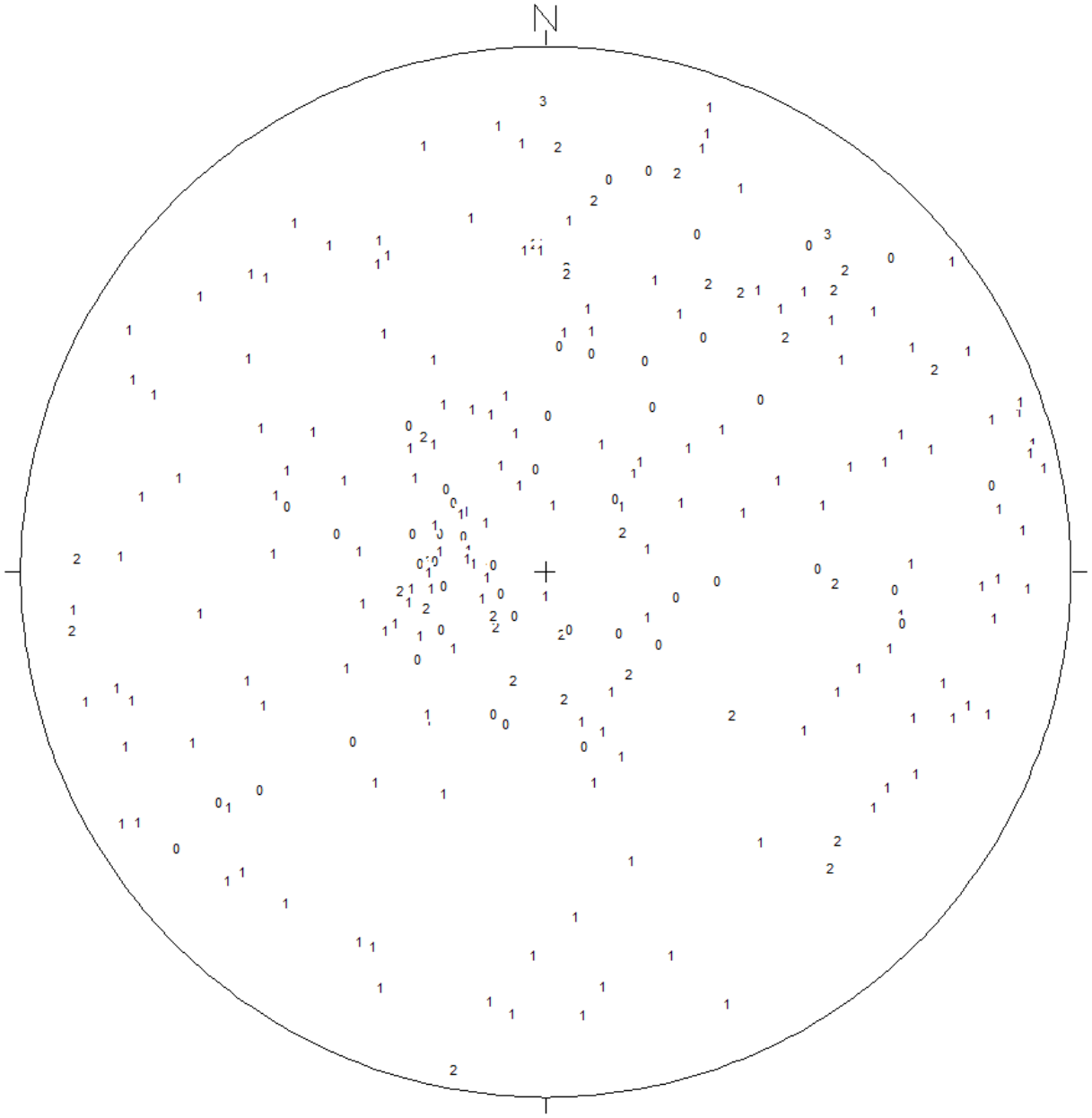

98
99
100
0
90
Tadpoles
2
inch
6
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
Projections
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-10
8 June 2019



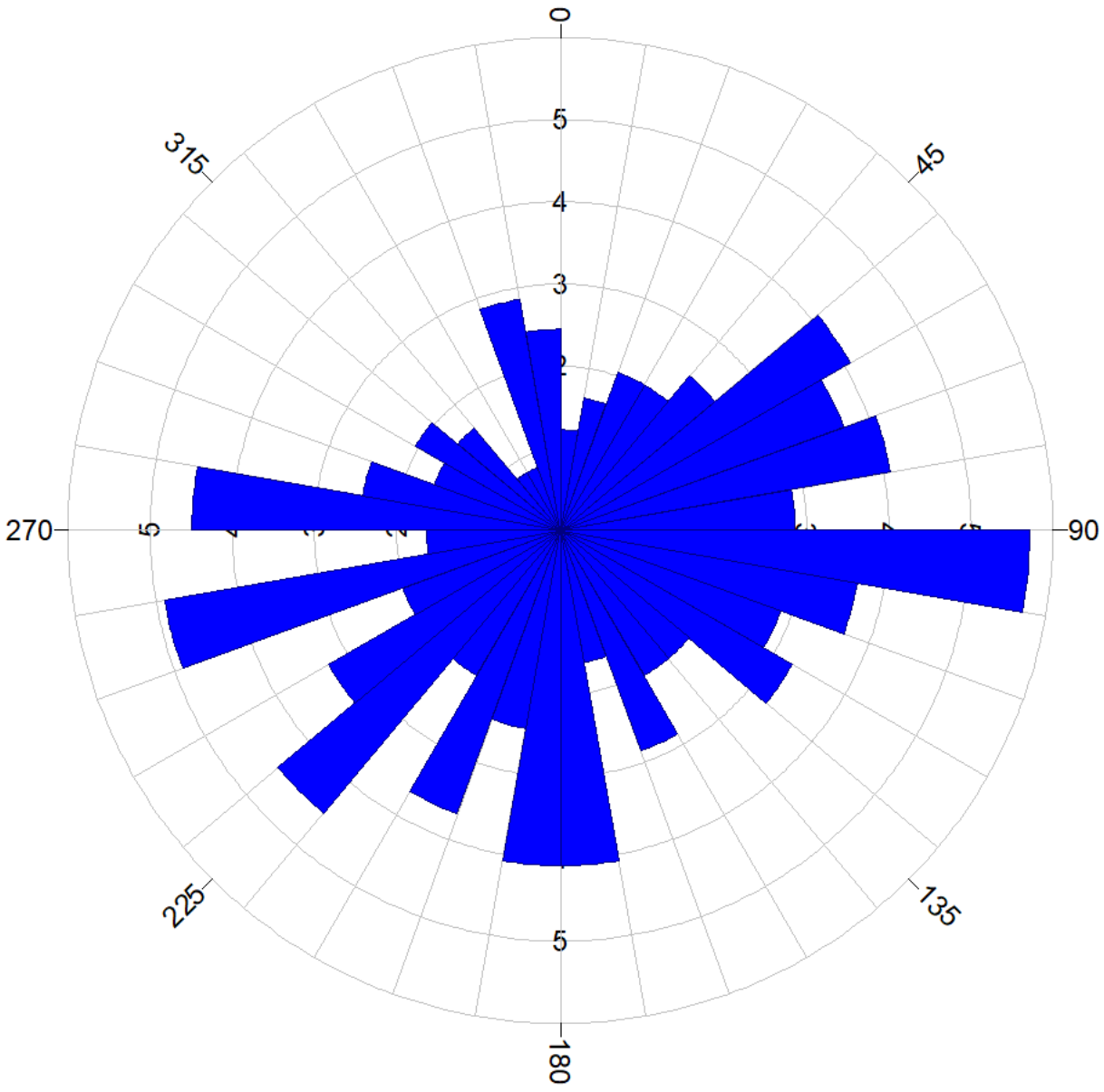
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-10
8 June 2019



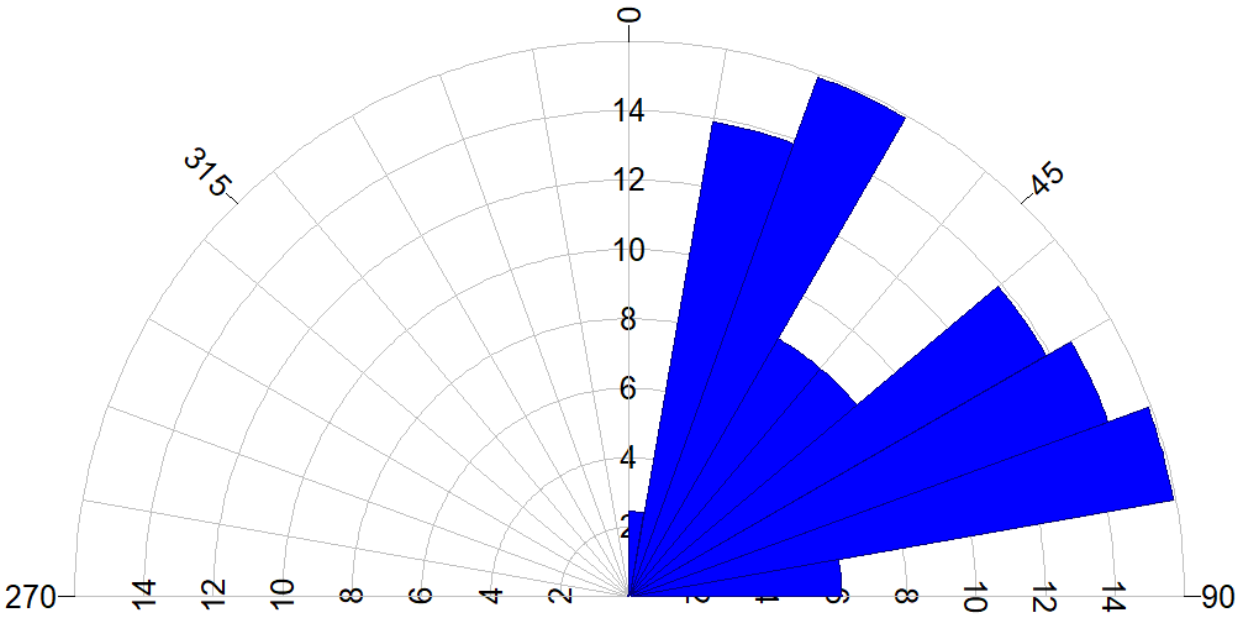
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-10
8 June 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-10
8 June 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-10

8 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	14.65	48.1	353	70	1
2	14.78	48.5	38	31	1
3	14.80	48.6	307	66	1
4	14.90	48.9	258	44	1
5	14.94	49.0	38	71	1
6	15.09	49.5	183	47	2
7	15.12	49.6	167	57	1
8	15.15	49.7	256	84	1
9	15.19	49.9	345	49	1
10	15.26	50.1	177	51	2
11	15.31	50.2	200	48	1
12	15.31	50.2	340	32	1
13	15.60	51.2	183	55	1
14	15.65	51.3	352	11	2
15	15.68	51.4	343	67	1
16	15.71	51.6	233	85	1
17	15.84	52.0	53	66	1
18	15.84	52.0	299	17	1
19	15.96	52.4	356	57	1
20	15.97	52.4	45	72	1
21	16.27	53.4	22	76	1
22	16.31	53.5	272	74	1
23	16.44	53.9	165	27	1
24	16.47	54.0	119	43	1
25	16.54	54.3	273	80	1
26	16.59	54.4	82	57	1
27	16.62	54.5	215	53	2
28	16.66	54.7	239	69	1
29	16.69	54.8	91	19	3
30	16.76	55.0	91	21	1
31	16.79	55.1	257	83	1
32	16.85	55.3	53	79	1
33	16.91	55.5	200	73	1
34	16.96	55.6	143	70	1
35	16.97	55.7	25	40	1
36	16.99	55.8	183	46	2
37	17.01	55.8	349	25	1
38	17.02	55.9	5	75	1
39	17.17	56.3	122	12	1
40	17.25	56.6	259	85	1
41	17.25	56.6	80	22	1
42	17.33	56.9	144	45	1
43	17.34	56.9	252	83	1
44	17.35	56.9	316	15	0
45	17.35	56.9	113	71	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-10

8 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	17.41	57.1	72	73	1
47	17.43	57.2	165	21	1
48	17.43	57.2	325	21	2
49	17.45	57.3	58.8	85.2	1
50	17.69	58.0	129.5	28.4	1
51	17.80	58.4	96.6	17.3	1
52	17.86	58.6	121.9	17.8	0
53	17.89	58.7	69.0	52.0	1
54	17.90	58.7	121.7	15.5	1
55	17.93	58.8	73.5	81.6	1
56	17.98	59.0	253.2	64.6	1
57	18.02	59.1	343.1	27.3	1
58	18.08	59.3	38.7	44.5	1
59	18.08	59.3	104.6	17.9	0
60	18.15	59.5	61.3	23.3	1
61	18.16	59.6	243.2	70.6	2
62	18.16	59.6	79.5	23.9	2
63	18.35	60.2	90.0	20.3	0
64	18.36	60.3	245.0	22.2	1
65	18.42	60.4	69.1	26.1	1
66	18.53	60.8	39.6	30.4	1
67	18.57	60.9	221.9	55.0	1
68	18.68	61.3	206.8	69.0	1
69	18.70	61.4	188.5	63.0	0
70	18.71	61.4	78.3	19.1	1
71	18.83	61.8	186.7	58.9	2
72	18.99	62.3	354.4	21.1	2
73	19.05	62.5	317.5	67.5	2
74	19.05	62.5	127.2	73.0	1
75	19.08	62.6	90.6	79.3	2
76	19.10	62.7	220.0	70.7	3
77	19.11	62.7	251.9	77.3	1
78	19.26	63.2	181.0	68.2	2
79	19.30	63.3	70.5	20.6	2
80	19.32	63.4	82.0	81.4	2
81	19.32	63.4	249.7	60.4	1
82	19.33	63.4	109.5	44.3	1
83	19.47	63.9	93.8	30.1	1
84	19.53	64.1	25.0	69.5	1
85	19.55	64.2	111.8	34.9	1
86	19.66	64.5	197.5	67.3	1
87	19.66	64.5	303.7	66.0	1
88	19.75	64.8	288.8	51.9	1
89	19.77	64.9	54.3	25.6	0
90	19.81	65.0	74.7	22.9	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-10

8 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	19.88	65.2	107.5	14.2	0
92	19.90	65.3	199.2	81.1	1
93	19.96	65.5	170.4	14.8	0
94	20.03	65.7	27.0	69.7	1
95	20.32	66.7	135.2	26.1	1
96	20.35	66.8	288.8	72.8	1
97	20.40	66.9	84.5	80.5	1
98	20.45	67.1	45.6	75.2	1
99	20.46	67.1	278.4	56.9	1
100	20.53	67.4	63.5	65.3	1
101	20.66	67.8	188.3	40.5	1
102	20.78	68.2	10.9	87.9	2
103	20.78	68.2	86.3	9.5	2
104	20.85	68.4	149.8	55.5	1
105	20.97	68.8	183.2	36.3	1
106	21.04	69.0	209.4	51.3	2
107	21.17	69.4	279.7	57.3	0
108	21.45	70.4	338.2	79.4	1
109	21.55	70.7	102.2	42.8	0
110	21.56	70.7	303.3	48.2	1
111	21.89	71.8	274.3	55.4	0
112	21.98	72.1	133.9	68.4	1
113	22.02	72.3	54.4	66.9	0
114	22.05	72.3	173.1	72.8	1
115	22.23	72.9	344.4	10.5	0
116	22.25	73.0	35.2	9.8	0
117	22.27	73.1	52.8	78.7	0
118	22.29	73.1	77.9	10.1	1
119	22.30	73.2	52.2	59.6	0
120	22.32	73.2	99.2	68.0	1
121	22.37	73.4	113.8	75.9	1
122	22.39	73.5	207.3	44.4	1
123	22.45	73.6	190.7	33.5	0
124	22.47	73.7	2.6	63.8	1
125	22.56	74.0	63.7	51.2	1
126	22.59	74.1	21.2	25.1	0
127	22.61	74.2	66.7	77.3	1
128	22.70	74.5	205	35	0
129	22.81	74.8	58	82	1
130	22.82	74.9	10	5	1
131	22.84	75.0	59	9	0
132	22.88	75.1	89	9	0
133	22.93	75.2	74	75	1
134	23.09	75.8	252	50	1
135	23.13	75.9	152	56	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-10

8 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	23.17	76.0	231	14	1
137	23.36	76.7	100	13	1
138	23.38	76.7	176	69	2
139	23.48	77.0	182	9	1
140	23.49	77.1	175	50	1
141	23.51	77.1	289	77	1
142	23.61	77.5	179	77	3
143	23.67	77.7	145	63	1
144	23.86	78.3	91	71	1
145	23.89	78.4	253	56	1
146	23.95	78.6	8	73	1
147	23.96	78.6	293	64	1
148	24.07	79.0	247	12	2
149	24.08	79.0	63	36	1
150	24.33	79.8	225	68	2
151	24.36	79.9	119	16	1
152	24.37	80.0	356	75	1
153	24.44	80.2	198	67	2
154	24.60	80.7	223	60	1
155	24.60	80.7	163	72	1
156	24.71	81.1	235	57	1
157	24.82	81.4	219	67	0
158	24.85	81.5	350	29	0
159	24.89	81.7	307	21	0
160	24.91	81.7	178	51	1
161	24.97	81.9	255	31	1
162	25.03	82.1	277	74	1
163	25.04	82.2	16	26	0
164	25.08	82.3	214	43	0
165	25.20	82.7	102	22	0
166	25.20	82.7	213	29	0
167	25.36	83.2	217	55	1
168	25.48	83.6	91	18	0
169	25.53	83.8	125	20	0
170	25.59	84.0	108	19	1
171	25.72	84.4	134	31	0
172	25.86	84.9	349	35	1
173	25.94	85.1	103	62	1
174	26.10	85.6	41	13	2
175	26.11	85.7	250	38	1
176	26.19	85.9	229	60	1
177	26.22	86.0	99	13	1
178	26.24	86.1	266	79	1
179	26.37	86.5	251	84	1
180	26.77	87.8	222	19	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-10

8 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	26.82	88.0	119	81	1
182	27.01	88.6	90	12	1
183	27.19	89.2	190	37	1
184	27.22	89.3	158	13	1
185	27.29	89.5	310	37	2
186	27.31	89.6	18	19	2
187	27.40	89.9	68	28	1
188	27.41	89.9	221	21	1
189	27.44	90.0	200	76	1
190	27.46	90.1	153	27	1
191	27.55	90.4	63	12	1
192	27.57	90.5	178	50	1
193	27.60	90.5	86	19	1
194	27.64	90.7	176	69	1
195	27.65	90.7	230	28	1
196	27.66	90.7	232	67	1
197	27.76	91.1	93	13	1
198	27.85	91.4	150	37	1
199	27.87	91.4	335	22	1
200	27.95	91.7	78	17	0
201	27.95	91.7	276	26	0
202	27.97	91.8	204	58	0
203	28.07	92.1	59	20	0
204	28.11	92.2	300	69	1
205	28.14	92.3	104	45	1
206	28.21	92.6	287	67	1
207	28.28	92.8	122	25	1
208	28.34	93.0	243	78	1
209	28.42	93.3	273	71	1
210	28.43	93.3	48	12	2
211	28.43	93.3	124	59	1
212	28.52	93.6	261	15	1
213	28.57	93.7	294	50	1
214	28.60	93.8	263	75	1
215	28.65	94.0	92	44	1
216	28.65	94.0	314	65	2
217	28.75	94.3	115	51	1
218	28.75	94.3	203	20	1
219	28.82	94.6	135	28	2
220	28.85	94.7	226	64	2
221	28.85	94.7	291	71	1
222	28.86	94.7	323	56	1
223	28.92	94.9	270	58	1
224	28.94	95.0	284	56	1
225	29.03	95.3	98	34	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-10

8 June 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	29.04	95.3	232	42	0
227	29.20	95.8	271	42	0
228	29.35	96.3	285	20	0
229	29.39	96.4	182	34	0
230	29.44	96.6	179	23	0
231	29.53	96.9	225	14	0
232	29.54	96.9	260	74	0
233	29.74	97.6	153	17	1
234	29.86	98.0	228	76	0
235	29.98	98.4	78	30	1
236	30.08	98.7	194	66	0
237	30.13	98.8	48	42	0
238	30.21	99.1	49	20	1
239	30.25	99.2	152	59	1
240	30.30	99.4	135	66	1
241	30.42	99.8	146	30	1
242	30.50	100.1	274	45	2
243	30.50	100.1	232	34	1
244	30.64	100.5	158	25	1
245	30.70	100.7	226	52	2

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-10
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-10
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78545 N
Longitude: 84.77588 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Electric log
P&S Suspension Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 662.6'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	8 June 2019	8 June 2019	8 June 2019	
RUN NUMBER	1	1	1	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	109'	109'	109'	
DEPTH-LOGGER	109'	109'	109'	
BTM LOG INTERVAL	109.1'	107.8'	105.8'	
TOP LOG INTERVAL	68.0'	45.4'	3.0'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP	
PROBE TYPE, S/N	2PFA #5969	Comprobe #5238	ELXG #4248	
LOGGING SPEED	10 ft/min	10 ft/min	10 ft/min	
A.S.D.E. / Sample Interval	.0.09' / 0.10'	0.08' / 0.10'	0.0' / 0.25'	
Fluid Level / Fluid Type	70' / water	70' / water	70' / water	

BOREHOLE RECORD

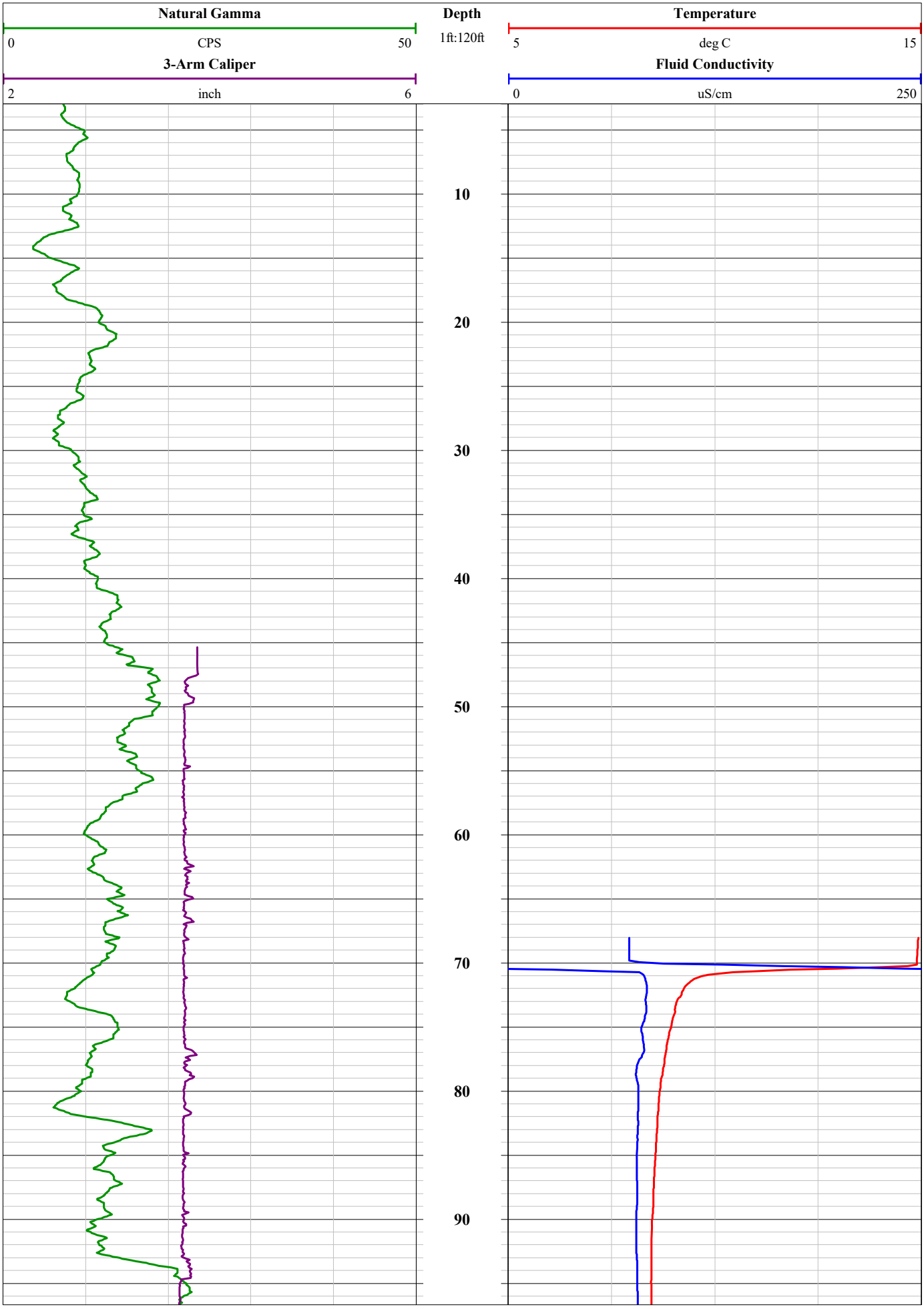
RUN No.	BIT	FROM	TO
1	HQ	47'	100'
1	NQ	100'	109'

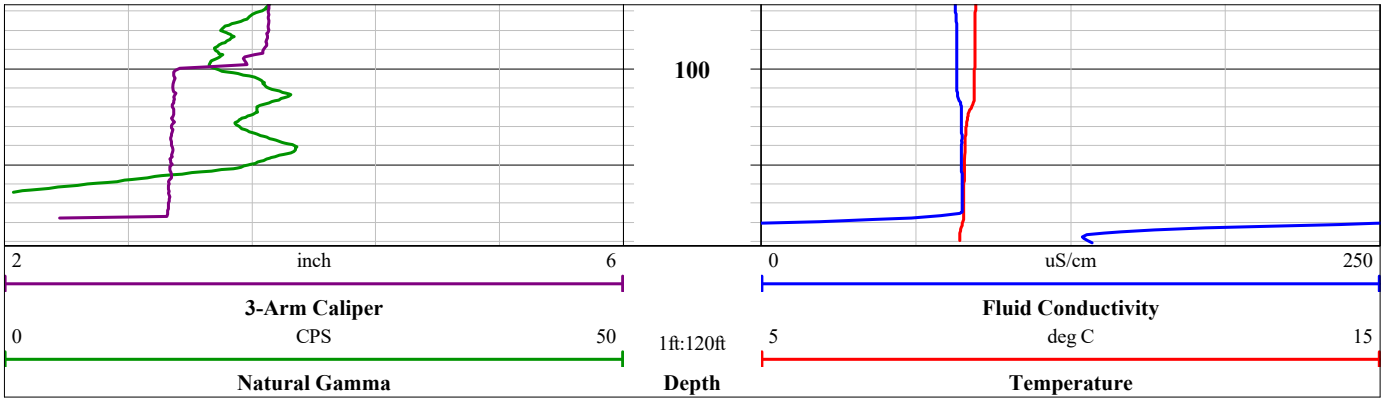
CASING RECORD

SIZE	WGT.	FROM	TO
HWT	Steel	GL	47'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
50
3-Arm Caliper
2
inch
6
Depth
1ft:120ft
10
20
30
40
50
60
70
80
90
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
250


100
2
inch
6
3-Arm Caliper
0
CPS
50
Natural Gamma
1ft:120ft
Depth
0
uS/cm
250
Fluid Conductivity
5
deg C
15
Temperature

Borehole Deviation

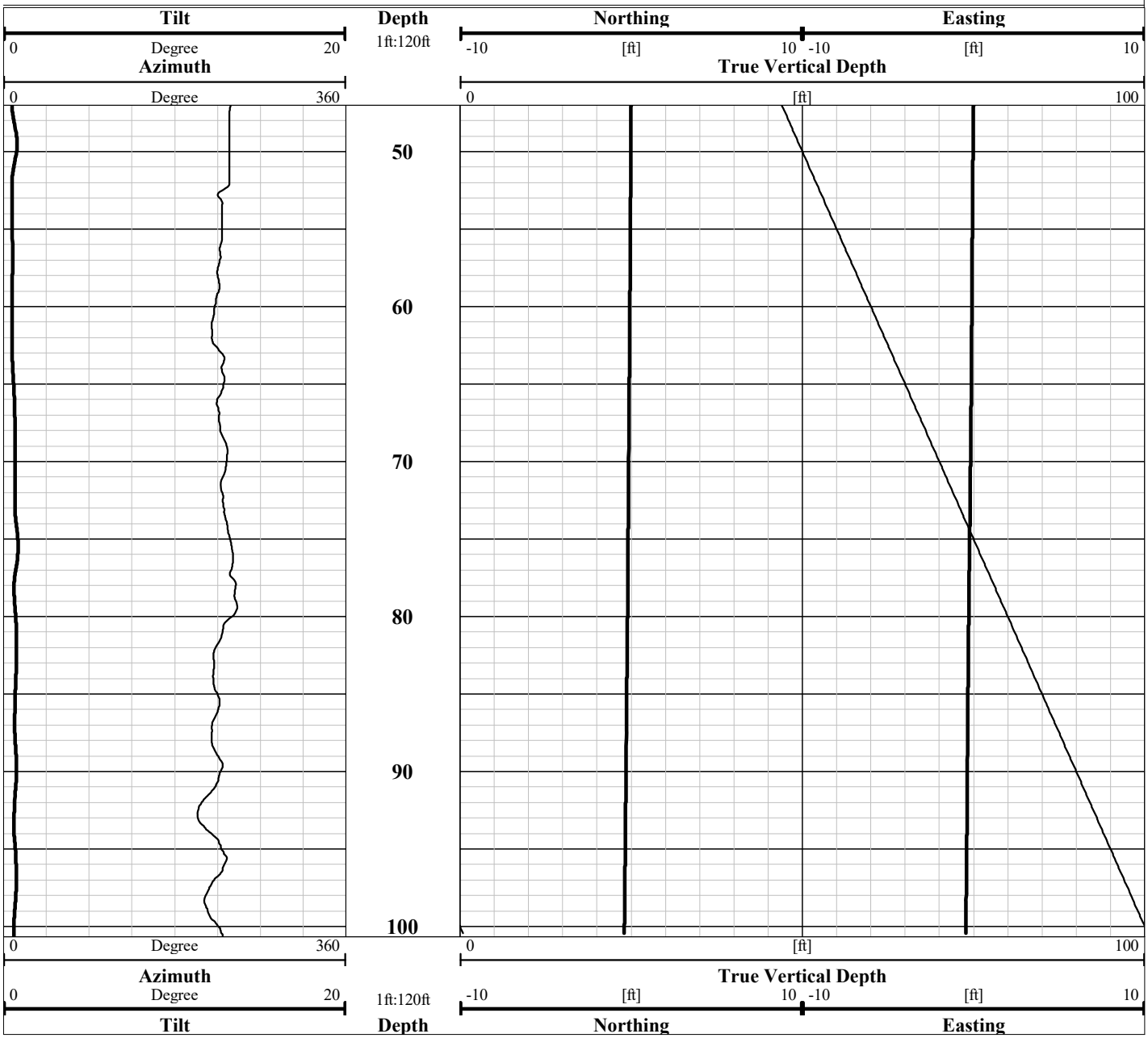
COLOG
borehole geophysics / hydrophysics

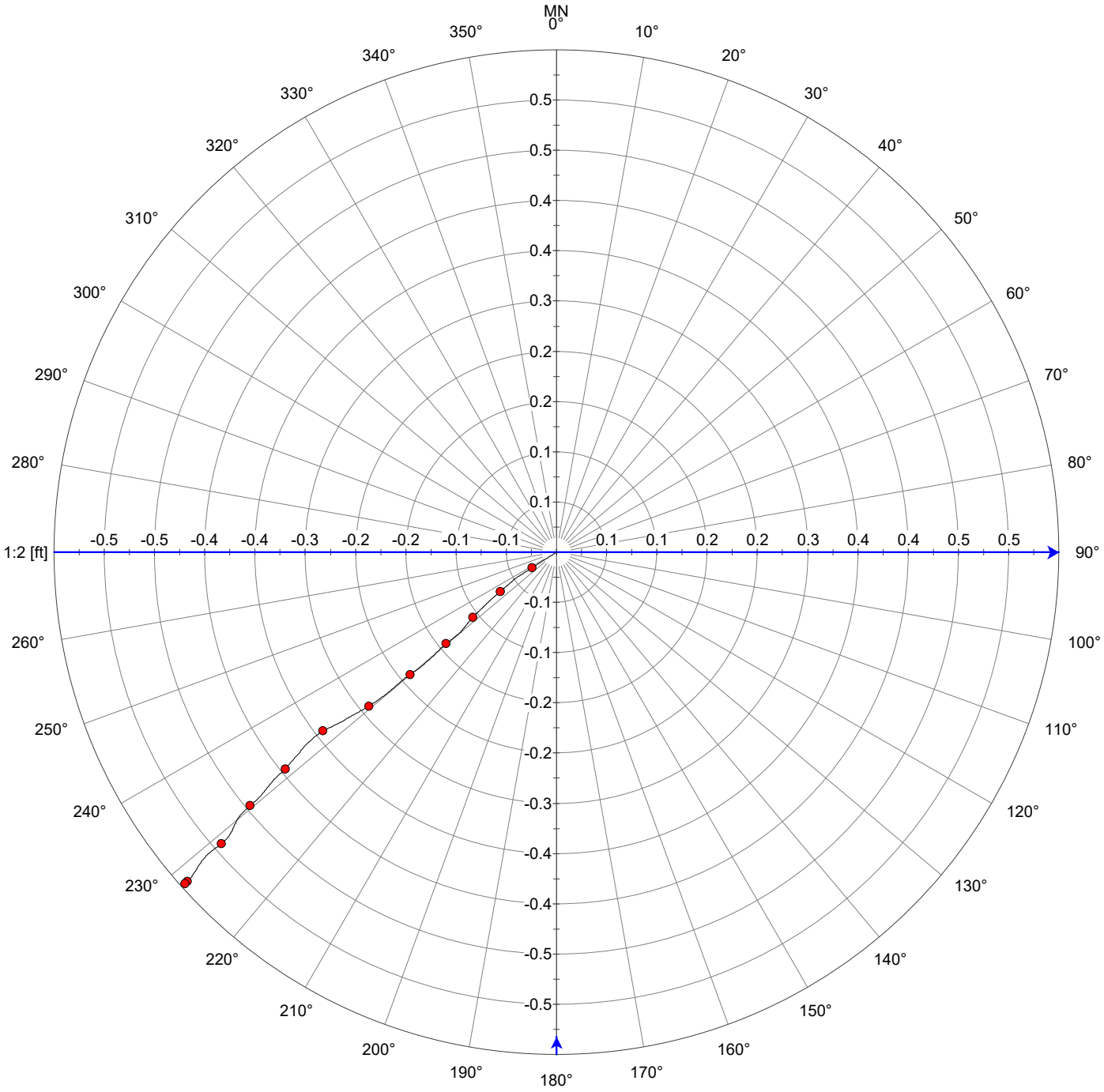
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 8 June 2019	WELL: BH19-10 - South Shore

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 662.6'** **Latitude: 45.78545 N** **Longitude: 84.77588 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
0.5
0.5
0.4
0.4
0.3
0.2
0.2
0.1
0.1
-0.1
-0.2
-0.2
-0.3
-0.4
-0.4
-0.5
-0.5
1:2 [ft]
-0.5
-0.5
-0.4
-0.4
-0.3
-0.2
-0.2
-0.1
-0.1
0.1
0.1
0.2
0.2
0.3
0.4
0.4
0.5
0.5

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-10
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-10
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78545 N
Longitude: 84.77588 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM GL **ELEVATION** 662.6'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	8 June 2019	8 June 2019		
RUN NUMBER	1	1		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	109'	109'		
DEPTH-LOGGER	109'	109'		
BTM LOG INTERVAL	106.4'	71.0'		
TOP LOG INTERVAL	3.0'	107.9'		
RECORDED BY	JBG	JBG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	ELXG #4248	ELXG #4248		
LOGGING SPEED	10 ft/min	10 ft/min		
A.S.D.E. / Sample Interval	0.0' / 0.25'	0.0' / 0.25'		
Fluid Level / Fluid Type	70' / water	70' / water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	47'	100'
1	NQ	100'	109'

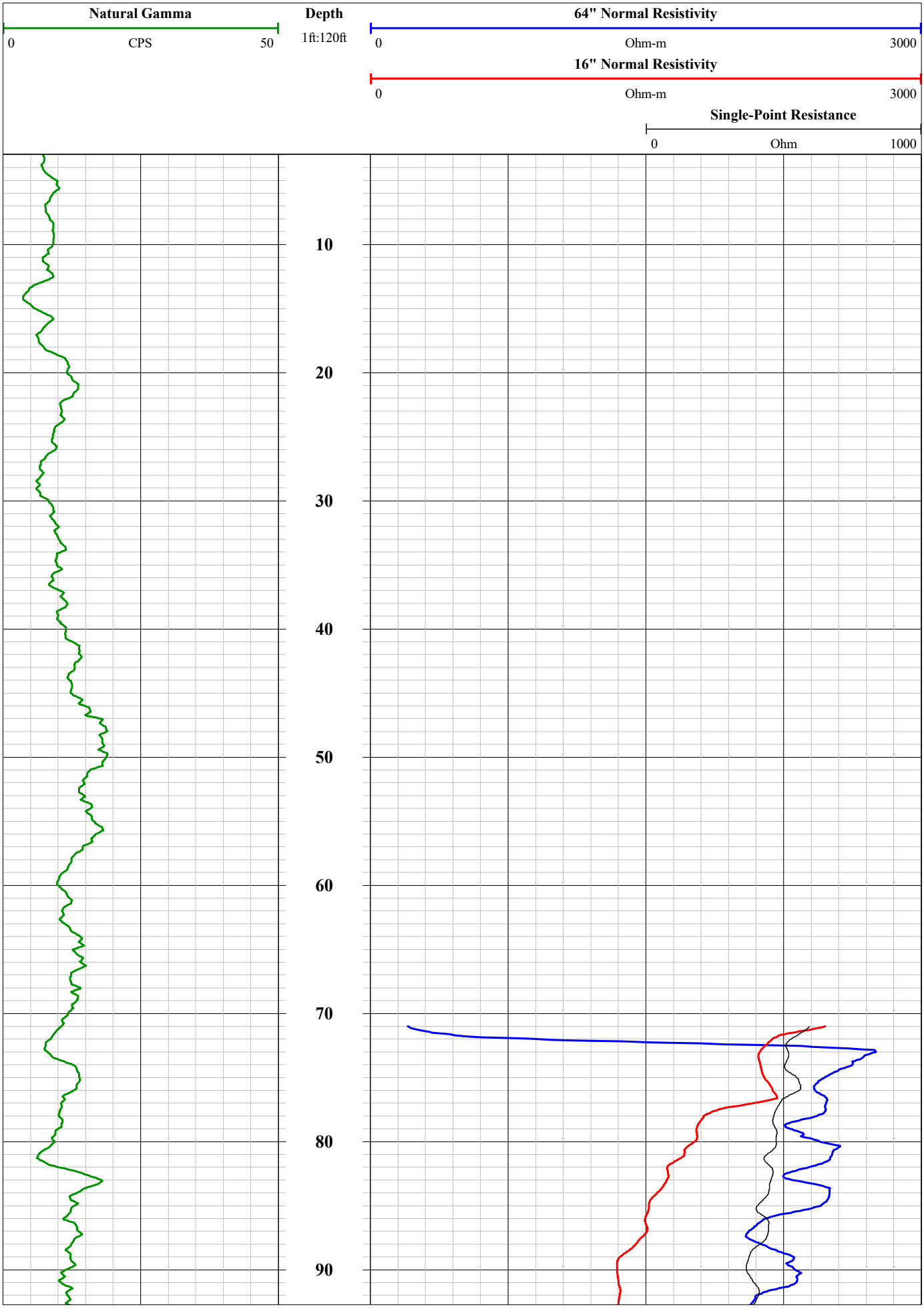
CASING RECORD

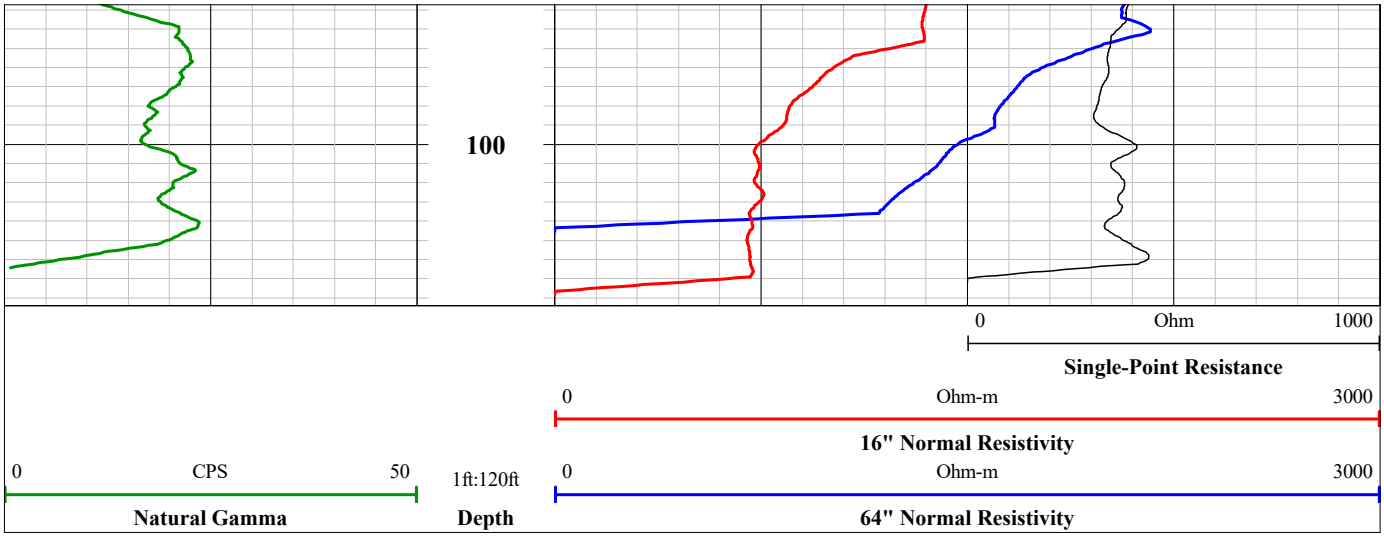
SIZE	WGT.	FROM	TO
6"	Steel	GL	47'

NA - Not Available, N/A - Not Applicable

COMMENTS

Spontaneous Potential omitted due to configuration error


Natural Gamma
0
CPS
50
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
3000
16" Normal Resistivity
0
Ohm-m
3000
Single-Point Resistance
0
Ohm
1000
10
20
30
40
50
60
70
80
90


100
0
Ohm
1000
Single-Point Resistance
0
Ohm-m
3000
16" Normal Resistivity
0
CPS
50
1ft:120ft
0
Ohm-m
3000
Natural Gamma
Depth
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-10
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-10
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Shore
Latitude: 45.78545 N
Longitude: 84.77588 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond
Electrical Log
Dilatometer

PERMANENT DATUM GL **ELEVATION** 662.6'

LOG MEAS. FROM GL 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM GL

DATE ACQUIRED	8 June 2019			
RUN NUMBER	1			
LOG TYPE	P&S log			
DEPTH-DRILLER	109'			
DEPTH-LOGGER	109'			
BTM LOG INTERVAL	97'			
TOP LOG INTERVAL	69'			
RECORDED BY	JBG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	PSlogger #10926			
LOGGING SPEED	stationary			
A.S.D.E. / Sample Interval	?' / 2.0'			
Fluid Level / Fluid Type	70' / water			

BOREHOLE RECORD

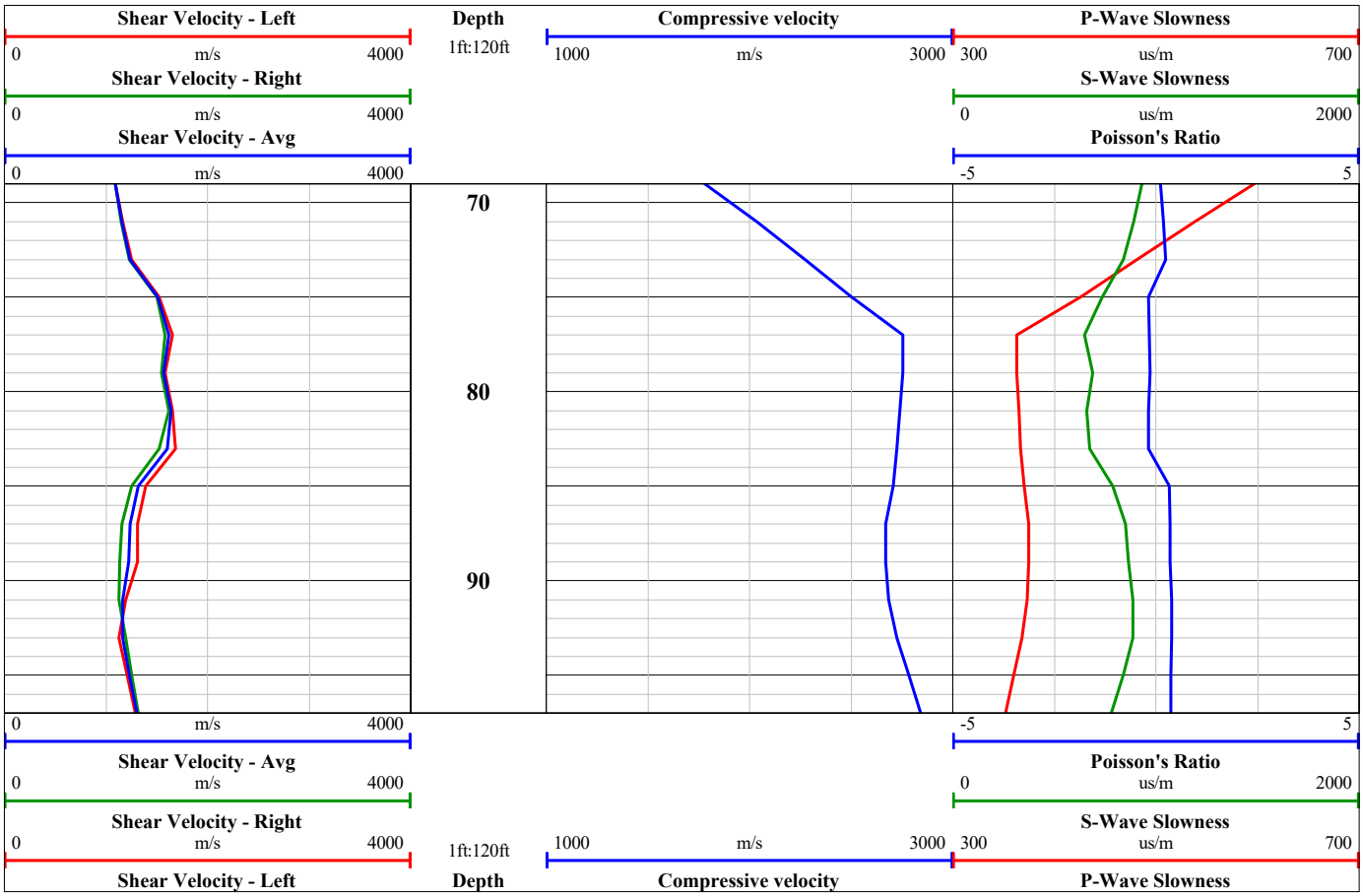
RUN No.	BIT	FROM	TO
1	HQ	47'	100'
1	NQ	100'	109'

CASING RECORD

SIZE	WGT.	FROM	TO
HWT	Steel	GL	47'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
Depth
Compressive velocity
P-Wave Slowness
0
m/s
4000
1ft:120ft
1000
m/s
3000
300
us/m
700
Shear Velocity - Right
S-Wave Slowness
0
m/s
4000
0
us/m
2000
Shear Velocity - Avg
Poisson's Ratio
0
m/s
4000
-5
5
70
80
90
0
m/s
4000
-5
5
Shear Velocity - Avg
Poisson's Ratio
0
m/s
4000
0
us/m
2000
Shear Velocity - Right
S-Wave Slowness
0
m/s
4000
1ft:120ft
1000
m/s
3000
300
us/m
700
Shear Velocity - Left
Depth
Compressive velocity
P-Wave Slowness

PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-10**	Test depth:	**107.00 ft**
Test date: (mm/dd/yyyy)	**6/8/2019**	C :	0.9546 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	ΔR/R$_{0\ Probe}$ %
0	0.00	139	0.00	0.00
53	31.70	137	31.65	0.82
3469	187.07	2984	183.76	4.68
5788	194.93	5267	189.40	4.82
8758	202.42	8205	194.06	4.93
12129	210.21	11547	198.63	5.05
14803	216.38	14198	202.25	5.14
18055	223.46	17425	206.23	5.23
20966	229.88	20312	209.87	5.32
24060	237.56	23378	214.59	5.44
26899	243.18	26196	217.51	5.51
29869	249.70	29141	221.19	5.60

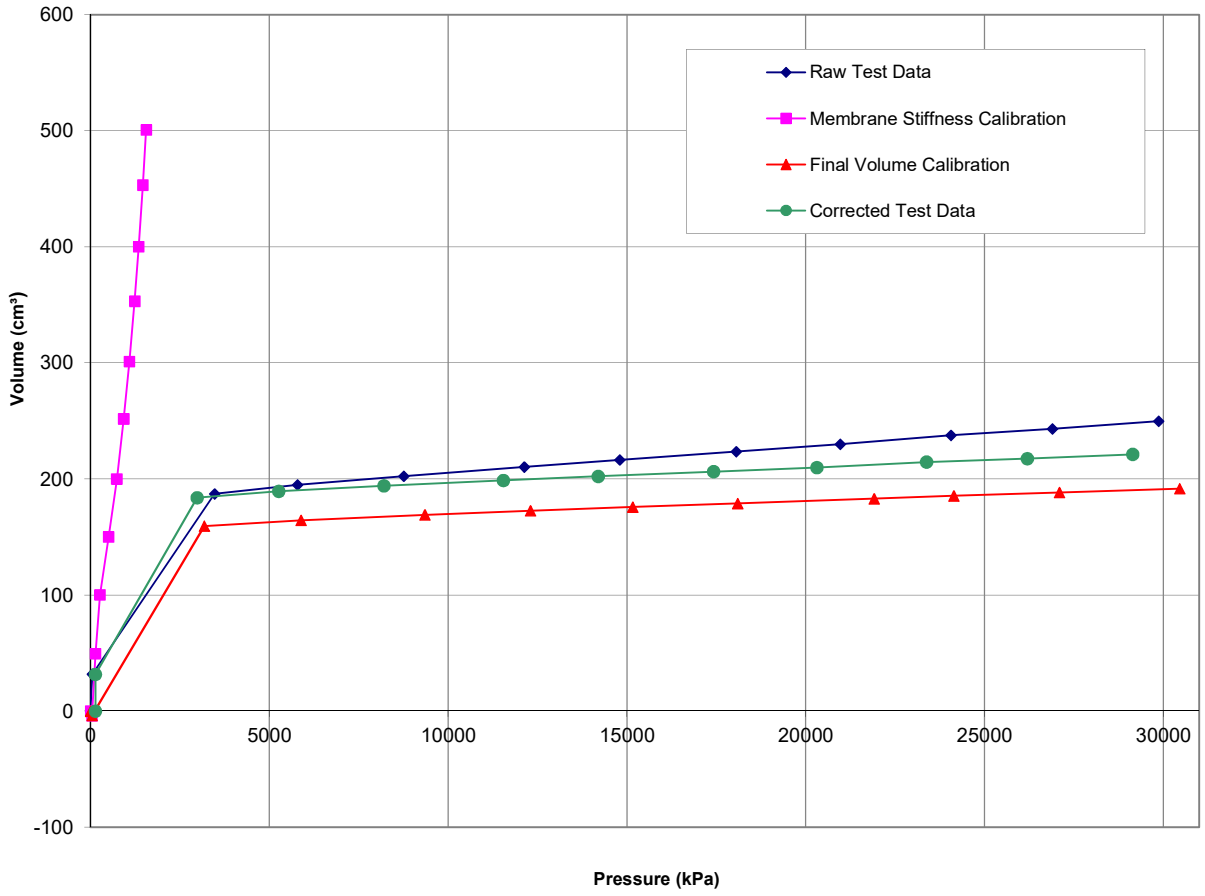
Test Results

PROBEX Modulus E:	**3,768,568 kPa**
Ultimate Pressure P_L:	**78,076**
Ratio E / P_L:	**48.27**

Volume & Pressure Calibrations ID

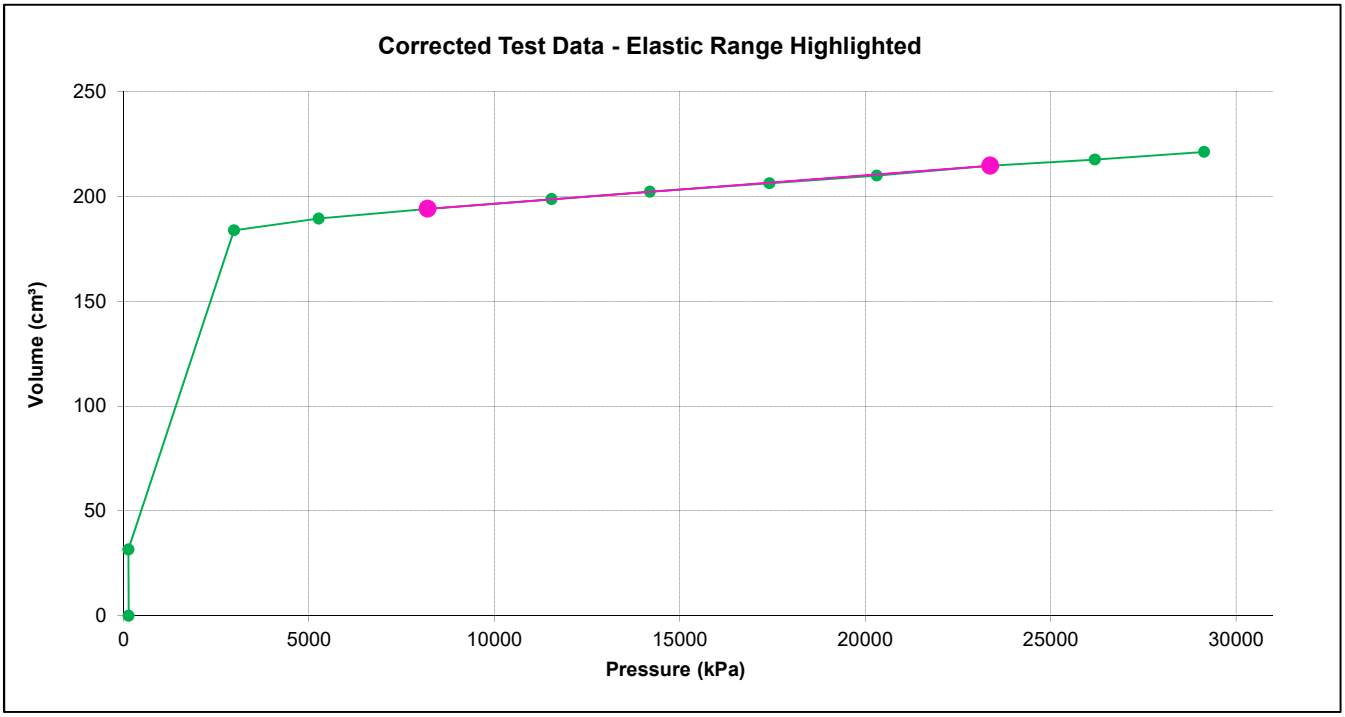
CalV4	CalP1

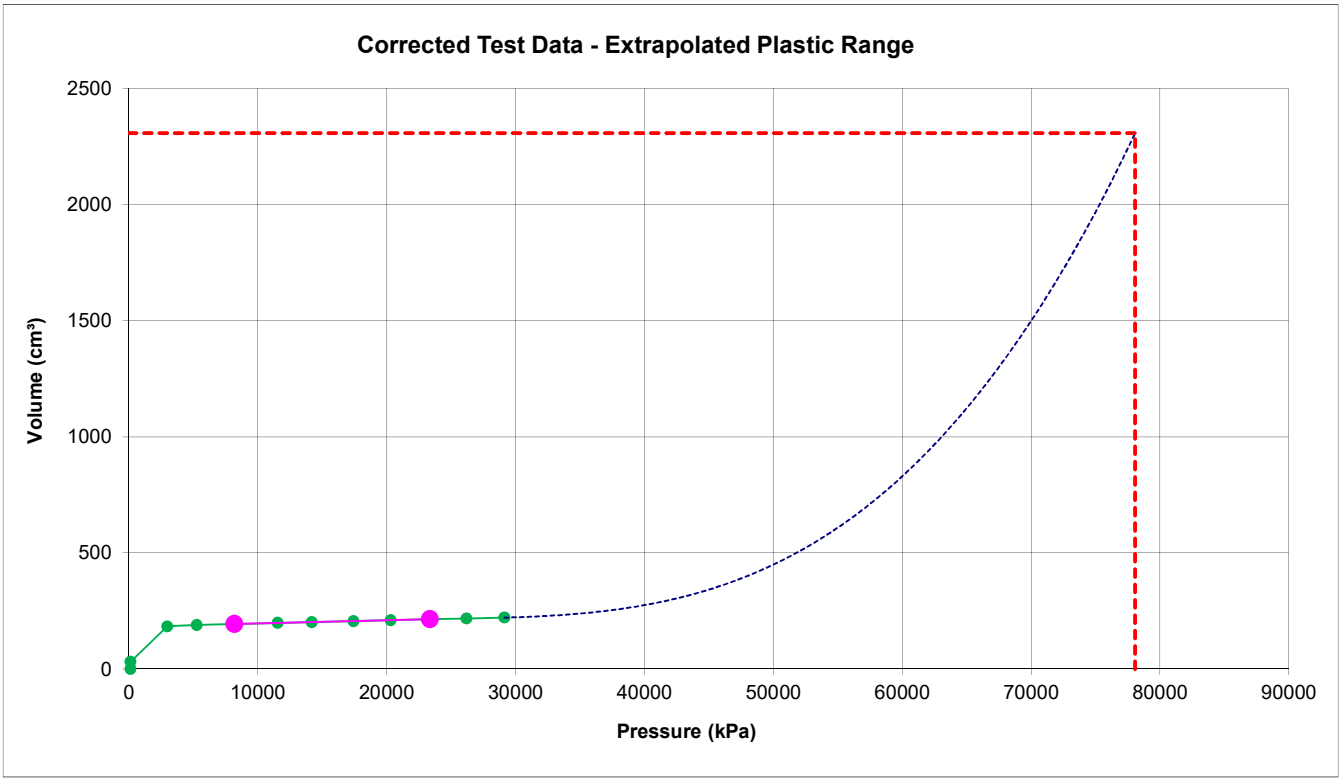
Test Data with Calibration Curves



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-10**	Test depth:	**107.00 ft**
Test date: (mm/dd/yyyy)	**6/8/2019**	C :	0.9546 cc/MPa
Test number:	1	Poisson's coefficient	0.20





ROCTEST TELEMAC

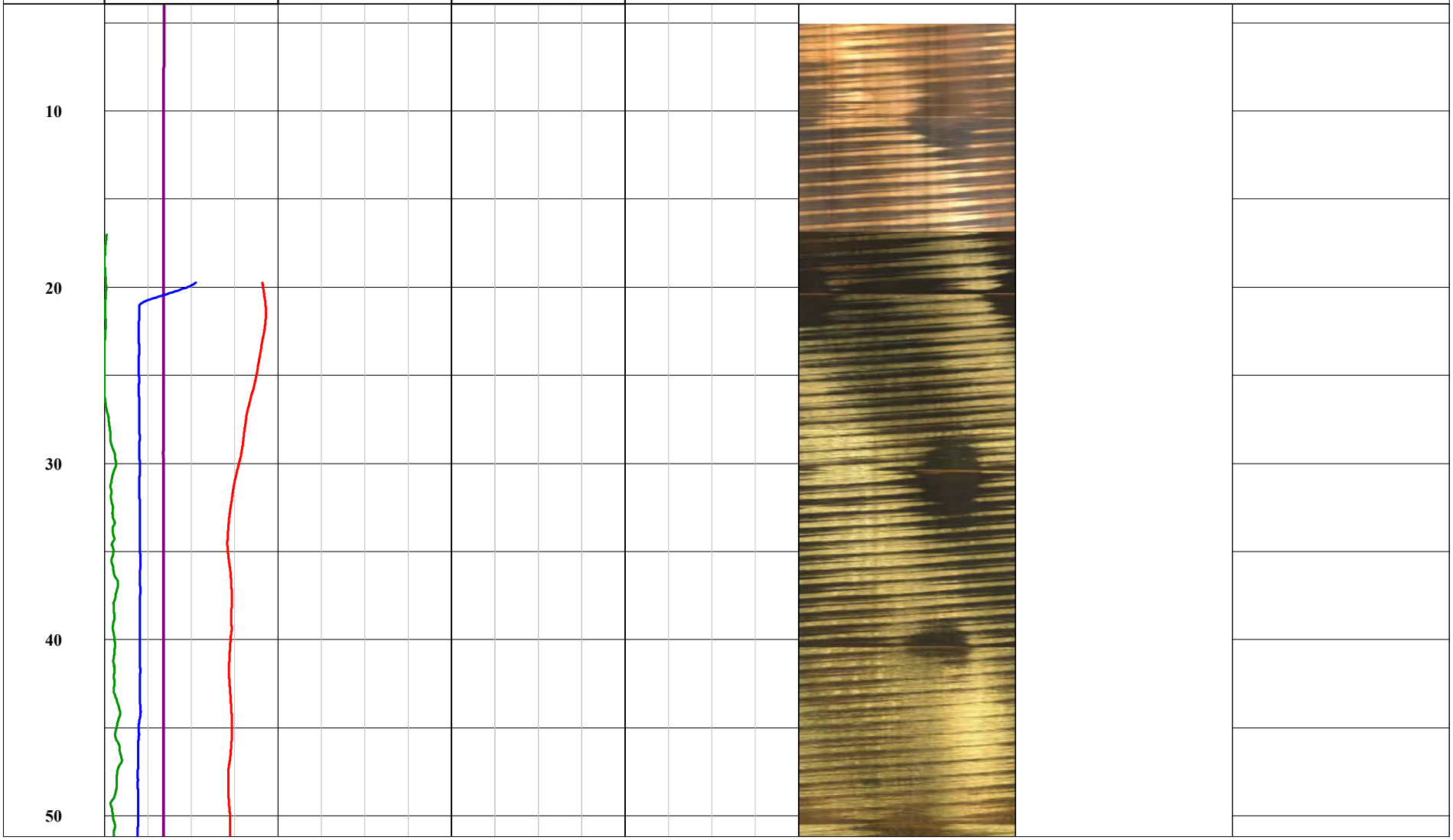
Geophysical Summary Plot

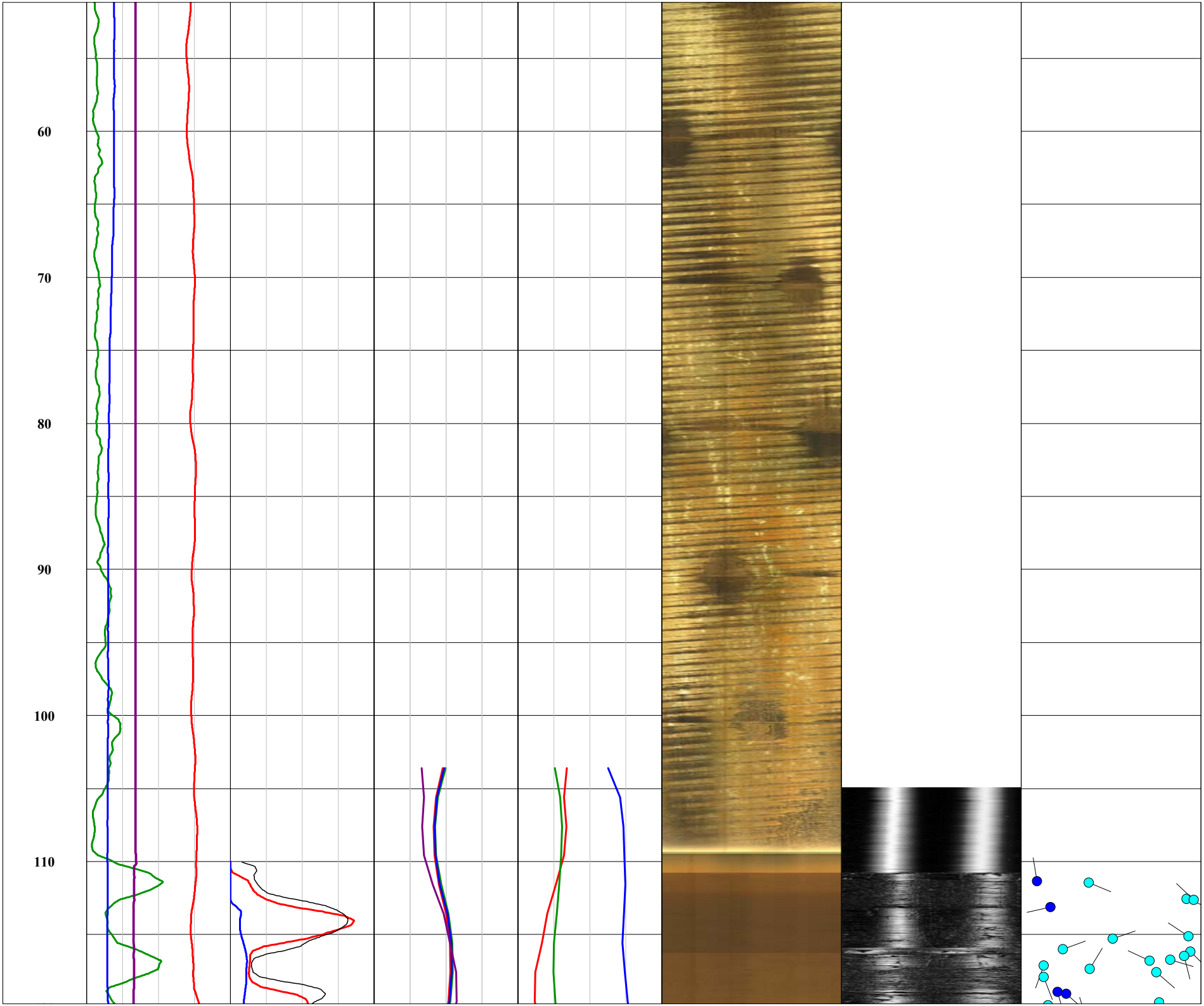
COLOG
borehole geophysics / hydrophysics

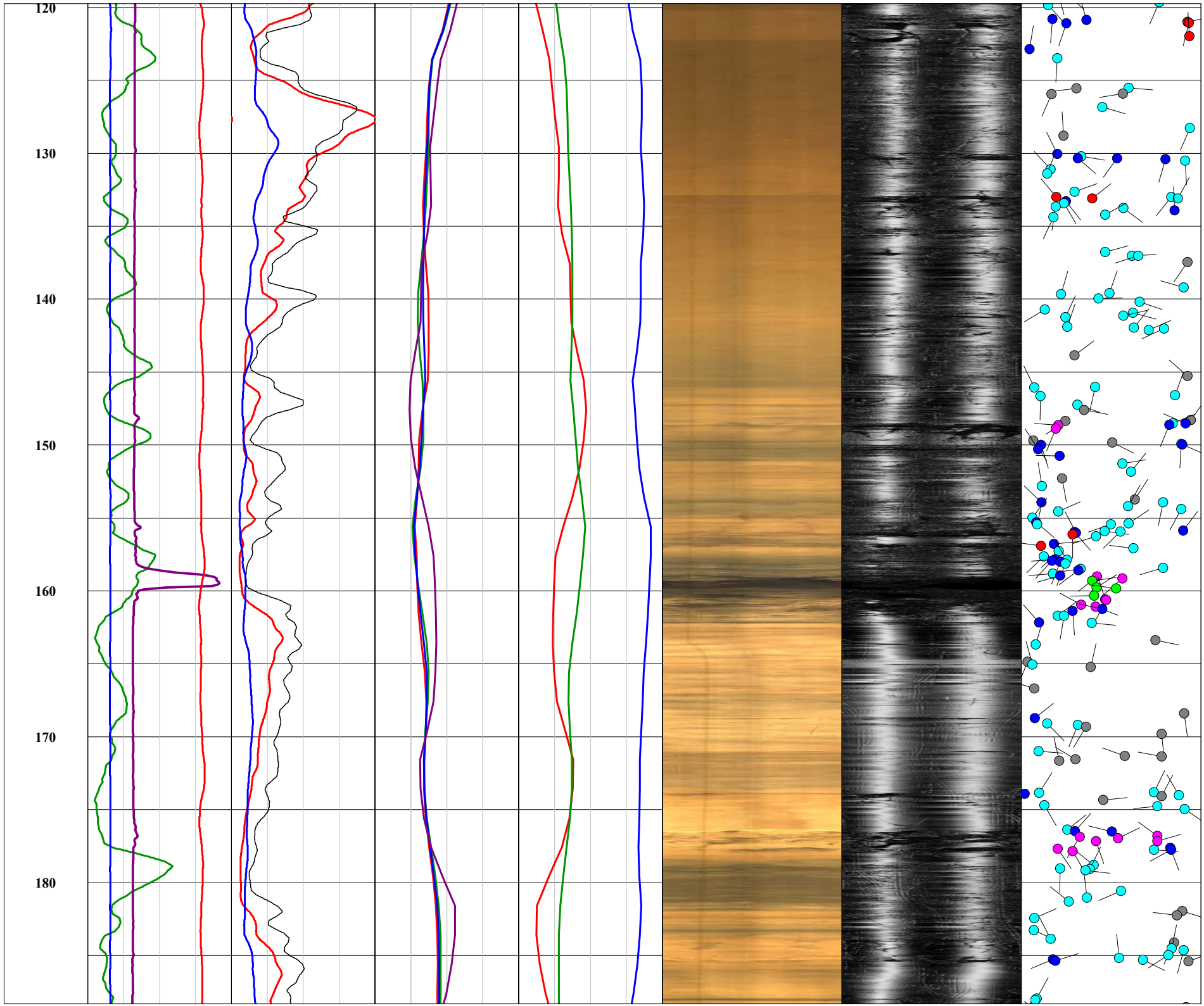
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 25 June - 17 July 2019
WELL: BH19-15 - North Side

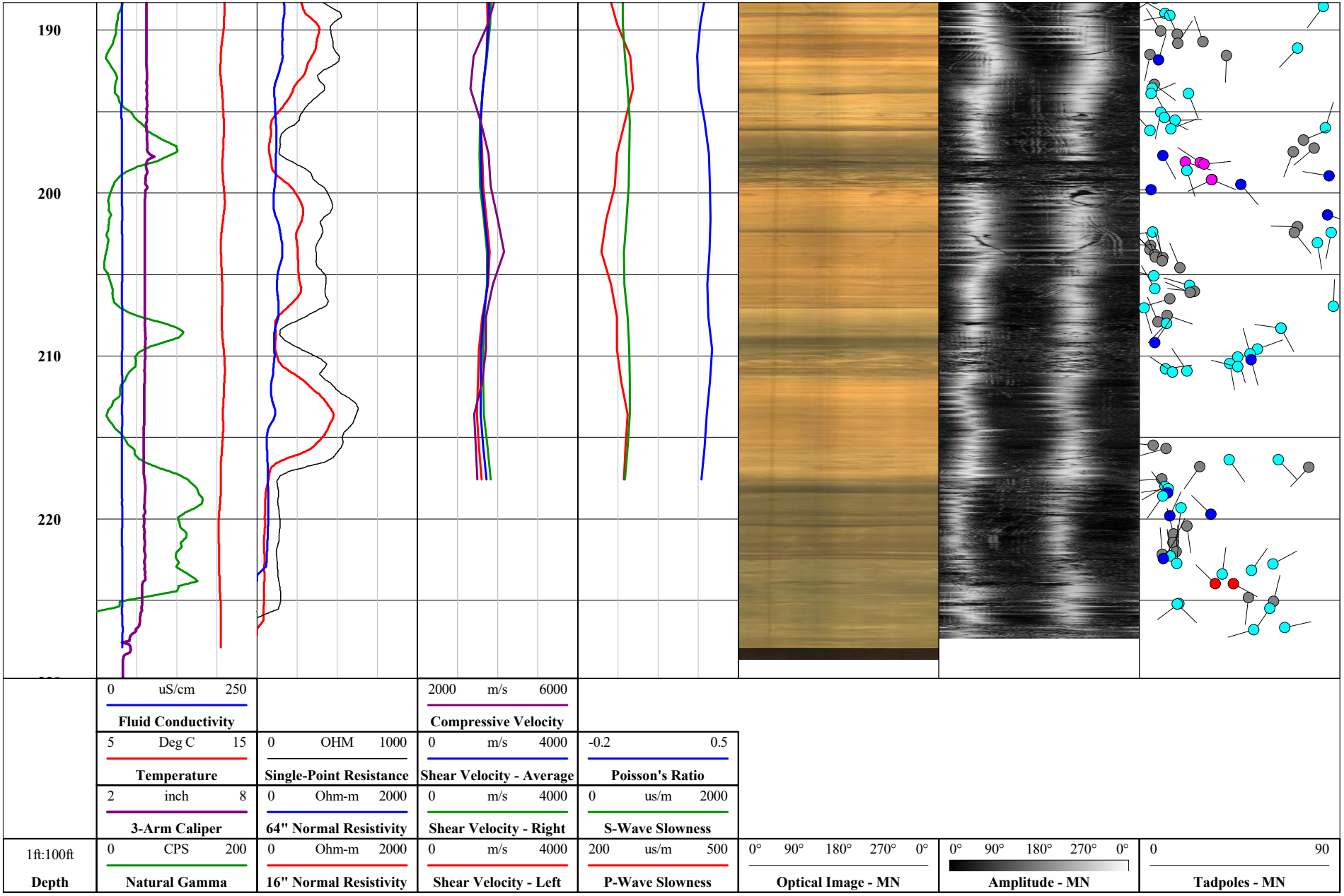
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN	Tadpoles - MN
1ft:100ft	0 CPS 200	0 Ohm-m 2000	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 inch 8	0 Ohm-m 2000	0 m/s 4000	0 us/m 2000			
	Temperature	Single-Point Resistance	Shear Velocity - Average	Poisson's Ratio			
	5 Deg C 15	0 OHM 1000	0 m/s 4000	-0.2 0.5			
	Fluid Conductivity		Compressive Velocity				
	0 uS/cm 250		2000 m/s 6000				




60
70
80
90
100
110


120
130
140
150
160
170
180


190
200
210
220
0 uS/cm 250
Fluid Conductivity
5 Deg C 15
Temperature
2 inch 8
3-Arm Caliper
0 CPS 200
Natural Gamma
0 OHM 1000
Single-Point Resistance
0 Ohm-m 2000
64" Normal Resistivity
0 Ohm-m 2000
16" Normal Resistivity
2000 m/s 6000
Compressive Velocity
0 m/s 4000
Shear Velocity - Average
0 m/s 4000
Shear Velocity - Right
0 m/s 4000
Shear Velocity - Left
-0.2 0.5
Poisson's Ratio
0 us/m 2000
S-Wave Slowness
200 us/m 500
P-Wave Slowness
0° 90° 180° 270° 0°
Optical Image - MN
0° 90° 180° 270° 0°
Amplitude - MN
0 90
Tadpoles - MN
1ft:100ft
Depth

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-15
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-15
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83538 N
Longitude: 84.75837 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.6'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	17 July 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	228'			
DEPTH-LOGGER	228'			
BTM LOG INTERVAL	220.29'			
TOP LOG INTERVAL	104'			
RECORDED BY	CKL			
WITNESSED BY				
PROBE TYPE, S/N	ABI/LIM #1730			
LOGGING SPEED	4.5 fpm			
A.S.D.E. / Sample Interval	0.13' / 0.0024'			
Fluid Level / Fluid Type	18'/Water			

BOREHOLE RECORD

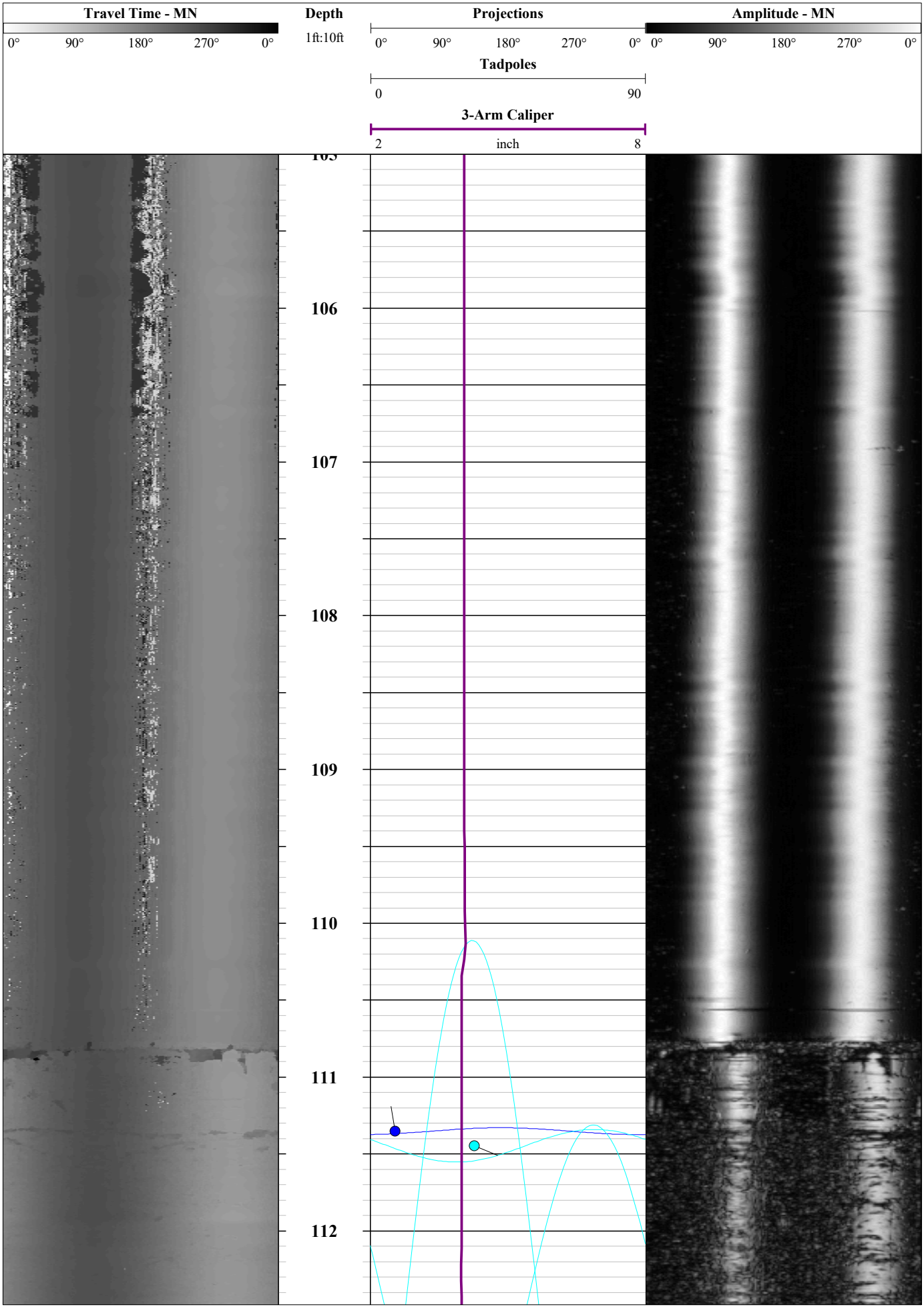
RUN No.	BIT	FROM	TO
1	HQ	0'	228'

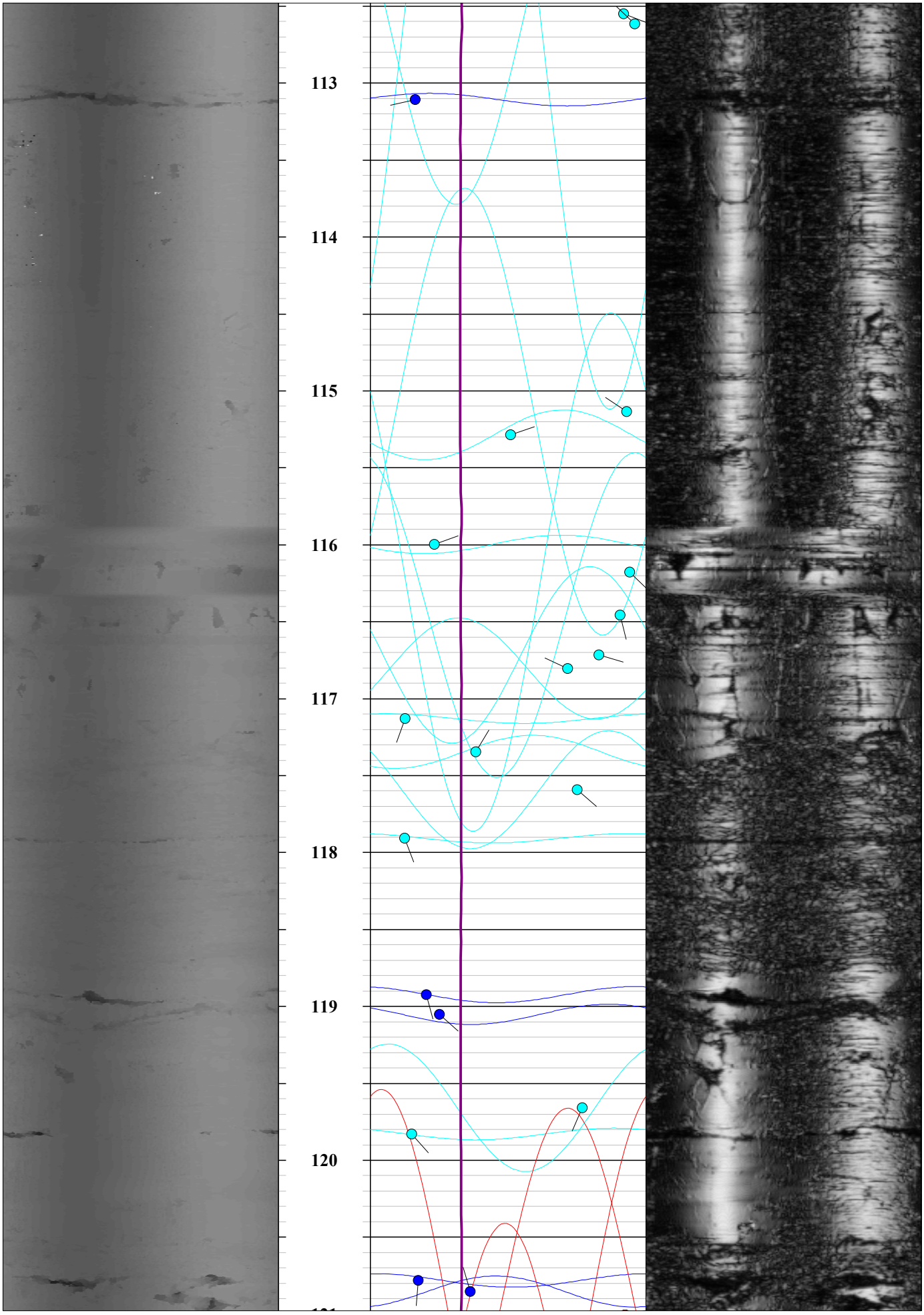
CASING RECORD

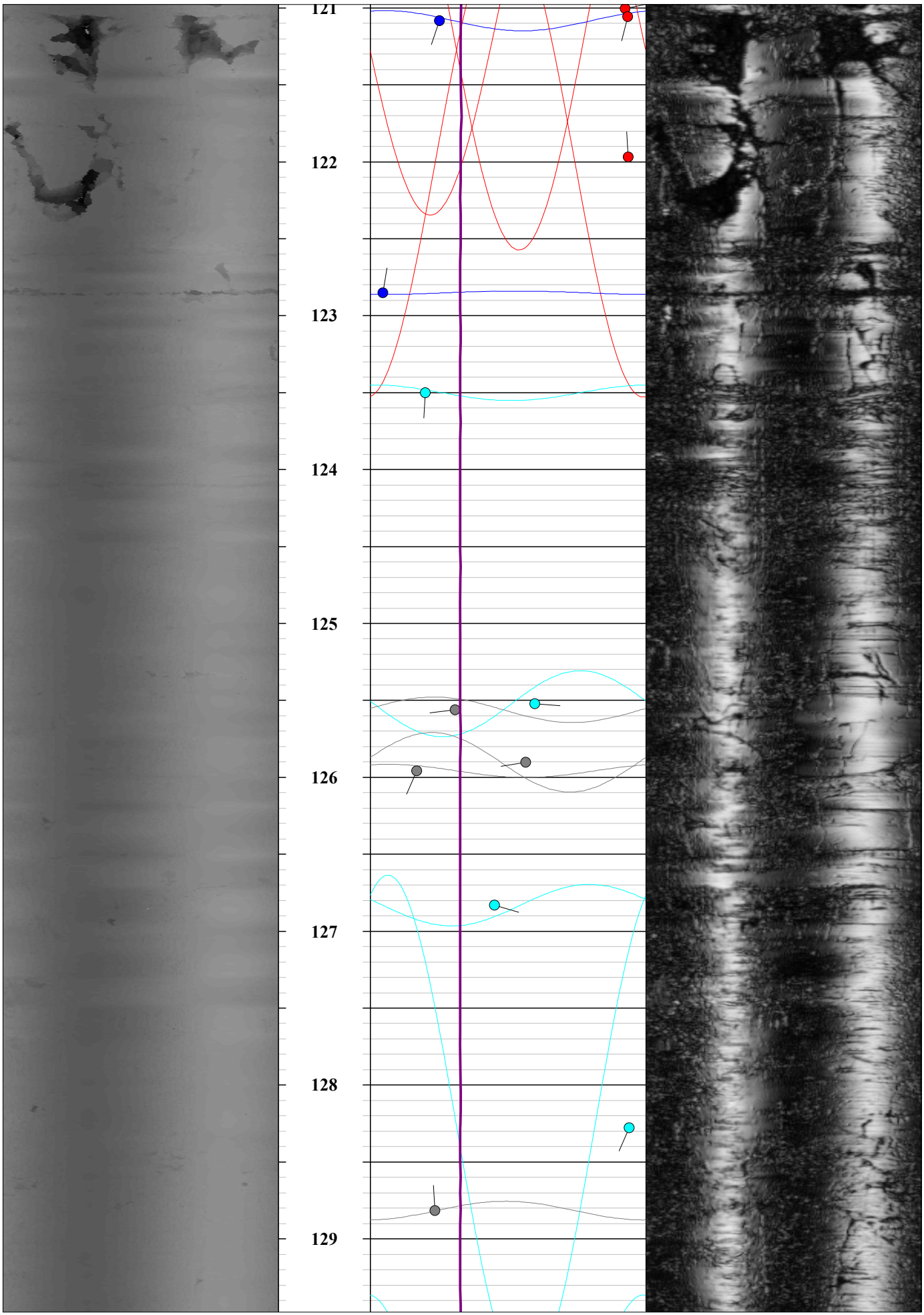
SIZE	WGT.	FROM	TO
PQ	Steel	0'	110'

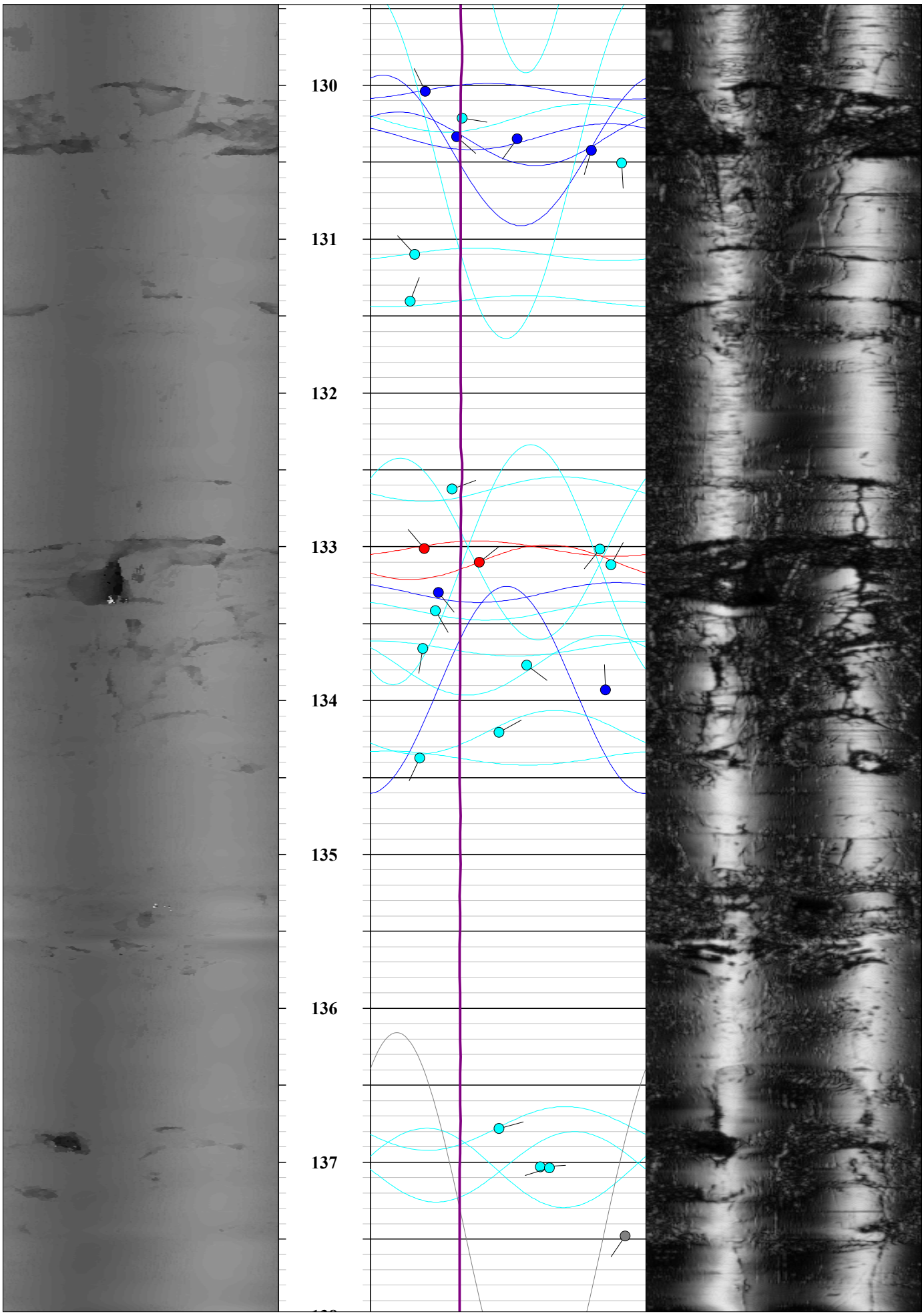
NA - Not Available, N/A - Not Applicable

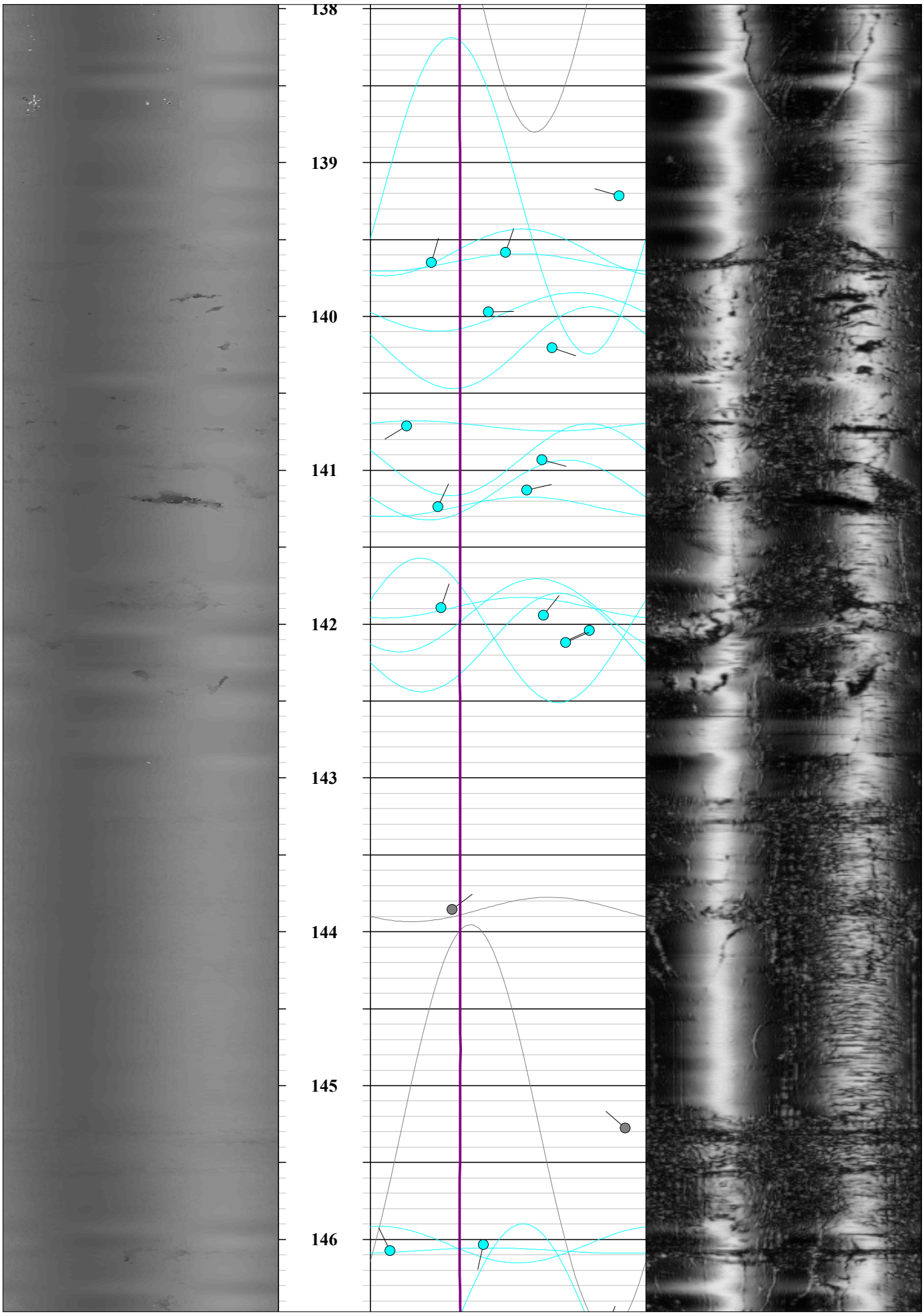
COMMENTS

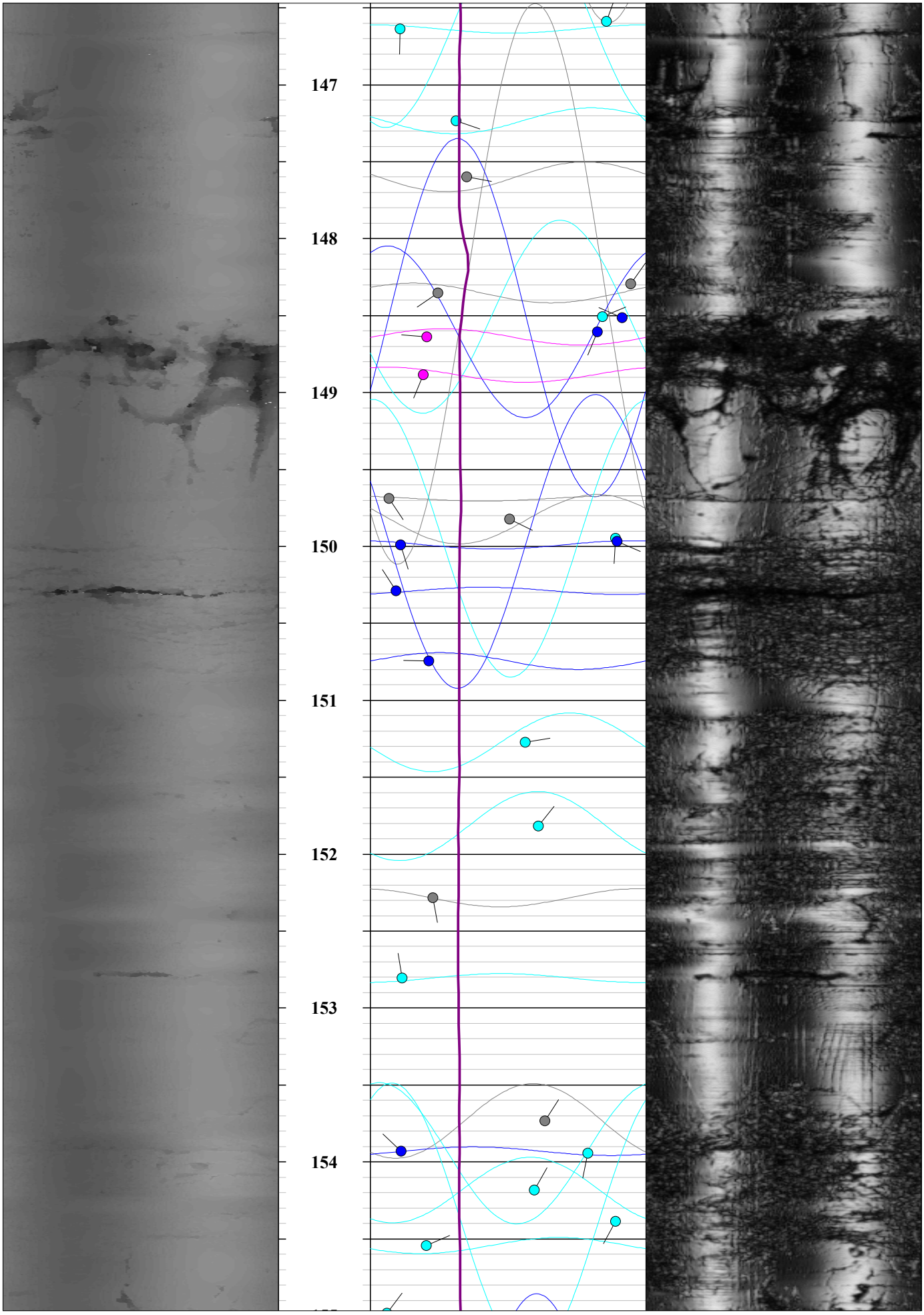

Travel Time - MN
0° 90° 180° 270° 0°
Depth
1ft:10ft
Projections
0° 90° 180° 270° 0°
Tadpoles
0 90
3-Arm Caliper
2 inch 8
Amplitude - MN
0° 90° 180° 270° 0°
106
107
108
109
110
111
112

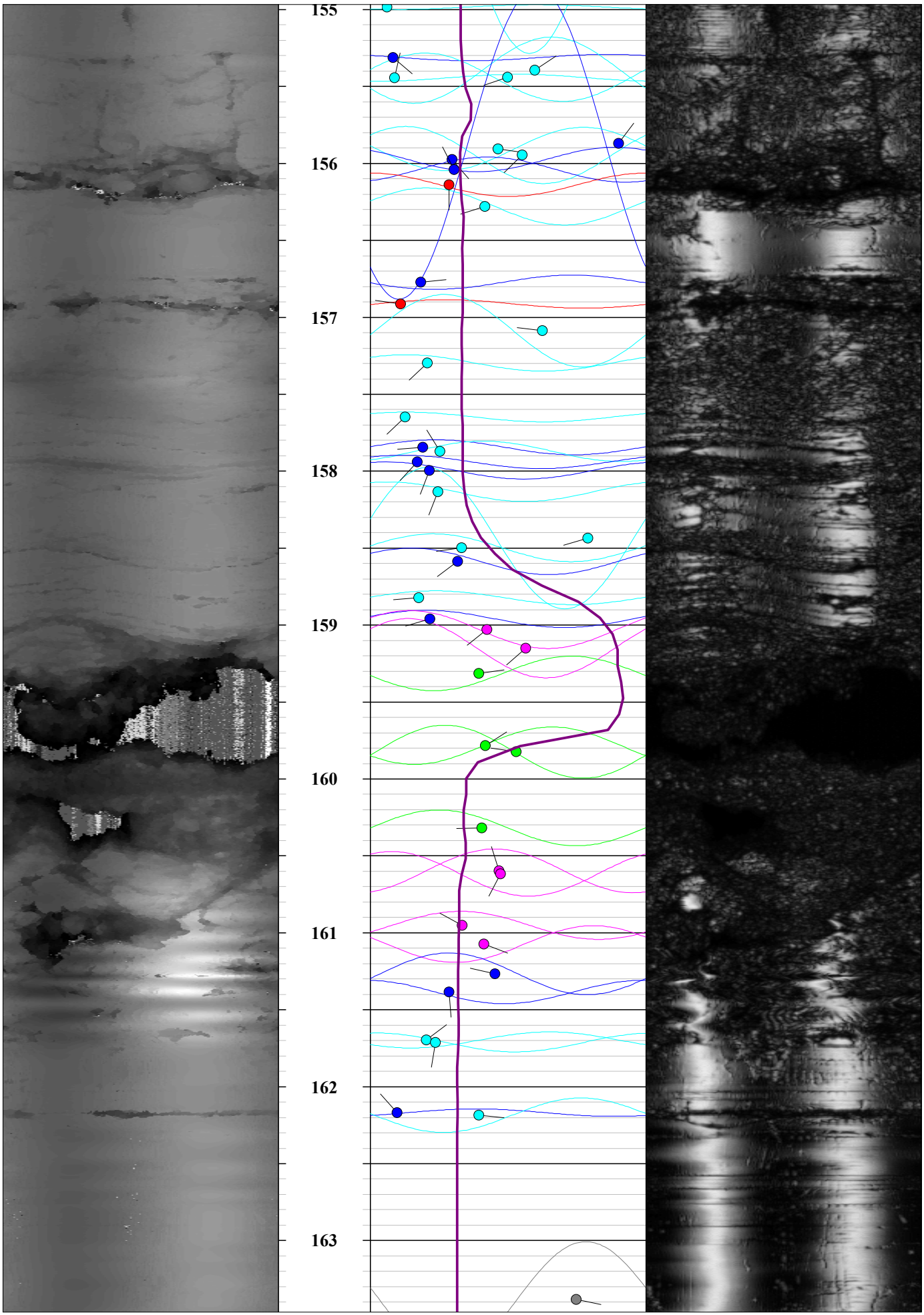

113
114
115
116
117
118
119
120

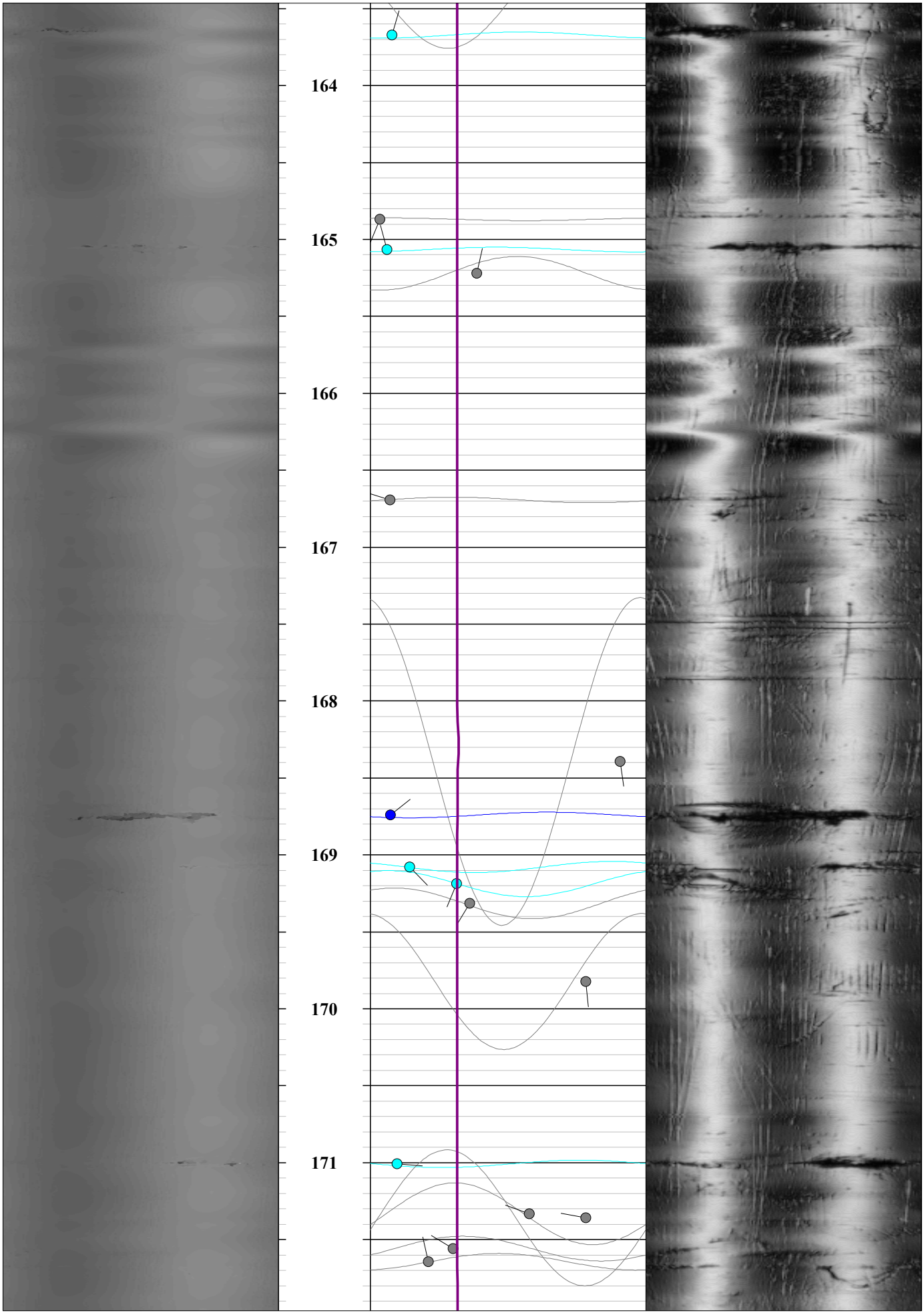

121
122
123
124
125
126
127
128
129

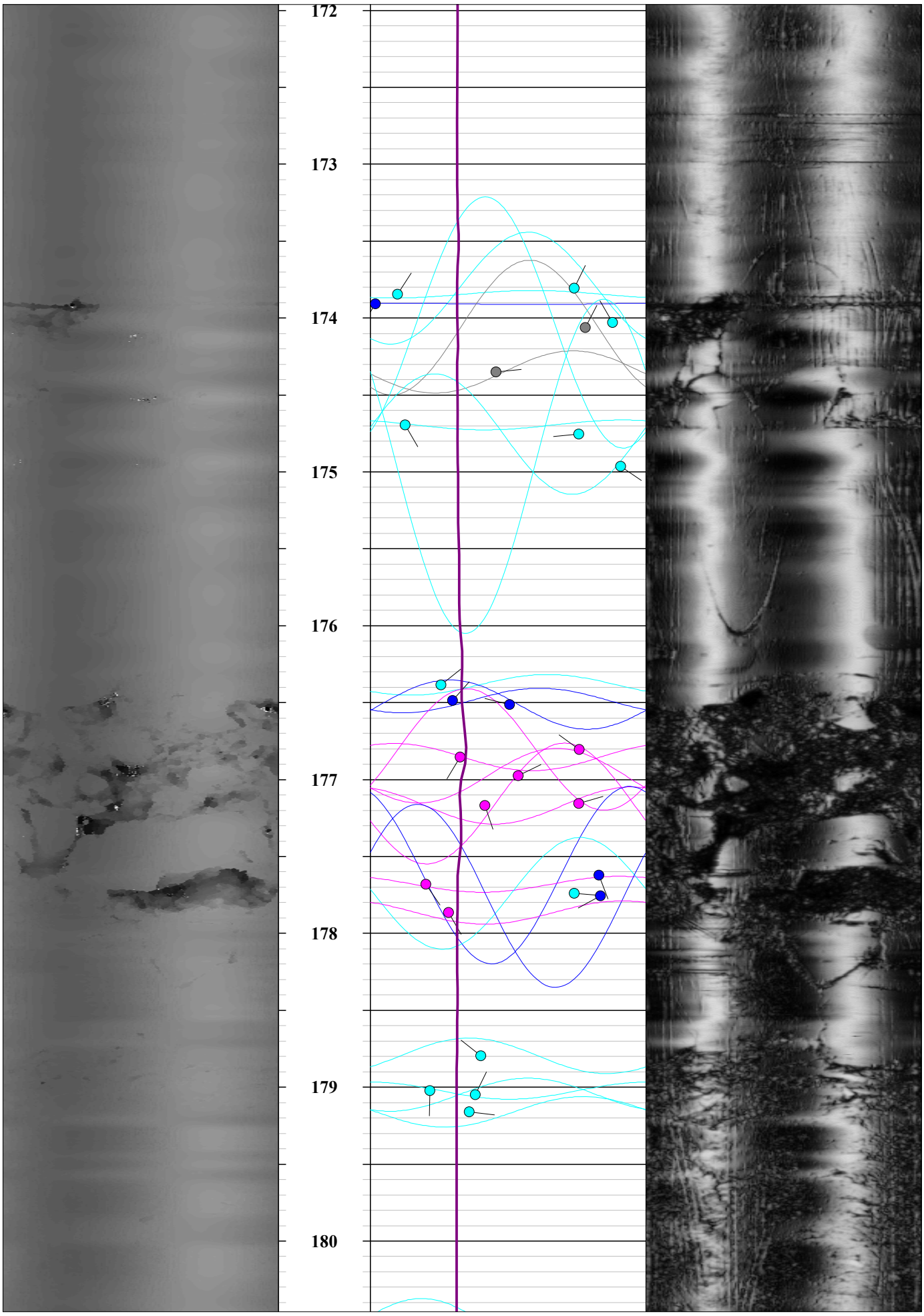

130
131
132
133
134
135
136
137

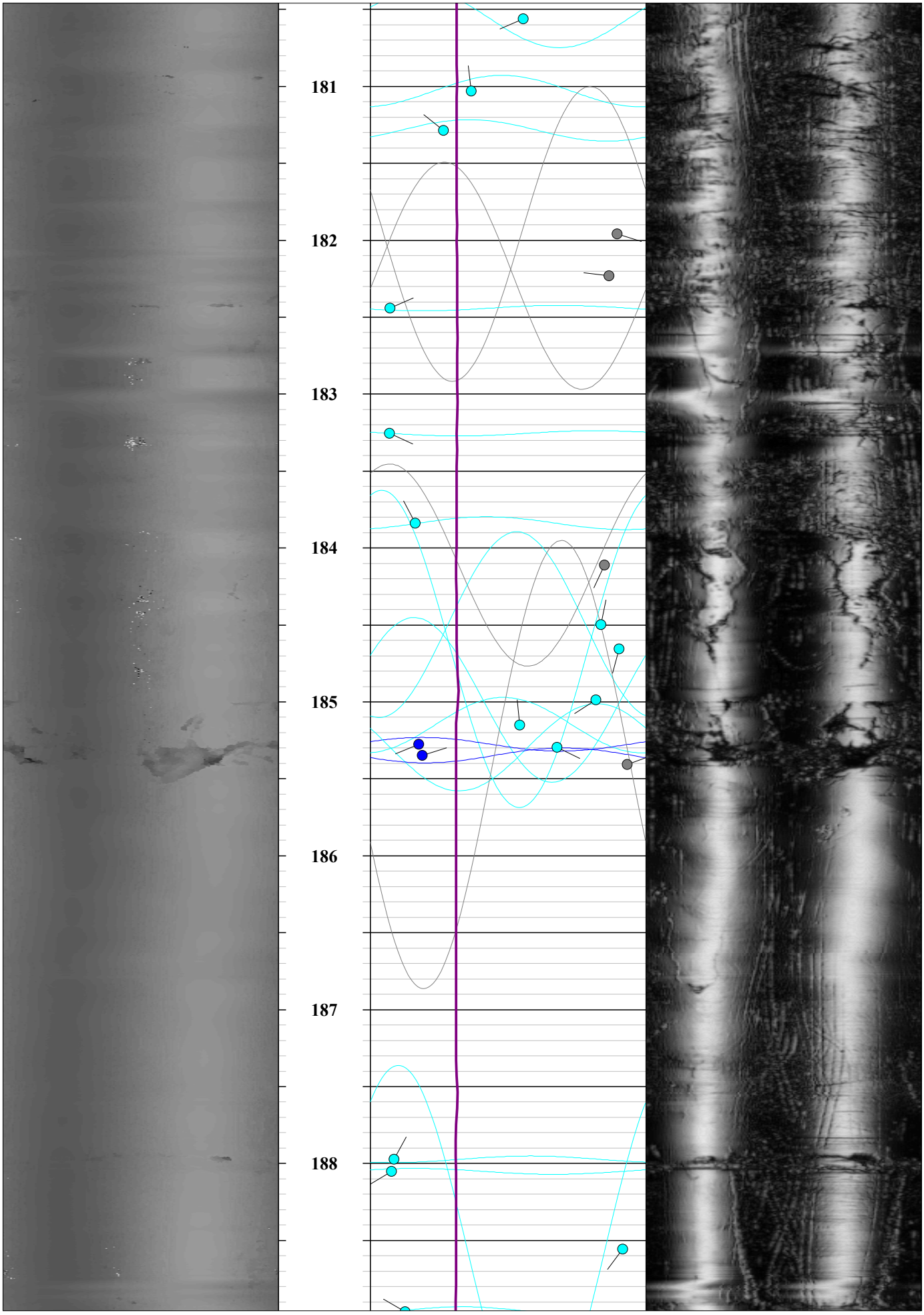

138
139
140
141
142
143
144
145
146

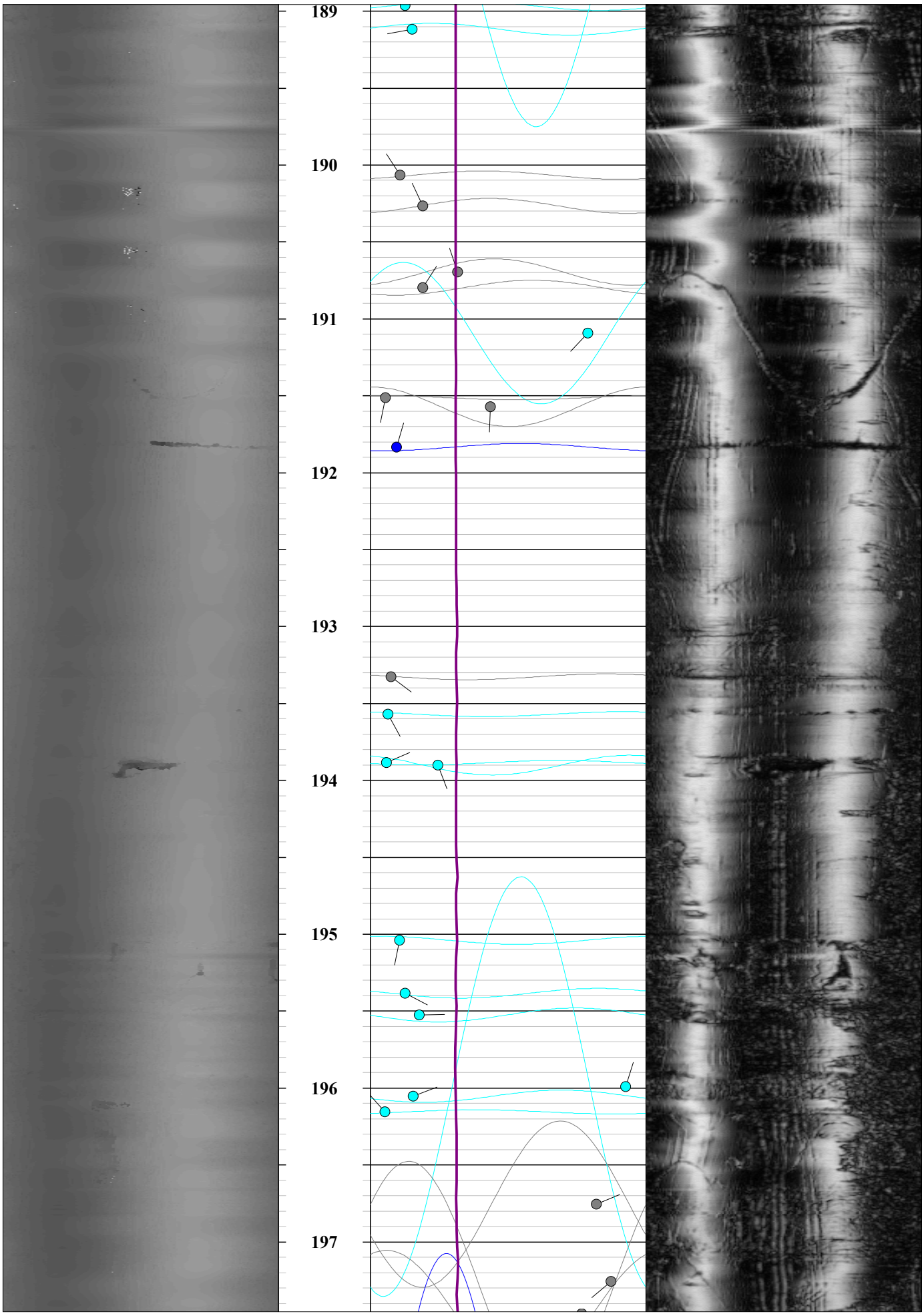

147
148
149
150
151
152
153
154

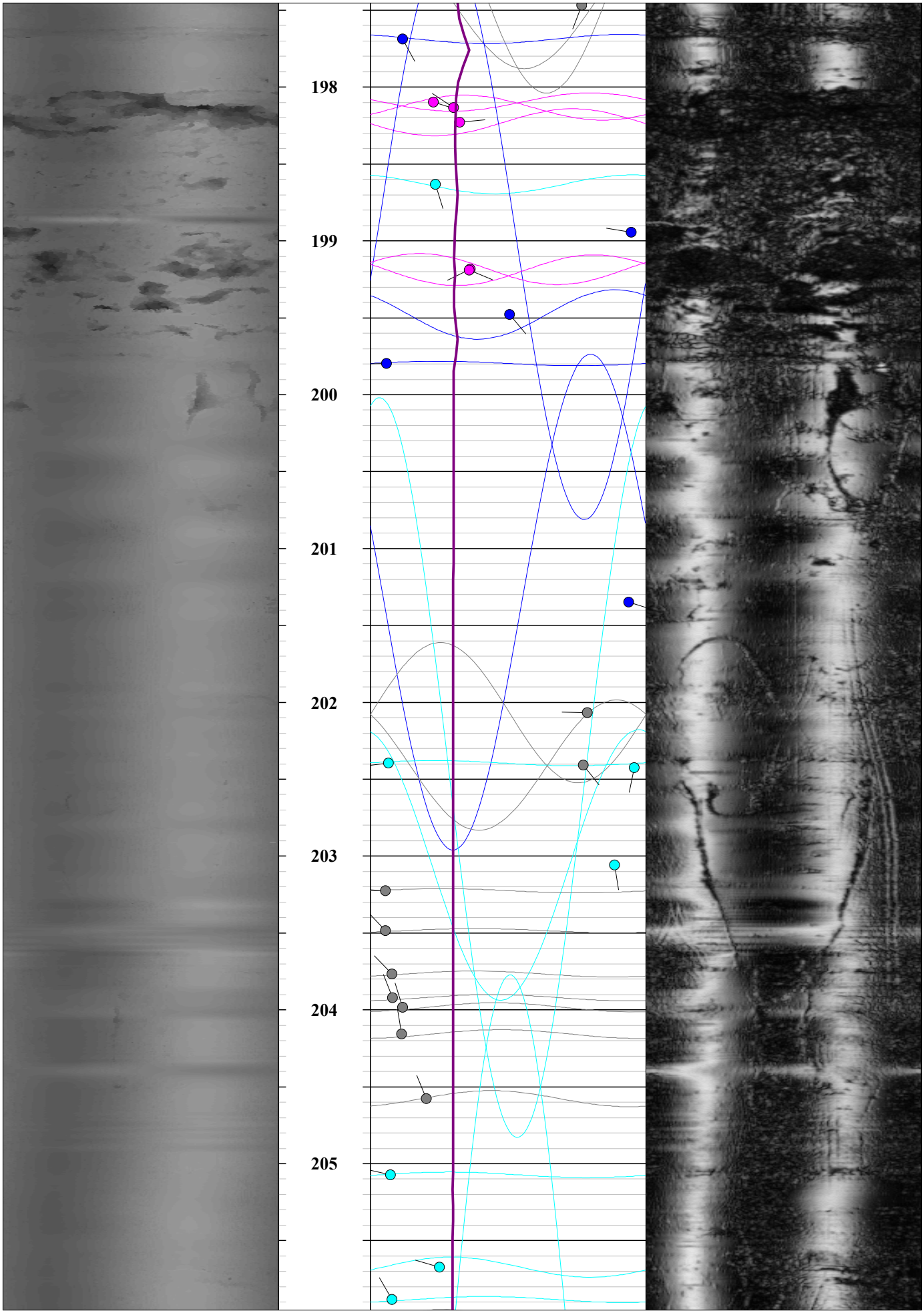

155
156
157
158
159
160
161
162
163

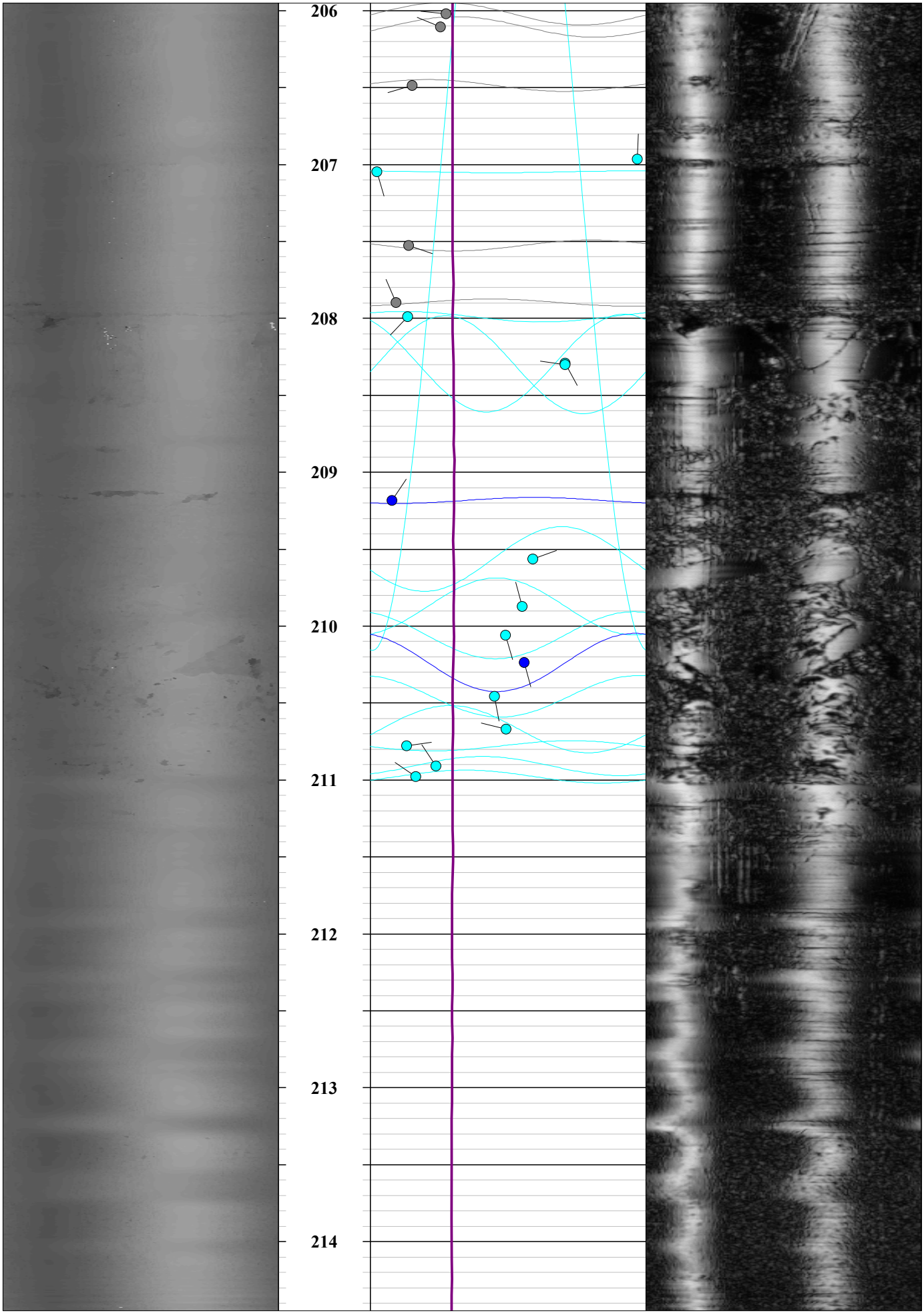

164
165
166
167
168
169
170
171

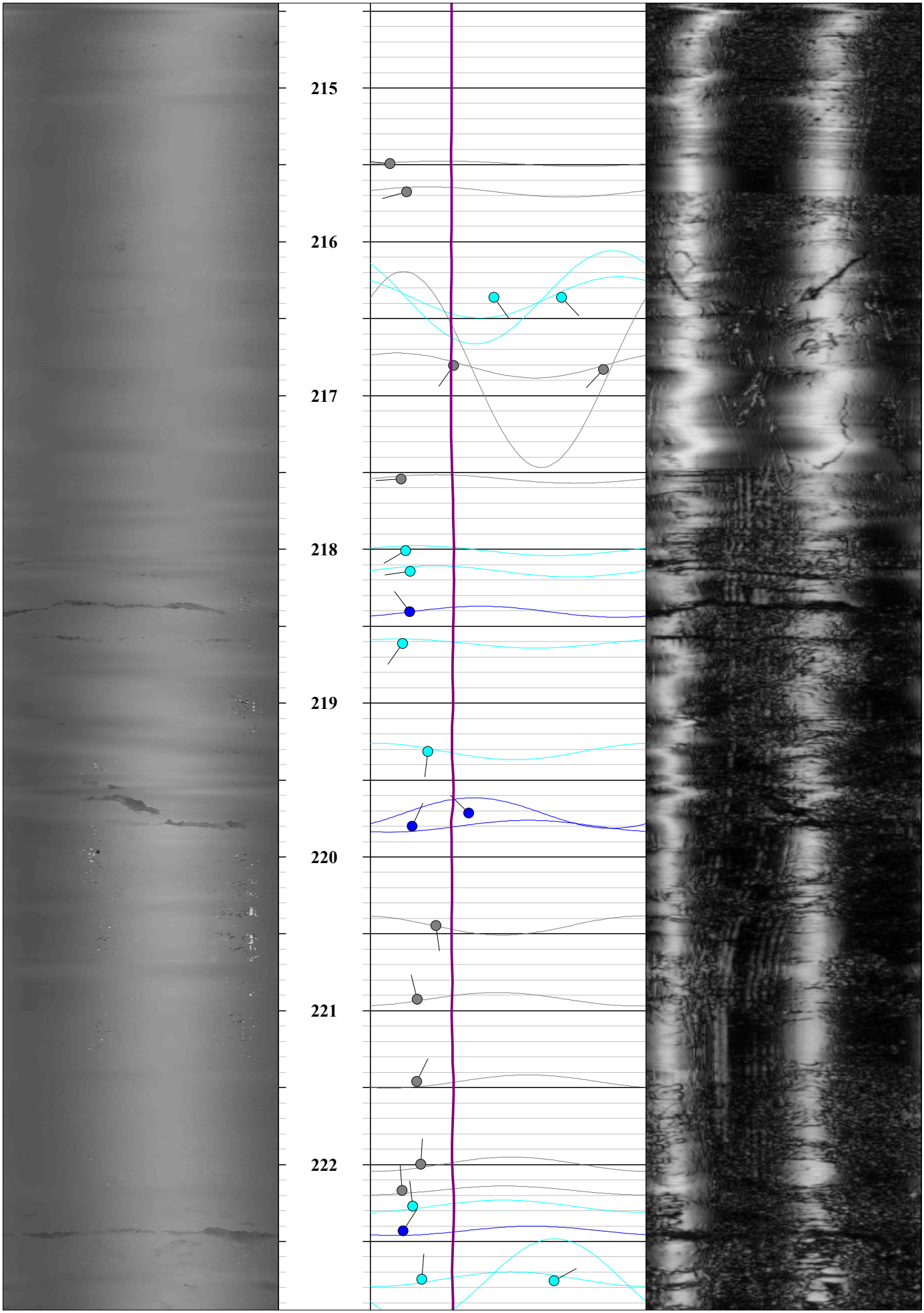

172
173
174
175
176
177
178
179
180

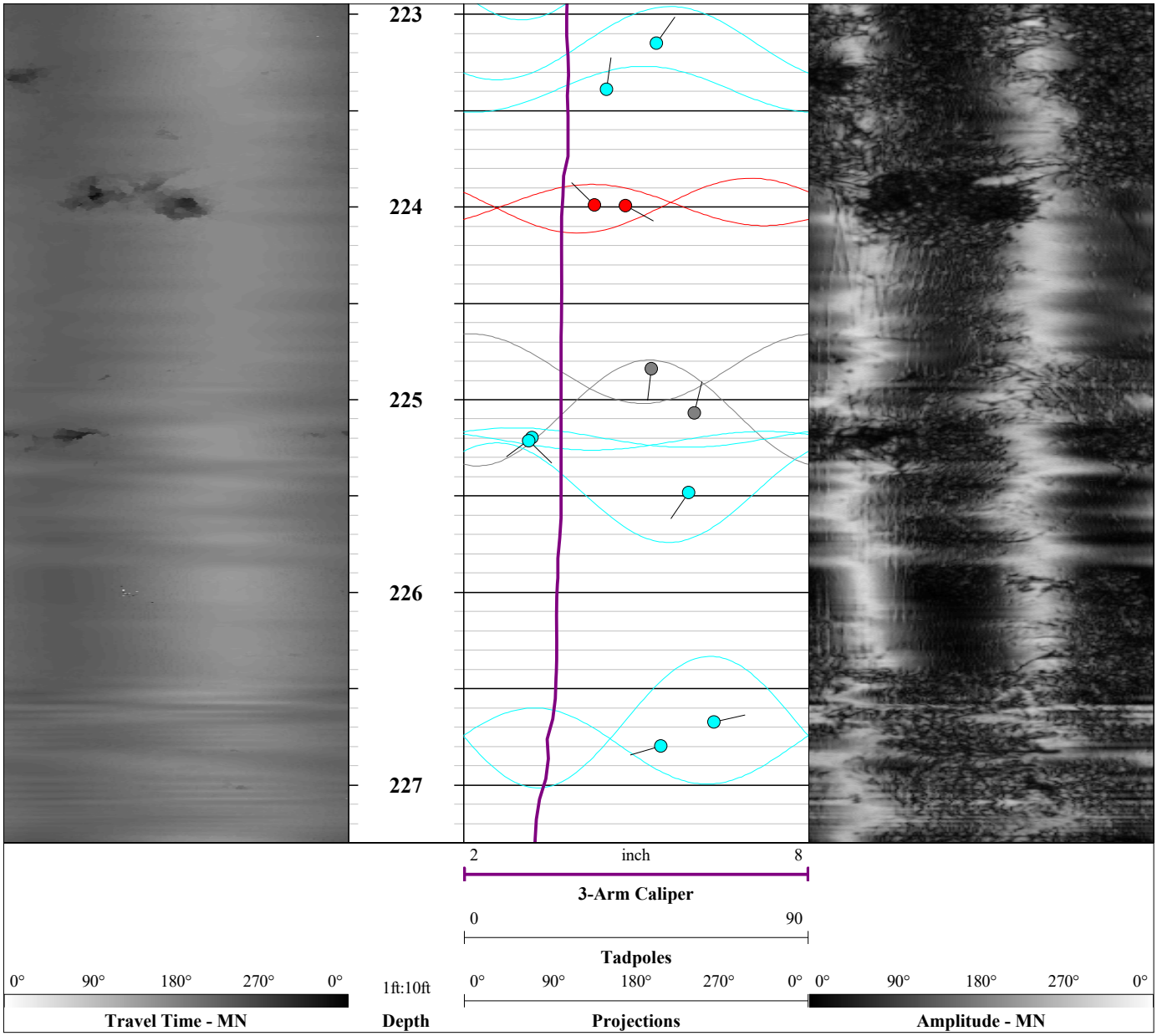

181
182
183
184
185
186
187
188


189
190
191
192
193
194
195
196
197


198
199
200
201
202
203
204
205


206
207
208
209
210
211
212
213
214


215
216
217
218
219
220
221
222


223
224
225
226
227
2
inch
8
3-Arm Caliper
0
90
Tadpoles
0°
90°
180°
270°
0°
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
Travel Time - MN
Depth
Projections
Amplitude - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-15
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-15
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83538 N
Longitude: 84.75837 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.6'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	17 July 2019			
RUN NUMBER	1			
LOG TYPE	Optical Televiewer			
DEPTH-DRILLER	228'			
DEPTH-LOGGER	228'			
BTM LOG INTERVAL	220.29'			
TOP LOG INTERVAL	104'			
RECORDED BY	CKL			
WITNESSED BY				
PROBE TYPE, S/N	OBI/LIM #1729			
LOGGING SPEED	4.4 fpm			
A.S.D.E. / Sample Interval	0.74' / 0.0024'			
Fluid Level / Fluid Type	18'/Water			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	228'

CASING RECORD

SIZE	WGT.	FROM	TO
PQ	Steel	0'	110'

NA - Not Available, N/A - Not Applicable

COMMENTS

3-Arm Caliper

2 inch 8

Depth

1ft:10ft

Projections

0° 90° 180° 270° 0°

Tadpoles

0 90

Optical Image - MN

0° 90° 180° 270° 0°

6

7

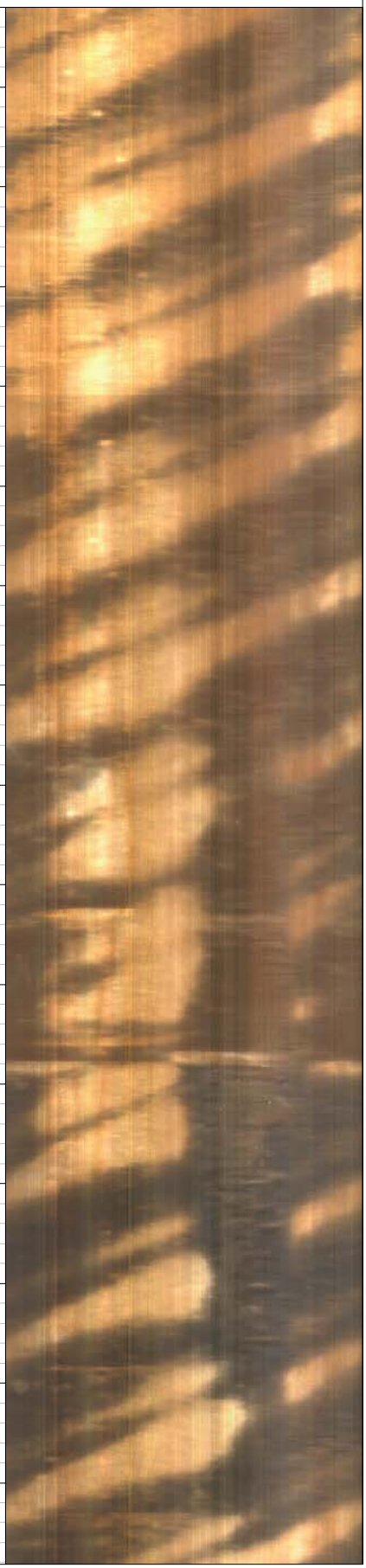
8

9

10

11

12



13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

29

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51

52

53

54

55

56

57

58

59

60

61

62

63

64

65

66

67

68

69

70

71

72

73

74

75

76

77

78

79

80

81

82

83

84

85

86

87

88

89

90

91

92

93

94

95

96

97

98

99

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116

117

118

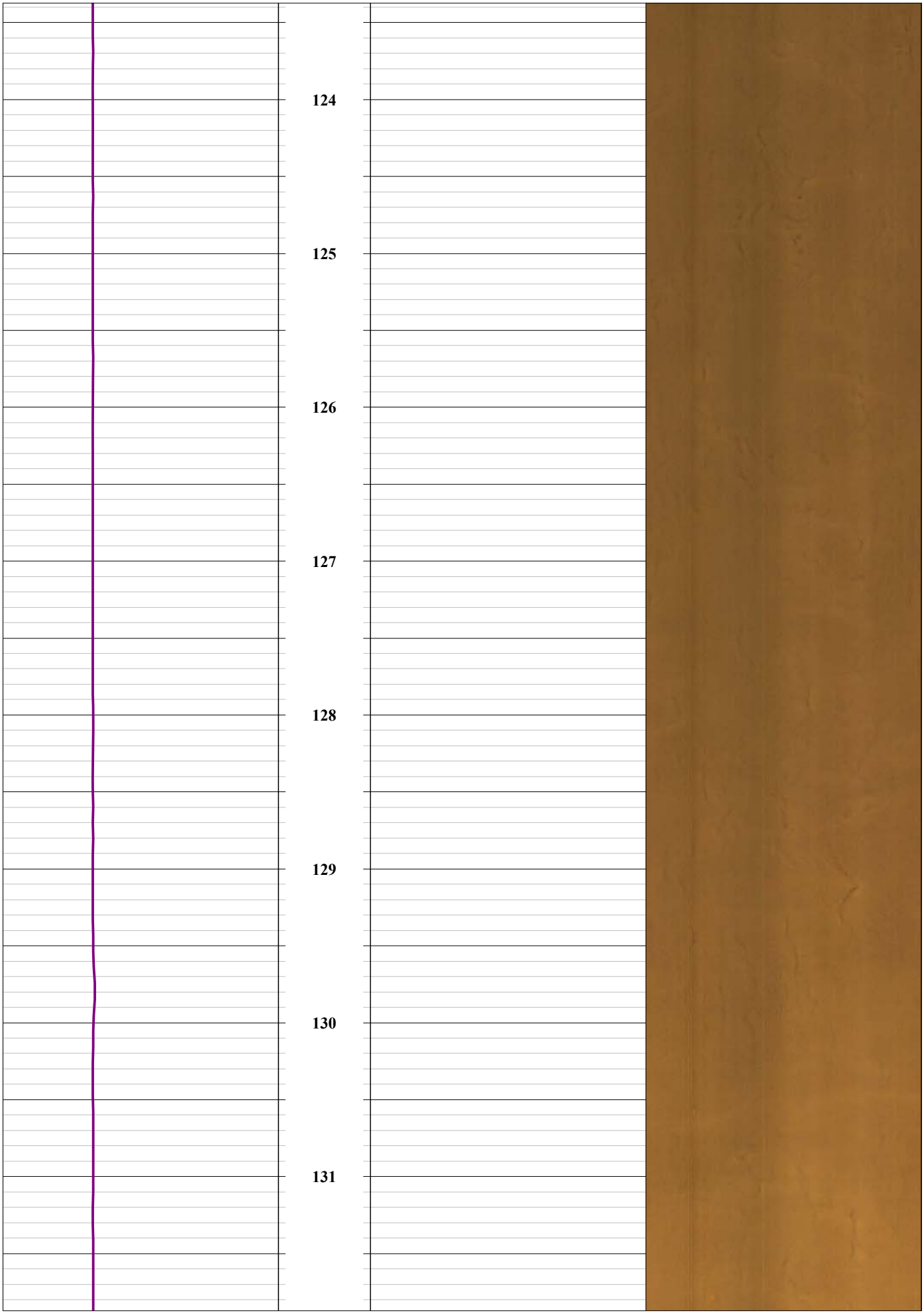
119

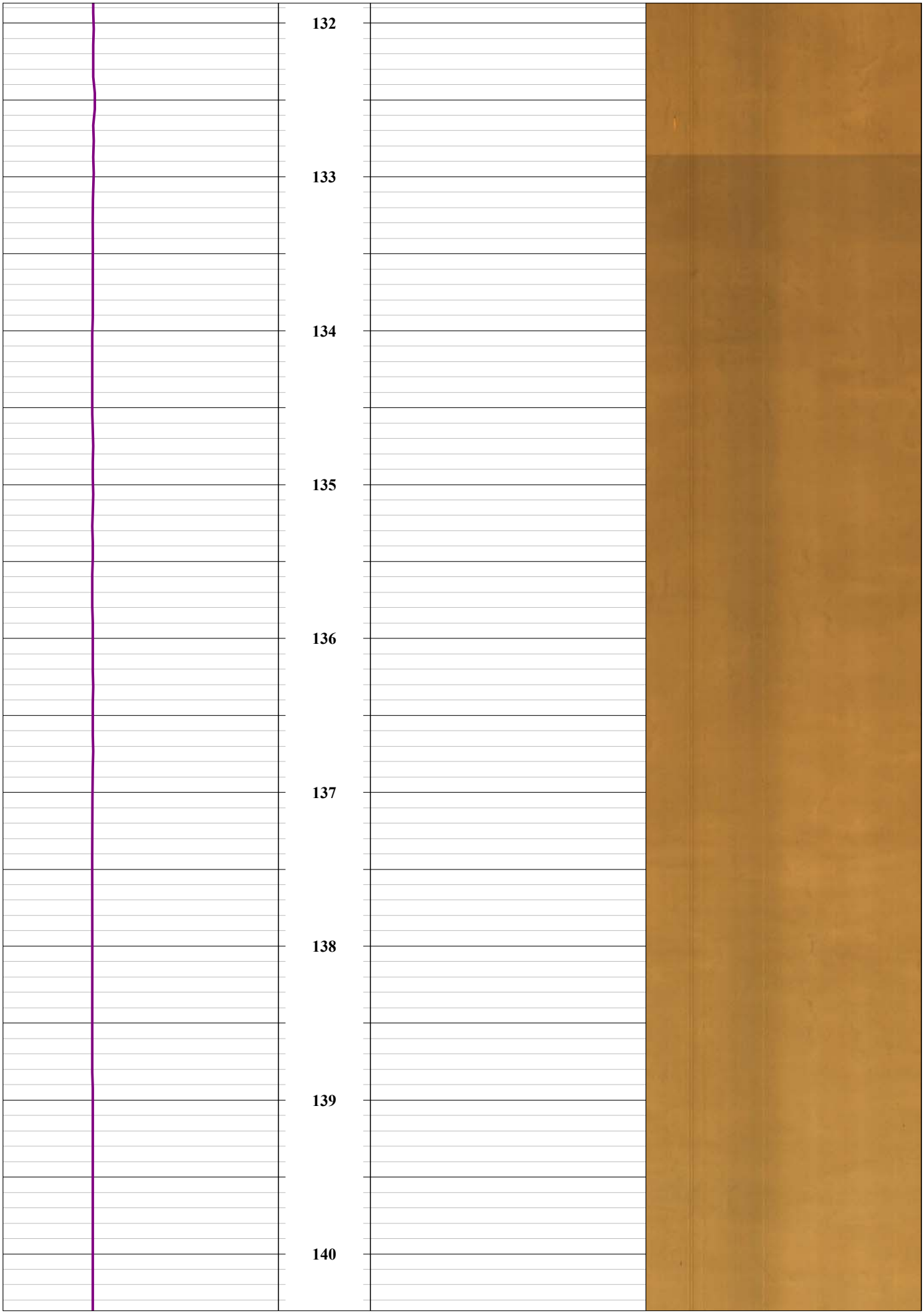
120

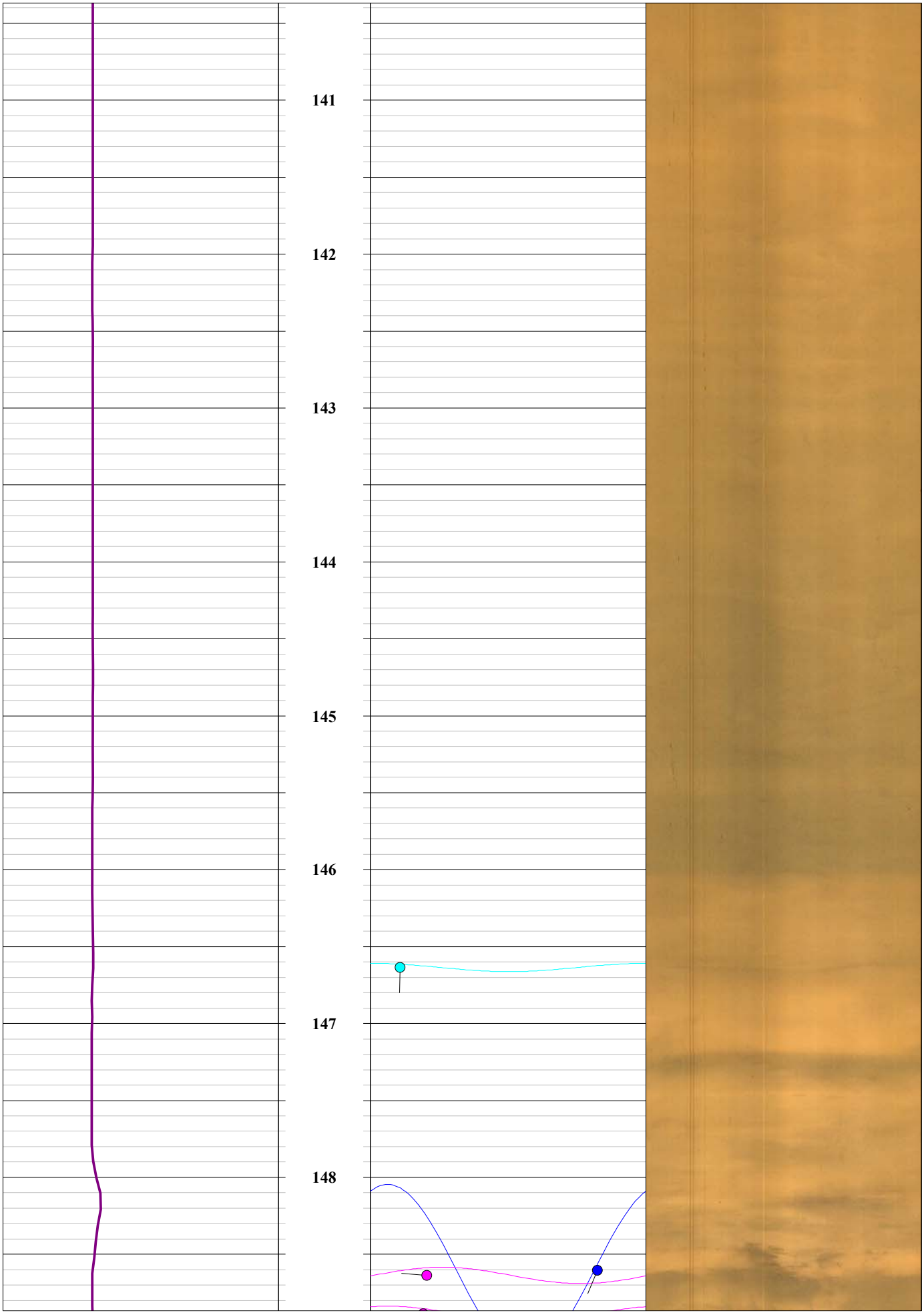
121

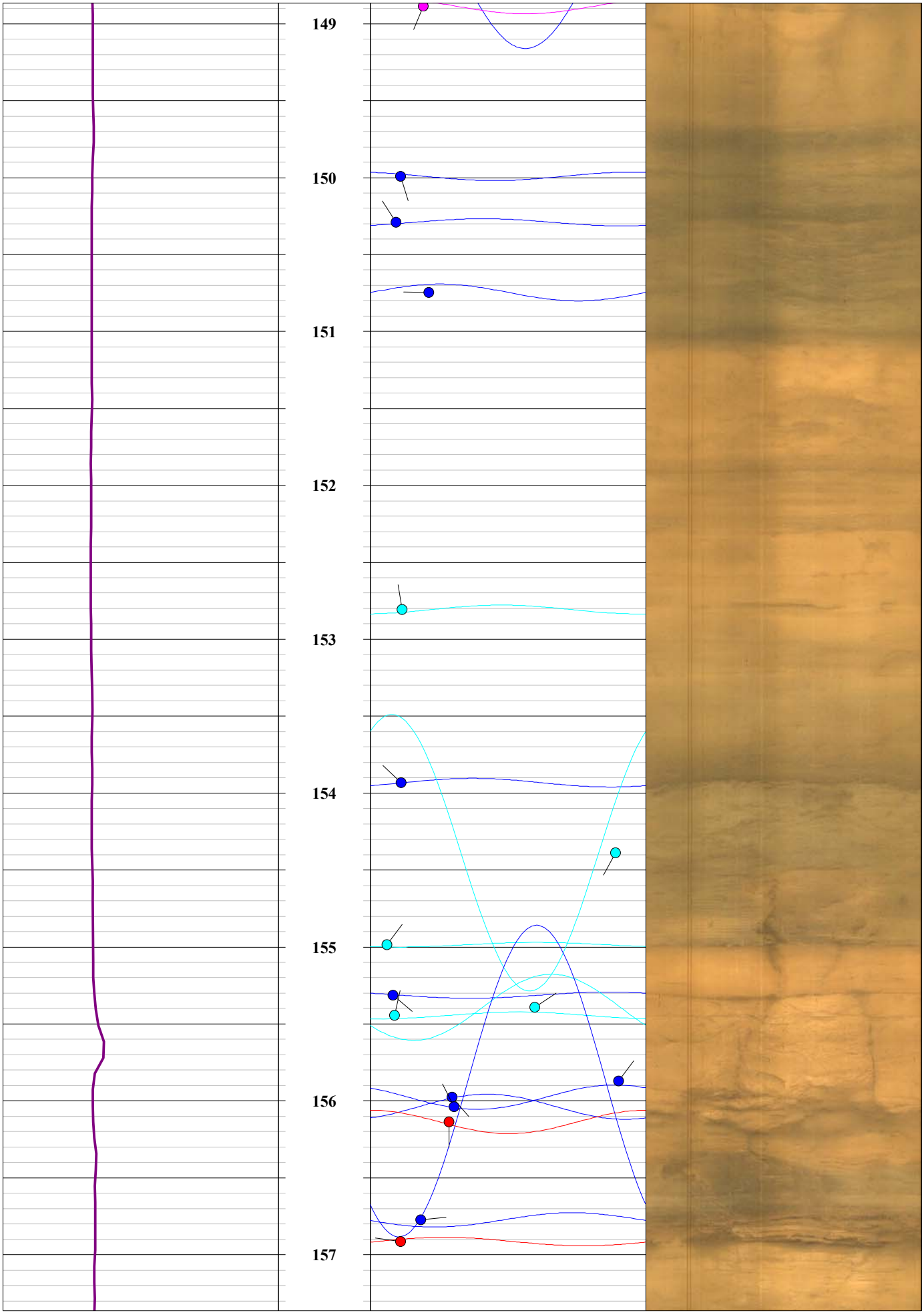
122

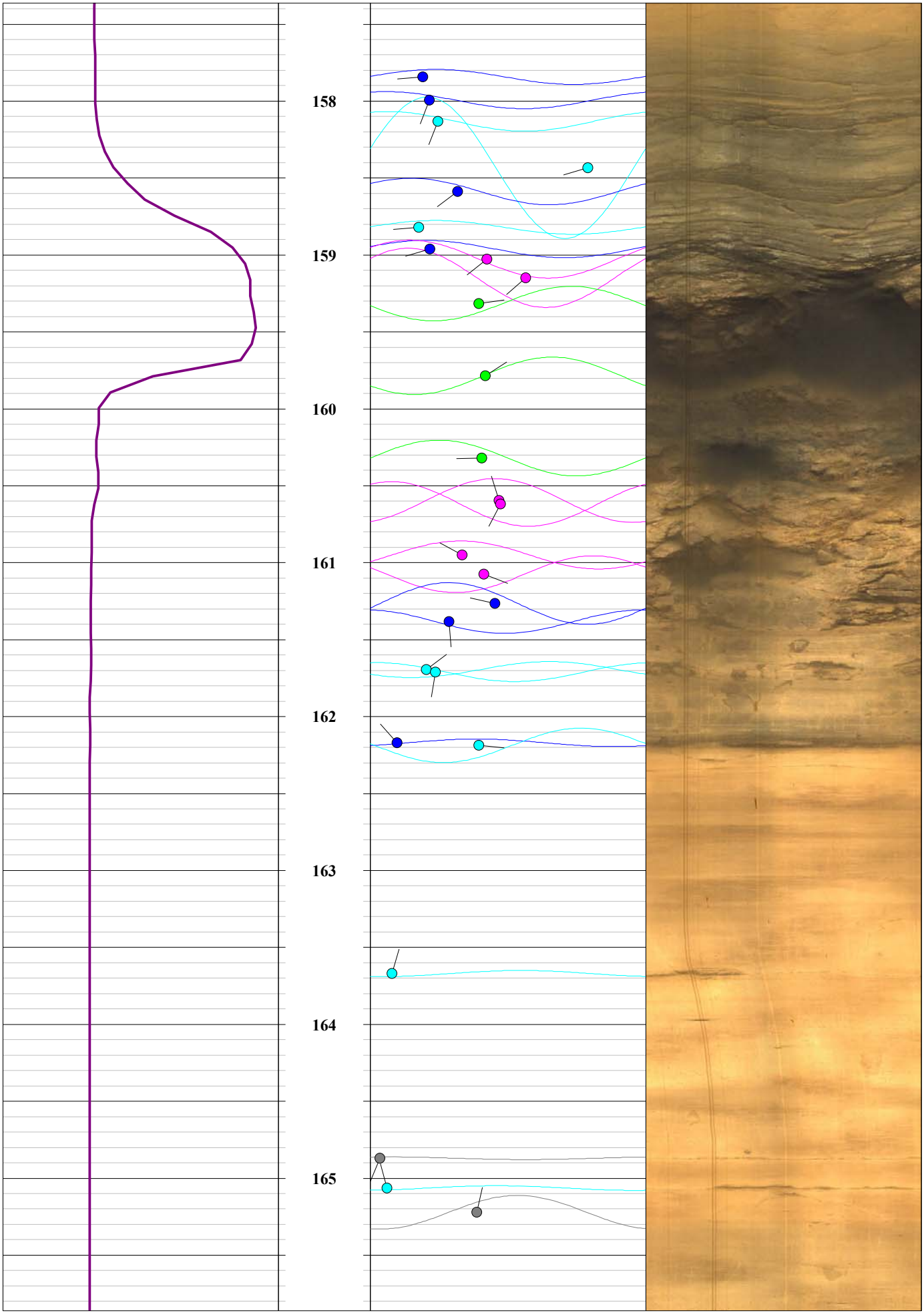
123

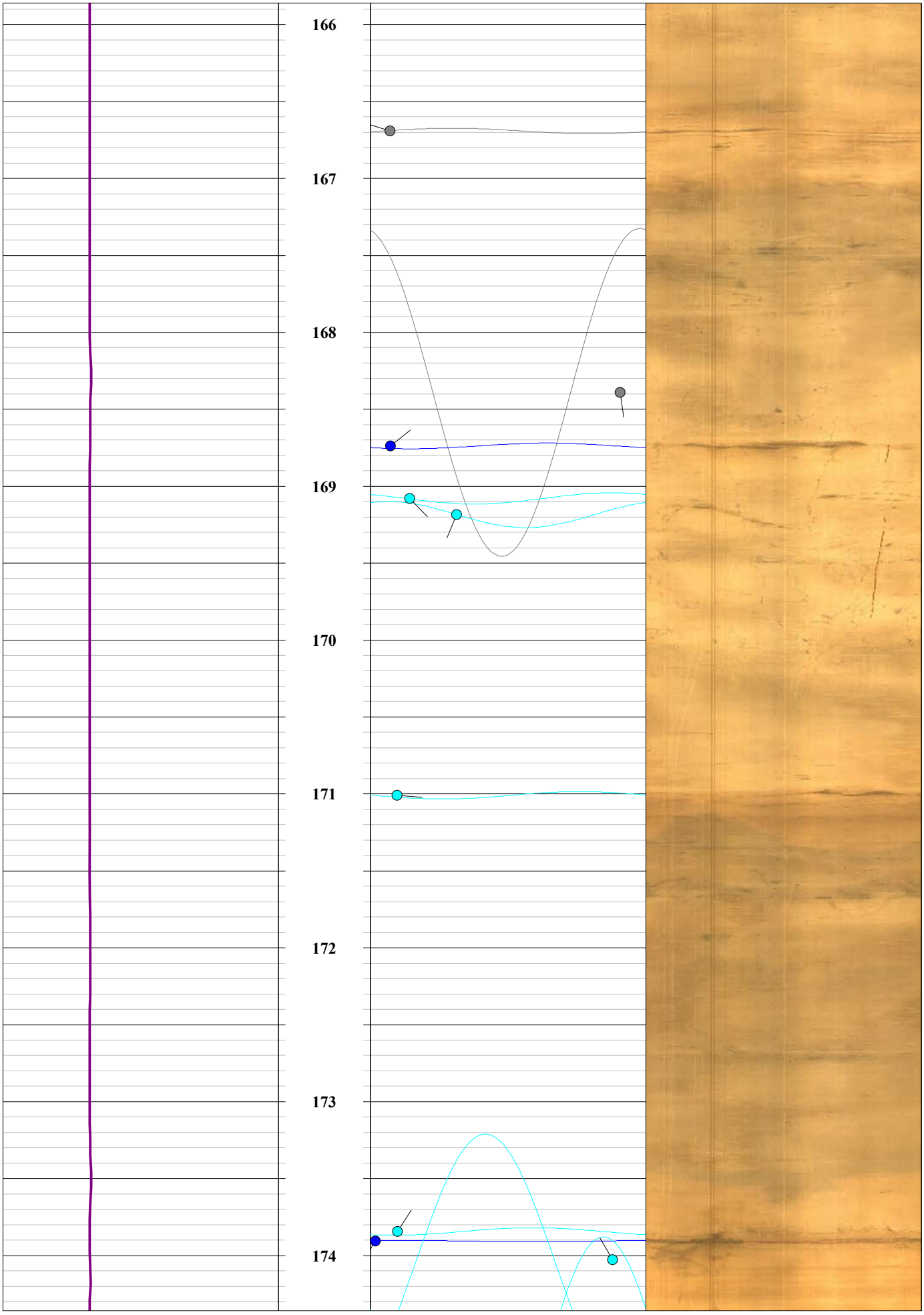

124
125
126
127
128
129
130
131

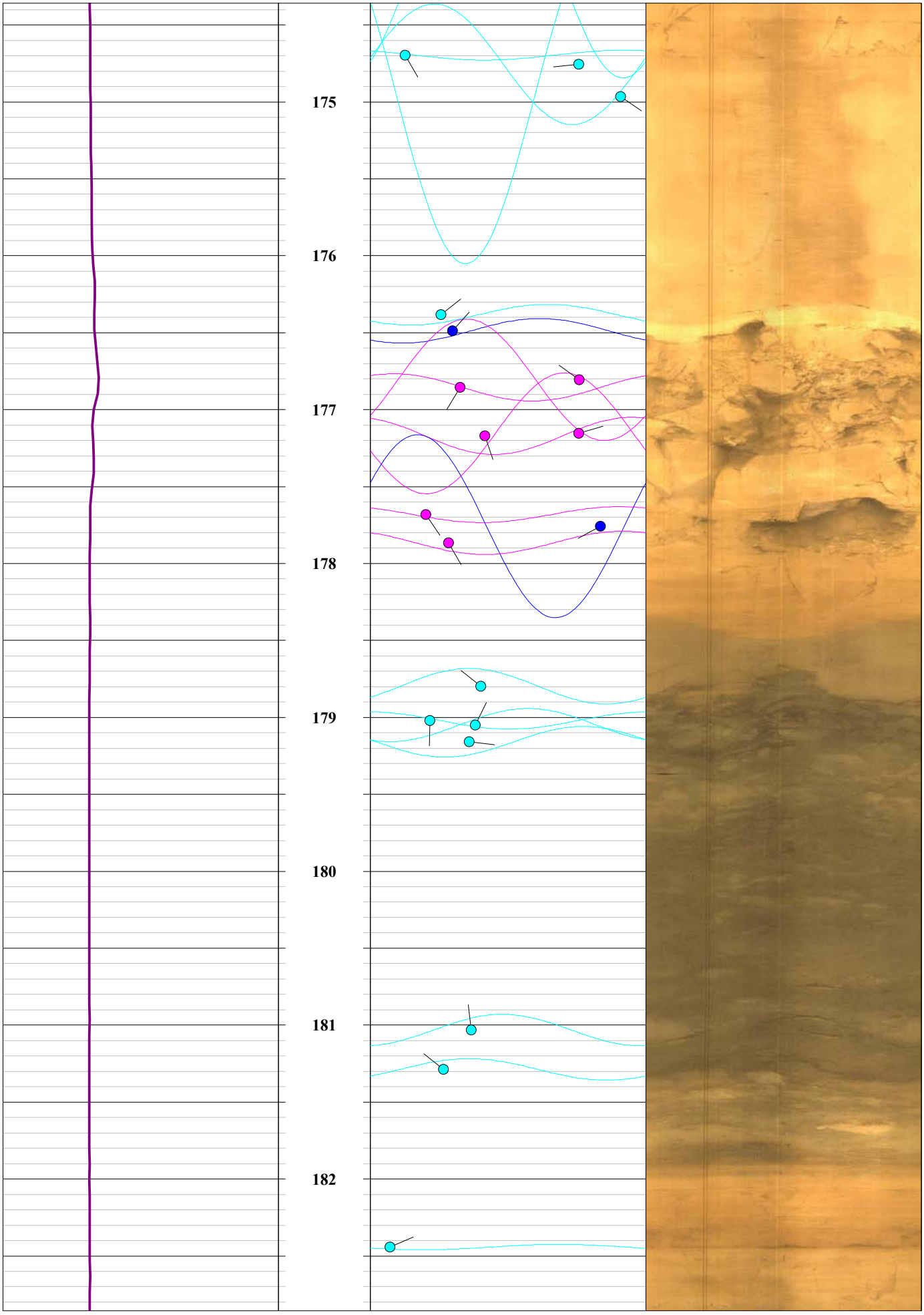

132
133
134
135
136
137
138
139
140

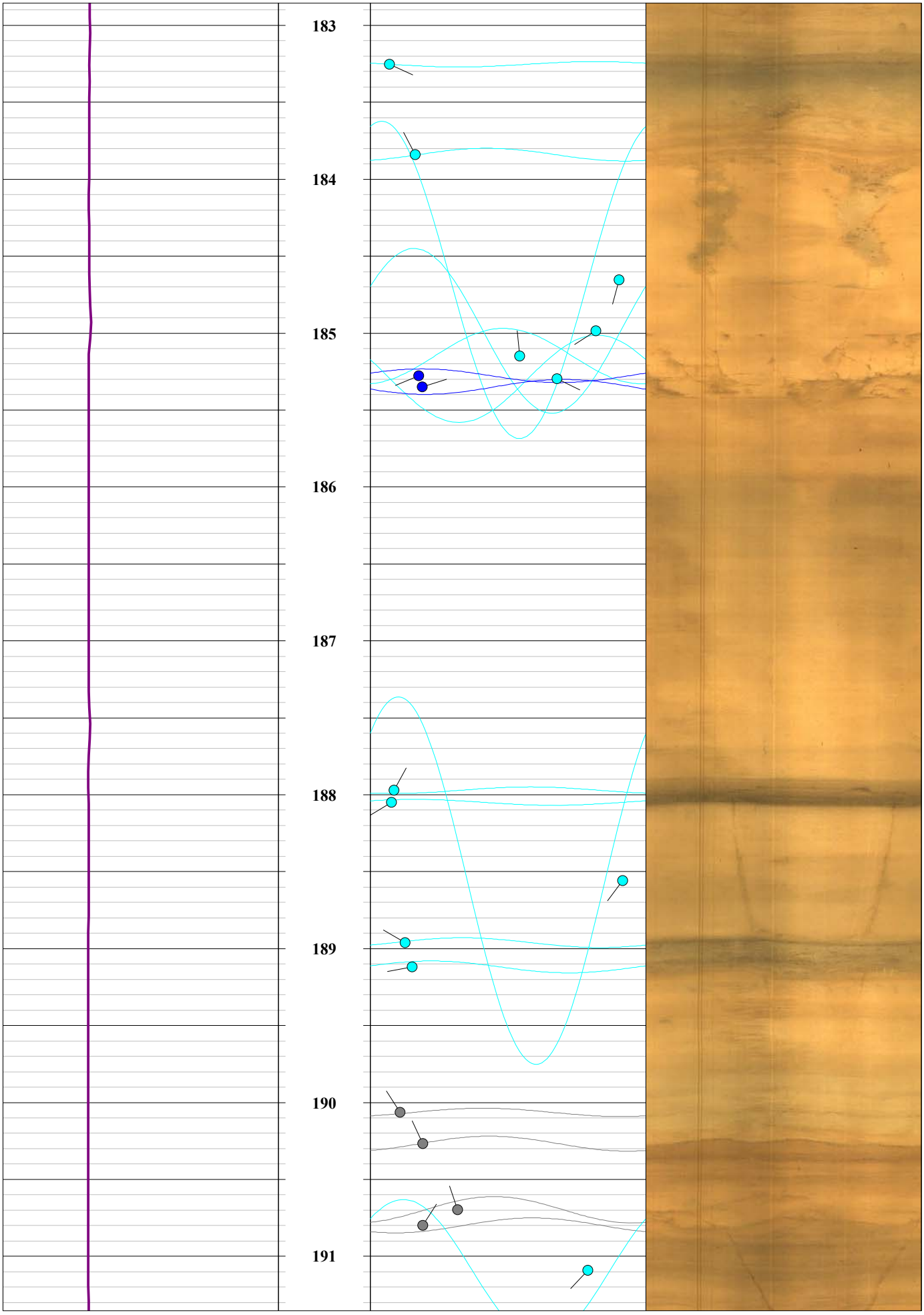

141
142
143
144
145
146
147
148

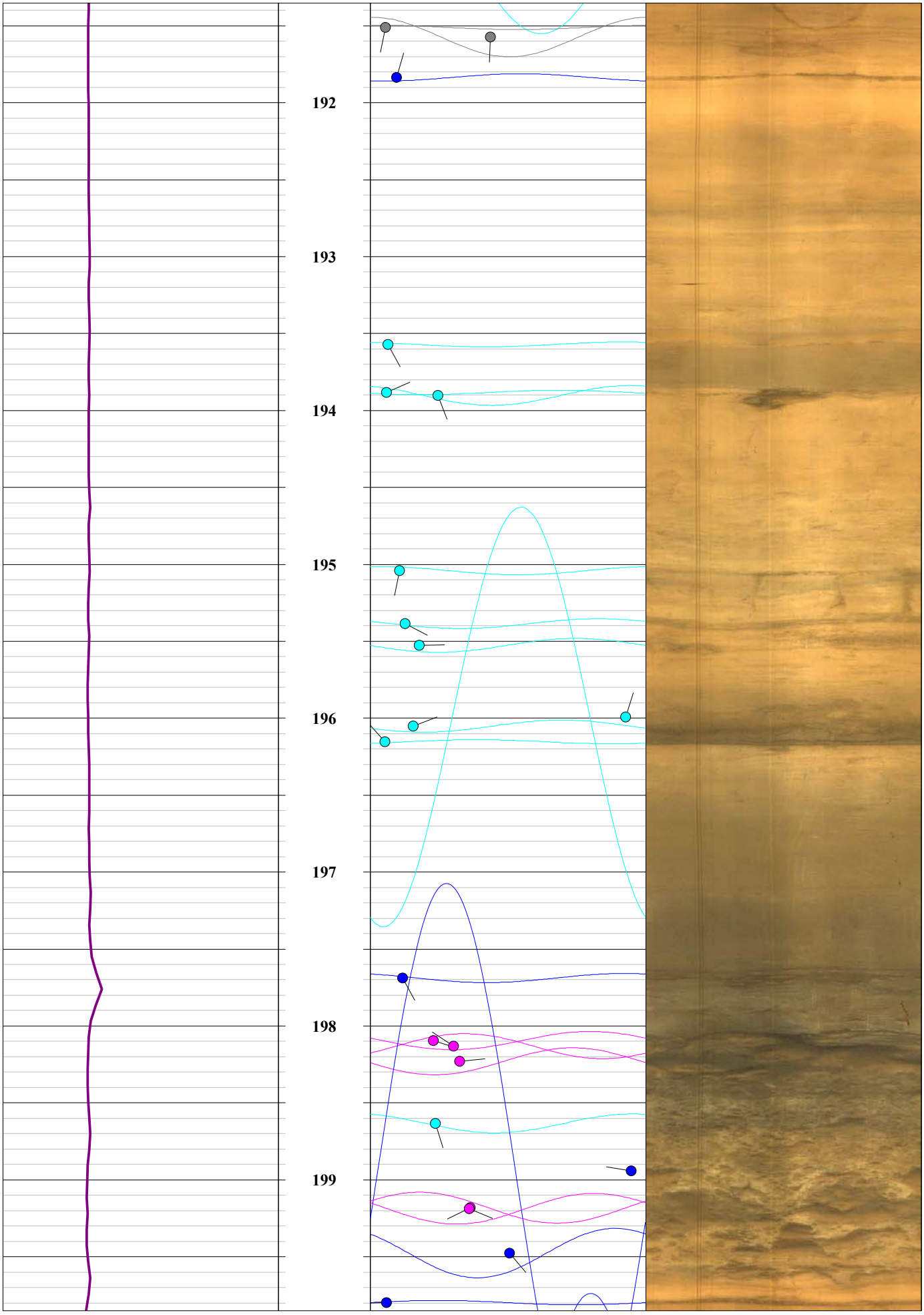

149
150
151
152
153
154
155
156
157

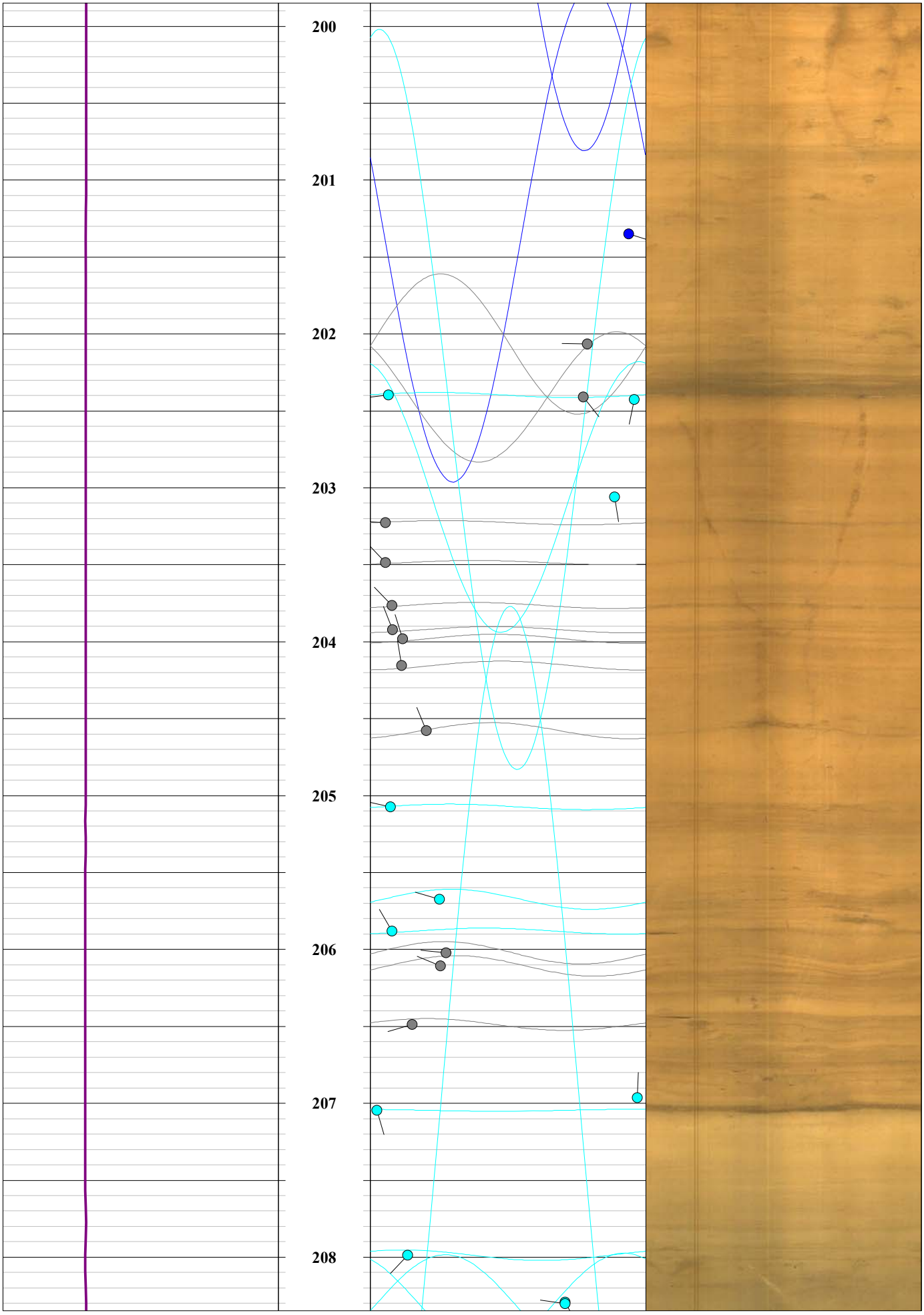

158
159
160
161
162
163
164
165

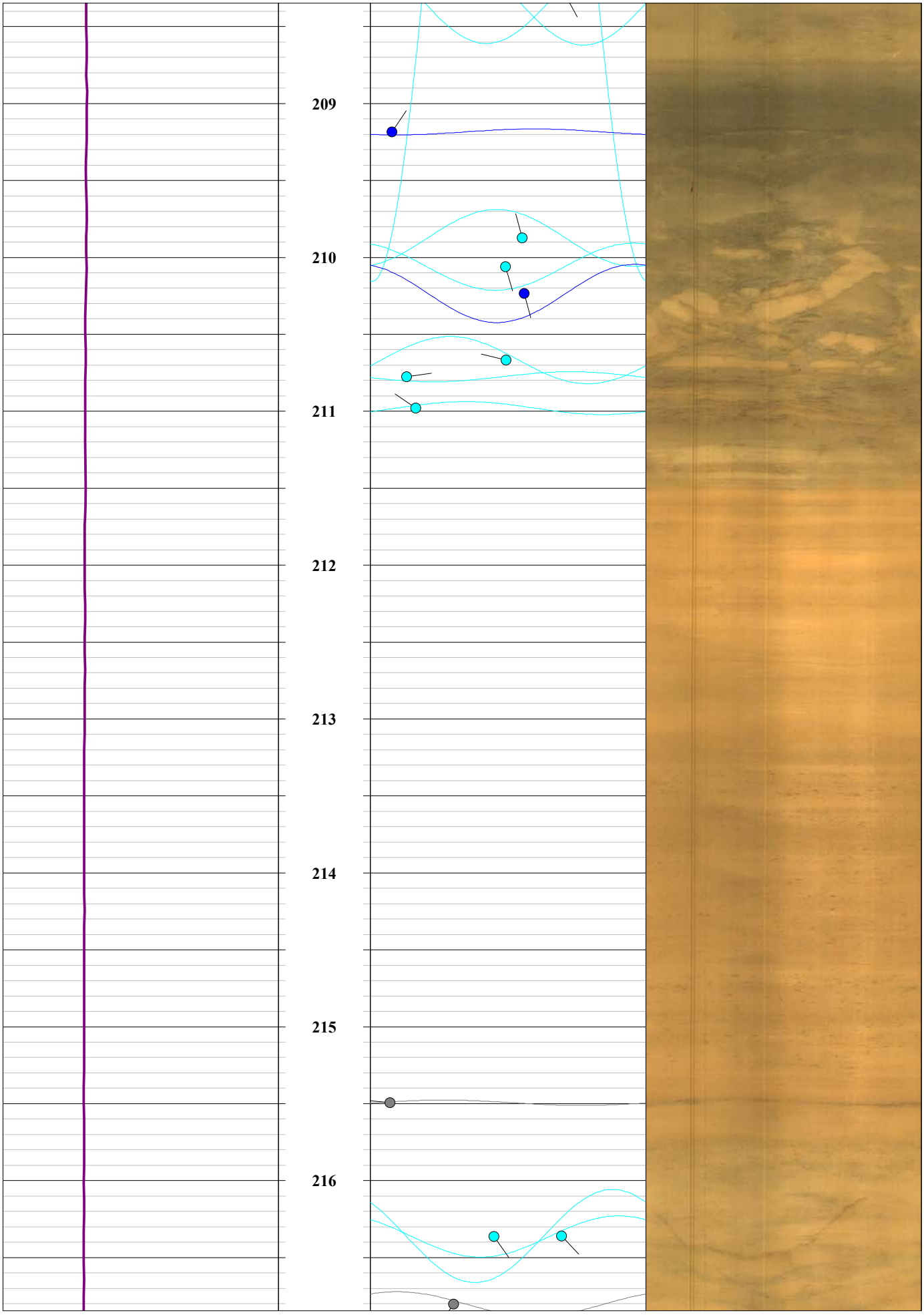

166
167
168
169
170
171
172
173
174

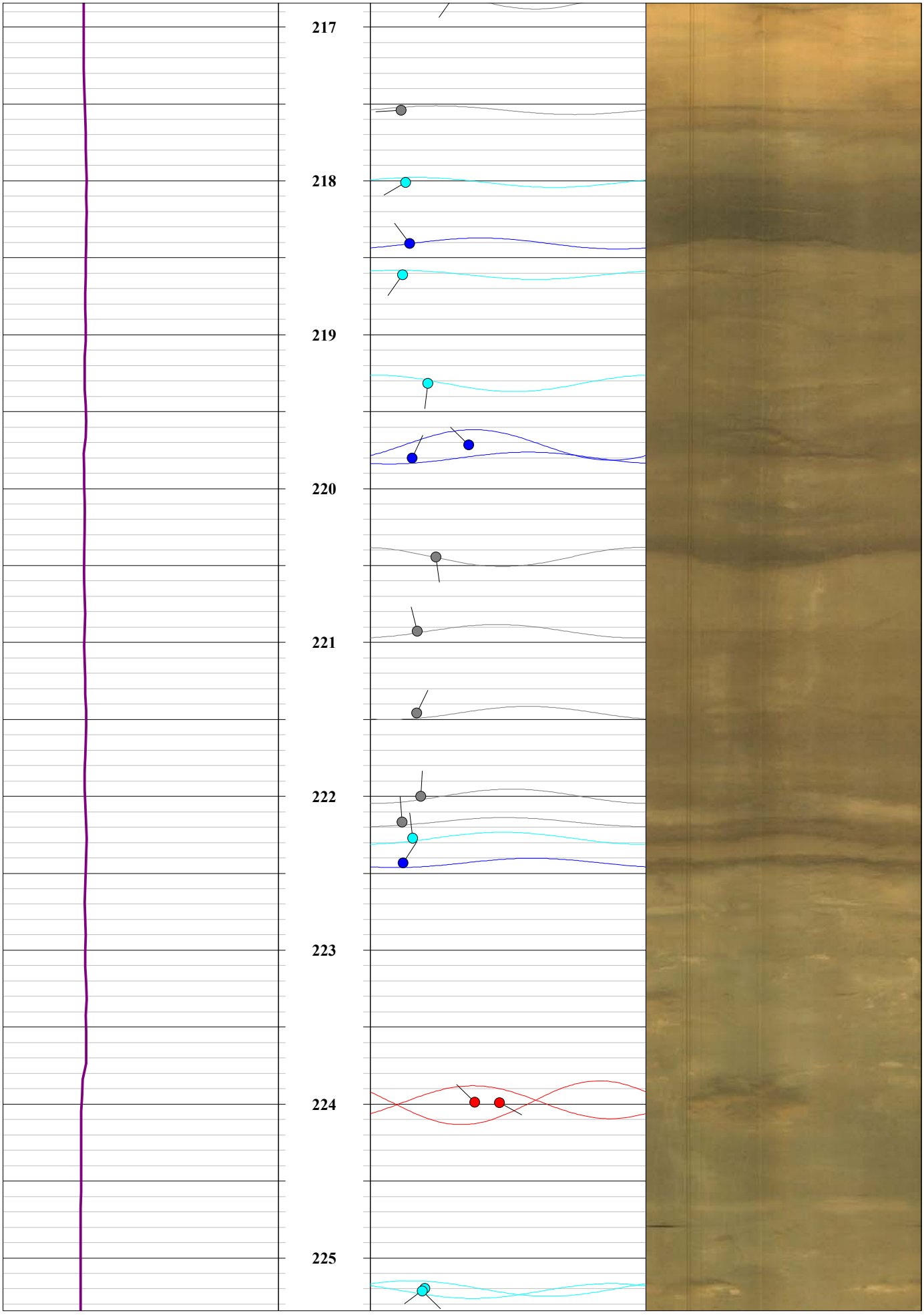

175
176
177
178
179
180
181
182

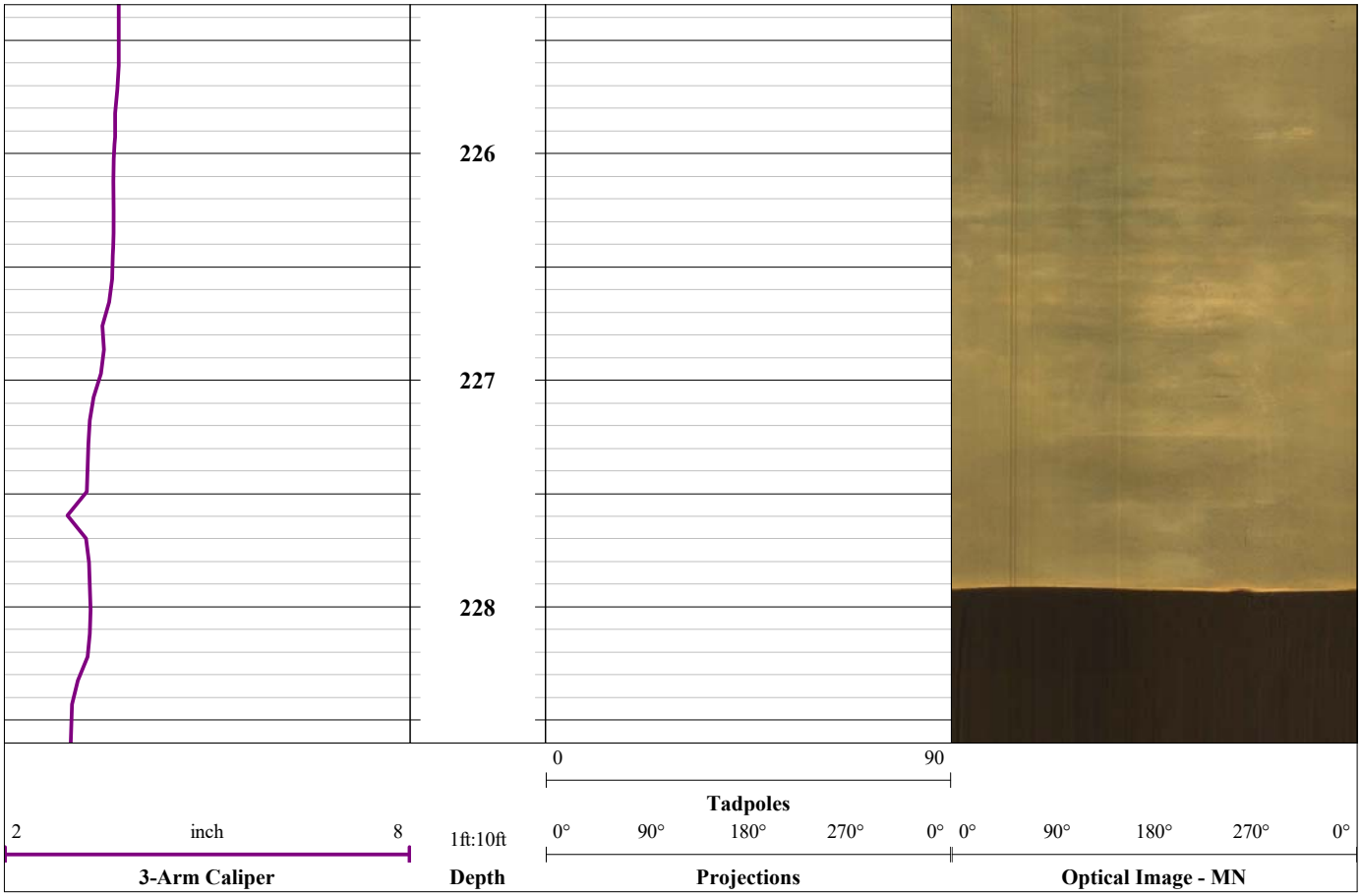

183
184
185
186
187
188
189
190
191


192
193
194
195
196
197
198
199

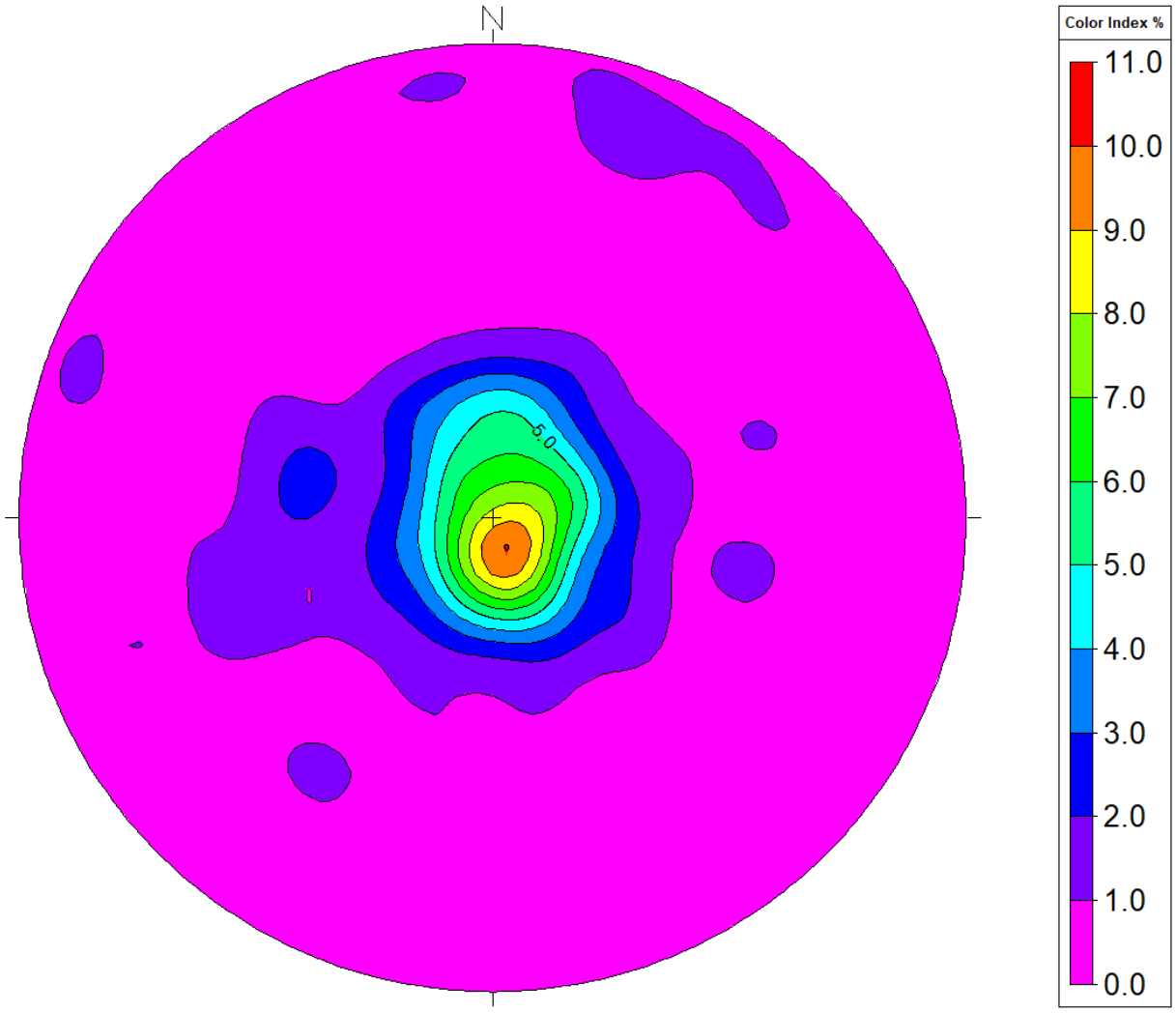

200
201
202
203
204
205
206
207
208


209
210
211
212
213
214
215
216


217
218
219
220
221
222
223
224
225

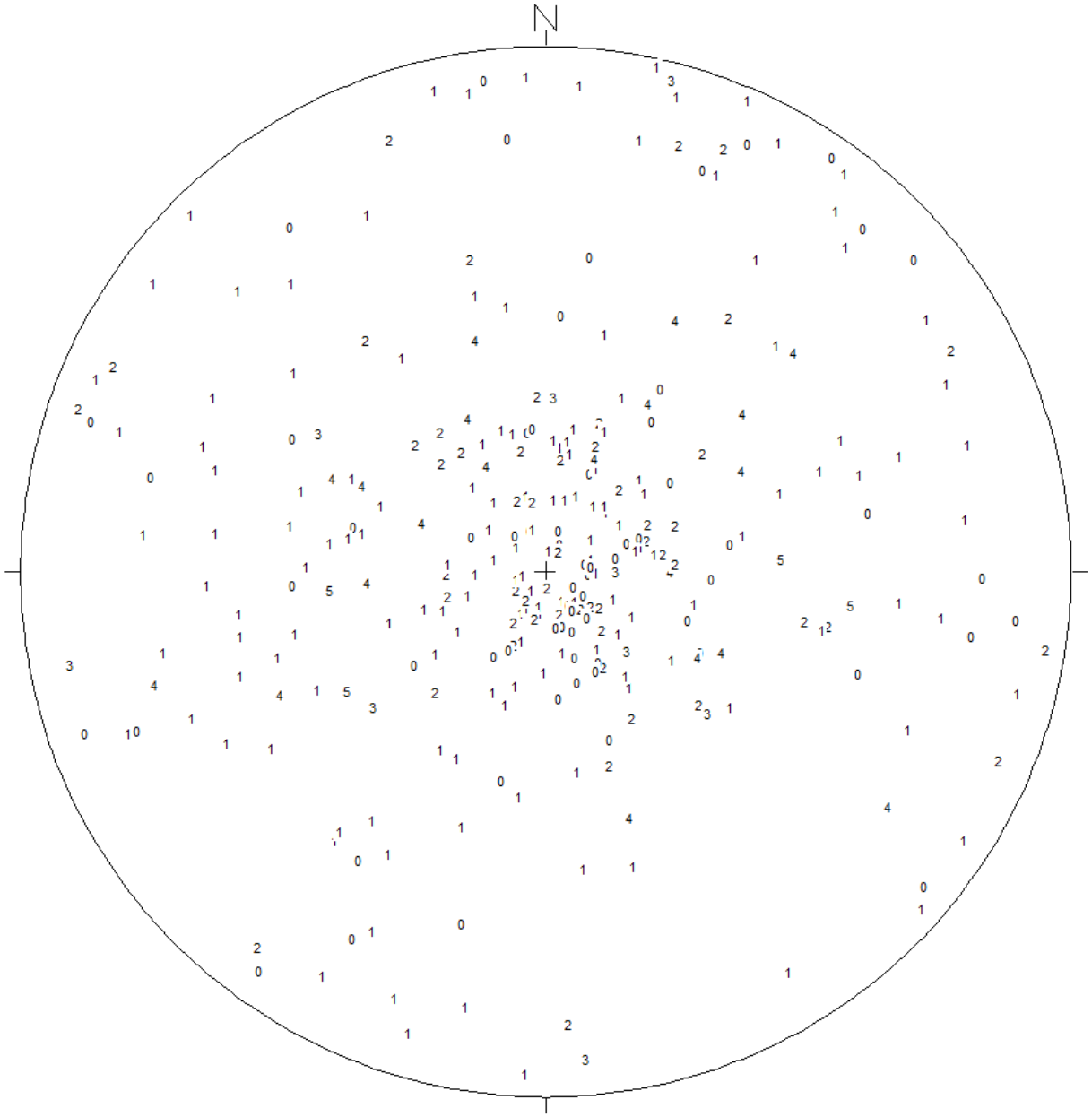

226
227
228
0
90
Tadpoles
2
inch
8
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
Projections
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-15
17 July 2019



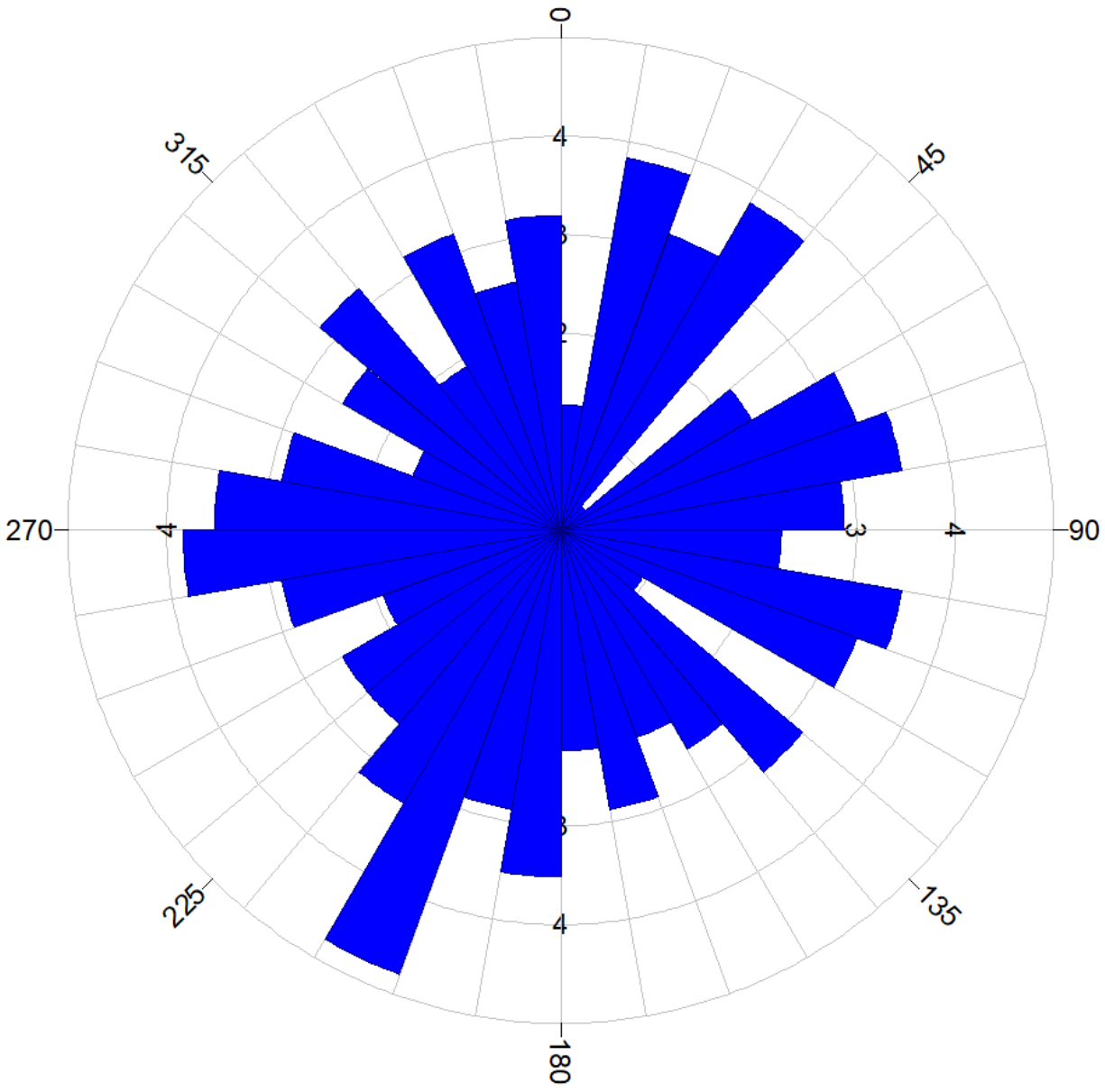
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-15
17 July 2019



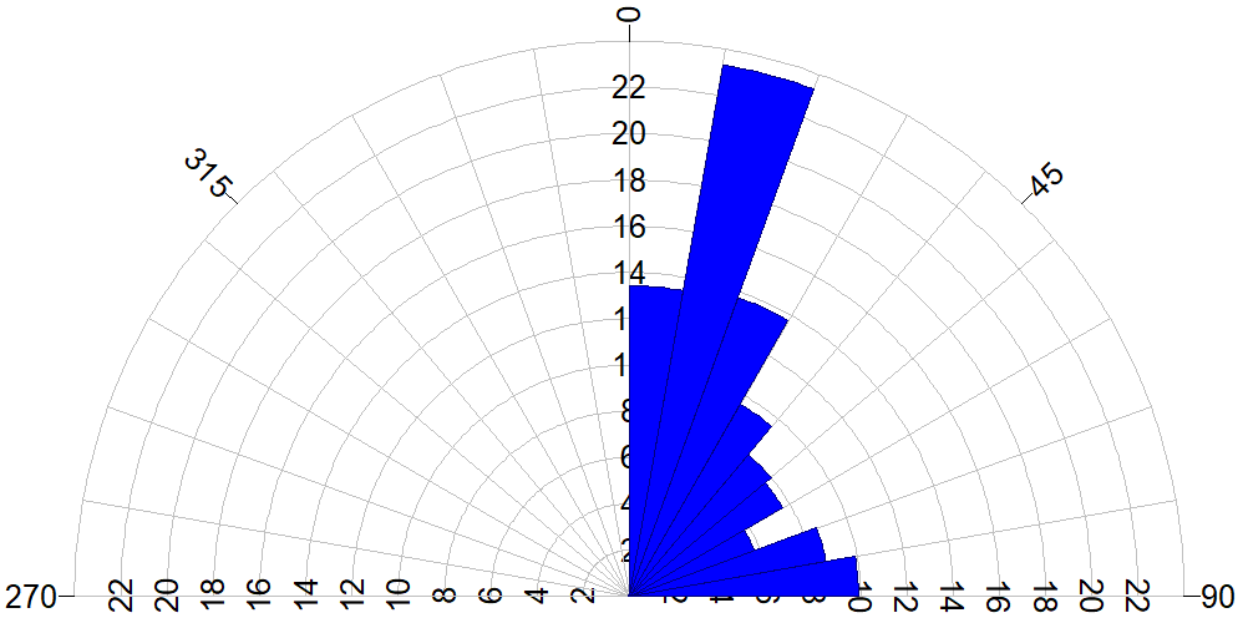
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-15
17 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-15
17 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	33.94	111.4	351	8	2
2	33.97	111.5	113	34	1
3	34.31	112.6	112	83	1
4	34.32	112.6	313	86	1
5	34.48	113.1	257	15	2
6	35.09	115.1	304	84	1
7	35.14	115.3	71	46	1
8	35.36	116.0	70	21	1
9	35.41	116.2	134	85	1
10	35.50	116.5	166	82	1
11	35.58	116.7	107	75	1
12	35.60	116.8	295	64	1
13	35.70	117.1	200	11	1
14	35.77	117.4	31	34	1
15	35.84	117.6	131	68	1
16	35.94	117.9	159	11	1
17	36.25	118.9	165	18	2
18	36.29	119.1	132	23	2
19	36.47	119.7	203	69	1
20	36.52	119.8	138	13	1
21	36.81	120.8	185	16	2
22	36.84	120.9	344	33	2
23	36.88	121.0	78	83	3
24	36.90	121.1	194	84	3
25	36.91	121.1	199	23	2
26	37.18	122.0	356	84	3
27	37.44	122.9	10	4	2
28	37.64	123.5	184	18	1
29	38.26	125.5	95	54	1
30	38.27	125.6	264	28	0
31	38.37	125.9	261	51	0
32	38.39	126.0	203	15	0
33	38.66	126.8	106	41	1
34	39.10	128.3	203	85	1
35	39.26	128.8	357	21	0
36	39.64	130.0	334	18	2
37	39.69	130.2	99	30	1
38	39.73	130.3	131	28	2
39	39.73	130.4	216	48	2
40	39.75	130.4	197	72	2
41	39.78	130.5	177	82	1
42	39.96	131.1	317	15	1
43	40.05	131.4	21	13	1
44	40.42	132.6	70	27	1
45	40.54	133.0	320	18	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	40.54	133.0	219	75	1
47	40.57	133.1	51	36	3
48	40.57	133.1	29	79	1
49	40.63	133.3	141.0	22.2	2
50	40.67	133.4	149.9	21.3	1
51	40.74	133.7	189.3	17.2	1
52	40.77	133.8	126.5	51.1	1
53	40.82	133.9	357.9	76.8	2
54	40.91	134.2	61.5	42.1	1
55	40.96	134.4	205.0	16.1	1
56	41.69	136.8	74.5	42.1	1
57	41.77	137.0	86.3	55.5	1
58	41.77	137.0	252.9	58.6	1
59	41.90	137.5	214.7	83.2	0
60	42.43	139.2	285.7	81.3	1
61	42.54	139.6	18.9	44.1	1
62	42.57	139.7	16.8	19.9	1
63	42.66	140.0	89.0	38.6	1
64	42.73	140.2	108.6	59.3	1
65	42.89	140.7	238.5	11.8	1
66	42.96	140.9	105.5	56.0	1
67	43.02	141.1	76.8	51.1	1
68	43.05	141.2	24.5	22.1	1
69	43.25	141.9	18.3	23.2	1
70	43.26	141.9	38.0	56.5	1
71	43.29	142.0	245.6	71.5	1
72	43.32	142.1	66.7	63.8	1
73	43.85	143.9	53.6	26.7	0
74	44.28	145.3	311.0	83.2	0
75	44.51	146.0	193.0	36.9	1
76	44.52	146.1	334.3	6.5	1
77	44.68	146.6	19.8	77.1	1
78	44.70	146.6	181.2	9.7	1
79	44.88	147.2	108.6	28.1	1
80	44.99	147.6	100.4	31.5	0
81	45.20	148.3	35.6	85.1	0
82	45.22	148.4	235.7	22.2	0
83	45.27	148.5	68.0	75.9	1
84	45.27	148.5	293.9	82.3	2
85	45.30	148.6	202.6	74.2	2
86	45.31	148.6	274.3	18.5	4
87	45.38	148.9	202.4	17.4	4
88	45.63	149.7	146.3	6.0	0
89	45.67	149.8	115.6	45.5	0
90	45.70	150.0	183.3	80.1	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	45.71	150.0	114.2	80.6	2
92	45.72	150.0	161.9	9.9	2
93	45.81	150.3	327.9	8.4	2
94	45.95	150.8	270.8	19.1	2
95	46.11	151.3	80.6	50.5	1
96	46.27	151.8	38.2	54.9	1
97	46.41	152.3	169.2	20.5	0
98	46.58	152.8	350.9	10.3	1
99	46.86	153.7	33.1	57.0	0
100	46.92	153.9	313.6	10.1	2
101	46.92	153.9	191.7	71.1	1
102	46.99	154.2	29.4	53.5	1
103	47.06	154.4	208.4	80.1	1
104	47.10	154.5	66.6	18.4	1
105	47.24	155.0	37.0	5.4	1
106	47.34	155.3	130.3	7.4	2
107	47.36	155.4	56.6	53.8	1
108	47.38	155.4	251.2	44.9	1
109	47.38	155.4	13.1	8.0	1
110	47.51	155.9	37.4	81.2	2
111	47.52	155.9	98.0	41.7	1
112	47.53	155.9	225.9	49.7	1
113	47.54	156.0	139.4	26.7	2
114	47.56	156.0	332.9	27.3	2
115	47.59	156.1	180.5	25.8	3
116	47.63	156.3	252.9	37.4	1
117	47.78	156.8	84.1	16.4	2
118	47.83	156.9	277.5	9.9	3
119	47.88	157.1	276.6	56.2	1
120	47.95	157.3	226.4	18.7	1
121	48.05	157.7	226.6	11.4	1
122	48.11	157.8	265.6	17.2	2
123	48.12	157.9	328.1	22.8	1
124	48.14	157.9	222.6	15.4	2
125	48.16	158.0	200.8	19.3	2
126	48.20	158.1	201.7	22.1	1
127	48.29	158.4	254.1	71.1	1
128	48.31	158.5	262	30	1
129	48.34	158.6	234	29	2
130	48.41	158.8	265	16	1
131	48.45	159.0	253	20	2
132	48.47	159.0	232	38	4
133	48.51	159.2	229	51	4
134	48.56	159.3	83	35	5
135	48.70	159.8	58	38	5

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	48.71	159.8	278	48	5
137	48.87	160.3	269	36	5
138	48.95	160.6	343	42	4
139	48.96	160.6	207	43	4
140	49.06	161.0	298	30	4
141	49.09	161.1	111	37	4
142	49.16	161.3	283	41	2
143	49.19	161.4	175	26	2
144	49.29	161.7	54	18	1
145	49.29	161.7	189	21	1
146	49.43	162.2	318	9	2
147	49.44	162.2	95	35	1
148	49.80	163.4	102	67	0
149	49.89	163.7	17	7	1
150	50.25	164.9	203	3	0
151	50.31	165.1	345	6	1
152	50.36	165.2	13	35	0
153	50.81	166.7	287	6	0
154	51.33	168.4	172	82	0
155	51.43	168.7	52	7	2
156	51.54	169.1	136	13	1
157	51.57	169.2	203	28	1
158	51.61	169.3	212	32	0
159	51.76	169.8	174	70	0
160	52.12	171.0	94	9	1
161	52.22	171.3	290	52	0
162	52.23	171.4	280	70	0
163	52.29	171.6	301	27	0
164	52.32	171.6	348	19	0
165	52.98	173.8	26	67	1
166	52.99	173.8	32	9	1
167	53.01	173.9	212	2	2
168	53.04	174.0	330	79	1
169	53.05	174.1	28	70	0
170	53.14	174.4	85	41	0
171	53.25	174.7	149	11	1
172	53.26	174.8	264	68	1
173	53.33	175.0	125	82	1
174	53.76	176.4	52	23	1
175	53.79	176.5	42	27	2
176	53.80	176.5	283	45	2
177	53.89	176.8	306	68	4
178	53.90	176.9	211	29	4
179	53.94	177.0	64	48	4
180	54.00	177.2	73	68	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	54.00	177.2	161	37	4
182	54.14	177.6	159	75	2
183	54.16	177.7	146	18	4
184	54.18	177.7	94	67	1
185	54.18	177.8	242	75	2
186	54.21	177.9	150	26	4
187	54.50	178.8	309	36	1
188	54.57	179.0	181	19	1
189	54.57	179.1	26	34	1
190	54.61	179.2	97	32	1
191	55.03	180.6	247	50	1
192	55.18	181.0	353	33	1
193	55.26	181.3	309	24	1
194	55.46	182.0	107	81	0
195	55.54	182.2	277	78	0
196	55.61	182.4	66	6	1
197	55.85	183.3	114	6	1
198	56.03	183.8	332	15	1
199	56.12	184.1	205	77	0
200	56.24	184.5	11	75	1
201	56.28	184.7	195	81	1
202	56.38	185.0	237	74	1
203	56.43	185.2	354	49	1
204	56.47	185.3	248	16	2
205	56.48	185.3	116	61	1
206	56.49	185.4	72	17	2
207	56.51	185.4	70	84	0
208	57.29	188.0	29	8	1
209	57.32	188.1	239	7	1
210	57.47	188.6	217	82	1
211	57.60	189.0	300	11	1
212	57.64	189.1	260	14	1
213	57.93	190.1	327	10	0
214	57.99	190.3	335	17	0
215	58.13	190.7	342	29	0
216	58.16	190.8	32	17	0
217	58.24	191.1	223	71	1
218	58.37	191.5	191	5	0
219	58.39	191.6	182	39	0
220	58.47	191.8	17	9	2
221	58.93	193.3	127	7	0
222	59.00	193.6	151	6	1
223	59.09	193.9	66	5	1
224	59.10	193.9	159	22	1
225	59.45	195.0	192	10	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	59.55	195.4	118	11	1
227	59.60	195.5	89	16	1
228	59.74	196.0	17	83	1
229	59.76	196.1	69	14	1
230	59.79	196.2	319	5	1
231	59.97	196.8	68	74	0
232	60.12	197.3	230	79	0
233	60.19	197.5	201	69	0
234	60.26	197.7	151	11	2
235	60.38	198.1	107	21	4
236	60.39	198.1	303	27	4
237	60.42	198.2	84	29	4
238	60.54	198.6	163	21	1
239	60.64	198.9	280	85	2
240	60.71	199.2	244	33	4
241	60.71	199.2	112	32	4
242	60.80	199.5	140	46	2
243	60.90	199.8	269	5	2
244	61.37	201.4	108	84	2
245	61.59	202.1	272	71	0
246	61.69	202.4	264	6	1
247	61.69	202.4	142	70	0
248	61.70	202.4	192	86	1
249	61.89	203.1	170	80	1
250	61.94	203.2	273	5	0
251	62.02	203.5	317	5	0
252	62.11	203.8	316	7	0
253	62.15	203.9	338	7	0
254	62.17	204.0	343	11	0
255	62.23	204.2	351	10	0
256	62.36	204.6	338	18	0
257	62.51	205.1	283	7	1
258	62.69	205.7	286	23	1
259	62.75	205.9	330	7	1
260	62.79	206.0	276	25	0
261	62.82	206.1	293	23	0
262	62.94	206.5	254	14	0
263	63.08	207.0	3	87	1
264	63.11	207.1	164	2	1
265	63.25	207.5	108	13	0
266	63.37	207.9	337	8	0
267	63.40	208.0	223	12	1
268	63.49	208.3	152	64	1
269	63.49	208.3	278	64	1
270	63.76	209.2	34	7	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-15

17 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	63.87	209.6	70	53	1
272	63.97	209.9	345	50	1
273	64.03	210.1	164	44	1
274	64.08	210.2	165	50	2
275	64.15	210.5	170	41	1
276	64.21	210.7	284	44	1
277	64.25	210.8	82	12	1
278	64.29	210.9	327	21	1
279	64.31	211.0	304	15	1
280	65.68	215.5	276	6	0
281	65.74	215.7	255	12	0
282	65.95	216.4	137	62	1
283	65.95	216.4	144	40	1
284	66.08	216.8	215	27	0
285	66.09	216.8	223	76	0
286	66.31	217.5	266	10	0
287	66.45	218.0	240	12	1
288	66.49	218.1	262	13	1
289	66.57	218.4	323	13	2
290	66.63	218.6	216	11	1
291	66.85	219.3	187	19	1
292	66.97	219.7	314	32	2
293	67.00	219.8	25	14	2
294	67.19	220.5	172	21	0
295	67.34	220.9	346	15	0
296	67.50	221.5	26	15	0
297	67.67	222.0	4	17	0
298	67.72	222.2	356	10	0
299	67.75	222.3	353	14	1
300	67.80	222.4	32	11	2
301	67.89	222.7	4	17	1
302	67.90	222.8	61	60	1
303	68.02	223.2	35	50	1
304	68.09	223.4	8	37	1
305	68.27	224.0	314	34	3
306	68.27	224.0	119	42	3
307	68.53	224.8	187	49	0
308	68.60	225.1	14	60	0
309	68.64	225.2	233	18	1
310	68.64	225.2	134	17	1
311	68.73	225.5	214	59	1
312	69.09	226.7	77	65	1
313	69.13	226.8	254	51	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-15
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-15
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83538 N
Longitude: 84.75837 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.6'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	25-26 June 2019	26 June 2019	26 June 2019	
RUN NUMBER	Multiple	1	1	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	228'	228'	228'	
DEPTH-LOGGER	228'	229'	228.2'	
BTM LOG INTERVAL	227.9'	228.7'	228.15'	
TOP LOG INTERVAL	19.7'	4.1'	19.5'	
RECORDED BY	JBG/CKL	JBG/CKL	JBG/CKL	
WITNESSED BY				
PROBE TYPE, S/N	2PFA #5959	3ACS #6011	ELXG #4248	
LOGGING SPEED	20 fpm	10 fpm	15 fpm	
A.S.D.E. / Sample Interval	0.25'/0.1	0.11' / 0.10'	0.05' / 0.25'	
Fluid Level / Fluid Type	18'/water	18'/water	18'/water	

BOREHOLE RECORD

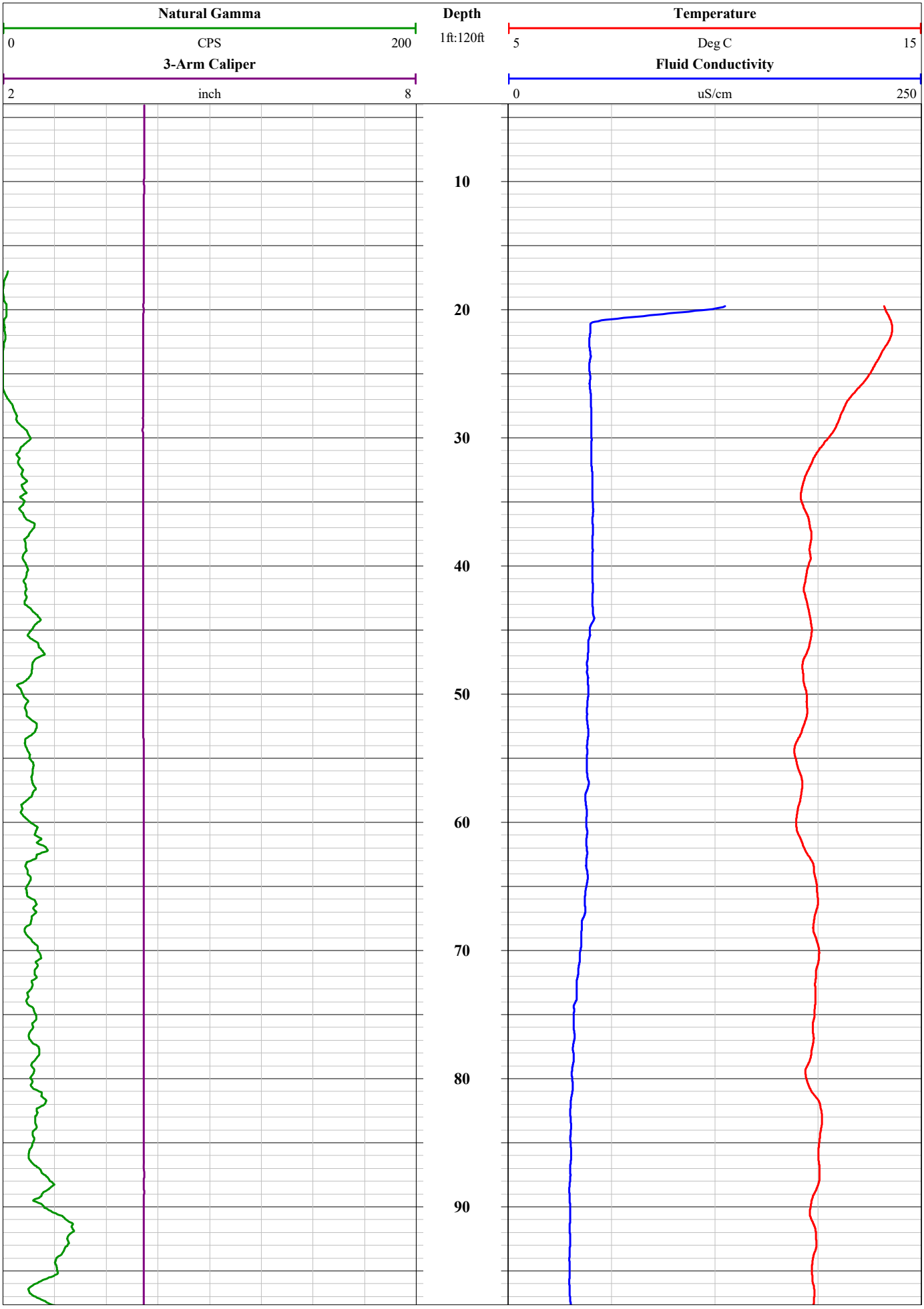
RUN No.	BIT	FROM	TO
1	HQ	0'	228'

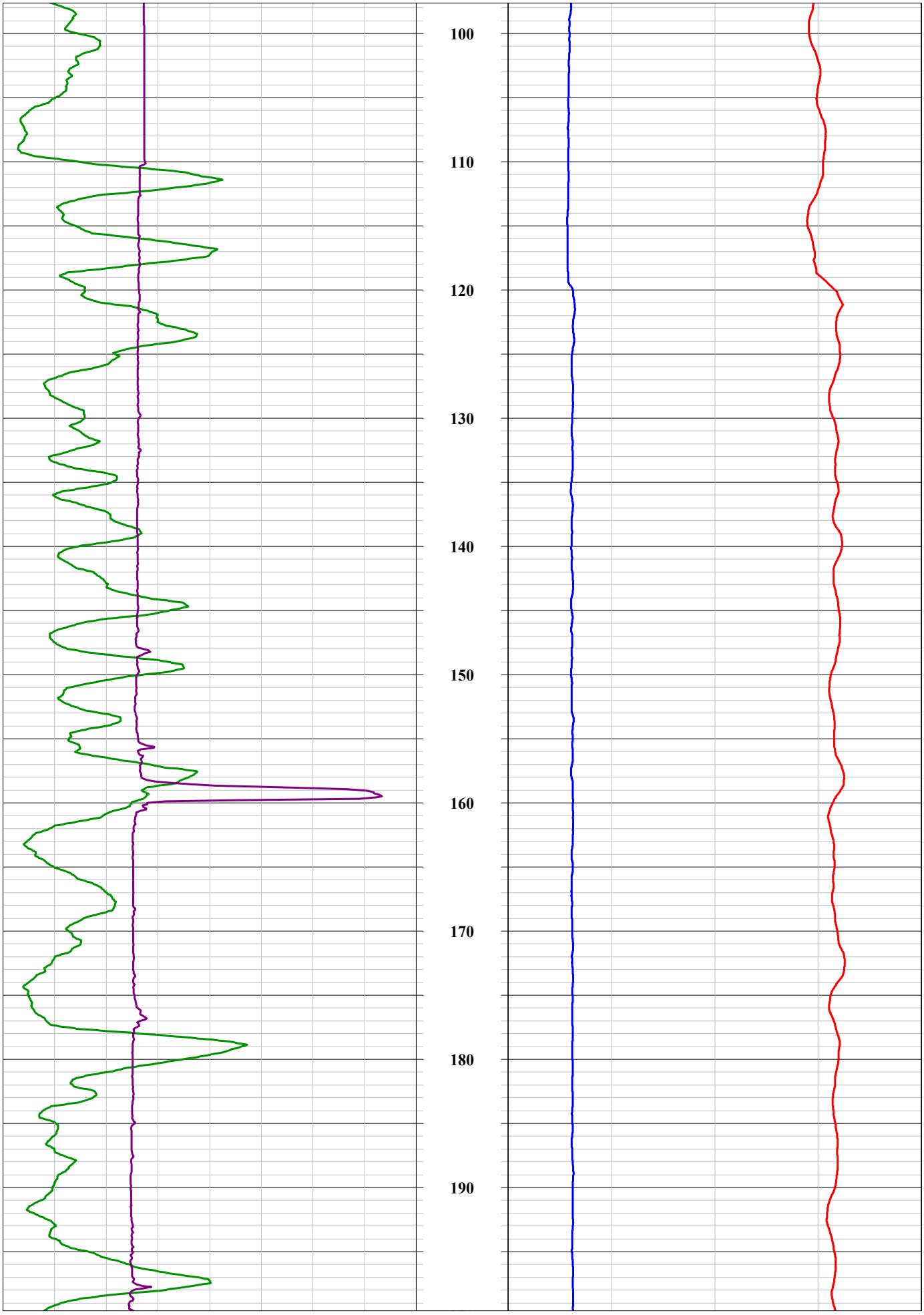
CASING RECORD

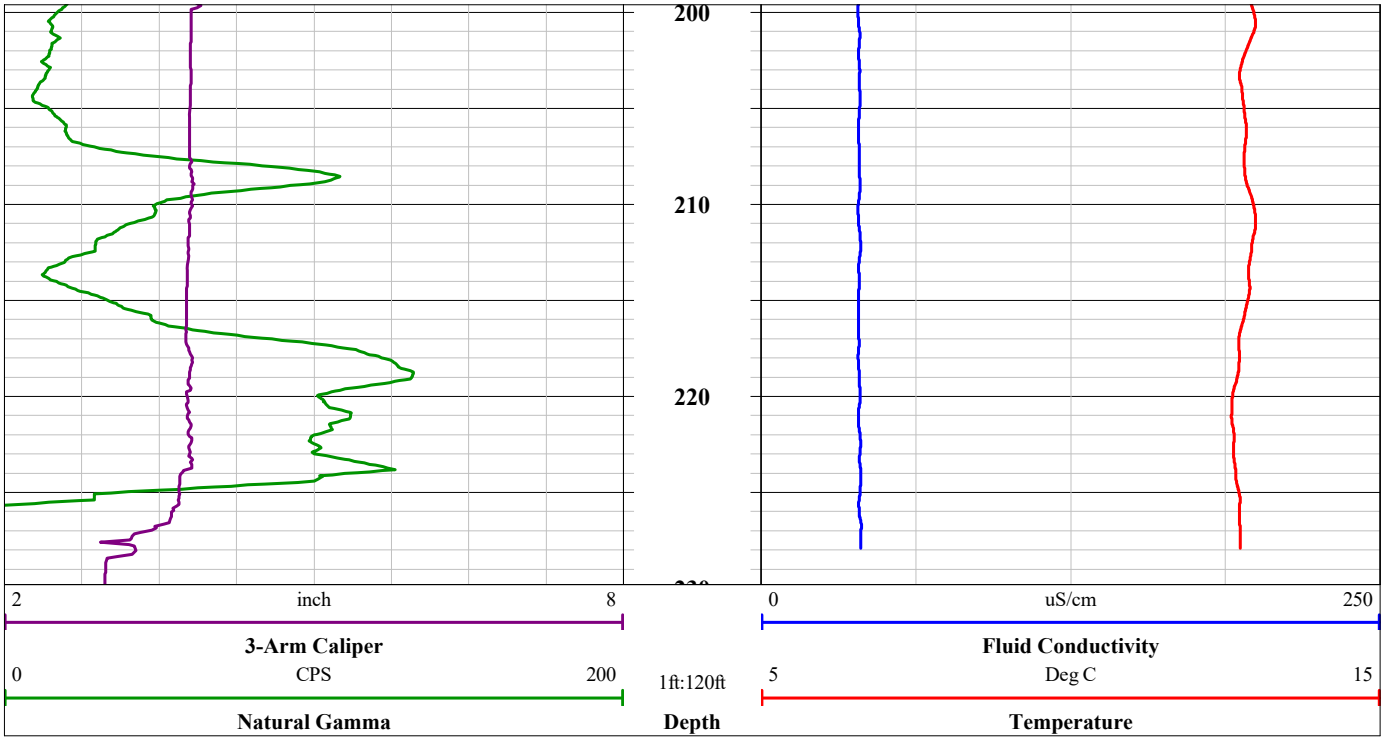
SIZE	WGT.	FROM	TO
PQ	Steel	0'	110'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
200
3-Arm Caliper
2
inch
8
Depth
1ft:120ft
Temperature
5
Deg C
15
Fluid Conductivity
0
uS/cm
250
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
2
inch
8
3-Arm Caliper
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
uS/cm
250
Fluid Conductivity
5
Deg C
15
Temperature

Borehole Deviation

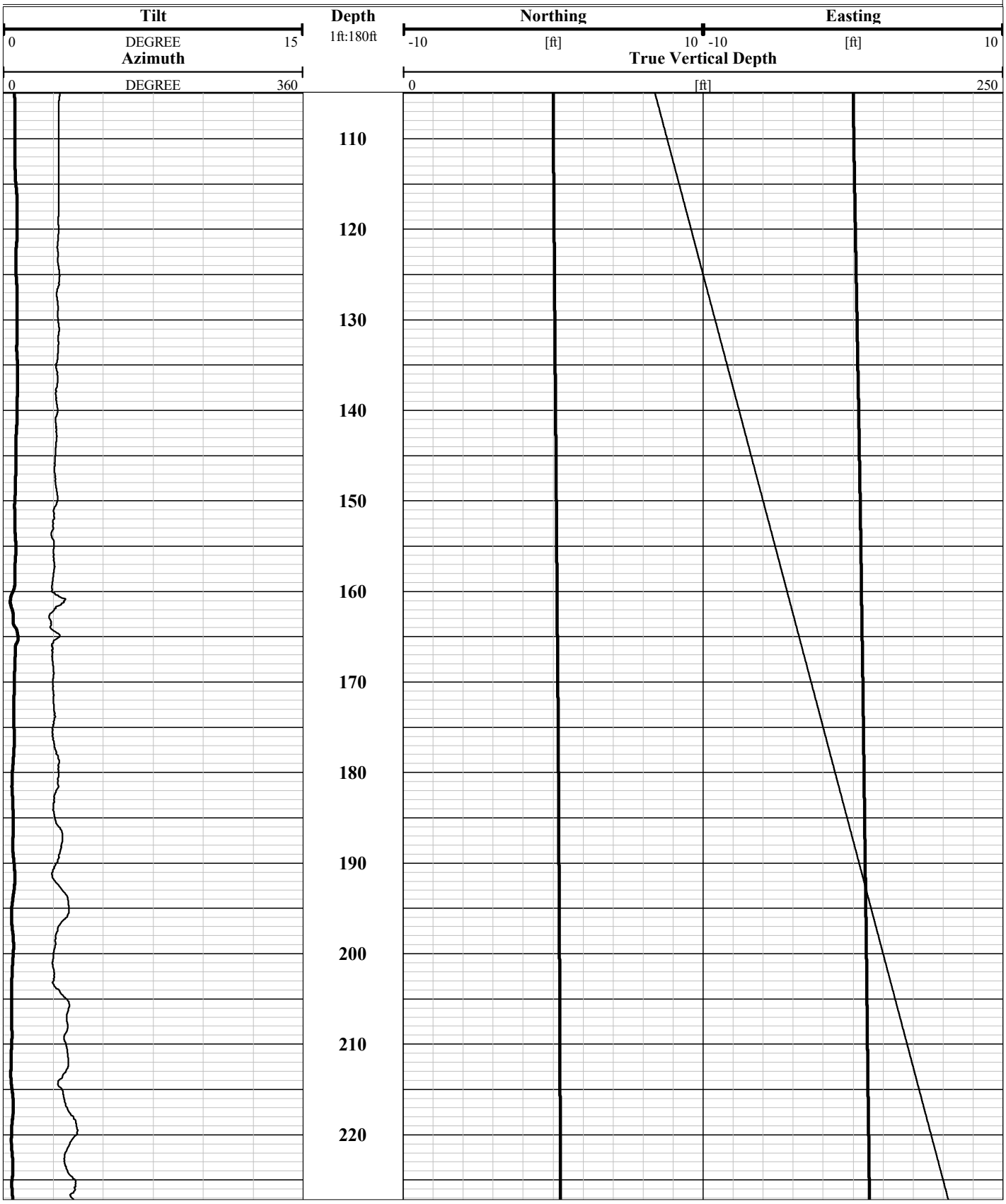
COLOG
borehole geophysics / hydrophysics

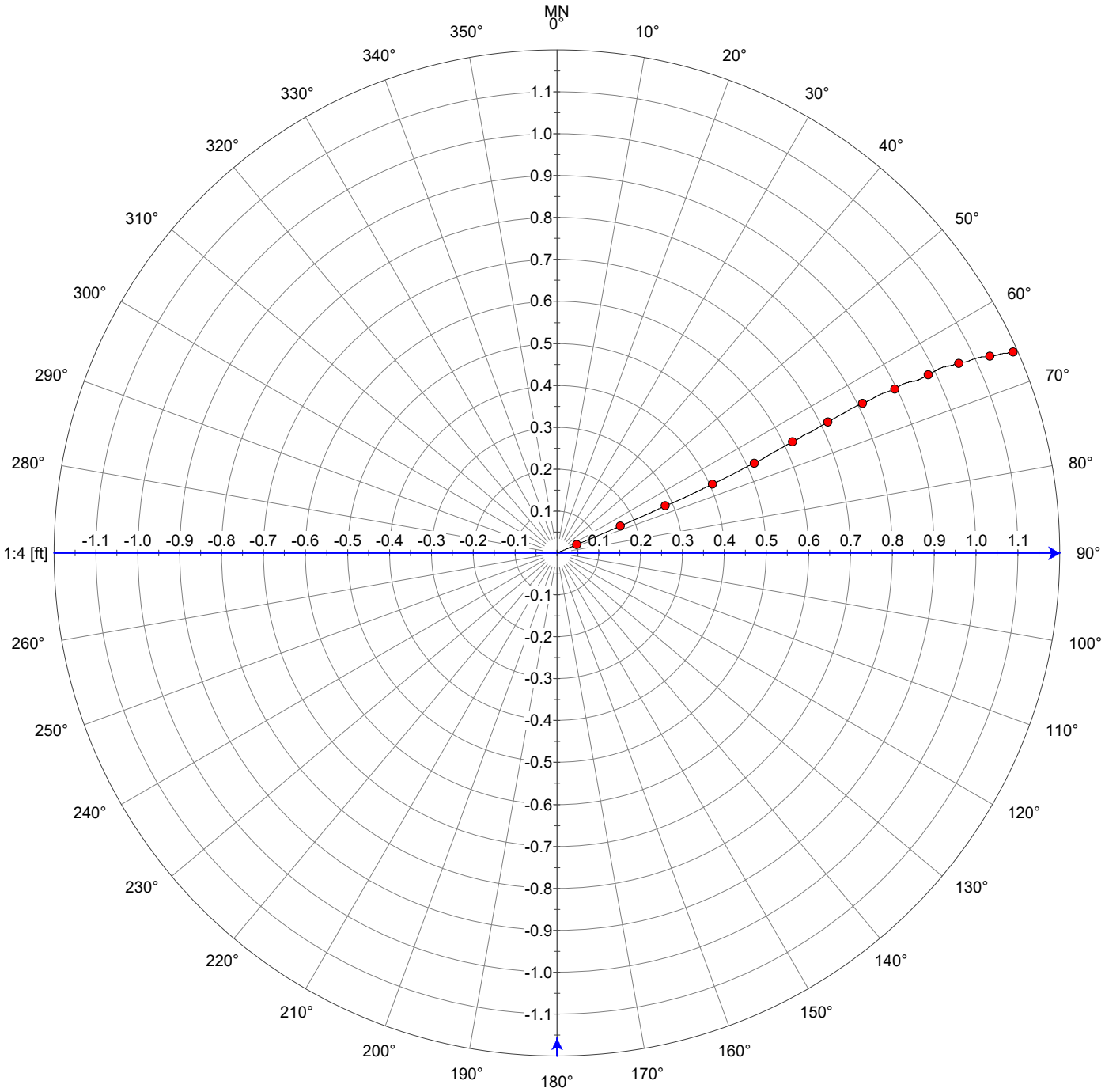
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 17 July 2019	WELL: BH19-15

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 598.6'** **Latitude: 45.83538 N** **Longitude: 84.75837 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
1:4 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-15
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-15
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83538 N
Longitude: 84.75837 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.6'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	26 June 2019	26 June 2019		
RUN NUMBER	1	1		
LOG TYPE	Natural Gamma	Eletcric Log		
DEPTH-DRILLER	228'	228'		
DEPTH-LOGGER	228.2'	228.2'		
BTM LOG INTERVAL	228.15'	228.15'		
TOP LOG INTERVAL	19.5'	19.5		
RECORDED BY	CKL/JBG	CKL/JBG		
WITNESSED BY				
PROBE TYPE, S/N	ELXG #4248	ELXG #4248		
LOGGING SPEED	15 fpm	15 fpm		
A.S.D.E. / Sample Interval	0.05' / 0.25'	0.05' / 0.25'		
Fluid Level / Fluid Type	18'/water	18'/water		

BOREHOLE RECORD

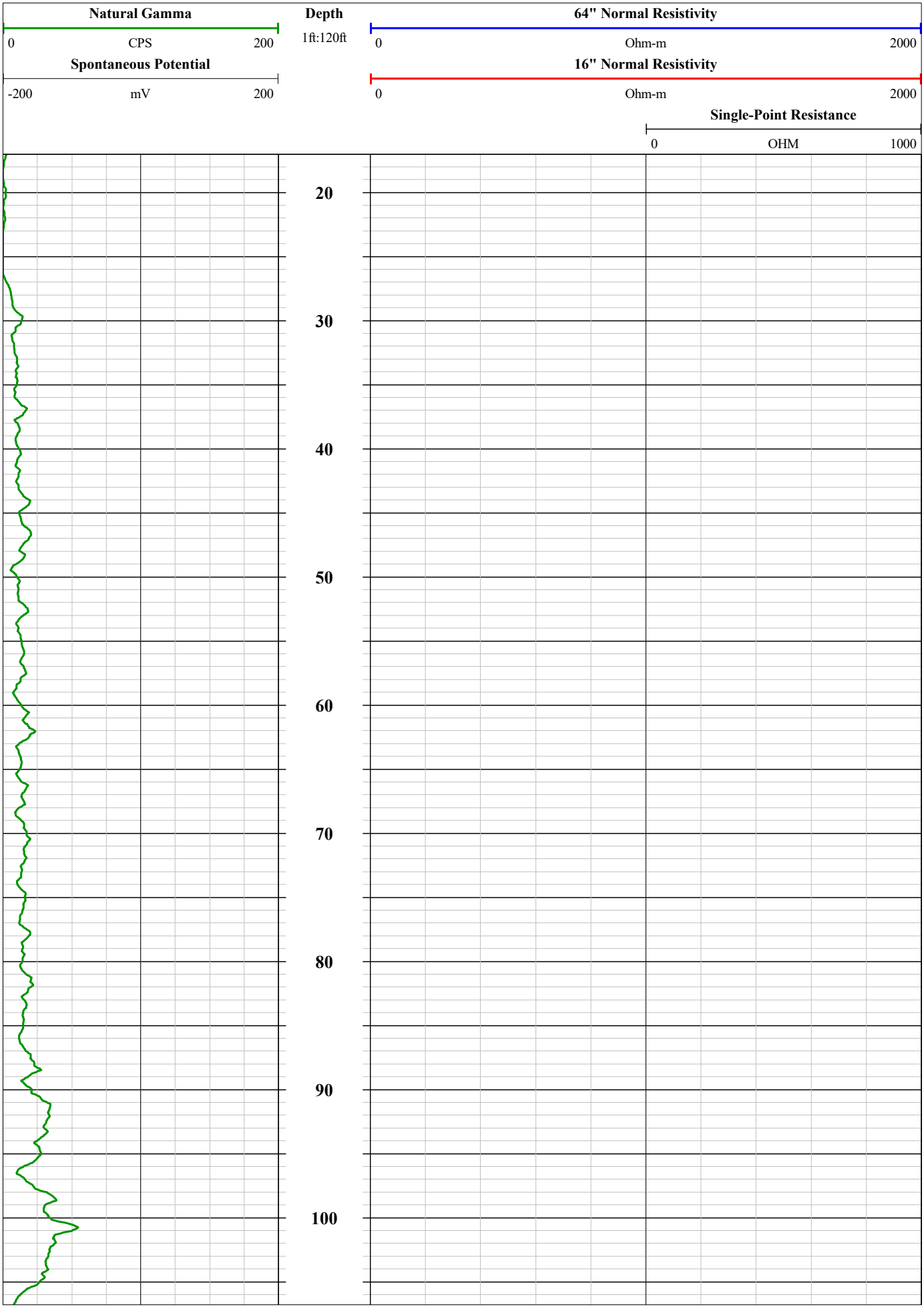
RUN No.	BIT	FROM	TO
1	HQ	0'	228'

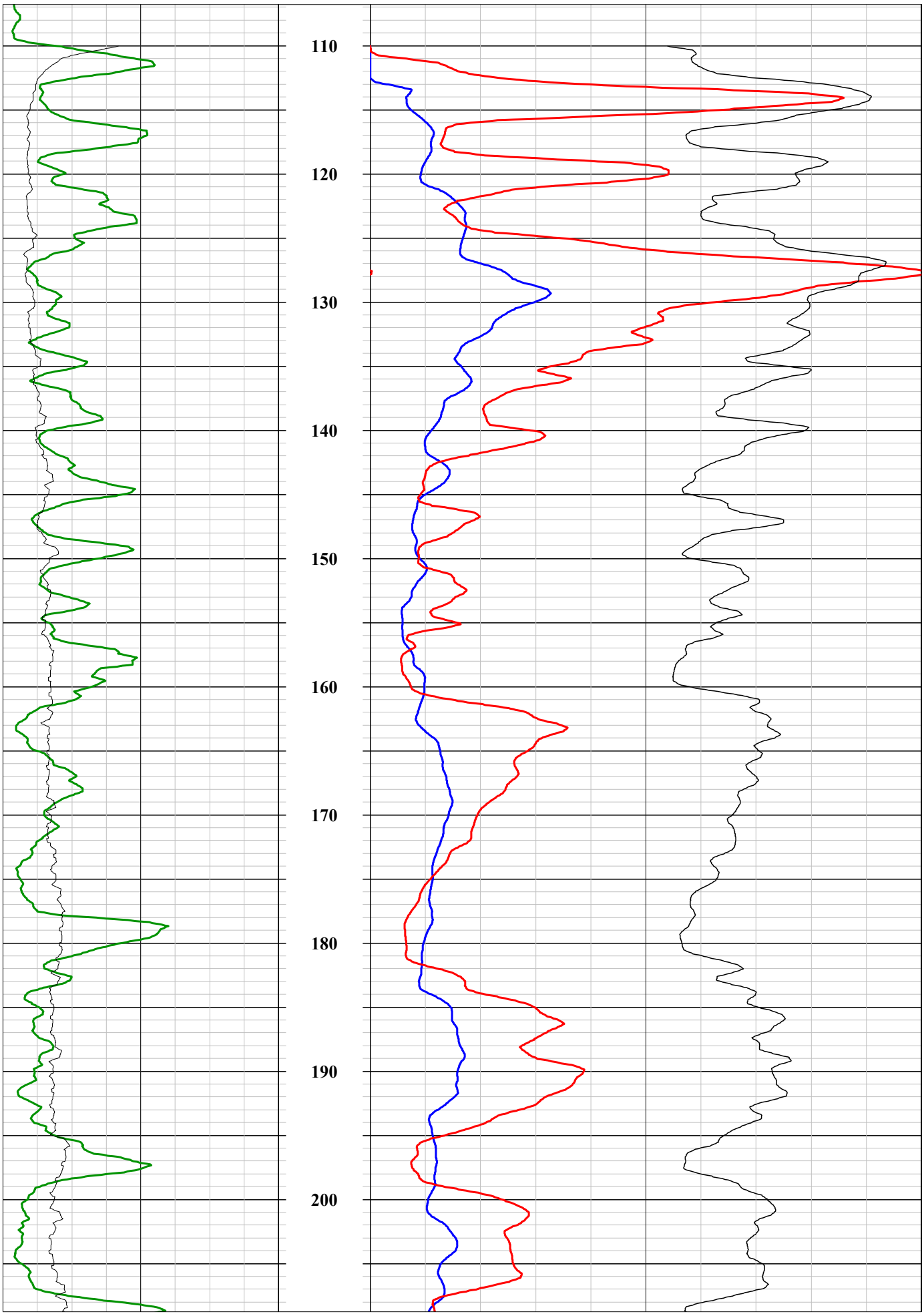
CASING RECORD

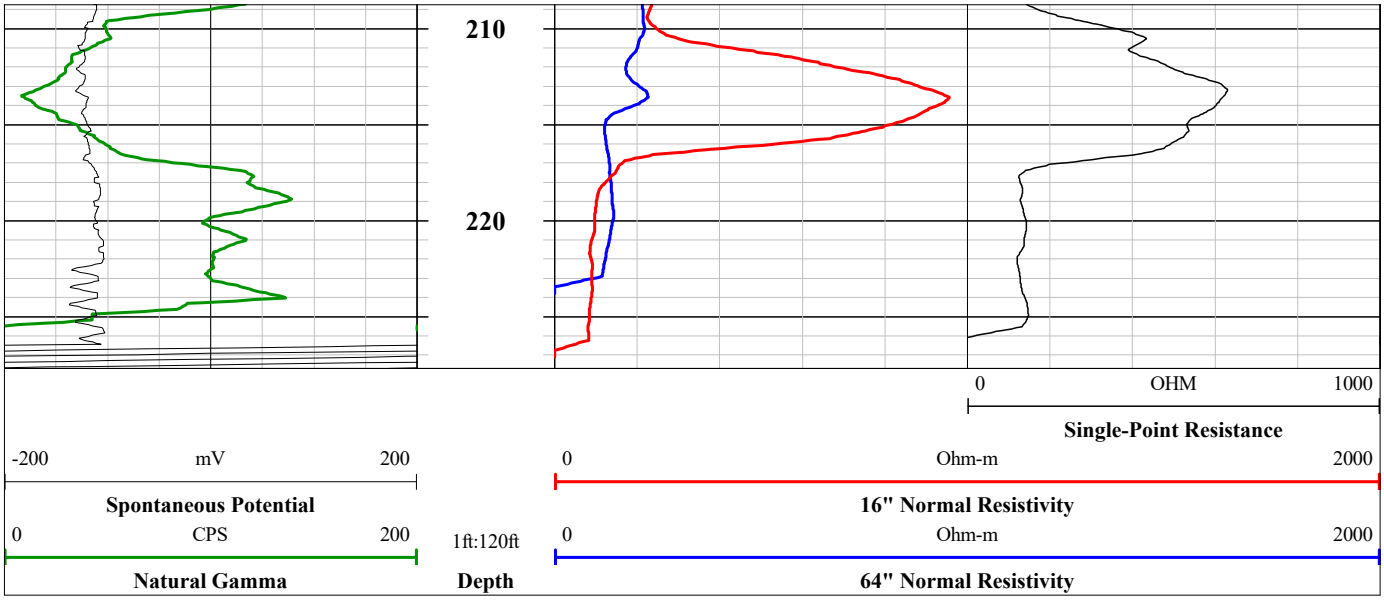
SIZE	WGT.	FROM	TO
PQ	Steel	0'	110'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
200
Spontaneous Potential
-200
mV
200
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
2000
16" Normal Resistivity
0
Ohm-m
2000
Single-Point Resistance
0
OHM
1000
20
30
40
50
60
70
80
90
100


110
120
130
140
150
160
170
180
190
200


210
220
0
OHM
1000
Single-Point Resistance
-200
mV
200
Spontaneous Potential
0
Ohm-m
2000
16" Normal Resistivity
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
2000
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-15
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-15
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83538 N
Longitude: 84.75837 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.6'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	17 July 2019			
RUN NUMBER	1			
LOG TYPE	P&S Log			
DEPTH-DRILLER	228'			
DEPTH-LOGGER	218'			
BTM LOG INTERVAL	218'			
TOP LOG INTERVAL	104'			
RECORDED BY	CKL			
WITNESSED BY				
PROBE TYPE, S/N	PSLogger #10926			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/ 2.0'			
Fluid Level / Fluid Type	18'/water			

BOREHOLE RECORD

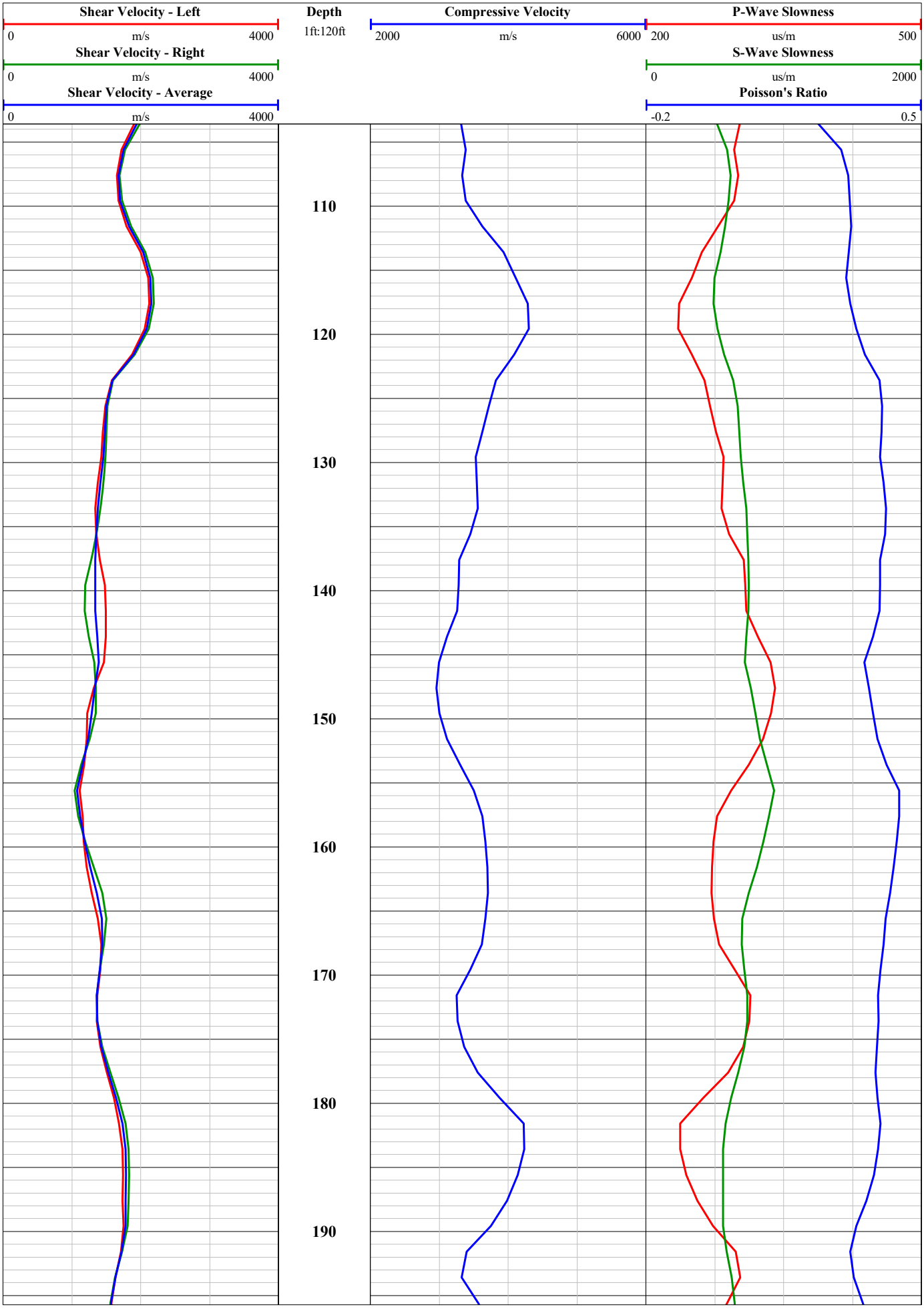
RUN No.	BIT	FROM	TO
1	HQ	0'	228'

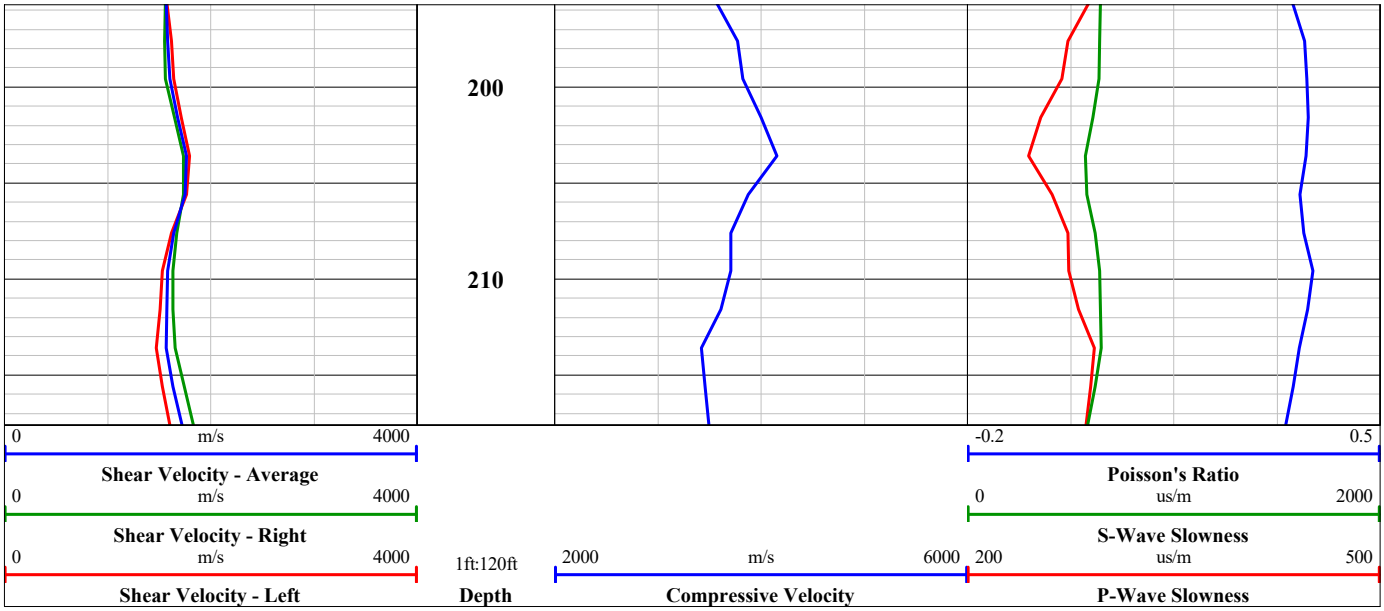
CASING RECORD

SIZE	WGT.	FROM	TO
PQ	Steel	0'	110'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Average
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
2000
m/s
6000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-0.2
0.5
110
120
130
140
150
160
170
180
190


200
210
0
m/s
4000
Shear Velocity - Average
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
2000
m/s
6000
Compressive Velocity
-0.2
0.5
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness

PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-15**	Test depth:	**149.00 ft**
Test date: (mm/dd/yyyy)	**6/22/2019**	C :	1.0581 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	$\Delta R/R_{0\ Probe}$ %
0	0.00	240	0.00	0.00
-7	8.96	214	8.97	0.23
1327	210.46	820	209.05	5.29
2267	231.21	1672	228.81	5.78
3482	245.67	2826	241.99	6.10
5158	259.75	4451	254.30	6.40
6748	270.33	6008	263.19	6.62
9350	283.69	8569	273.80	6.88
11997	294.94	11183	282.25	7.08
15499	308.06	14646	291.66	7.31
18246	317.62	17365	298.31	7.47
21682	329.42	20767	306.47	7.67
25887	344.14	24930	316.75	7.92

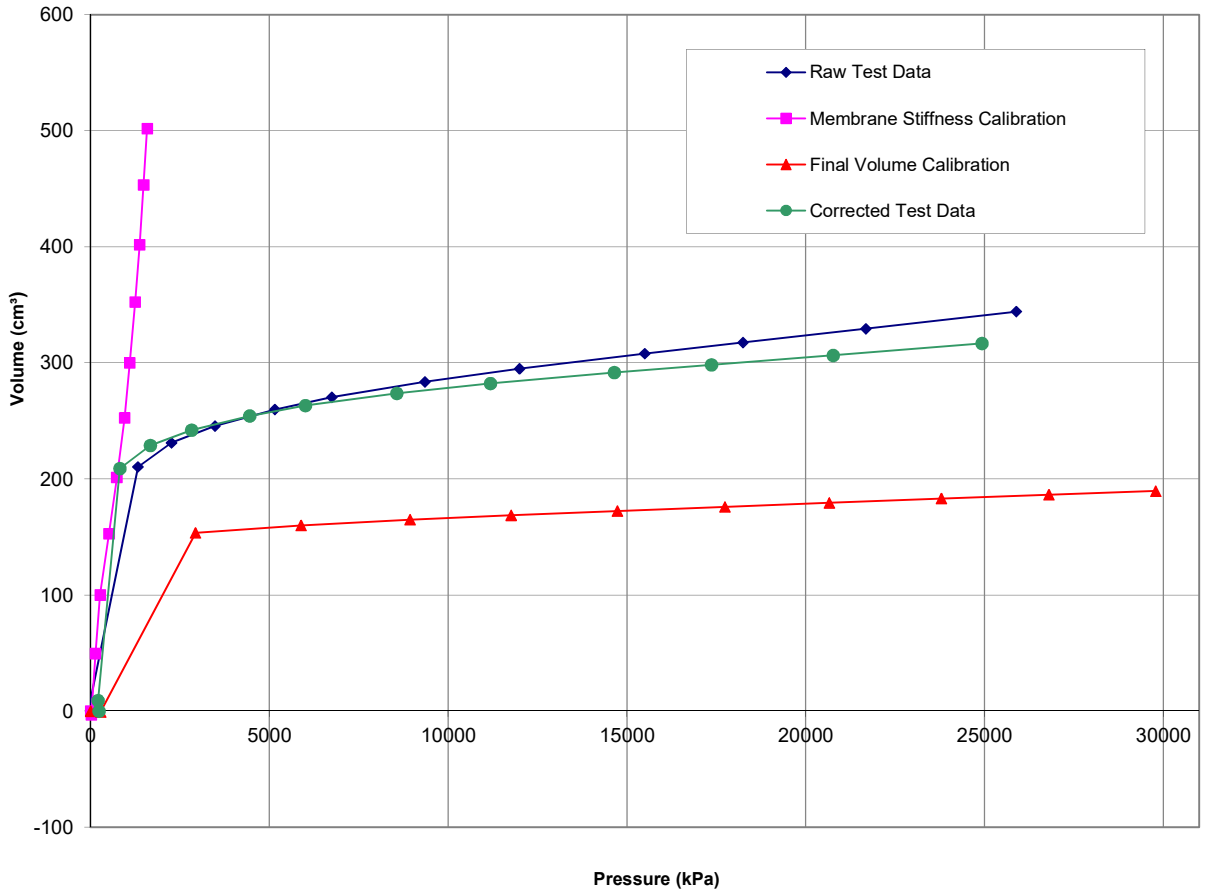
Test Results

PROBEX Modulus E:	**1,903,636 kPa**
Ultimate Pressure P_L:	**123,693**
Ratio E / P_L:	**15.39**

Volume & Pressure Calibrations ID

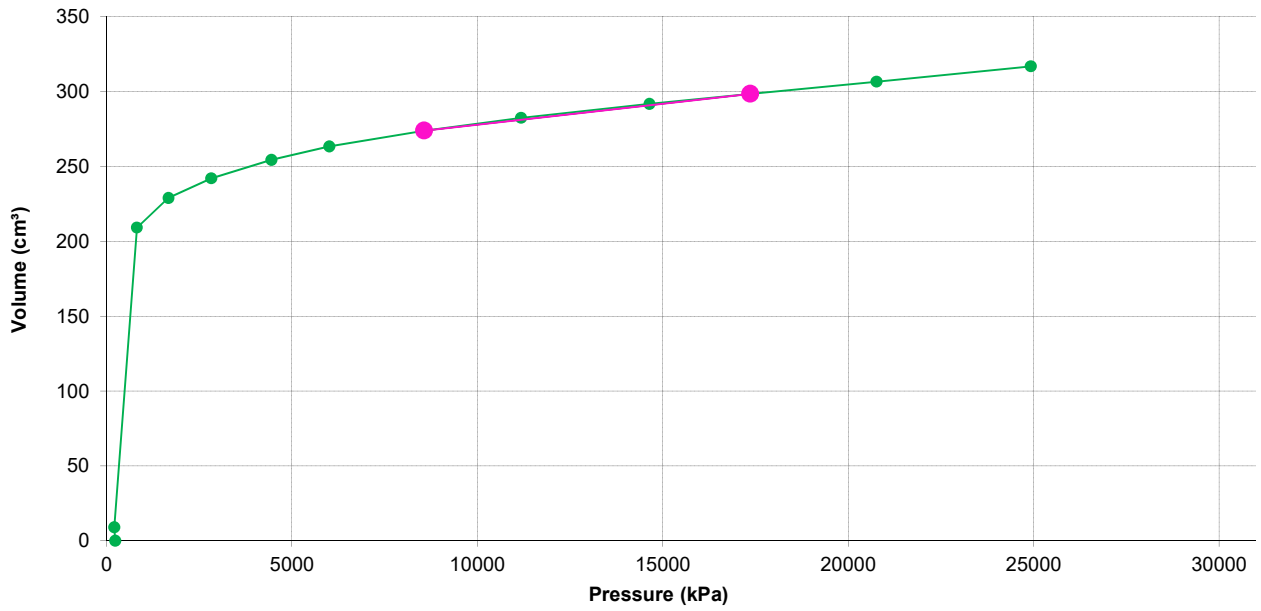
CalV3	CalP1

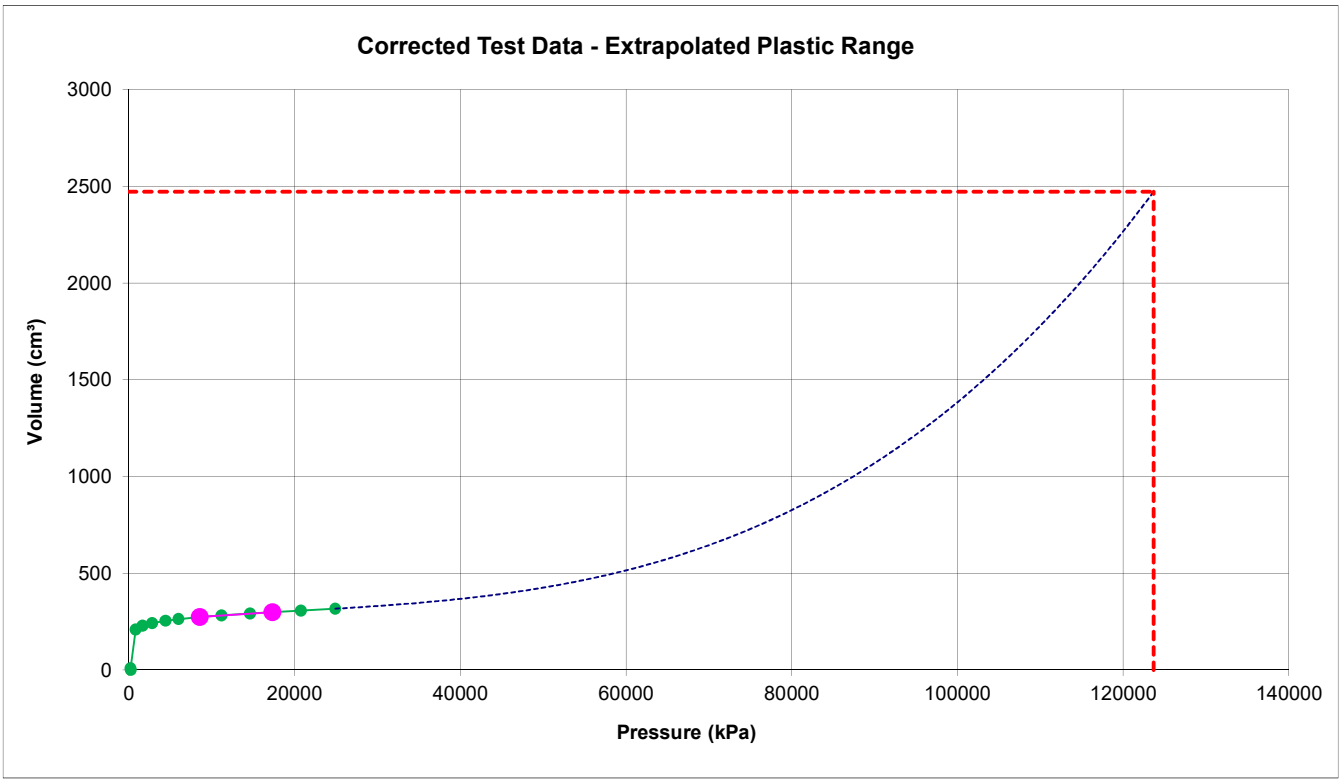
Test Data with Calibration Curves



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-15**	Test depth:	**149.00 ft**
Test date: (mm/dd/yyyy)	**6/22/2019**	C :	1.0581 cc/MPa
Test number:	1	Poisson's coefficient	0.20





PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-15**	Test depth:	**206.00 ft**
Test date: (mm/dd/yyyy)	**6/22/2019**	C :	0.9531 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	$\Delta R/R_{0\ Probe}$ %
0	0.00	350	0.00	0.00
20	-3.88	372	-3.90	-0.10
3101	181.58	2896	178.62	4.58
5933	189.71	5692	184.05	4.72
8942	196.63	8671	188.10	4.82
11899	202.48	11603	191.14	4.90
15020	208.30	14703	193.98	4.97
18049	213.39	17714	196.18	5.02
20821	218.07	20469	198.23	5.07
24139	223.39	23768	200.38	5.13
26781	227.45	26395	201.92	5.17
30296	232.80	29890	203.92	5.22

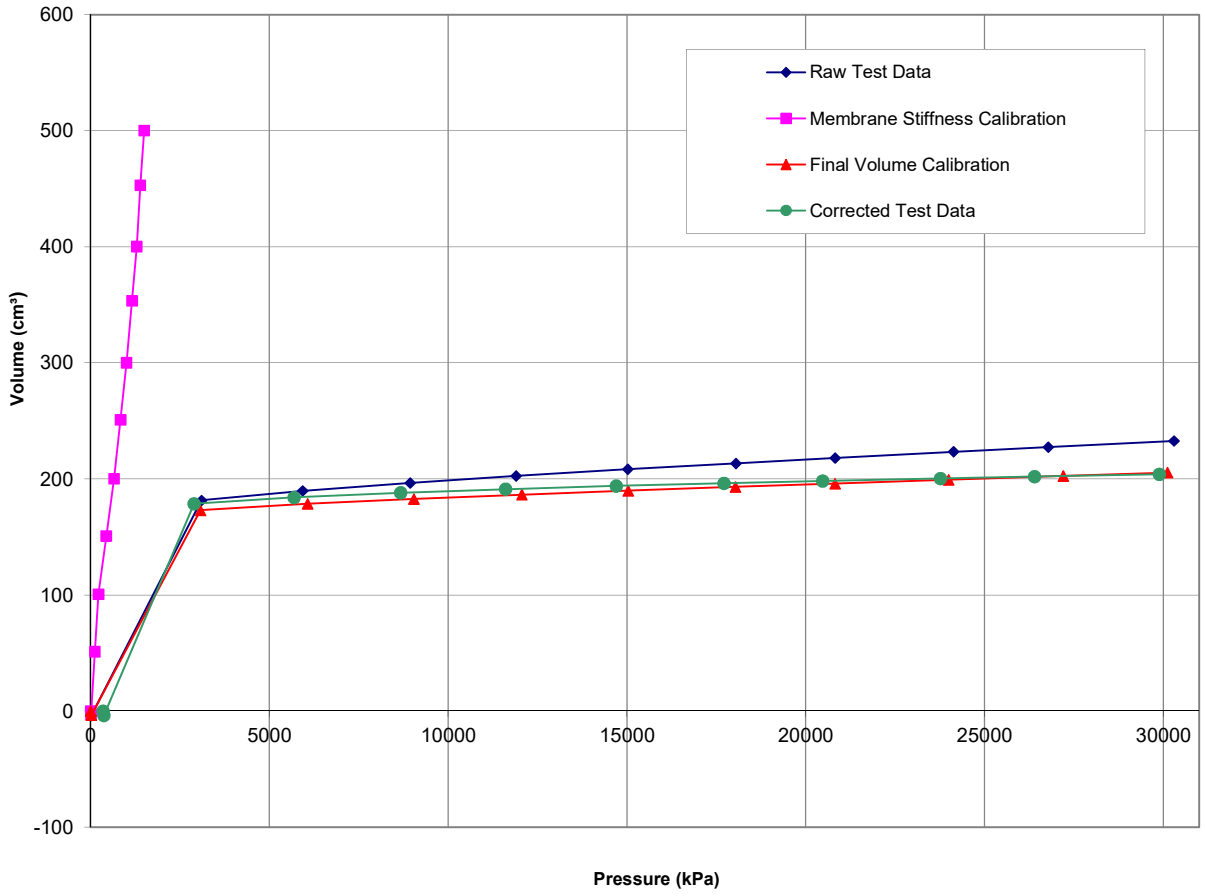
Test Results

PROBEX Modulus E:	**6,639,920 kPa**
Ultimate Pressure P_L:	**158,925**
Ratio E / P_L:	**41.78**

Volume & Pressure Calibrations ID

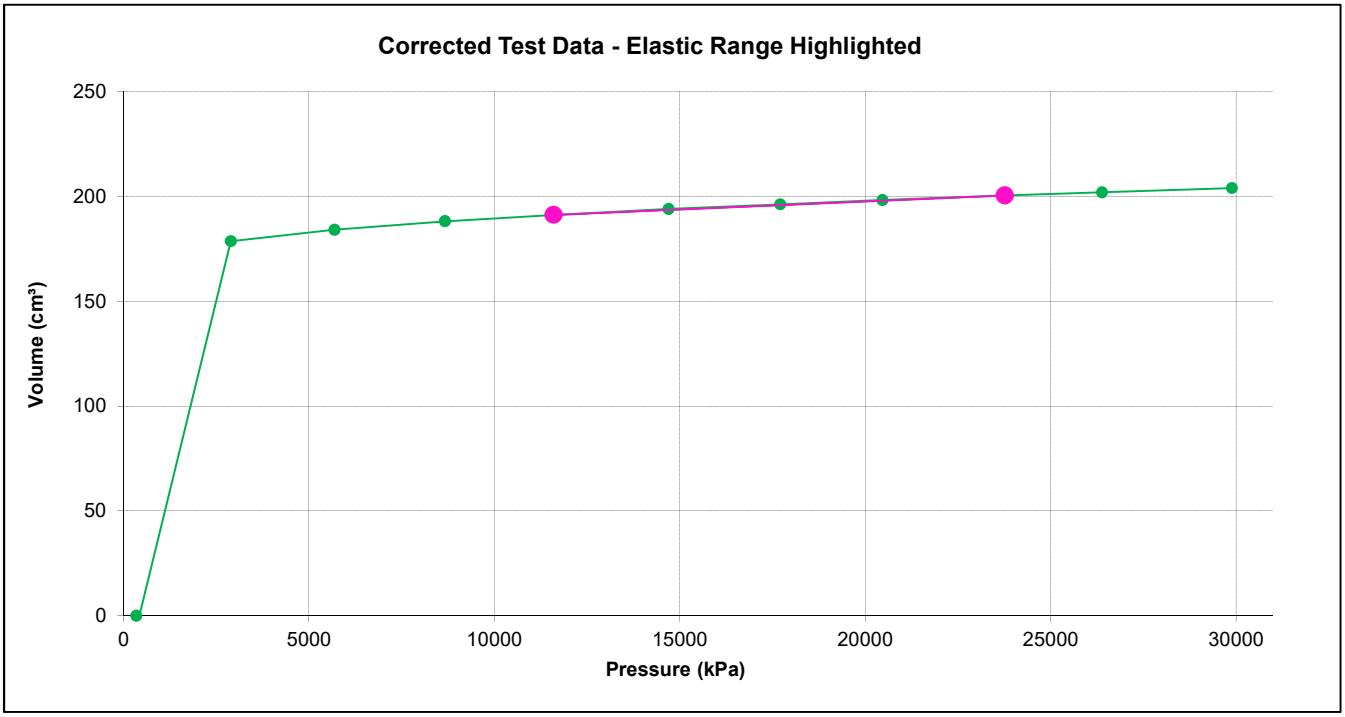
CalV3	CalP1

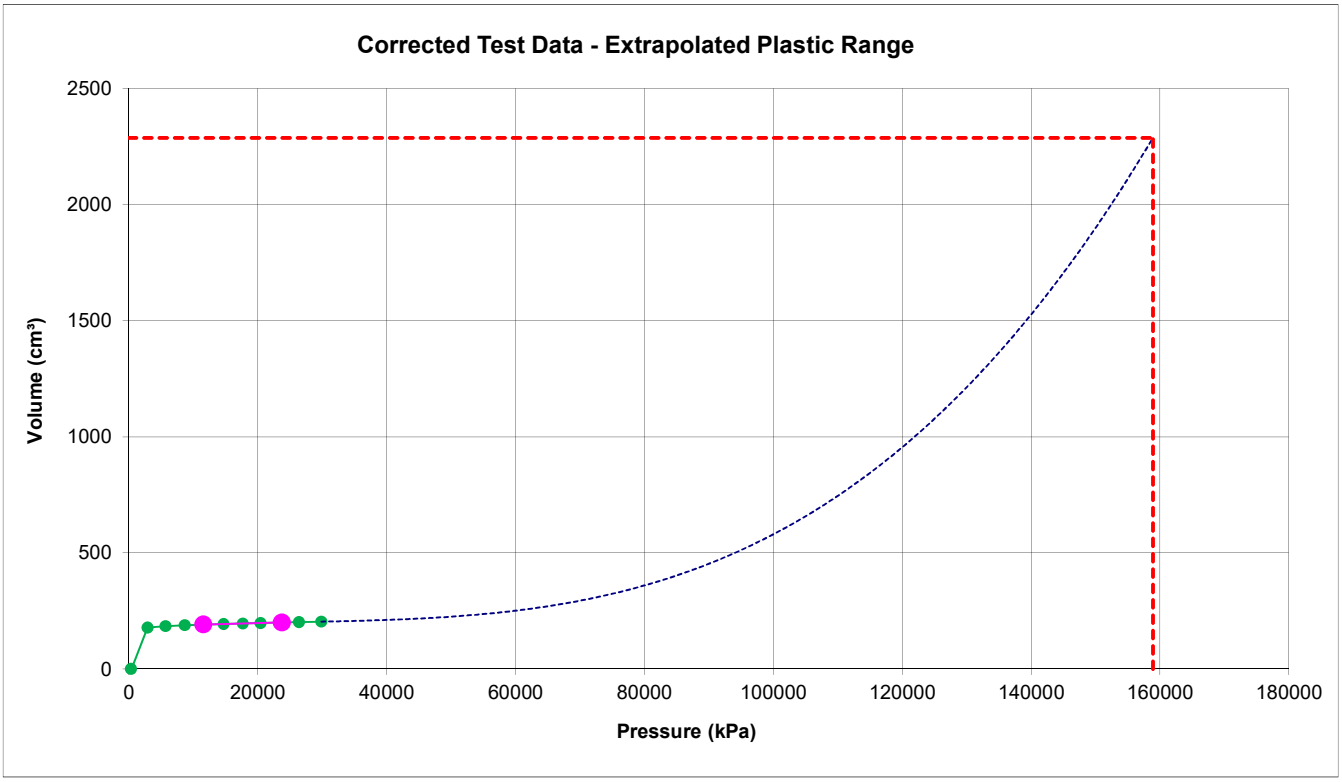
Test Data with Calibration Curves



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-15**	Test depth:	**206.00 ft**
Test date: (mm/dd/yyyy)	**6/22/2019**	C :	0.9531 cc/MPa
Test number:	1	Poisson's coefficient	0.20





ROCTEST TELEMAC

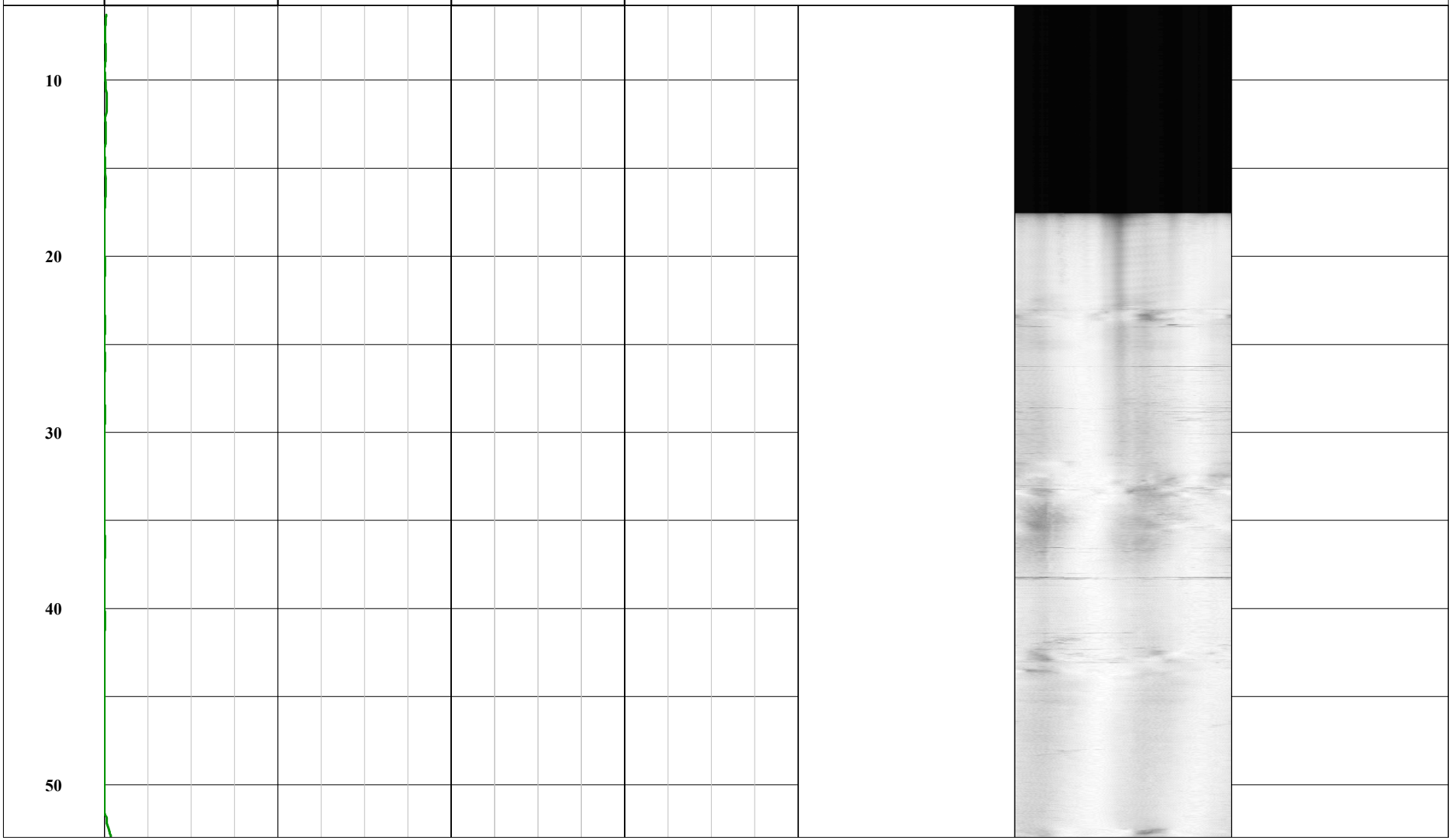
Geophysical Summary Plot

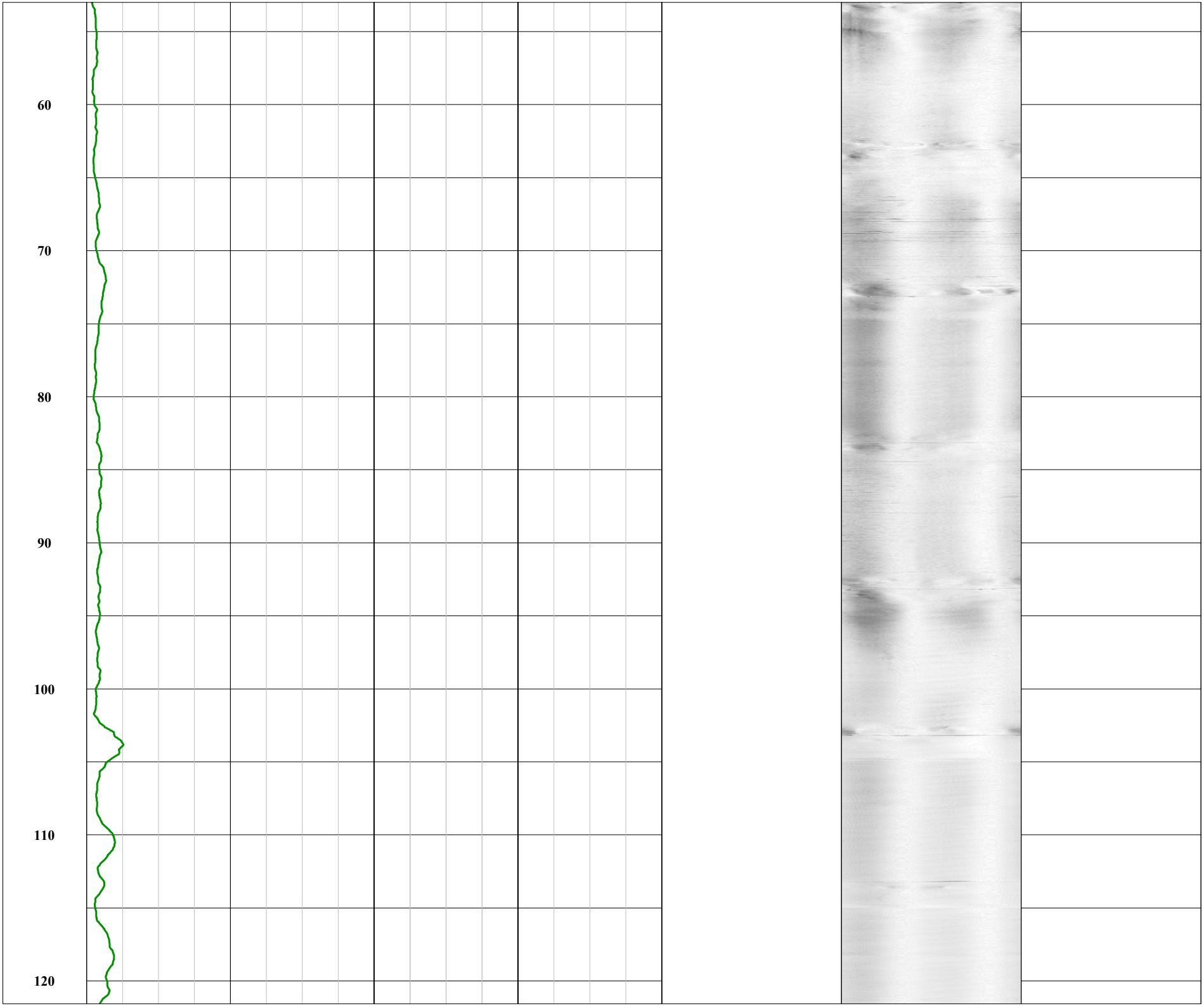
COLOG
borehole geophysics / hydrophysics

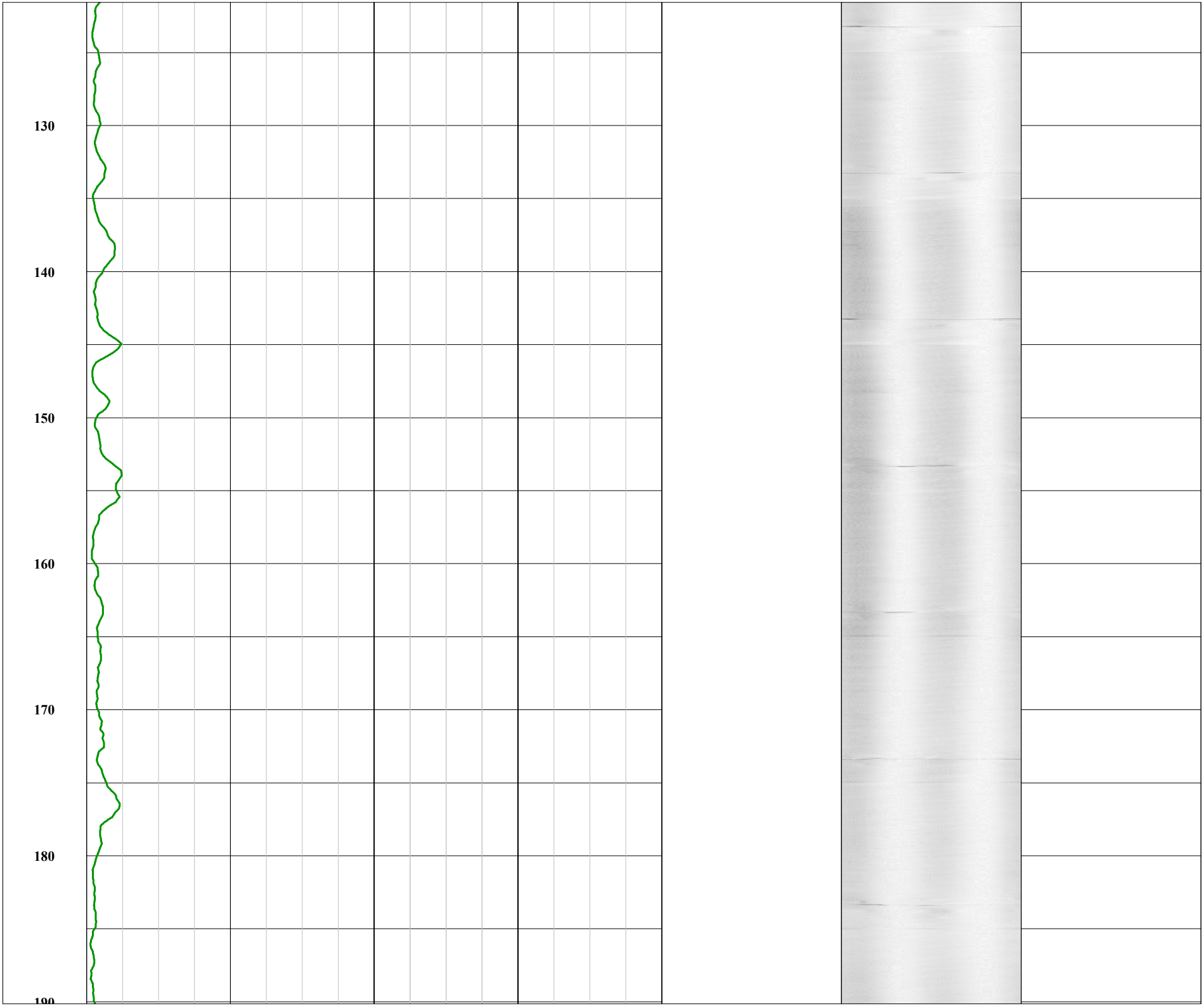
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 1, 17 July 2019
WELL: BH19-16 - North Side

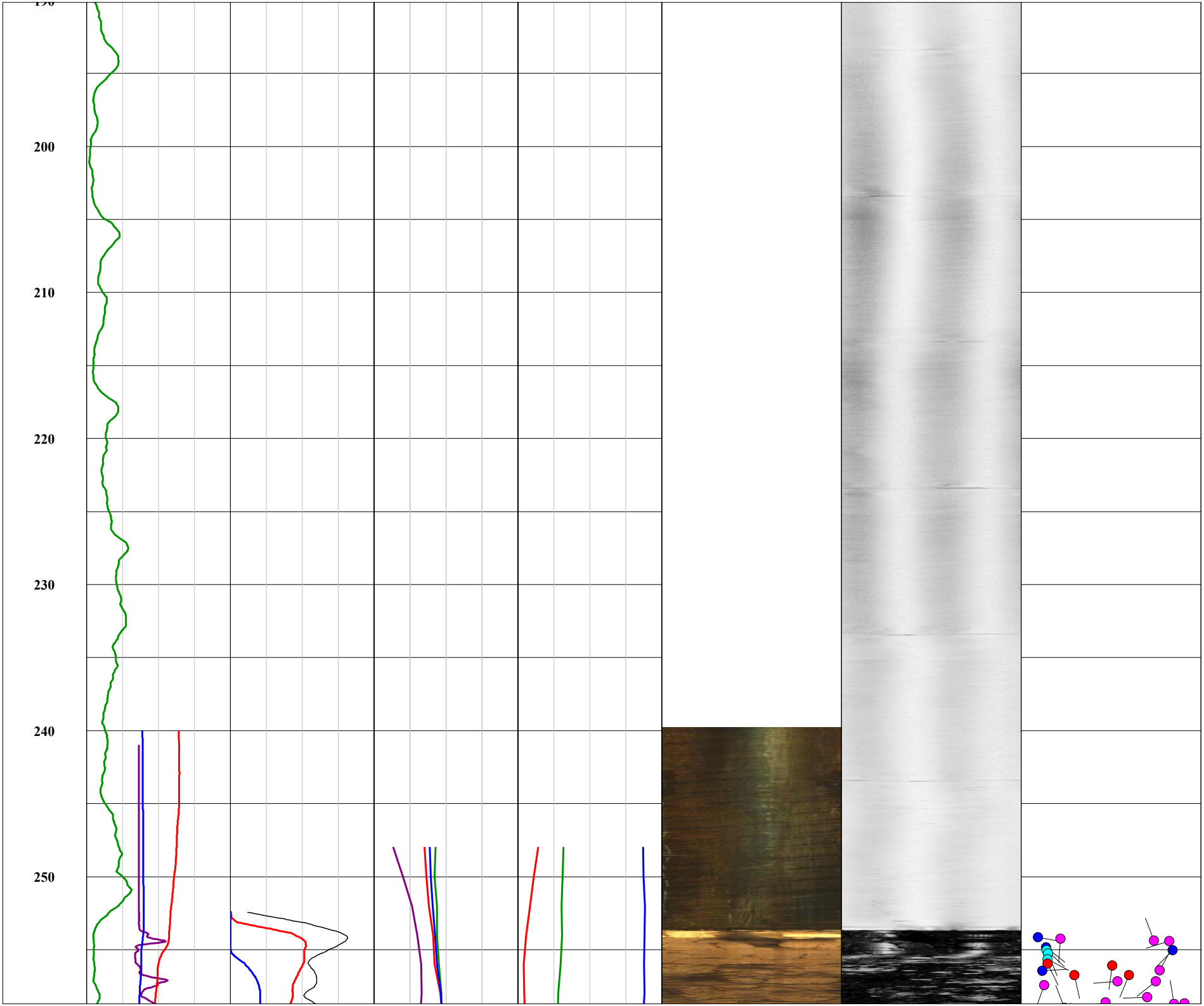
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

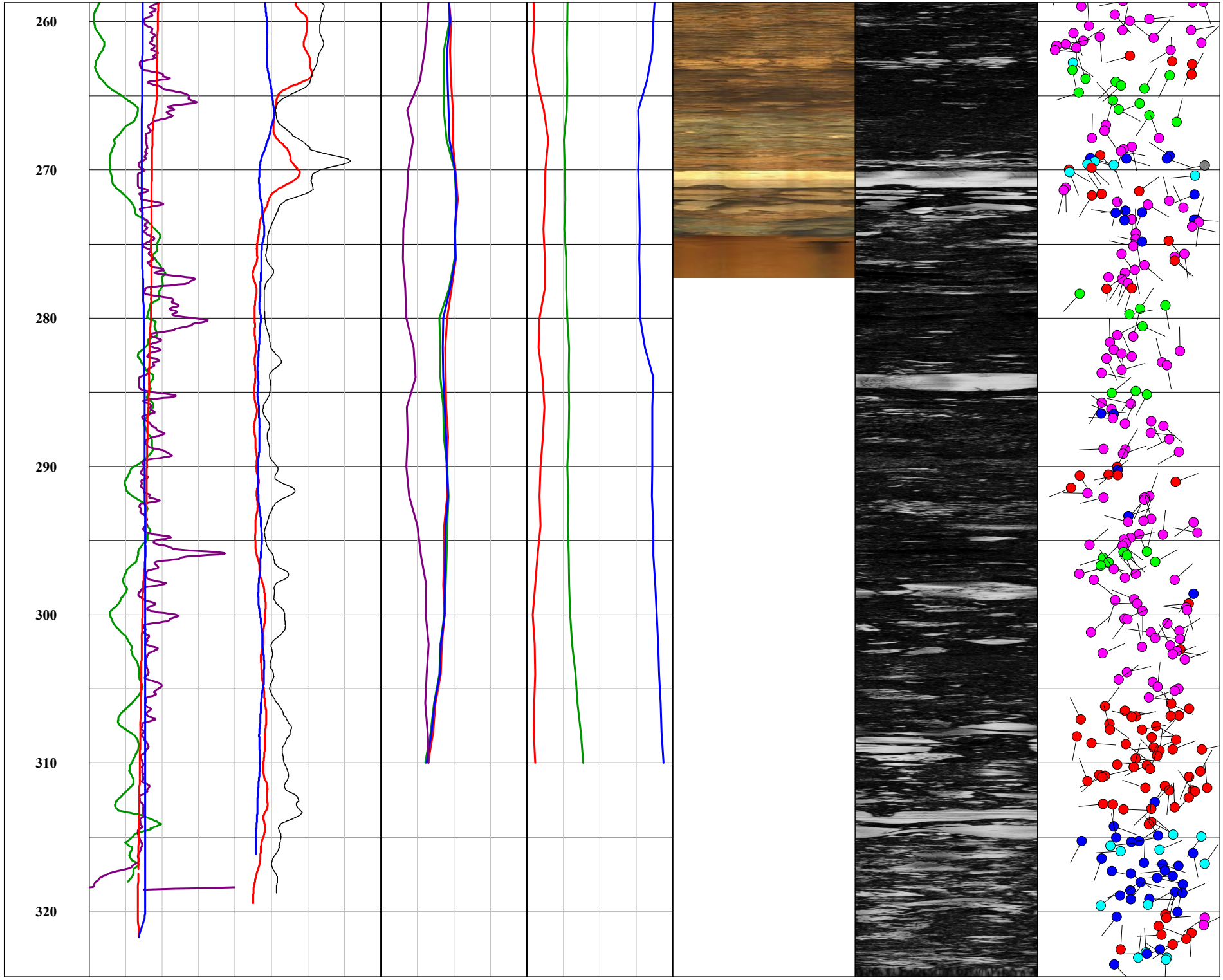
Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN	Tadpoles - MN
1ft:100ft	0 CPS 200	0 OHMM 400	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 in. 8	0 OHMM 400	0 m/s 4000	0 us/m 2000			
	Temperature	Single-Point Resistance	Shear Velocity - Avg	Poisson's Ratio			
	5 deg C 15	0 OHM 400	0 4000	-0.2 0.5			
	Fluid Conductivity		Compressive Velocity				
	0 uS/cm 200		2000 m/s 4000				




60
70
80
90
100
110
120


130
140
150
160
170
180
190


200
210
220
230
240
250


260
270
280
290
300
310
320

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-16
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-16
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83164 N
Longitude: 84.76097 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.0'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	1 July 2019			
RUN NUMBER	2			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	325'			
DEPTH-LOGGER	324'			
BTM LOG INTERVAL	323.8'			
TOP LOG INTERVAL	5.7'			
RECORDED BY	CKL/JBG			
WITNESSED BY				
PROBE TYPE, S/N	BHTV 1730			
LOGGING SPEED	4.5ft/min			
A.S.D.E. / Sample Interval	0.4'/0.00045			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

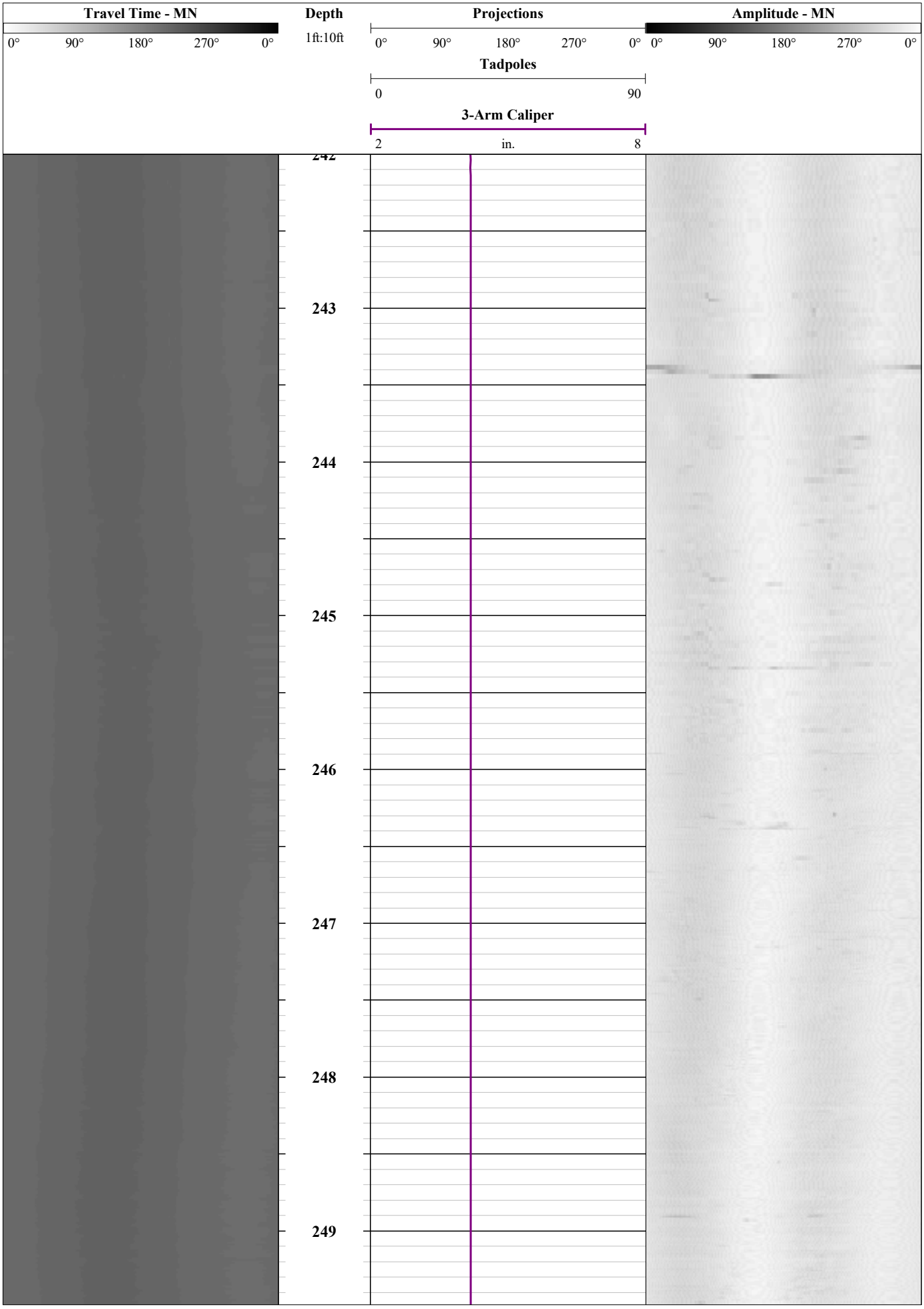
RUN No.	BIT	FROM	TO
1	HQ	253'	325'

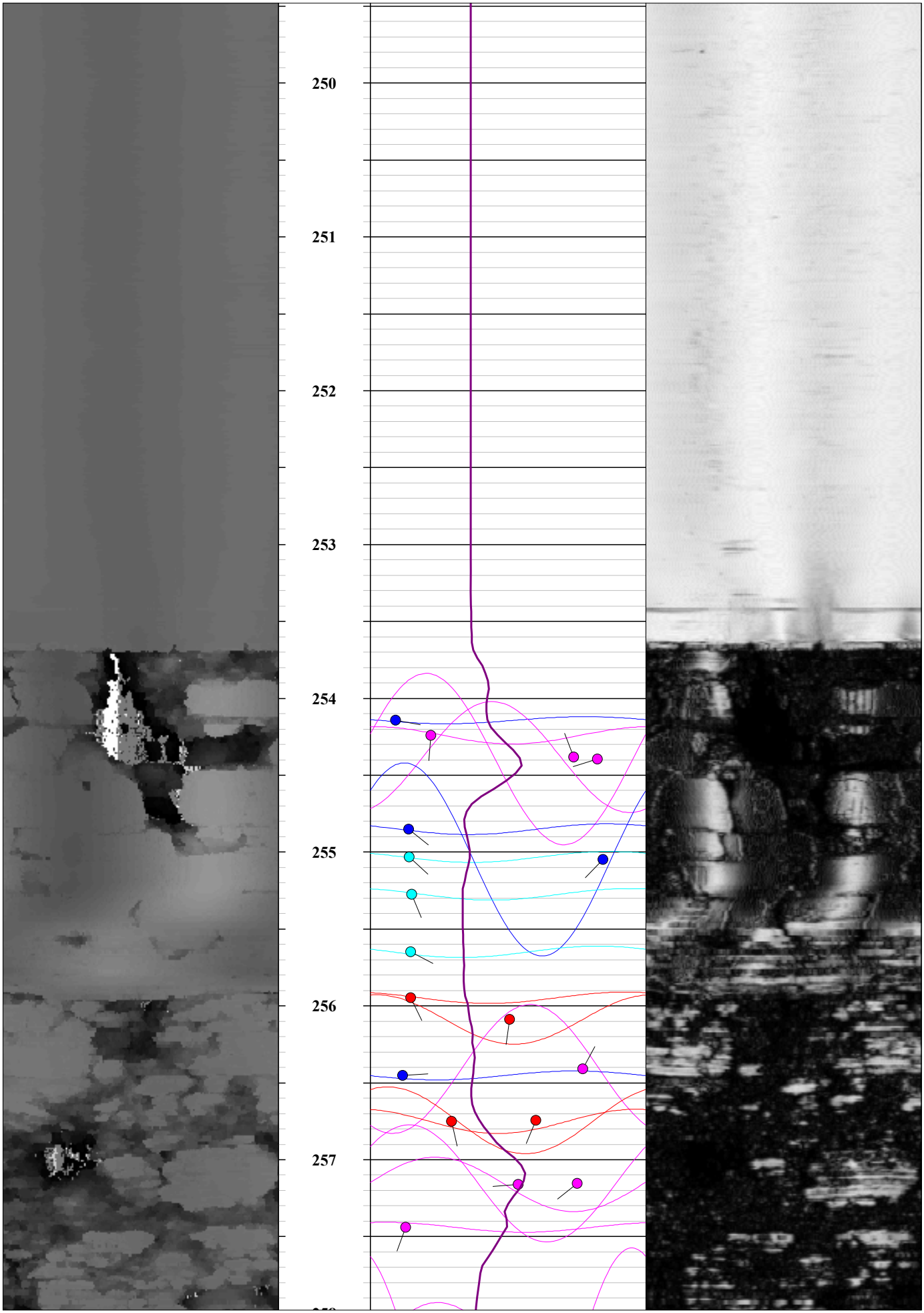
CASING RECORD

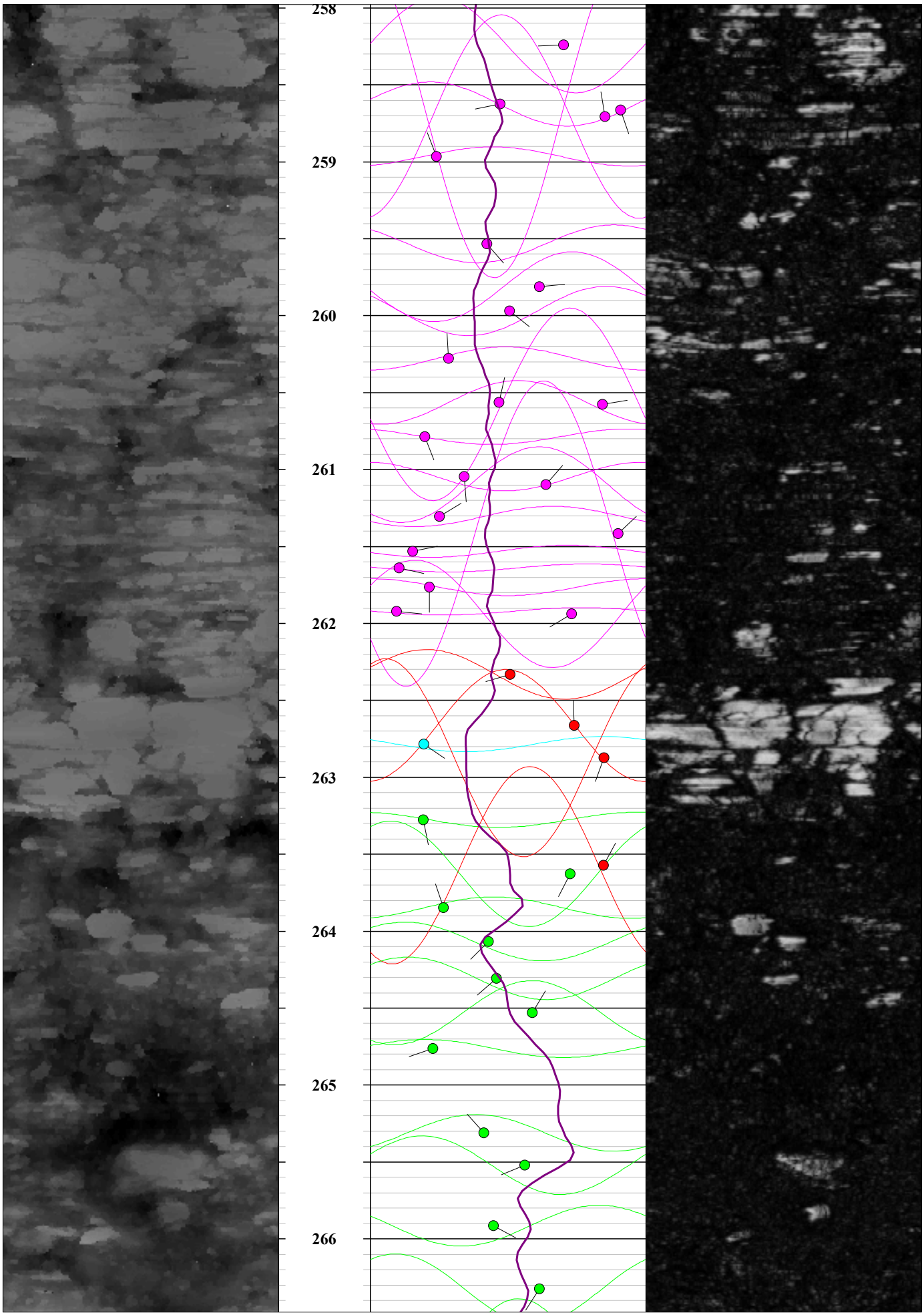
SIZE	WGT.	FROM	TO
7"	Steel	SU	70'
6"	Steel	SU	248'

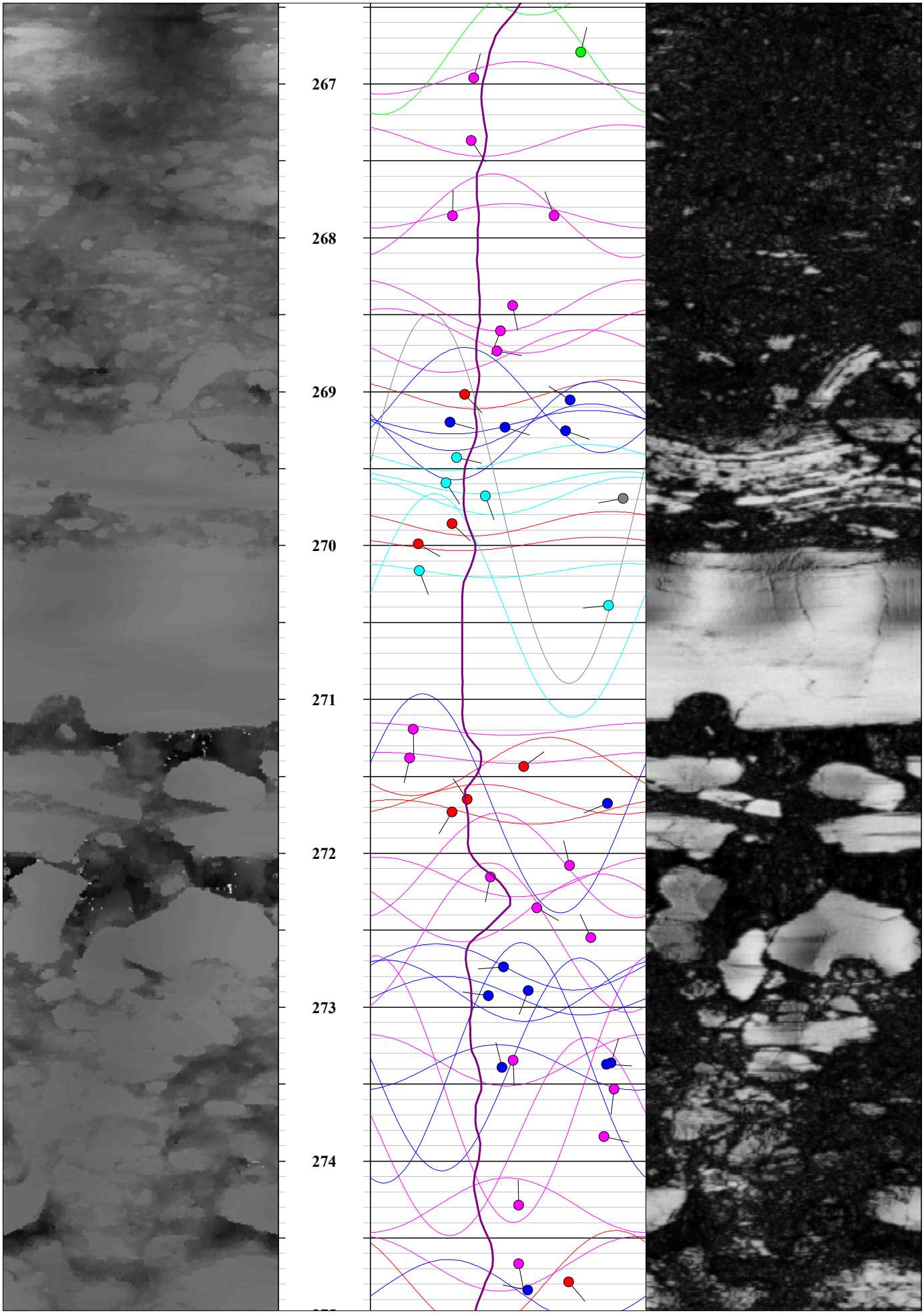
NA - Not Available, N/A - Not Applicable

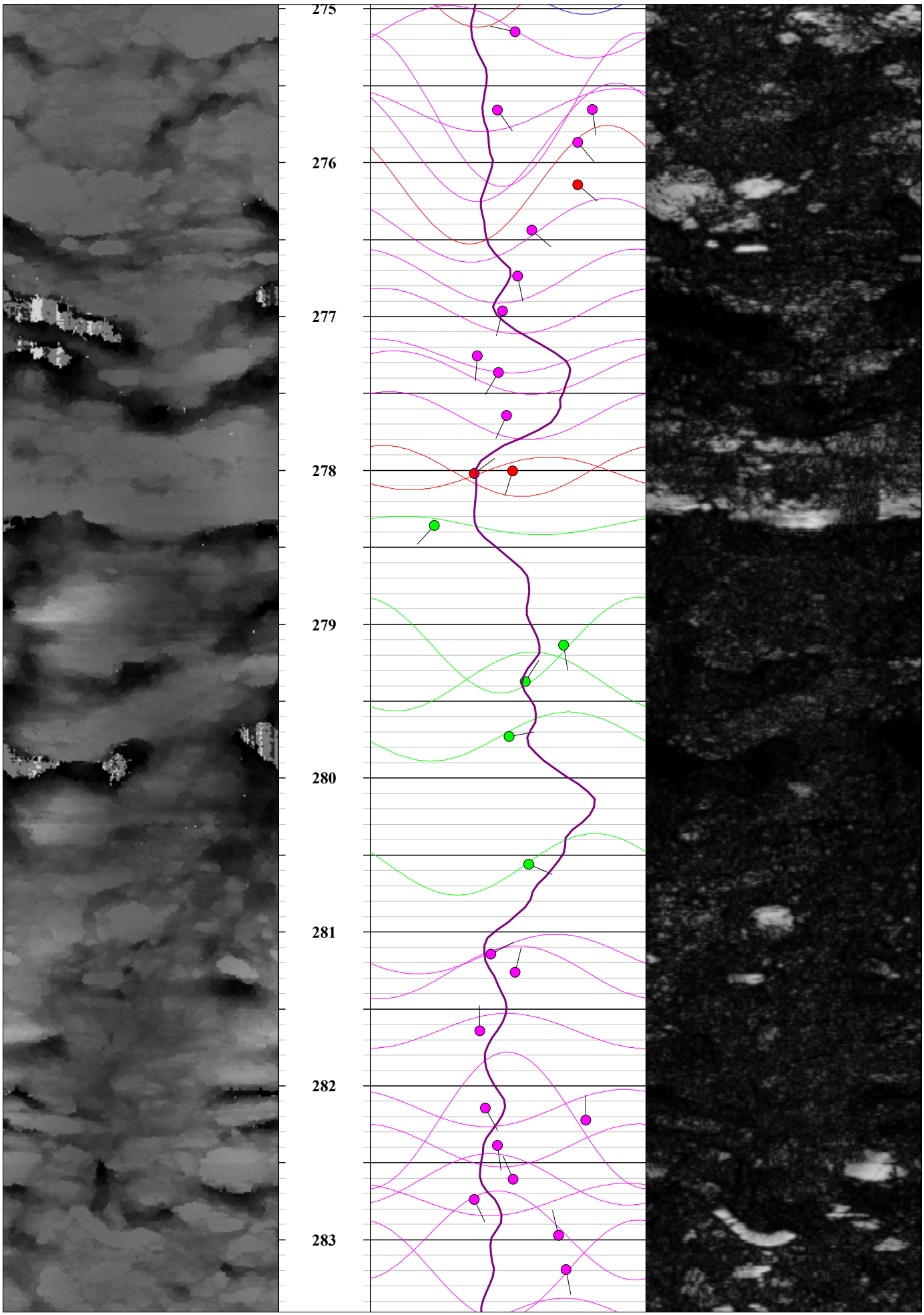
COMMENTS

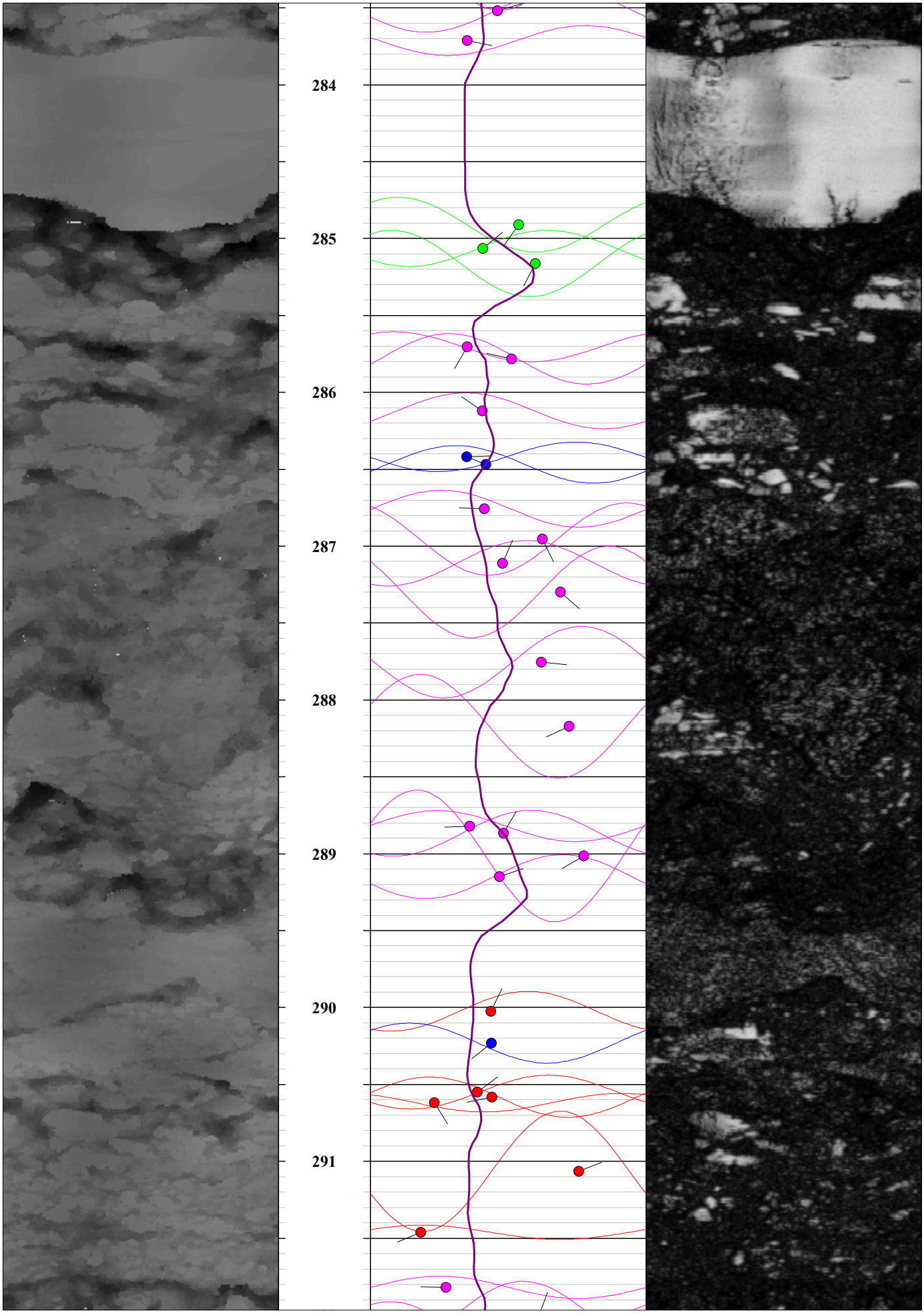

Travel Time - MN
0° 90° 180° 270° 0°
Depth
1ft:10ft
Projections
0° 90° 180° 270° 0°
Tadpoles
0 90
3-Arm Caliper
2 in. 8
Amplitude - MN
0° 90° 180° 270° 0°
243
244
245
246
247
248
249

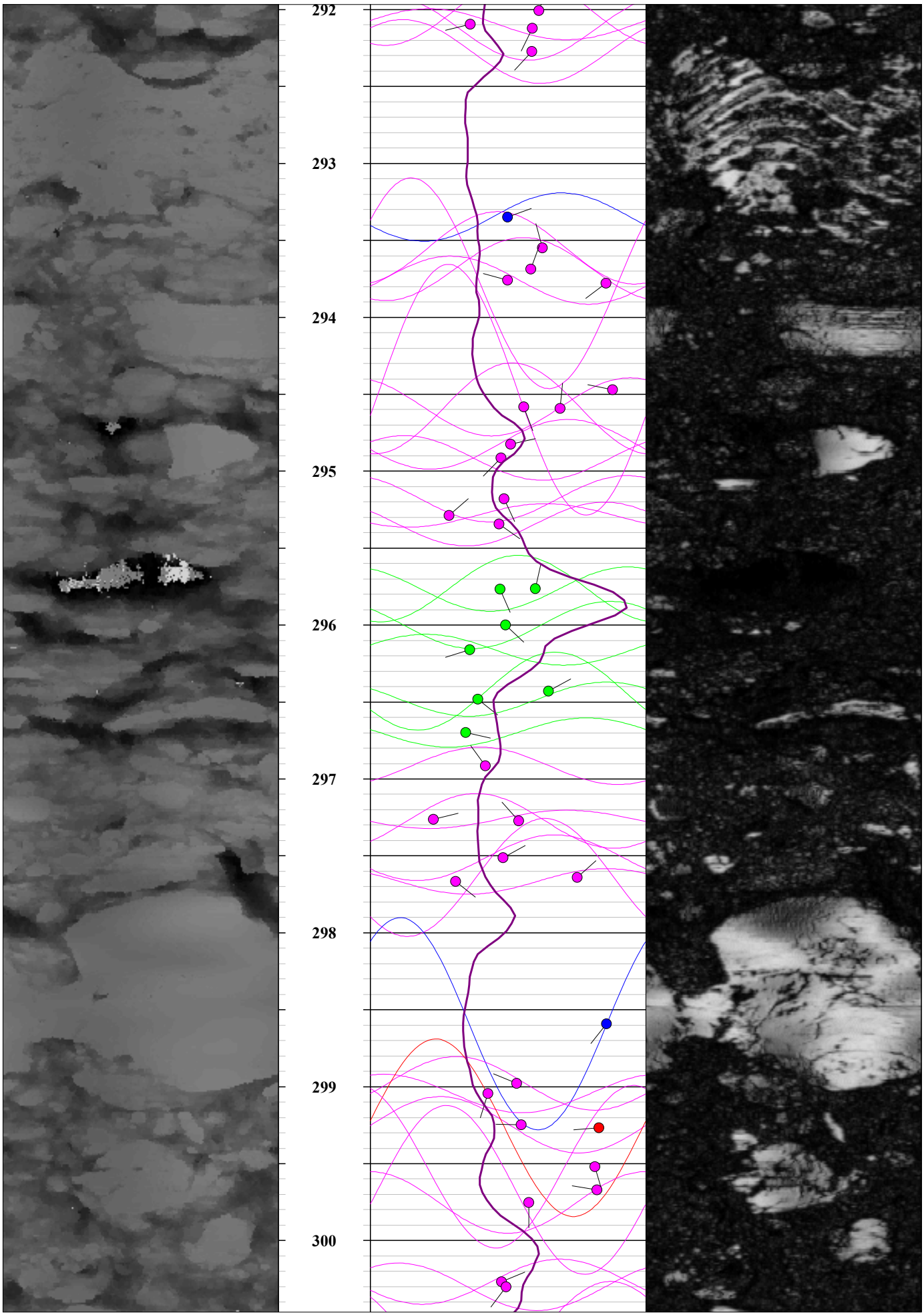

250
251
252
253
254
255
256
257

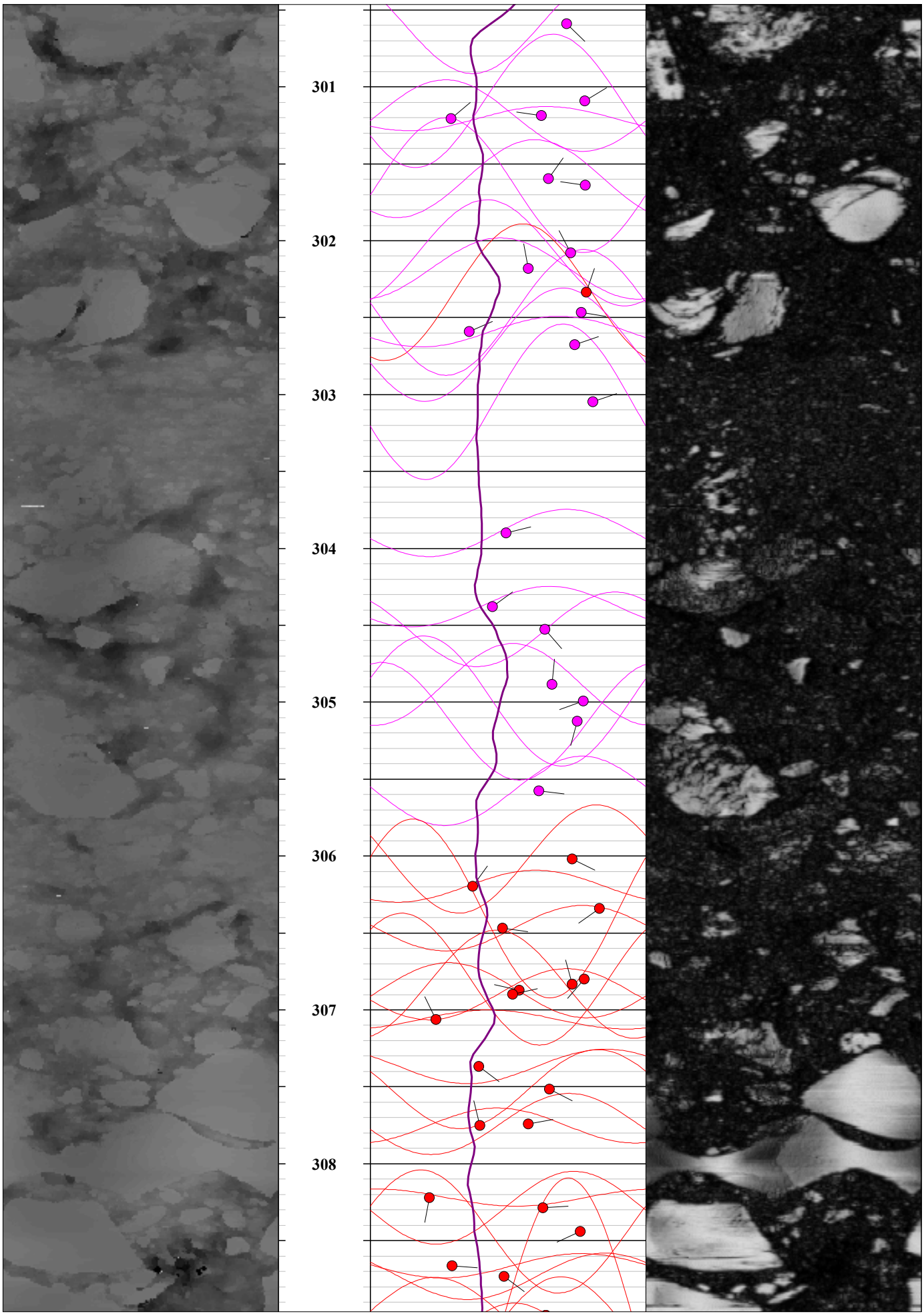

258
259
260
261
262
263
264
265
266

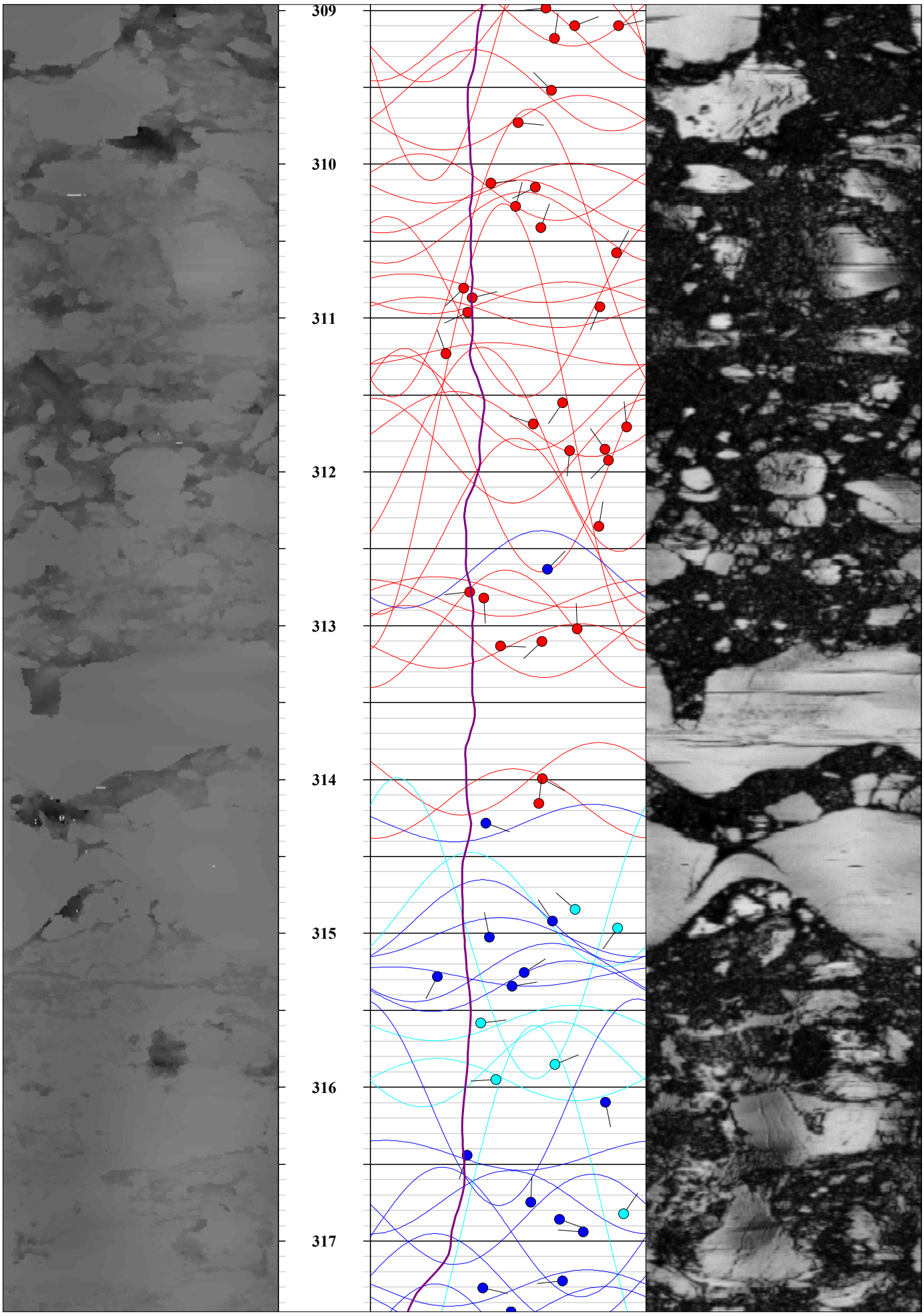

267
268
269
270
271
272
273
274

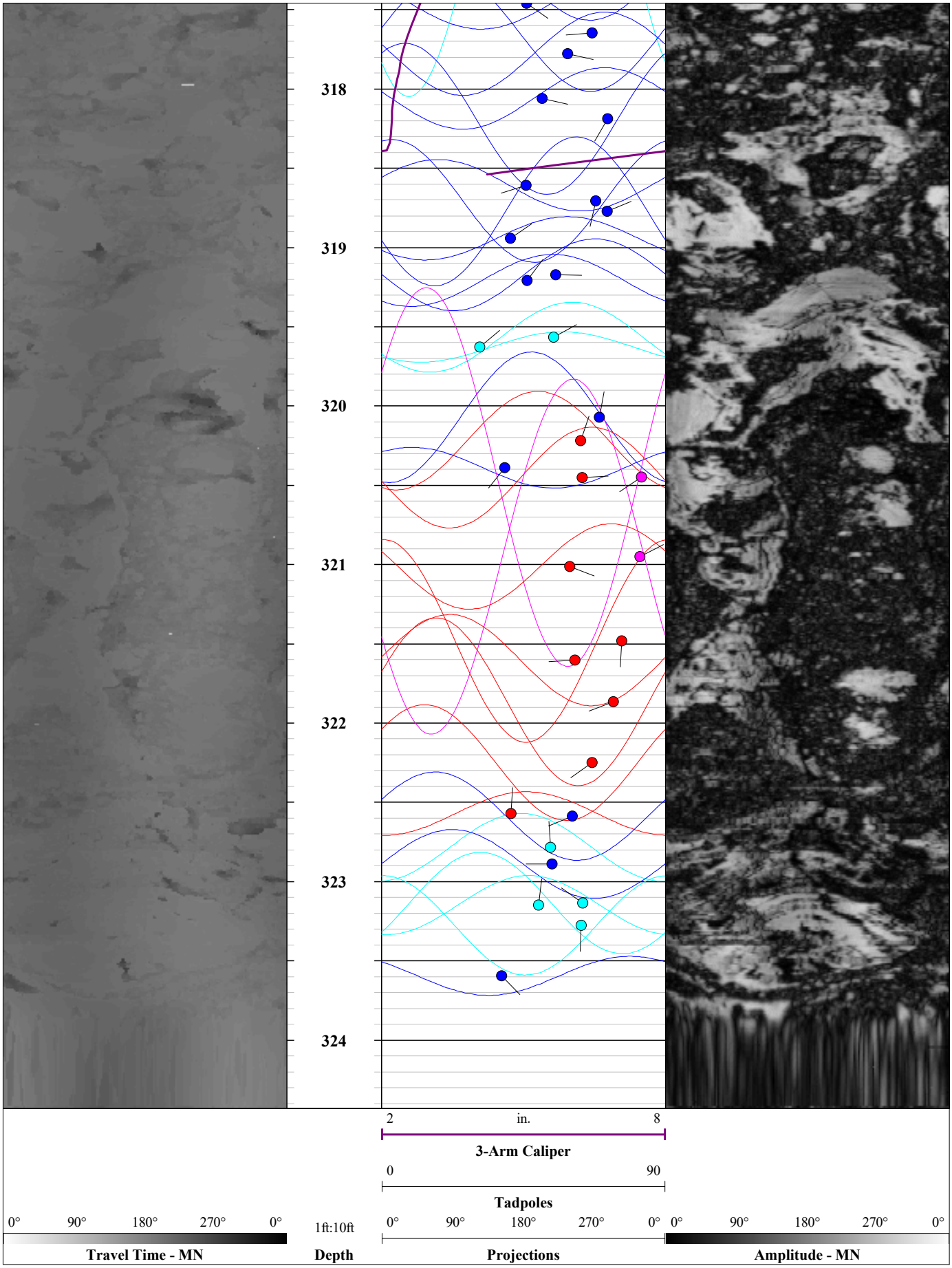

275
276
277
278
279
280
281
282
283


284
285
286
287
288
289
290
291


292
293
294
295
296
297
298
299
300


301
302
303
304
305
306
307
308


309
310
311
312
313
314
315
316
317


318
319
320
321
322
323
324
2
in.
8
3-Arm Caliper
0
90
Tadpoles
0°
90°
180°
270°
0°
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
Travel Time - MN
Depth
Projections
Amplitude - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-16
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-16
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83164 N
Longitude: 84.76097 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.0'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	1 July 2019			
RUN NUMBER	1			
LOG TYPE	Optical Televiewer			
DEPTH-DRILLER	325'			
DEPTH-LOGGER	277'			
BTM LOG INTERVAL	277'			
TOP LOG INTERVAL	239.7'			
RECORDED BY	CKL/JBG			
WITNESSED BY				
PROBE TYPE, S/N	OPTV 1729			
LOGGING SPEED	4.8ft/min			
A.S.D.E. / Sample Interval	0.1'/.00038			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

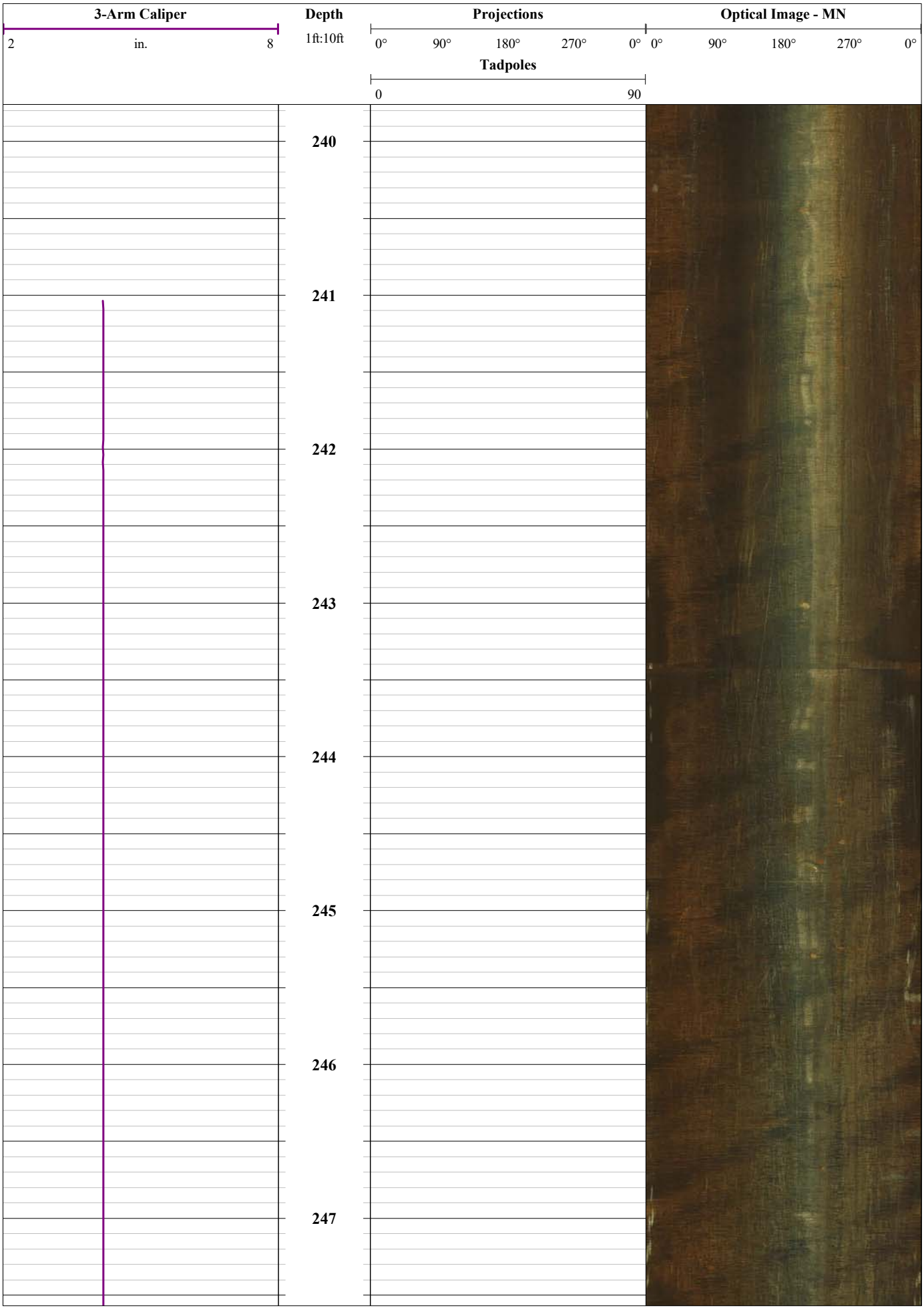
RUN No.	BIT	FROM	TO
1	HQ	253'	325'

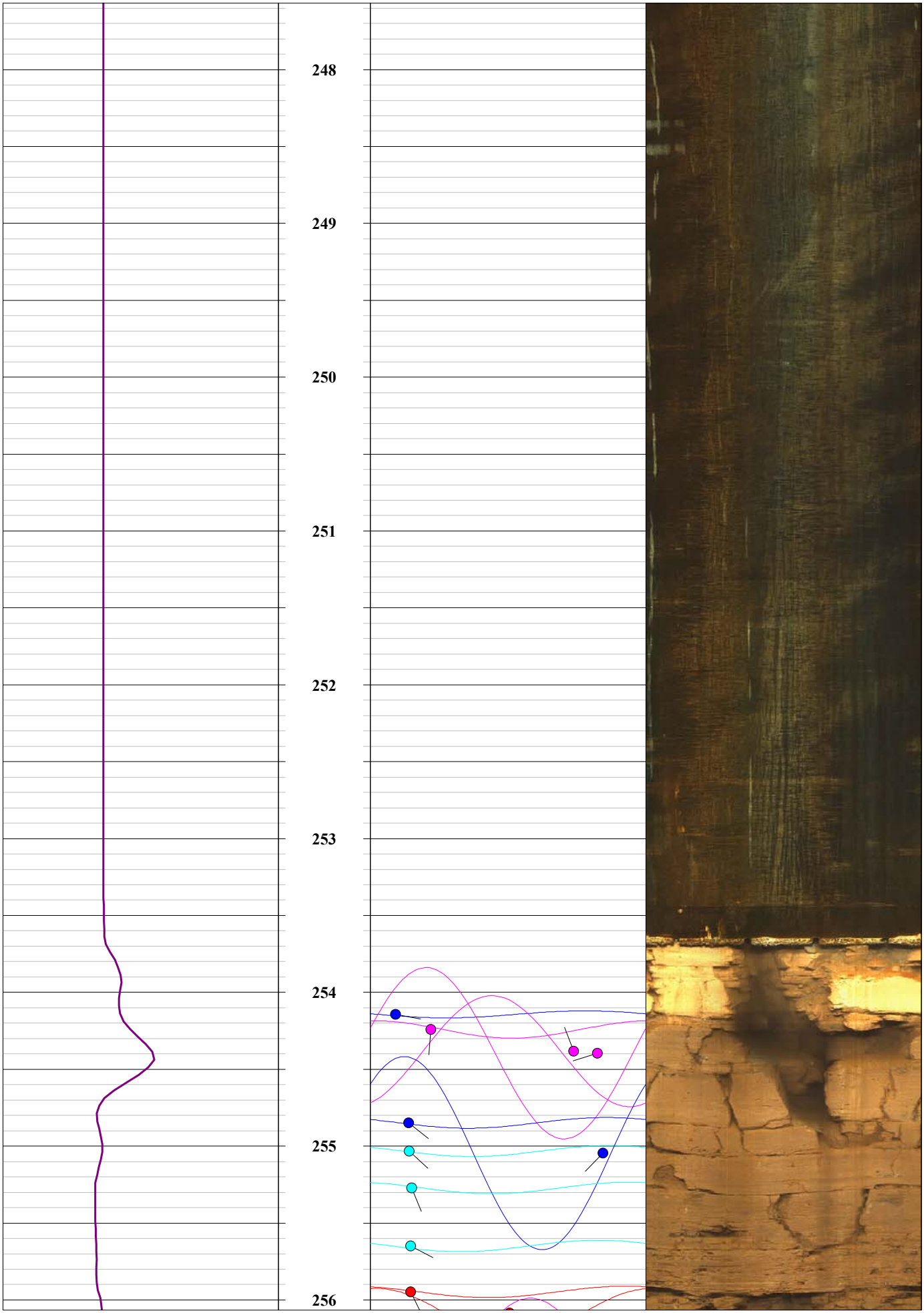
CASING RECORD

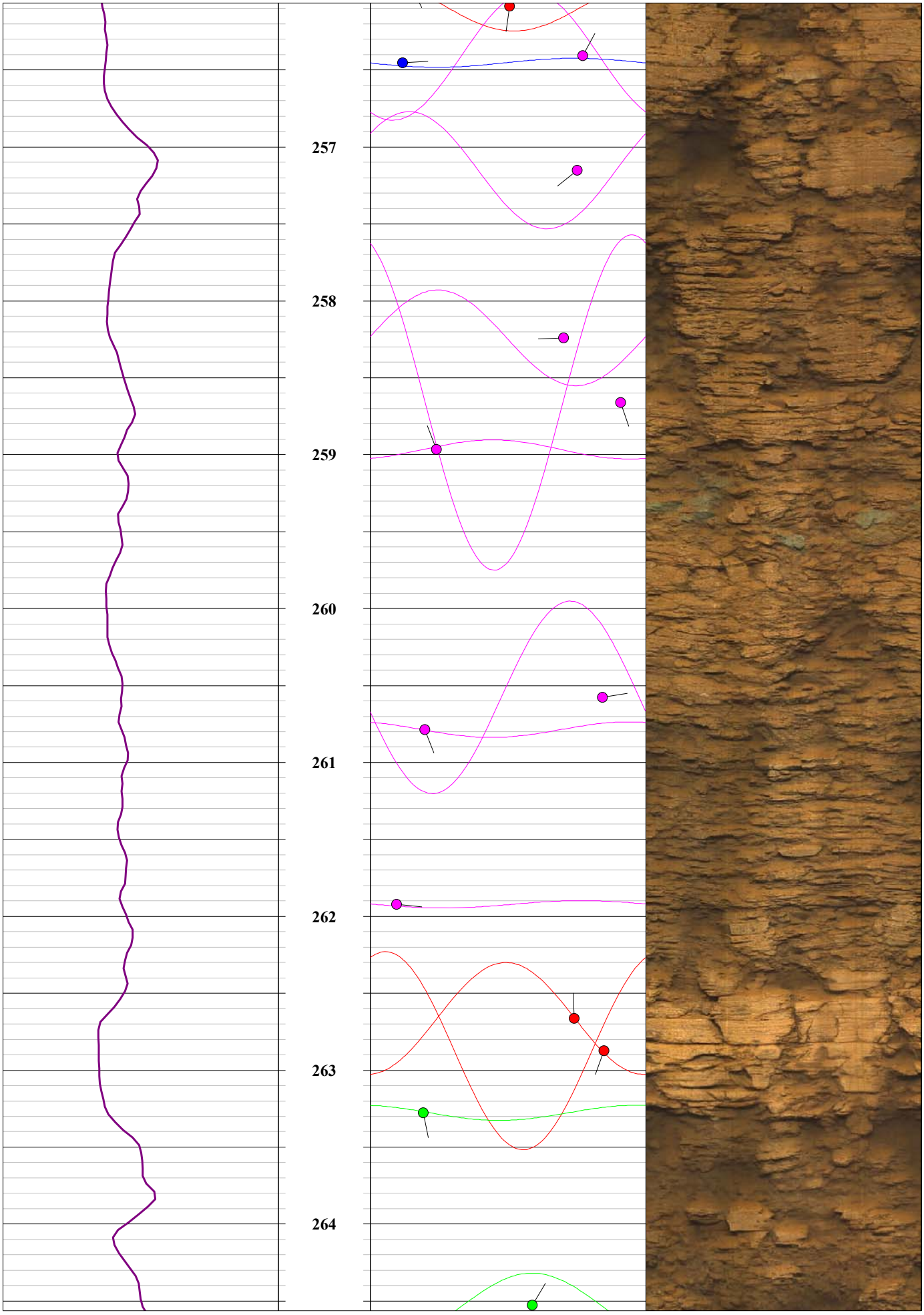
SIZE	WGT.	FROM	TO
7"	Steel	SU	70'
6"	Steel	SU	248'

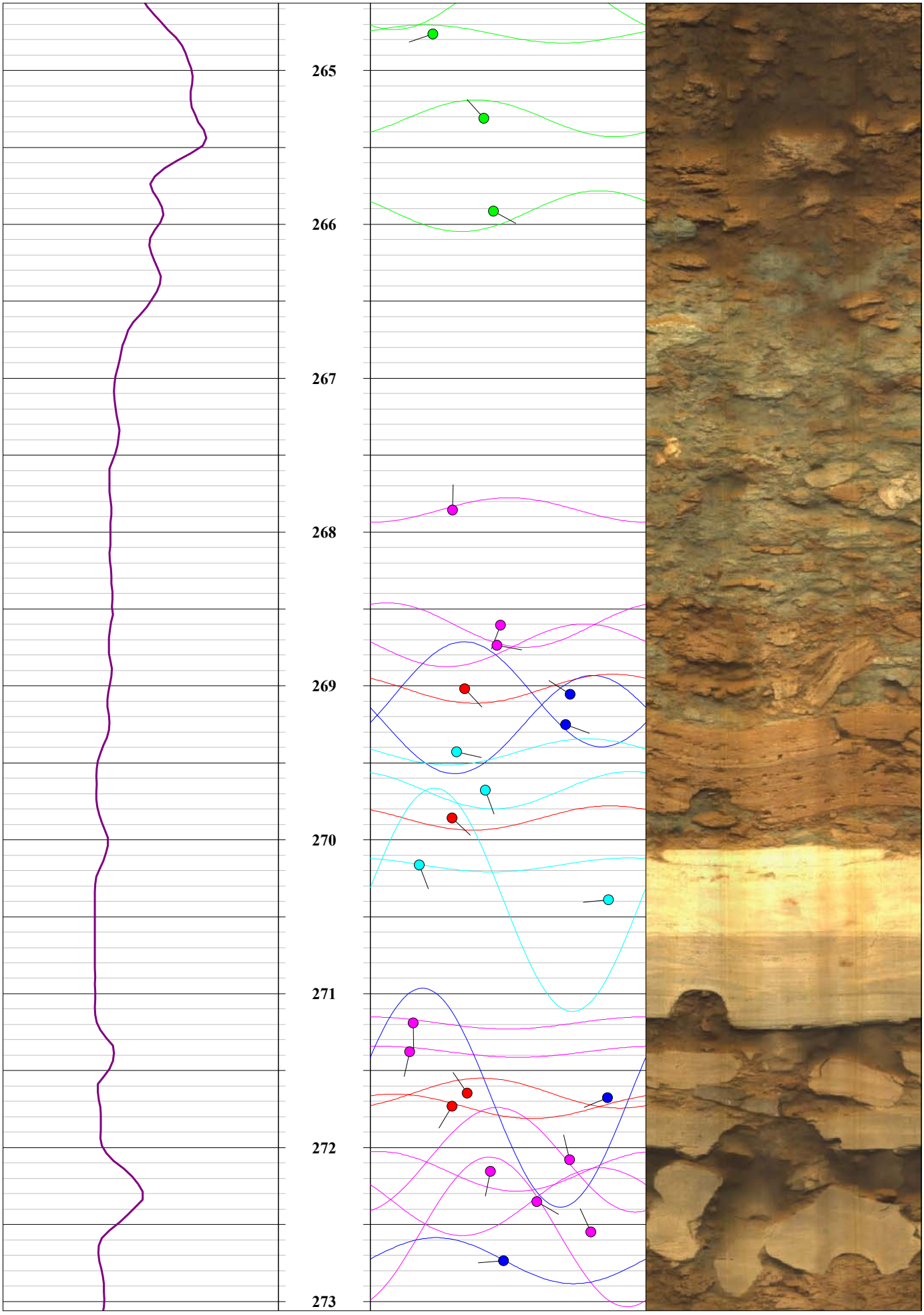
NA - Not Available, N/A - Not Applicable

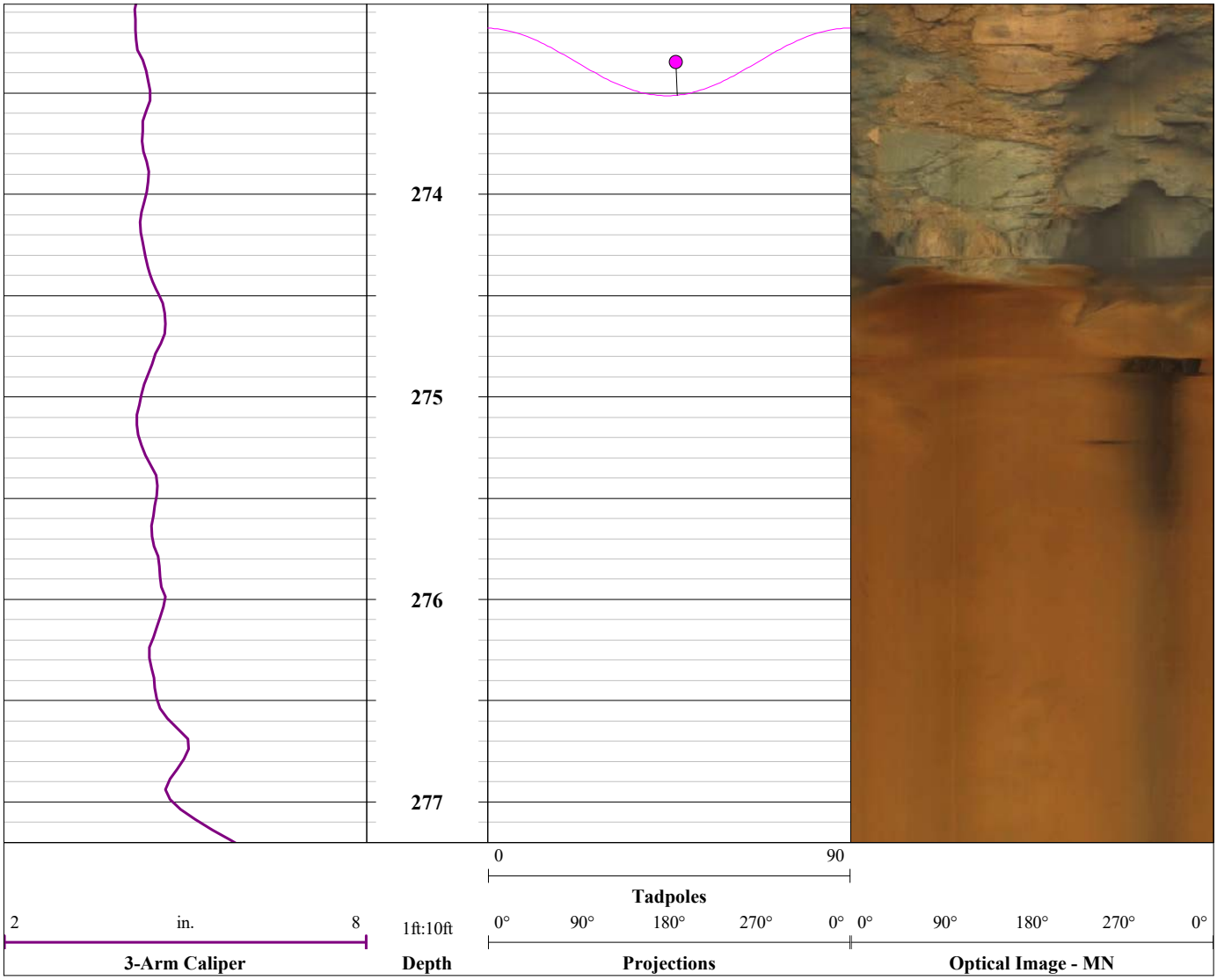
COMMENTS


3-Arm Caliper
2
in.
8
Depth
1ft:10ft
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Optical Image - MN
0°
90°
180°
270°
0°
240
241
242
243
244
245
246
247

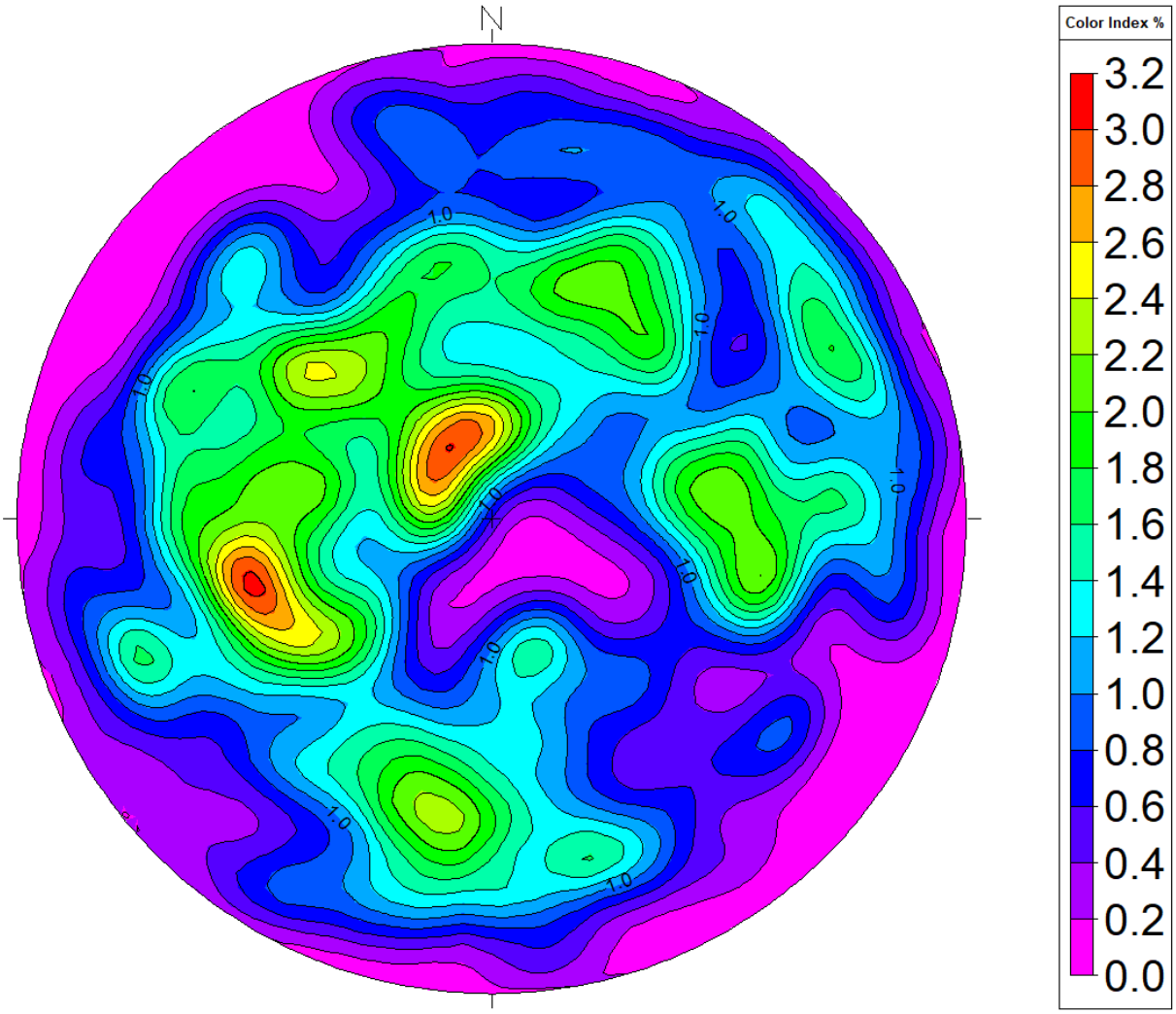

248
249
250
251
252
253
254
255
256


257
258
259
260
261
262
263
264


265
266
267
268
269
270
271
272
273

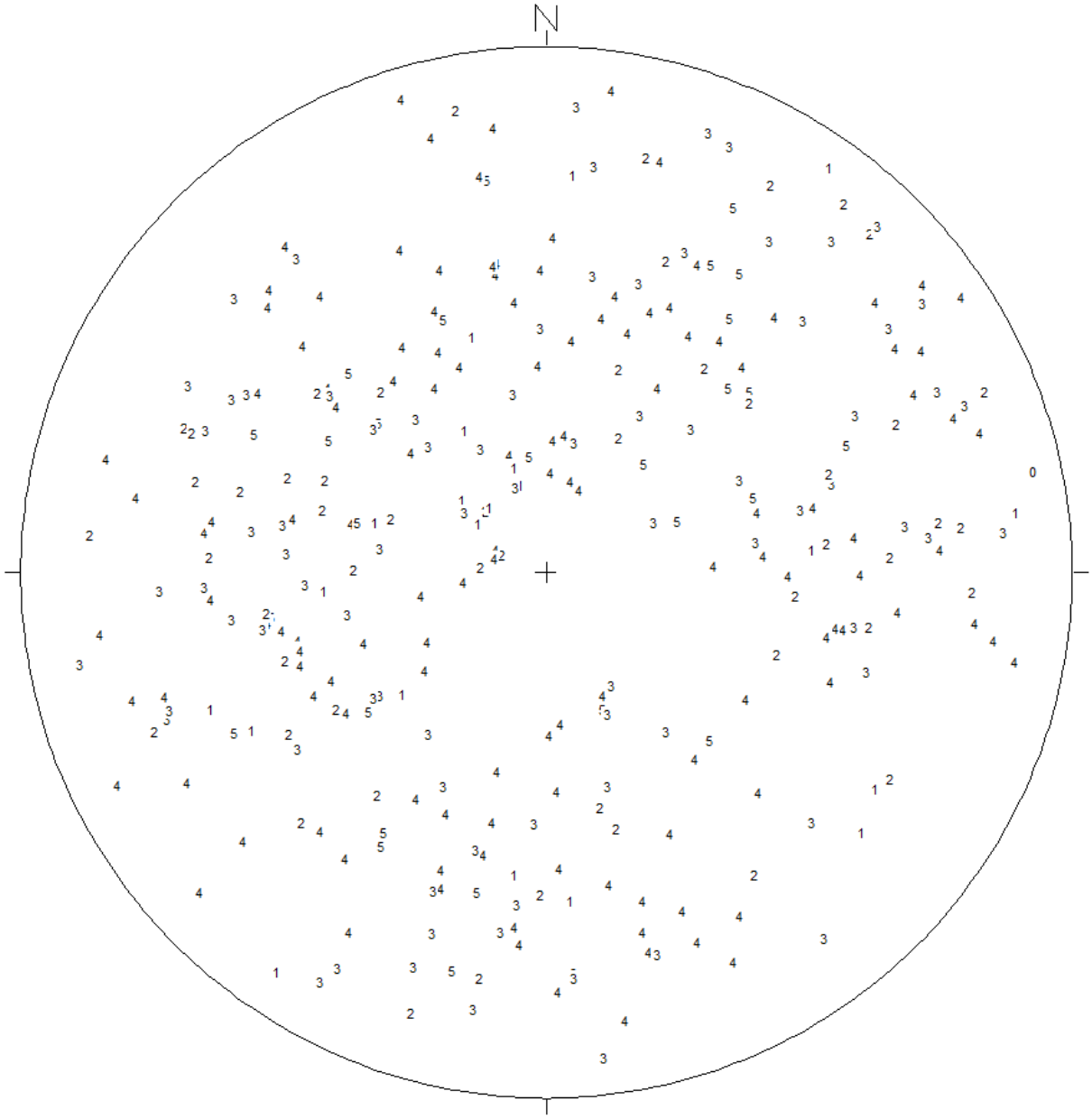

274
275
276
277
0
90
Tadpoles
2
in.
8
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
Projections
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-16
1 July 2019



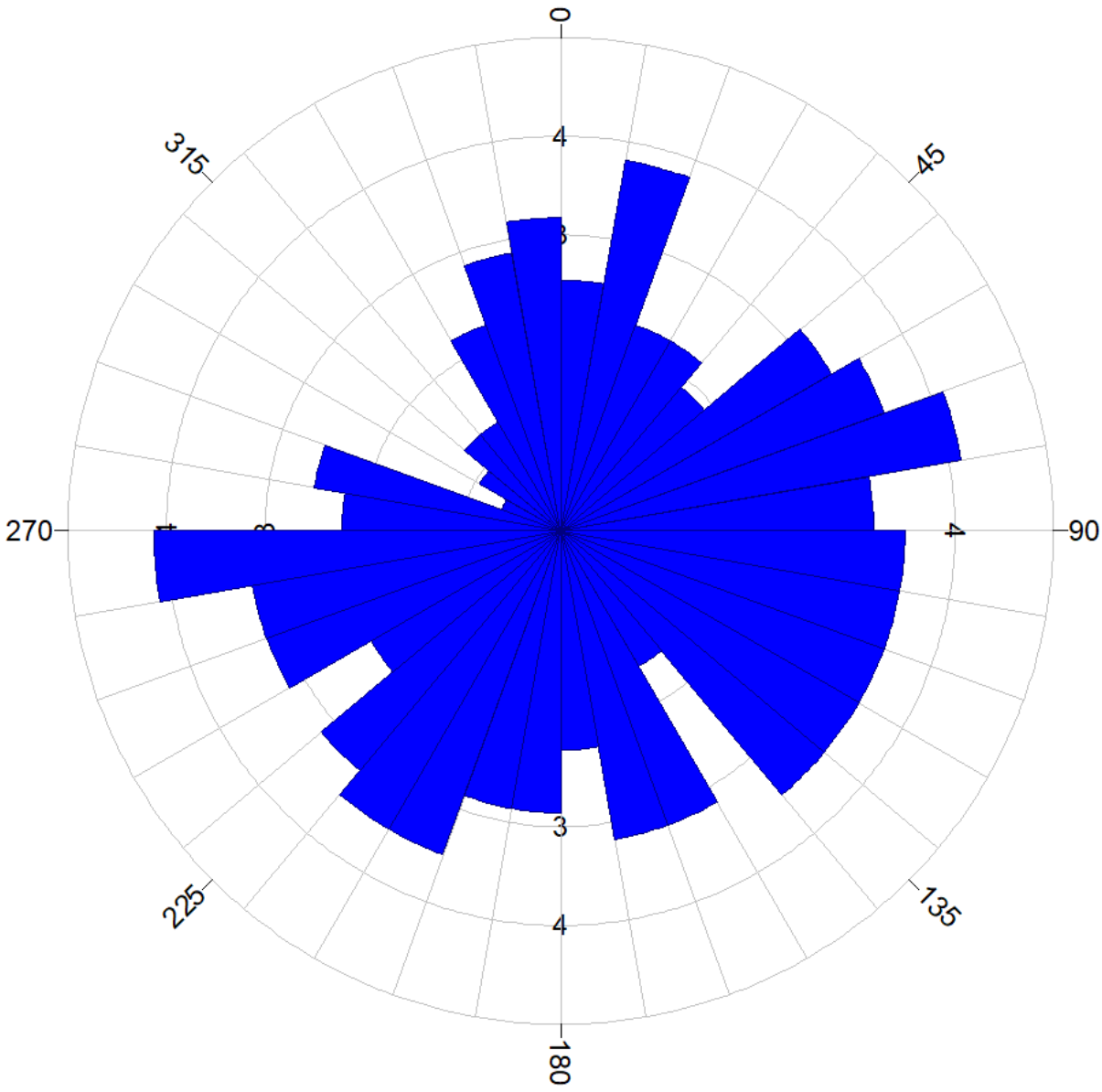
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-16
1 July 2019



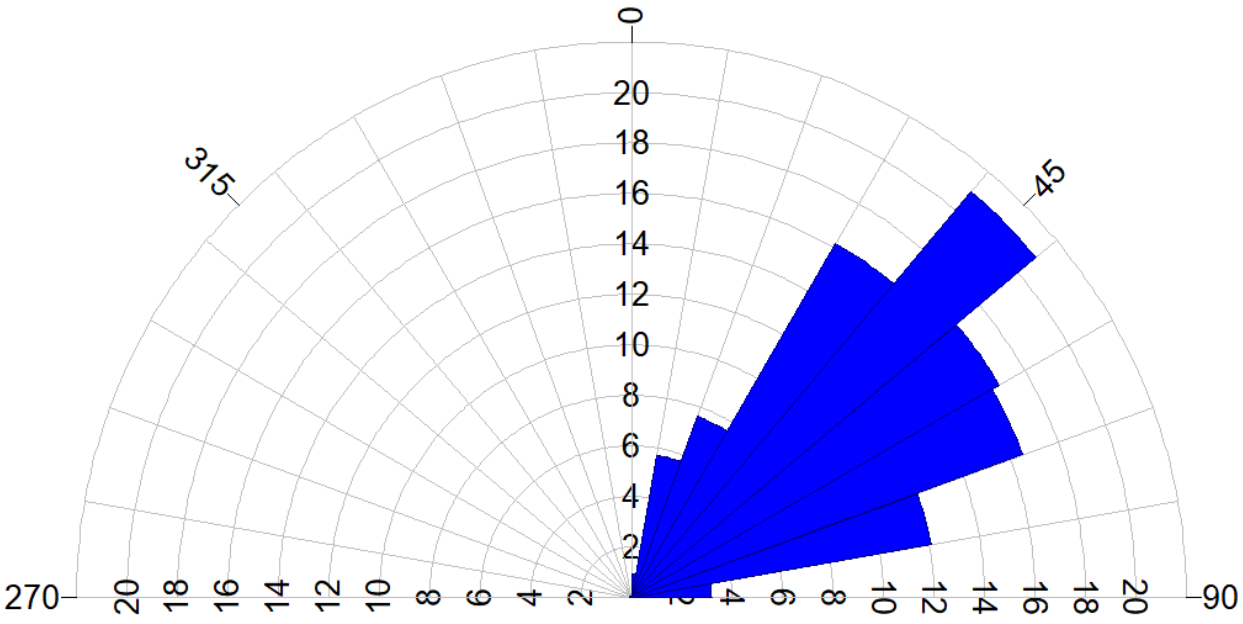
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-16
1 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-16
1 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	77.46	254.1	100	8	2
2	77.49	254.2	185	20	4
3	77.54	254.4	339	66	4
4	77.54	254.4	253	74	4
5	77.68	254.9	128	13	2
6	77.73	255.0	132	13	1
7	77.74	255.1	224	76	2
8	77.81	255.3	158	13	1
9	77.92	255.7	118	13	1
10	78.01	256.0	154	13	3
11	78.06	256.1	188	46	3
12	78.15	256.4	29	69	4
13	78.17	256.5	87	11	2
14	78.26	256.8	203	54	3
15	78.26	256.8	167	27	3
16	78.38	257.2	231	68	4
17	78.38	257.2	265	48	4
18	78.47	257.4	200	12	4
19	78.71	258.2	268	63	4
20	78.83	258.6	258	42	4
21	78.84	258.7	162	82	4
22	78.85	258.7	351	77	4
23	78.93	259.0	339	22	4
24	79.10	259.5	139	38	4
25	79.19	259.8	84	55	4
26	79.24	260.0	128	45	4
27	79.33	260.3	357	25	4
28	79.42	260.6	13	42	4
29	79.42	260.6	81	76	4
30	79.49	260.8	158	18	4
31	79.57	261.1	176	31	4
32	79.58	261.1	41	57	4
33	79.64	261.3	58	23	4
34	79.68	261.4	47	81	4
35	79.71	261.5	78	14	4
36	79.75	261.6	103	9	4
37	79.78	261.8	180	19	4
38	79.83	261.9	95	9	4
39	79.84	261.9	238	66	4
40	79.96	262.3	254	46	3
41	80.06	262.7	357	67	3
42	80.10	262.8	125	17	1
43	80.12	262.9	200	76	3
44	80.25	263.3	168	17	5
45	80.34	263.6	28	76	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	80.35	263.6	207	65	5
47	80.42	263.9	341	24	5
48	80.49	264.1	225	39	5
49	80.56	264.3	229.1	41.2	5
50	80.63	264.5	31.2	52.9	5
51	80.70	264.8	251.5	20.4	5
52	80.87	265.3	318.2	37.1	5
53	80.93	265.5	248.1	50.4	5
54	81.05	265.9	118.8	40.2	5
55	81.18	266.3	212.9	55.3	5
56	81.32	266.8	13.8	68.7	5
57	81.37	267.0	14.9	33.7	4
58	81.49	267.4	146.2	33.0	4
59	81.64	267.9	339.4	59.9	4
60	81.64	267.9	0.9	26.8	4
61	81.82	268.4	169.0	46.6	4
62	81.87	268.6	201.3	42.6	4
63	81.91	268.7	99.8	41.4	4
64	82.00	269.0	136.6	30.9	3
65	82.01	269.1	302.5	65.2	2
66	82.05	269.2	105.5	26.1	2
67	82.06	269.2	108.0	44.0	2
68	82.07	269.3	110.2	63.7	2
69	82.12	269.4	102.9	28.3	1
70	82.17	269.6	146.8	24.8	1
71	82.20	269.7	160.5	37.6	1
72	82.20	269.7	259.2	82.5	0
73	82.25	269.9	133.3	26.6	3
74	82.29	270.0	119.7	15.7	3
75	82.34	270.2	158.5	16.0	1
76	82.41	270.4	263.8	77.8	1
77	82.66	271.2	178.8	14.0	4
78	82.72	271.4	192.8	12.9	4
79	82.73	271.4	54.0	50.2	3
80	82.80	271.7	325.9	31.7	3
81	82.81	271.7	248.3	77.5	2
82	82.82	271.7	210.8	26.8	3
83	82.93	272.1	346.1	65.1	4
84	82.95	272.2	191.2	39.3	4
85	83.01	272.4	120.1	54.4	4
86	83.07	272.6	335.6	72.1	4
87	83.13	272.7	265.8	43.5	2
88	83.18	272.9	200.6	51.6	2
89	83.19	272.9	277.7	38.6	2
90	83.32	273.4	177.8	46.6	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	83.32	273.4	17.4	78.6	2
92	83.32	273.4	93.5	77.2	2
93	83.33	273.4	346.3	43.0	2
94	83.37	273.5	187.1	79.7	4
95	83.47	273.8	103.1	76.2	4
96	83.60	274.3	358.8	48.4	4
97	83.72	274.7	169.6	48.5	4
98	83.75	274.8	140.0	64.7	3
99	83.77	274.8	281.4	51.5	2
100	83.87	275.2	282.8	47.3	4
101	84.02	275.7	172.3	72.5	4
102	84.02	275.7	145.2	41.5	4
103	84.09	275.9	139.9	67.7	4
104	84.17	276.2	129.8	67.8	3
105	84.26	276.4	131.1	52.8	4
106	84.35	276.7	168.7	48.1	4
107	84.42	277.0	193.3	43.3	4
108	84.51	277.3	184.8	35.0	4
109	84.54	277.4	210.9	41.8	4
110	84.62	277.6	204.6	44.6	4
111	84.73	278.0	197.1	46.5	3
112	84.74	278.0	52.5	34.0	3
113	84.84	278.4	222.4	20.9	5
114	85.08	279.1	170.4	63.1	5
115	85.15	279.4	32.1	50.6	5
116	85.26	279.7	79.1	45.3	5
117	85.51	280.6	113.4	51.8	5
118	85.69	281.1	62.1	39.4	4
119	85.73	281.3	13.3	47.4	4
120	85.84	281.6	358.8	35.7	4
121	86.00	282.1	151.7	37.6	4
122	86.02	282.2	359.3	70.4	4
123	86.07	282.4	171.7	41.6	4
124	86.14	282.6	336.6	46.7	4
125	86.18	282.7	154.9	34.0	4
126	86.25	283.0	346.2	61.5	4
127	86.32	283.2	169.4	64.0	4
128	86.42	283.5	73	42	4
129	86.47	283.7	101	32	4
130	86.84	284.9	216	48	5
131	86.89	285.1	51	37	5
132	86.92	285.2	208	54	5
133	87.08	285.7	211	32	4
134	87.11	285.8	283	46	4
135	87.21	286.1	305	37	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	87.30	286.4	88	31	2
137	87.32	286.5	292	38	2
138	87.40	286.8	273	37	4
139	87.47	287.0	154	56	4
140	87.51	287.1	23	43	4
141	87.57	287.3	132	62	4
142	87.71	287.8	95	56	4
143	87.83	288.2	245	65	4
144	88.03	288.8	268	33	4
145	88.05	288.9	30	43	4
146	88.09	289.0	240	70	4
147	88.13	289.2	71	42	4
148	88.40	290.0	26	39	3
149	88.46	290.2	231	40	2
150	88.56	290.6	53	35	3
151	88.57	290.6	258	40	3
152	88.58	290.6	148	21	3
153	88.72	291.1	68	68	3
154	88.84	291.5	248	17	3
155	88.95	291.8	271	25	4
156	89.00	292.0	19	55	4
157	89.03	292.1	256	33	4
158	89.04	292.1	206	53	4
159	89.08	292.3	222	53	4
160	89.41	293.4	70	45	2
161	89.47	293.6	345	56	4
162	89.52	293.7	20	52	4
163	89.54	293.8	285	45	4
164	89.54	293.8	233	77	4
165	89.75	294.5	282	79	4
166	89.79	294.6	159	50	4
167	89.79	294.6	5	62	4
168	89.86	294.8	78	46	4
169	89.89	294.9	224	43	4
170	89.97	295.2	155	44	4
171	90.00	295.3	49	26	4
172	90.02	295.3	126	42	4
173	90.15	295.8	13	54	5
174	90.15	295.8	156	42	5
175	90.22	296.0	133	44	5
176	90.27	296.2	252	33	5
177	90.35	296.4	62	58	5
178	90.37	296.5	129	35	5
179	90.43	296.7	102	31	5
180	90.50	296.9	324	38	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	90.60	297.3	76	21	4
182	90.61	297.3	318	49	4
183	90.68	297.5	61	43	4
184	90.72	297.6	48	68	4
185	90.73	297.7	128	28	4
186	91.01	298.6	219	77	2
187	91.13	299.0	293	48	4
188	91.15	299.0	198	38	4
189	91.21	299.3	272	49	4
190	91.22	299.3	266	75	3
191	91.29	299.5	164	73	4
192	91.34	299.7	280	74	4
193	91.36	299.8	180	52	4
194	91.52	300.3	68	43	4
195	91.53	300.3	217	44	4
196	91.62	300.6	134	64	4
197	91.77	301.1	59	70	4
198	91.80	301.2	278	56	4
199	91.81	301.2	50	26	4
200	91.93	301.6	35	58	4
201	91.94	301.6	278	70	4
202	92.07	302.1	332	65	4
203	92.10	302.2	350	52	4
204	92.15	302.3	19	70	3
205	92.19	302.5	99	69	4
206	92.23	302.6	67	32	4
207	92.26	302.7	71	67	4
208	92.37	303.1	72	73	4
209	92.63	303.9	76	44	4
210	92.78	304.4	54	40	4
211	92.82	304.5	139	57	4
212	92.93	304.9	6	59	4
213	92.96	305.0	250	70	4
214	93.00	305.1	195	68	4
215	93.14	305.6	97	55	4
216	93.27	306.0	116	66	3
217	93.33	306.2	36	33	3
218	93.37	306.3	235	75	3
219	93.41	306.5	98	43	3
220	93.51	306.8	221	70	3
221	93.52	306.8	345	66	3
222	93.53	306.9	282	49	3
223	93.54	306.9	77	47	3
224	93.59	307.1	334	21	3
225	93.69	307.4	127	35	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	93.73	307.5	117	58	3
227	93.80	307.7	80	52	3
228	93.80	307.8	346	36	3
229	93.95	308.2	190	19	3
230	93.97	308.3	86	56	3
231	94.01	308.4	246	69	3
232	94.08	308.7	95	27	3
233	94.10	308.7	127	44	3
234	94.18	309.0	264	57	3
235	94.21	309.1	78	81	3
236	94.21	309.1	69	67	3
237	94.24	309.2	8	60	3
238	94.34	309.5	315	59	3
239	94.41	309.7	96	48	3
240	94.52	310.1	85	39	3
241	94.53	310.2	244	54	3
242	94.57	310.3	15	47	3
243	94.61	310.4	20	56	3
244	94.66	310.6	29	80	3
245	94.73	310.8	226	30	3
246	94.75	310.9	76	33	3
247	94.77	310.9	203	75	3
248	94.78	311.0	246	32	3
249	94.86	311.2	340	25	3
250	94.96	311.6	214	63	3
251	95.00	311.7	289	53	3
252	95.01	311.7	354	84	3
253	95.05	311.9	324	77	3
254	95.05	311.9	186	65	3
255	95.07	311.9	224	78	3
256	95.21	312.4	10	75	3
257	95.29	312.6	44	58	2
258	95.34	312.8	264	32	3
259	95.35	312.8	177	37	3
260	95.41	313.0	357	68	3
261	95.43	313.1	226	56	3
262	95.44	313.1	92	42	3
263	95.70	314.0	119	56	3
264	95.76	314.2	6	55	3
265	95.79	314.3	110	38	2
266	95.96	314.8	311	67	1
267	95.99	314.9	327	60	2
268	96.00	315.0	215	81	1
269	96.02	315.0	349	39	2
270	96.09	315.3	57	50	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-16

1 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	96.10	315.3	208	22	2
272	96.12	315.3	80	46	2
273	96.19	315.6	83	36	1
274	96.27	315.9	67	60	1
275	96.30	316.0	267	41	1
276	96.35	316.1	168	77	2
277	96.45	316.4	199	32	2
278	96.55	316.8	2	53	2
279	96.57	316.8	34	83	1
280	96.58	316.9	110	62	2
281	96.60	316.9	274	69	2
282	96.70	317.3	264	63	2
283	96.72	317.3	103	37	2
284	96.76	317.5	126	46	2
285	96.82	317.7	265	67	2
286	96.86	317.8	103	59	2
287	96.94	318.1	103	51	2
288	96.98	318.2	210	72	2
289	97.11	318.6	252	46	2
290	97.14	318.7	193	68	2
291	97.16	318.8	67	71	2
292	97.21	318.9	56	41	2
293	97.28	319.2	91	55	2
294	97.30	319.2	37	46	2
295	97.40	319.6	61	55	1
296	97.42	319.6	49	31	1
297	97.56	320.1	10	69	2
298	97.60	320.2	18	63	3
299	97.65	320.4	218	39	2
300	97.67	320.5	237	82	4
301	97.67	320.5	86	64	3
302	97.83	321.0	63	82	4
303	97.84	321.0	111	60	3
304	97.99	321.5	183	76	3
305	98.02	321.6	266	61	3
306	98.11	321.9	249	73	3
307	98.22	322.3	235	67	3
308	98.32	322.6	4	41	3
309	98.33	322.6	248	60	2
310	98.38	322.8	357	54	1
311	98.42	322.9	269	54	2
312	98.49	323.1	305	64	1
313	98.50	323.2	7	50	1
314	98.54	323.3	183	63	1
315	98.63	323.6	135	38	2

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-16
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-16
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83164 N
Longitude: 84.76097 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.0'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	1 July 2019	1 July 2019	1 July 2019	
RUN NUMBER	1	2	4	
LOG TYPE	FTC	Natural Gamma	Caliper	
DEPTH-DRILLER	325'	325'	325'	
DEPTH-LOGGER	322'	320'	320'	
BTM LOG INTERVAL	321.7'	318.1'	318.4'	
TOP LOG INTERVAL	240'	6.4'	241'	
RECORDED BY	CKL/JBG	CKL/JBG	CKL/JBG	
WITNESSED BY				
PROBE TYPE, S/N	2PFA 5959	ELXG 4248	3ACS	
LOGGING SPEED	20ft/min	20ft/min	10ft/min	
A.S.D.E. / Sample Interval	0.63'/0.1'	0.5'/0.25'	0.3'/0.1'	
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

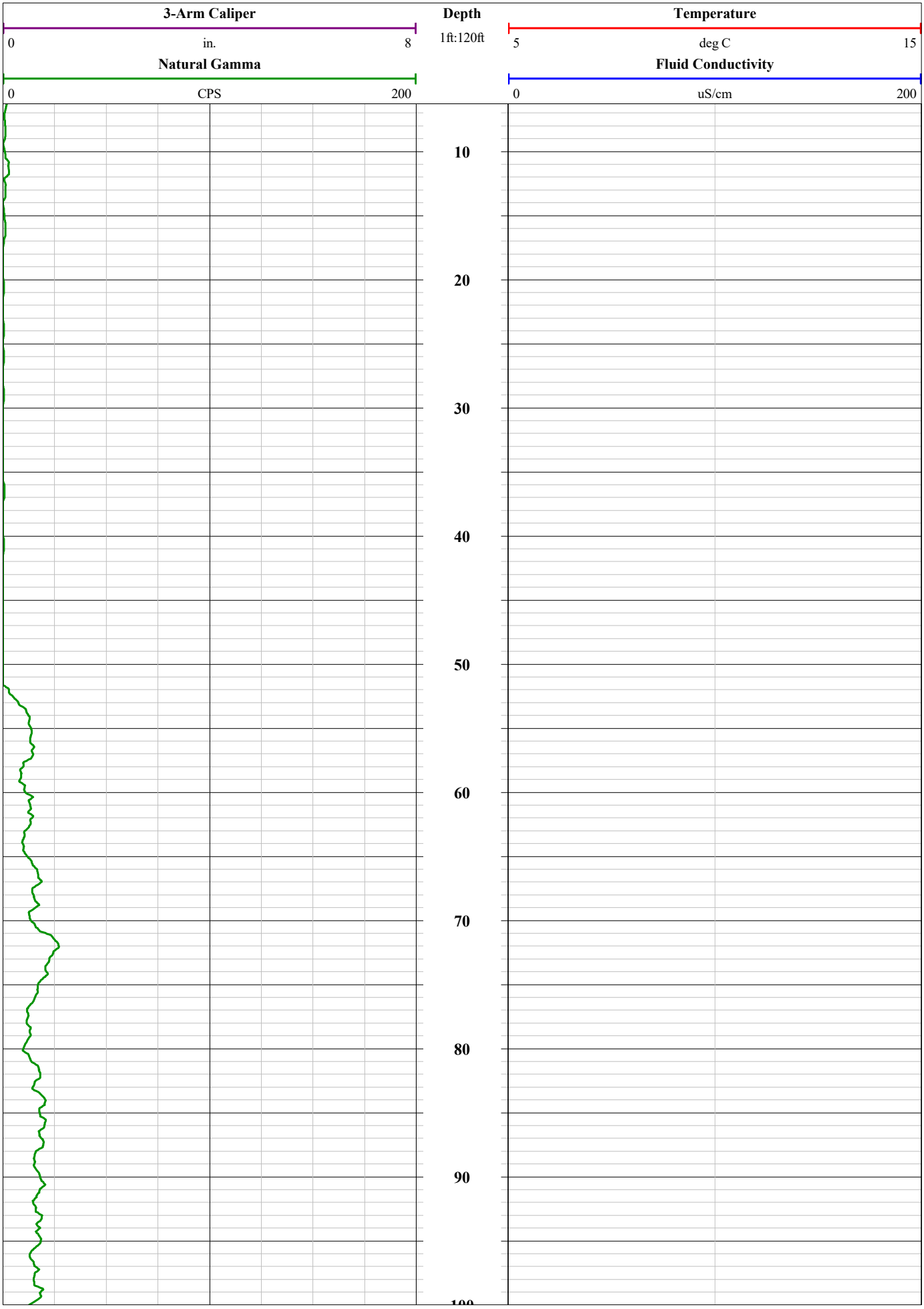
RUN No.	BIT	FROM	TO
1	HQ	235'	325'

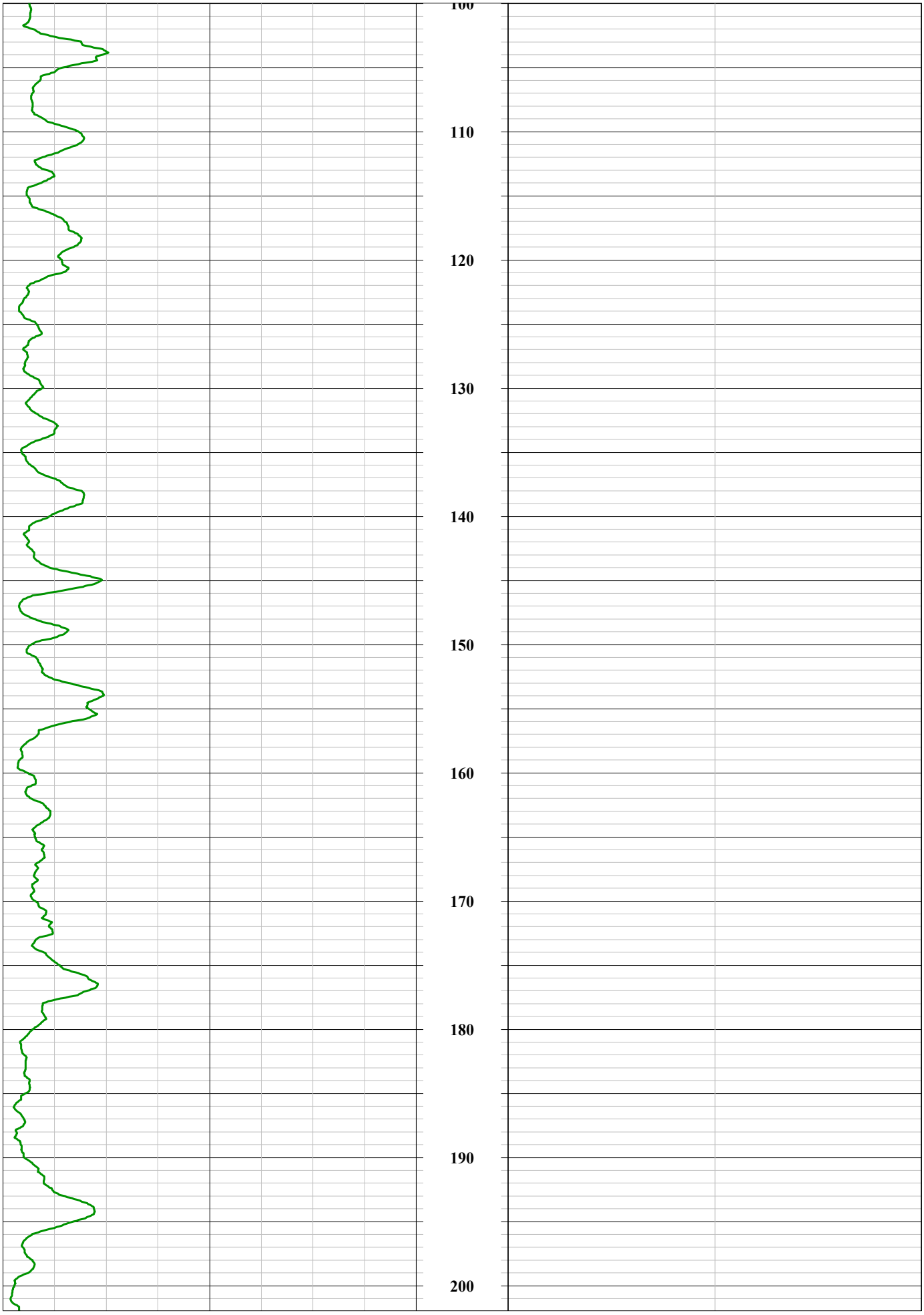
CASING RECORD

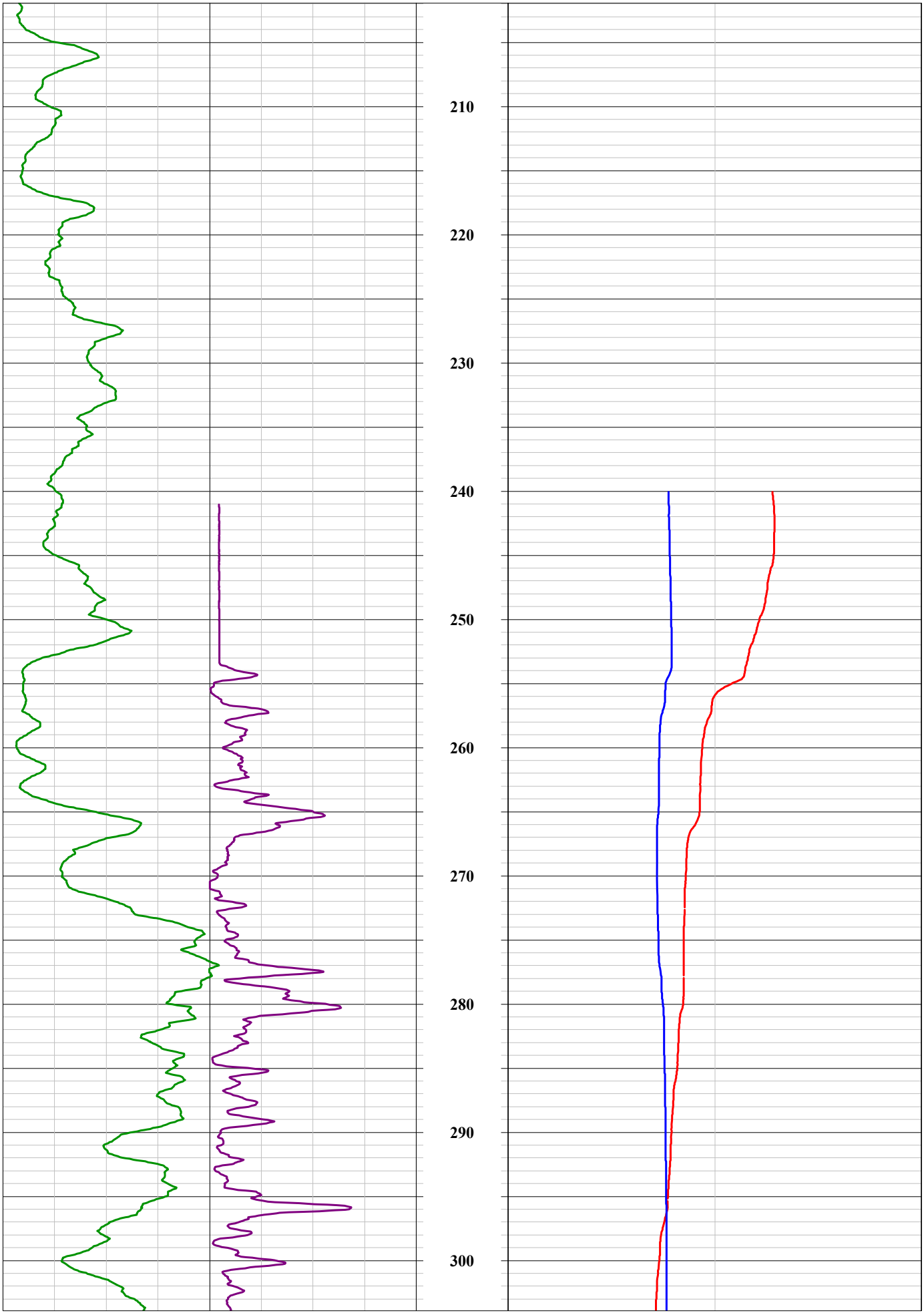
SIZE	WGT.	FROM	TO
7"	Steel	SU	70'
6"	Steel	SU	248'

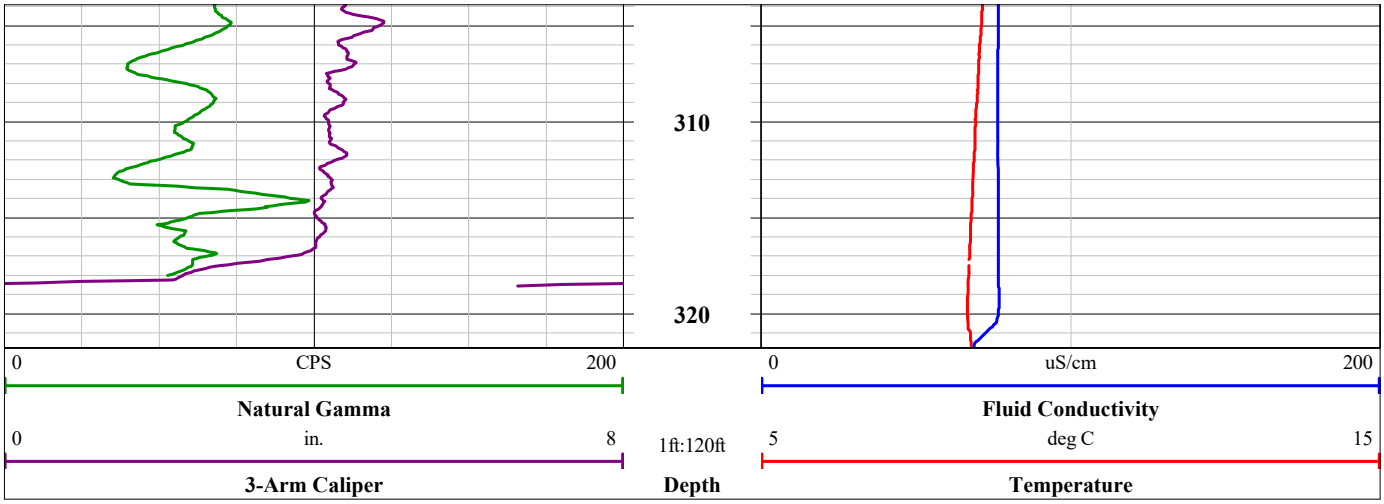
NA - Not Available, N/A - Not Applicable

COMMENTS


3-Arm Caliper
0
in.
8
Natural Gamma
0
CPS
200
Depth
1ft:120ft
10
20
30
40
50
60
70
80
90
100
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
200


100
110
120
130
140
150
160
170
180
190
200


210
220
230
240
250
260
270
280
290
300


310
320
0
CPS
200
Natural Gamma
0
in.
8
3-Arm Caliper
1ft:120ft
Depth
0
uS/cm
200
Fluid Conductivity
5
deg C
15
Temperature

Borehole Deviation

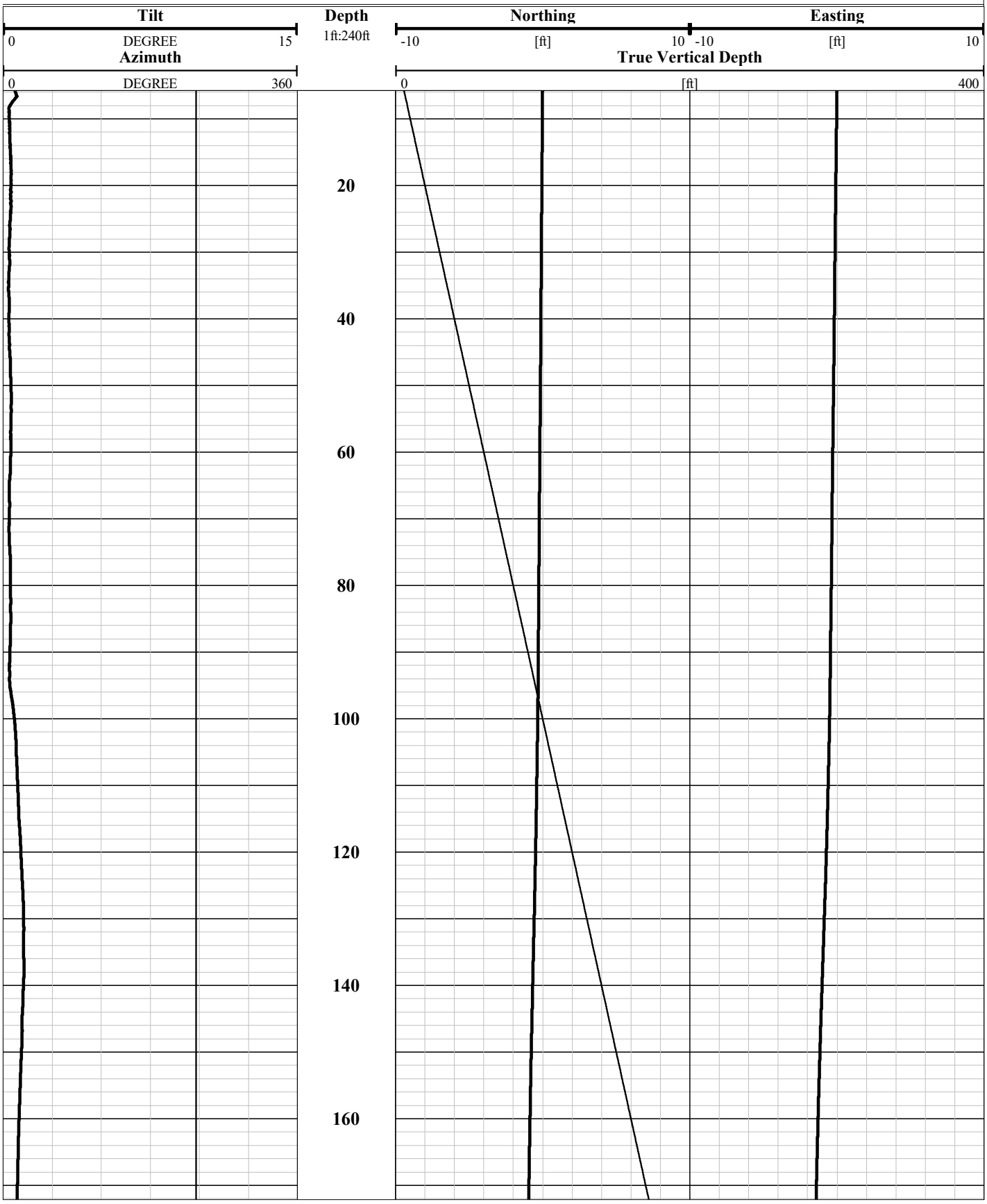
COLOG
borehole geophysics / hydrophysics

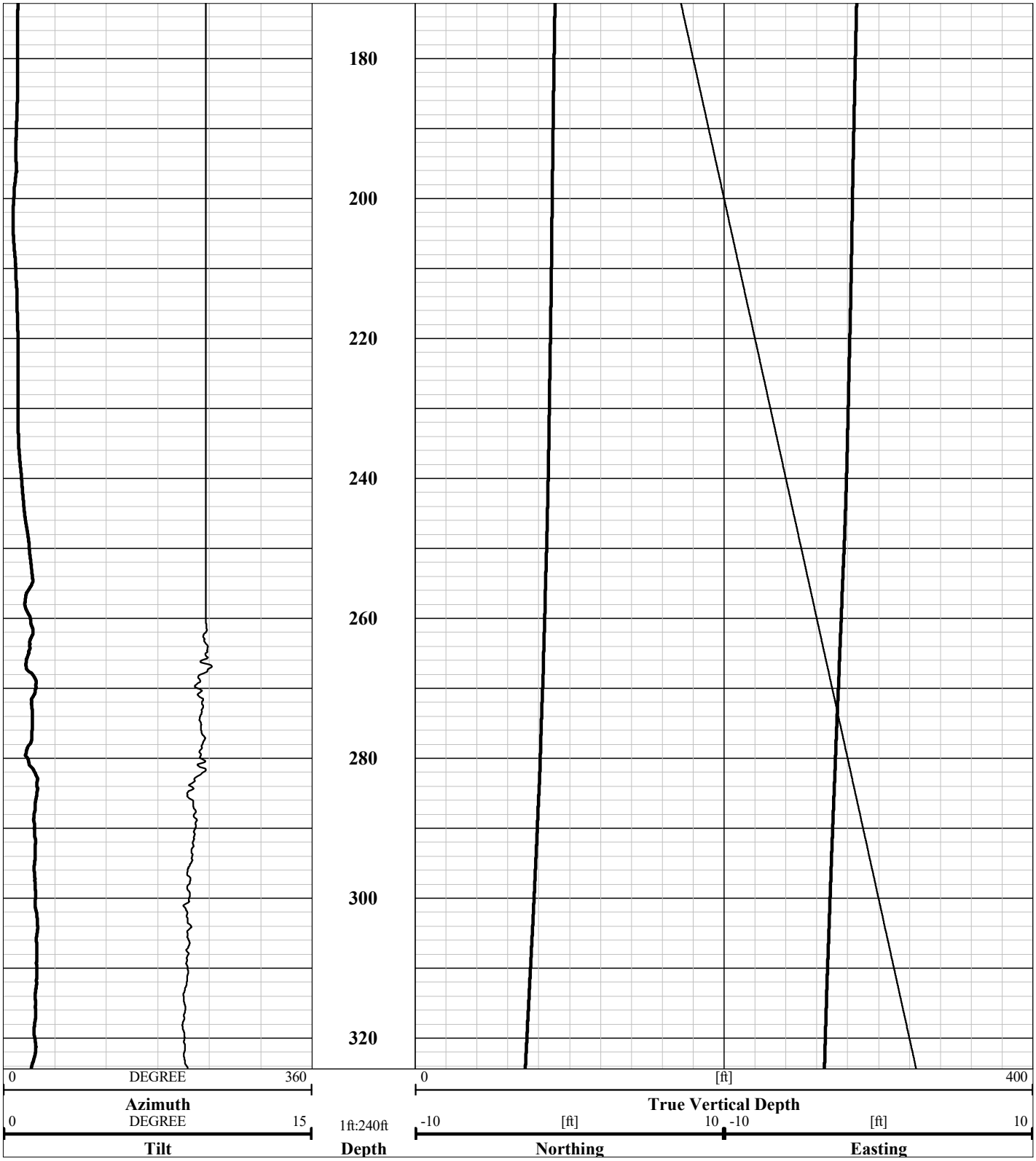
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 1 July 2019	WELL: BH19-16 - North Side

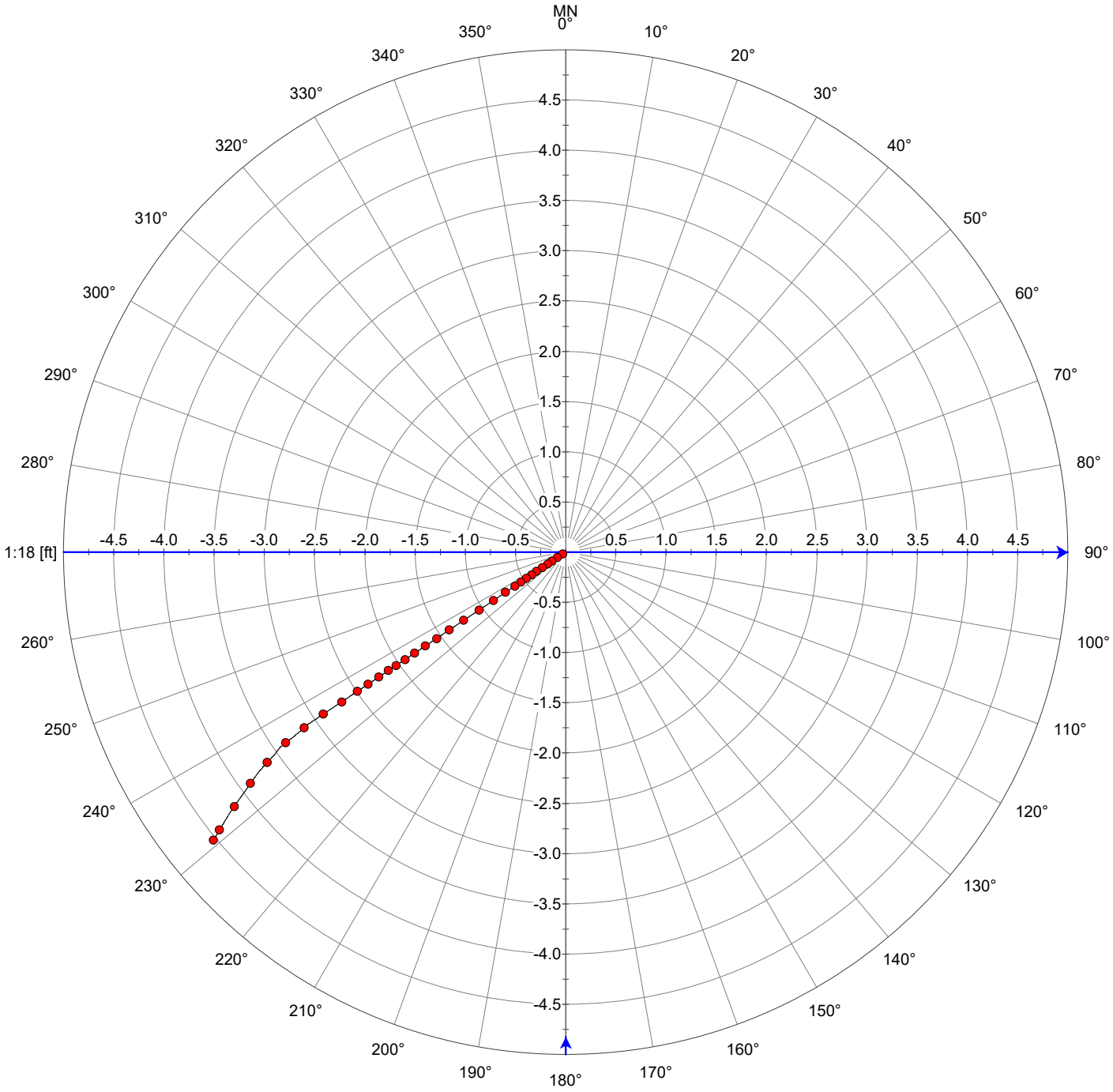
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 600.0'** **Latitude: 45.83164 N** **Longitude: 84.76097 W**




180
200
220
240
260
280
300
320
0
DEGREE
360
Azimuth
0
DEGREE
15
Tilt
1ft:240ft
Depth
0
[ft]
400
True Vertical Depth
-10
[ft]
10
Northing
-10
[ft]
10
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1:18 [ft]
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-16
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-16
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83164 N
Longitude: 84.76097 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.0'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	1 July 2019			
RUN NUMBER	2	2		
LOG TYPE	Natural Gamma	Eletcric Log		
DEPTH-DRILLER	325'	325'		
DEPTH-LOGGER	320'	320'		
BTM LOG INTERVAL	318.1'	319.4'		
TOP LOG INTERVAL	6.4'	252.4'		
RECORDED BY	CKL/JBG	CKL/JBG		
WITNESSED BY				
PROBE TYPE, S/N	ELXG 4248	ELXG 4248		
LOGGING SPEED	20ft/min	20ft/min		
A.S.D.E. / Sample Interval	0.5'/0.25'	0.5'/0.25'		
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

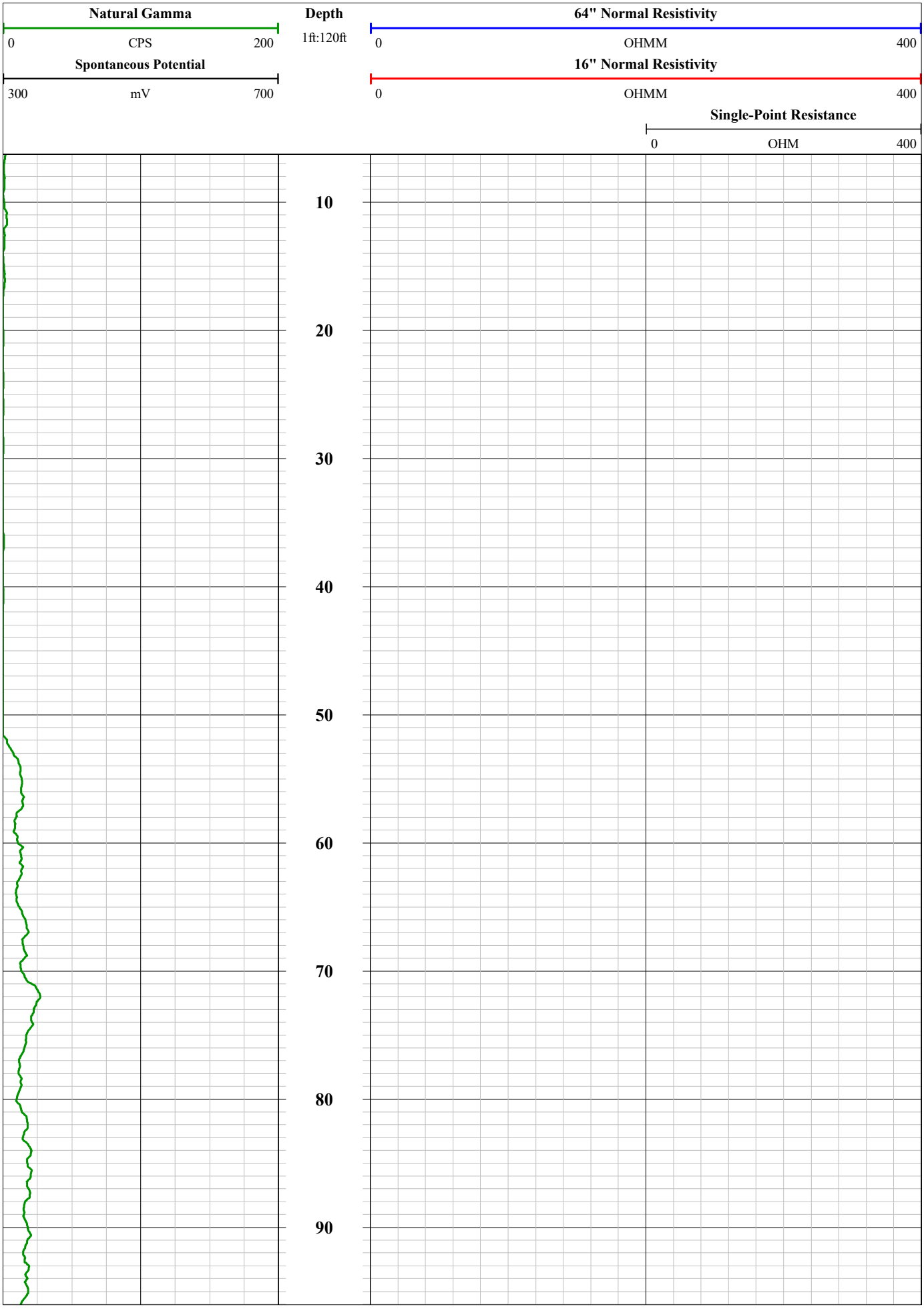
RUN No.	BIT	FROM	TO
1	HQ	253'	325'

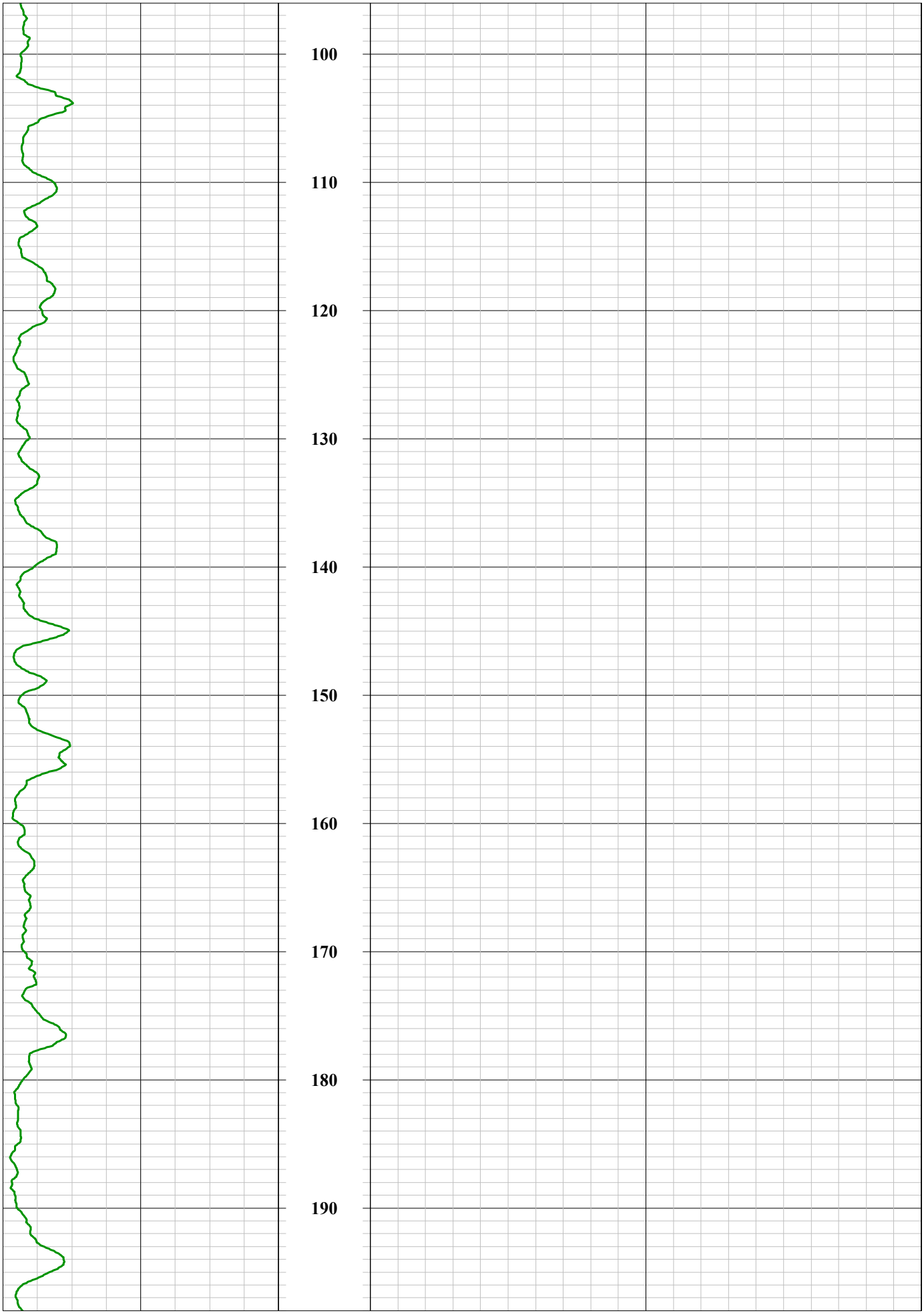
CASING RECORD

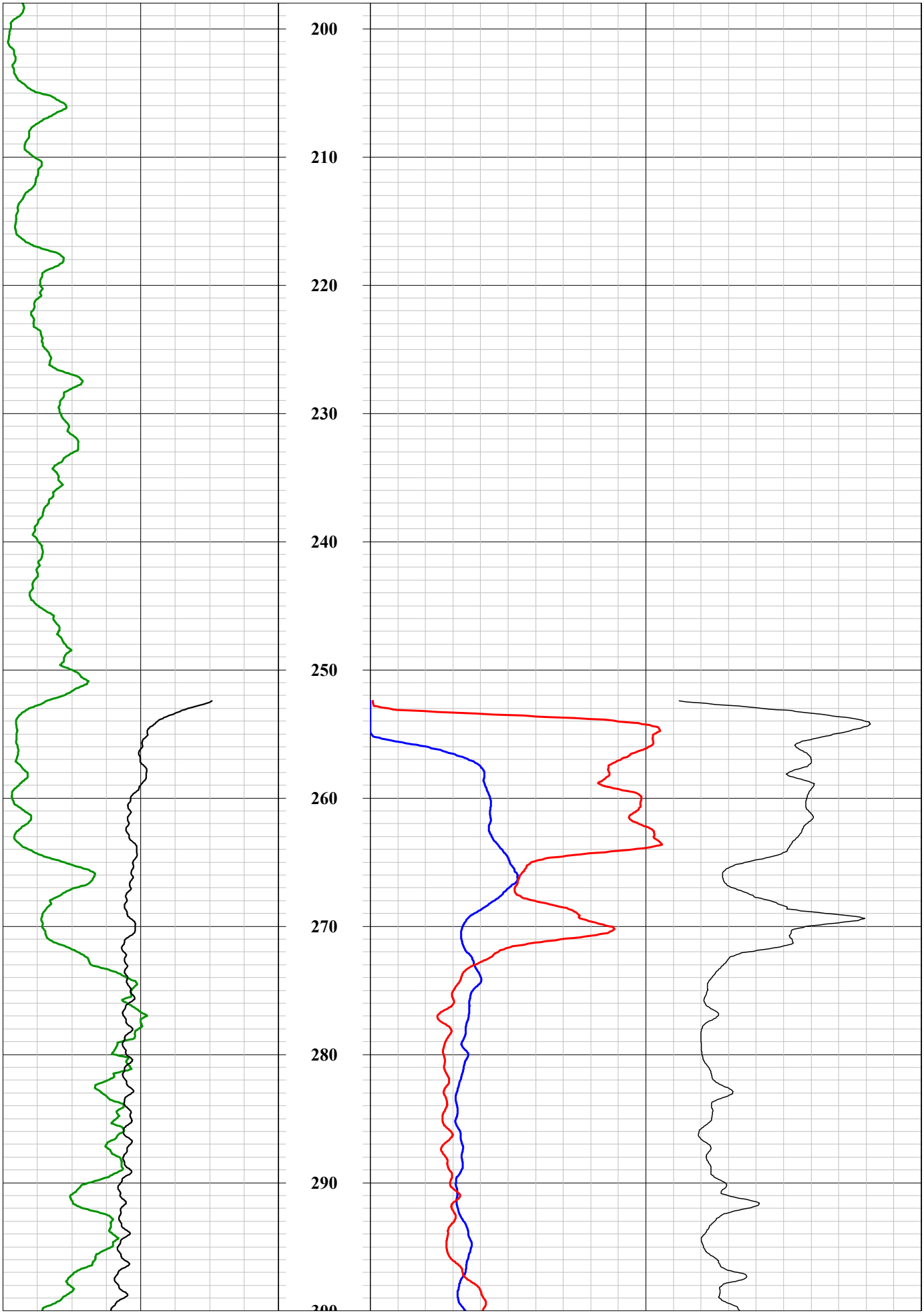
SIZE	WGT.	FROM	TO
7"	Steel	SU	70'
6"	Steel	SU	248'

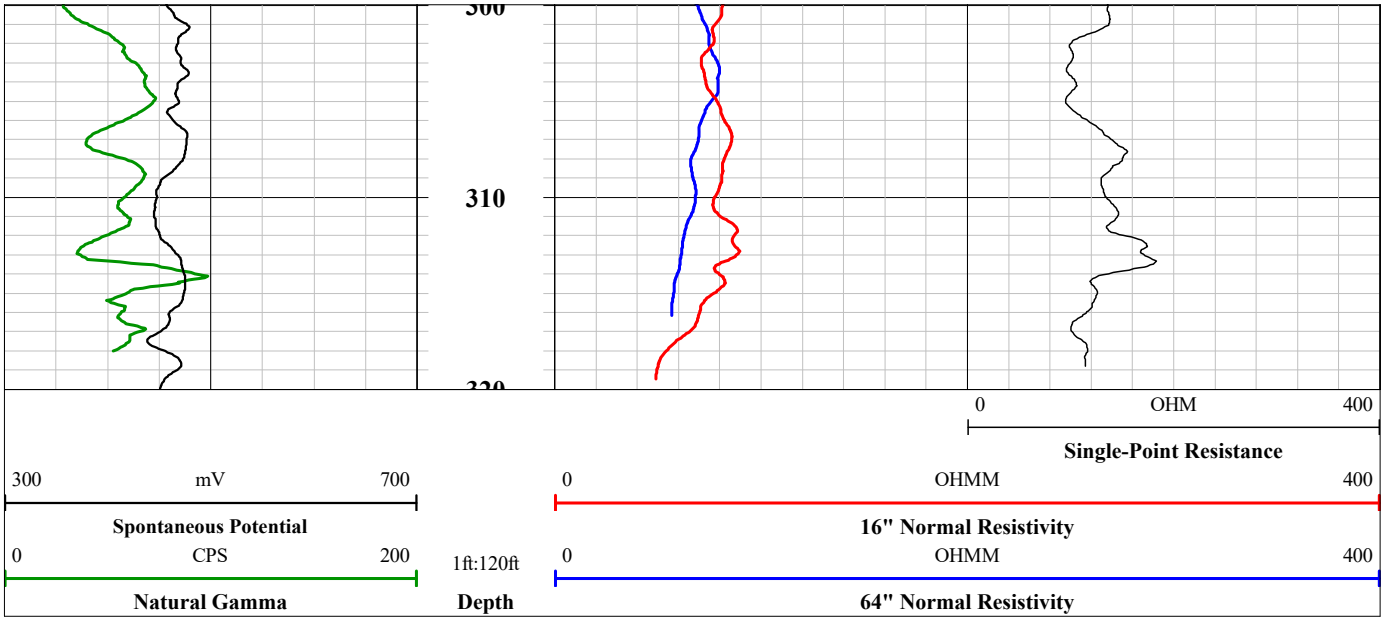
NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
200
Spontaneous Potential
300
mV
700
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
400
16" Normal Resistivity
0
OHMM
400
Single-Point Resistance
0
OHM
400
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
320
0
OHM
400
Single-Point Resistance
300
mV
700
Spontaneous Potential
0
OHMM
400
16" Normal Resistivity
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
OHMM
400
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-16
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-16
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.83164 N
Longitude: 84.76097 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond.
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.0'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	17 July 2019			
RUN NUMBER	1			
LOG TYPE	P&S Log			
DEPTH-DRILLER	325'			
DEPTH-LOGGER	310'			
BTM LOG INTERVAL	310'			
TOP LOG INTERVAL	248'			
RECORDED BY	CKL/JBG			
WITNESSED BY				
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

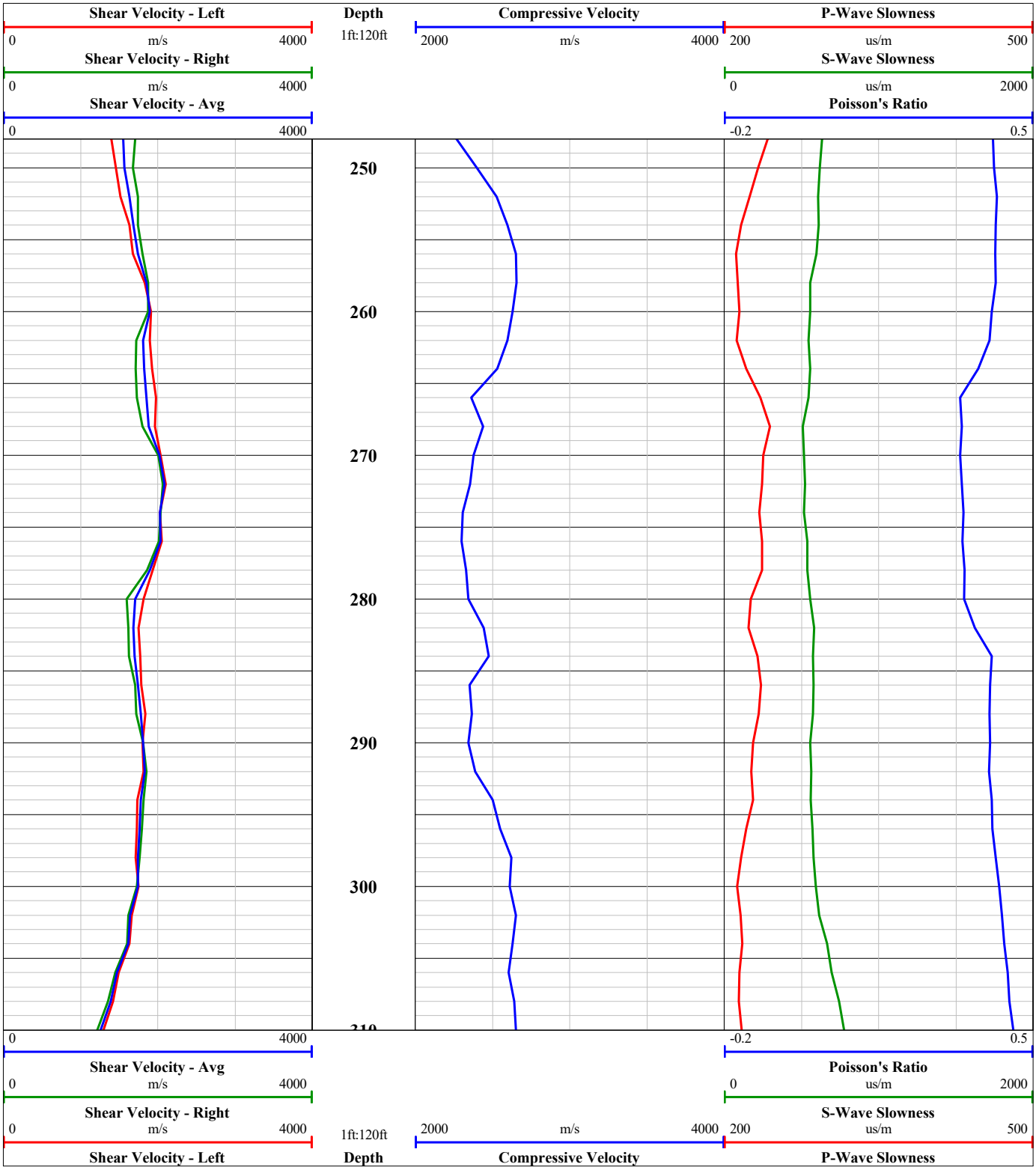
RUN No.	BIT	FROM	TO
1	HQ	253'	325'

CASING RECORD

SIZE	WGT.	FROM	TO
7"	Steel	SU	70'
6"	Steel	SU	248'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
4000
Depth
1ft:120ft
Compressive Velocity
2000
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-0.2
0.5
250
260
270
280
290
300
310
0
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
2000
m/s
4000
Compressive Velocity
-0.2
0.5
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness

PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-16**	Test depth:	**294.00 ft**
Test date: (mm/dd/yyyy)	**6/30/2019**	C :	0.9546 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	ΔR/R$_{0\ Probe}$ %
0	0.00	502	0.00	0.00
-7	17.79	460	17.80	0.47
1472	205.99	1300	204.58	5.22
2011	217.63	1793	215.71	5.50
2858	230.69	2588	227.96	5.80
4178	245.81	3848	241.82	6.15
5736	260.60	5357	255.13	6.48
7562	275.56	7139	268.34	6.80
9520	290.15	9054	281.06	7.11
11905	305.60	11393	294.24	7.43
14396	321.59	13838	307.85	7.77
16557	335.55	15958	319.74	8.05
18601	350.57	17958	332.81	8.37

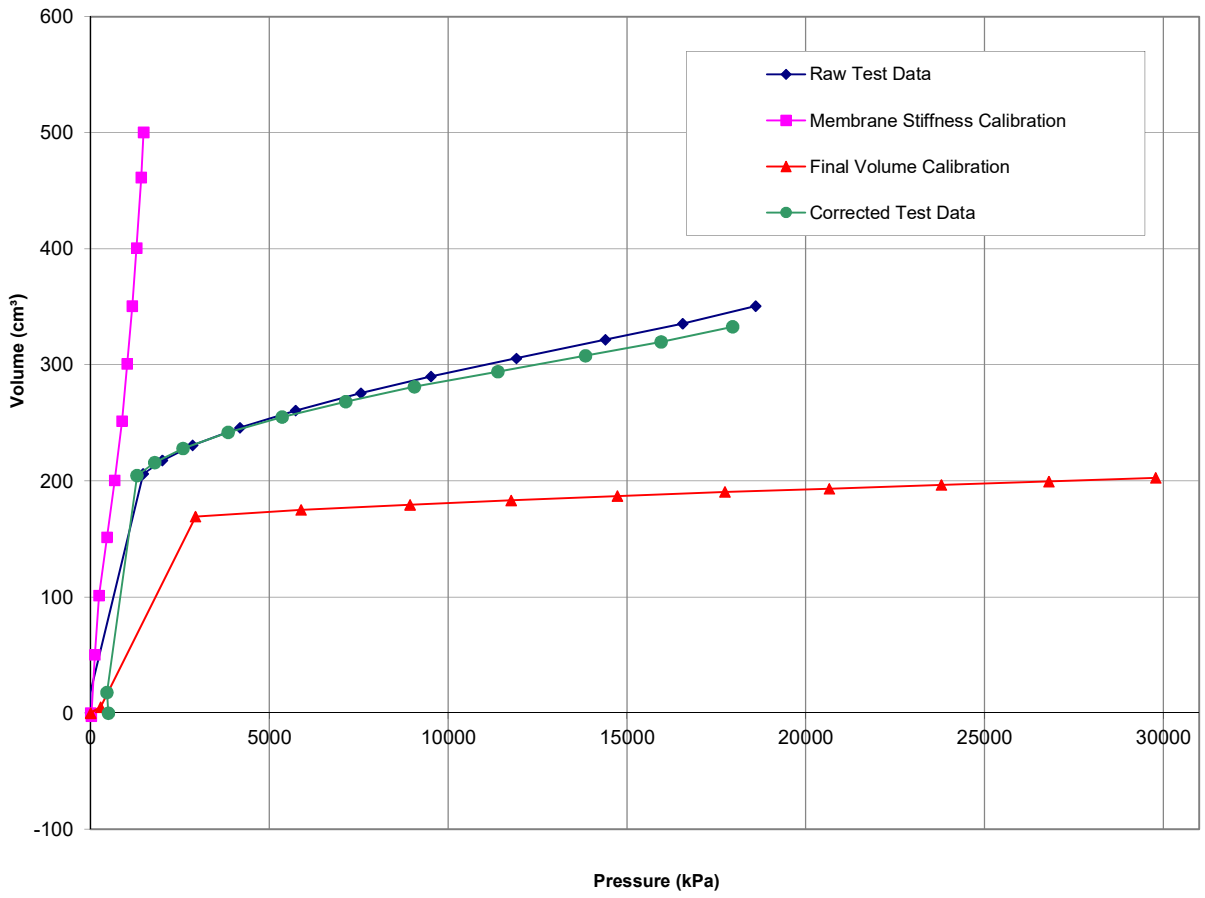
Test Results

PROBEX Modulus E:	**893,801 kPa**
Ultimate Pressure P_L:	**52,475**
Ratio E / P_L:	**17.03**

Volume & Pressure Calibrations ID

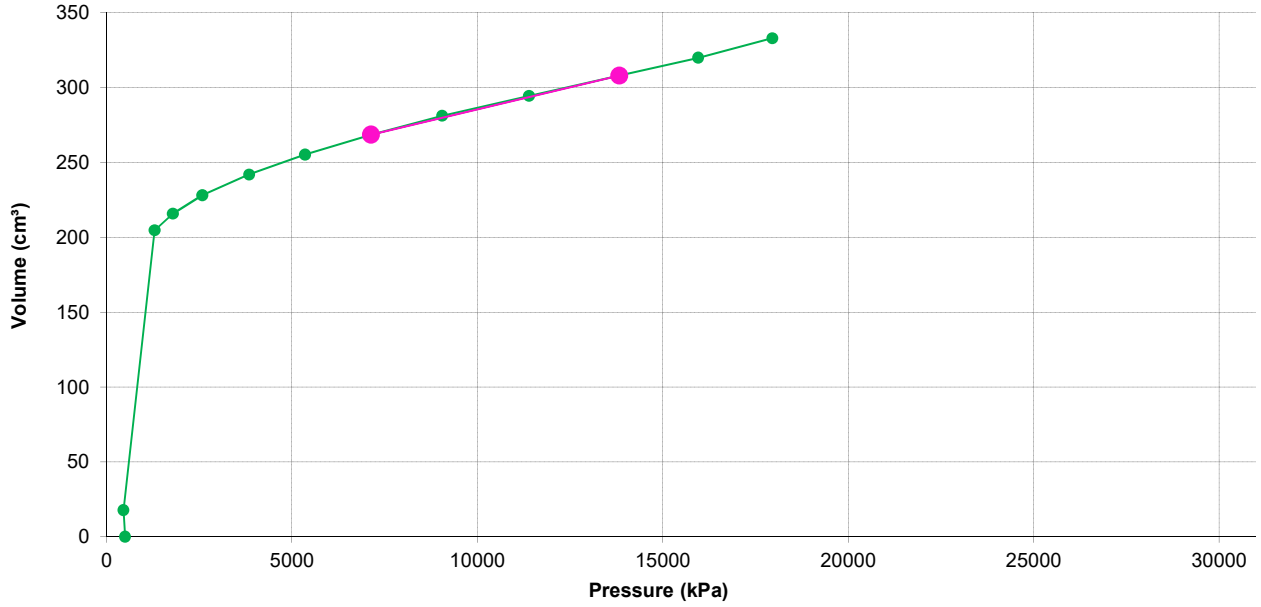
CalV3	CalP1

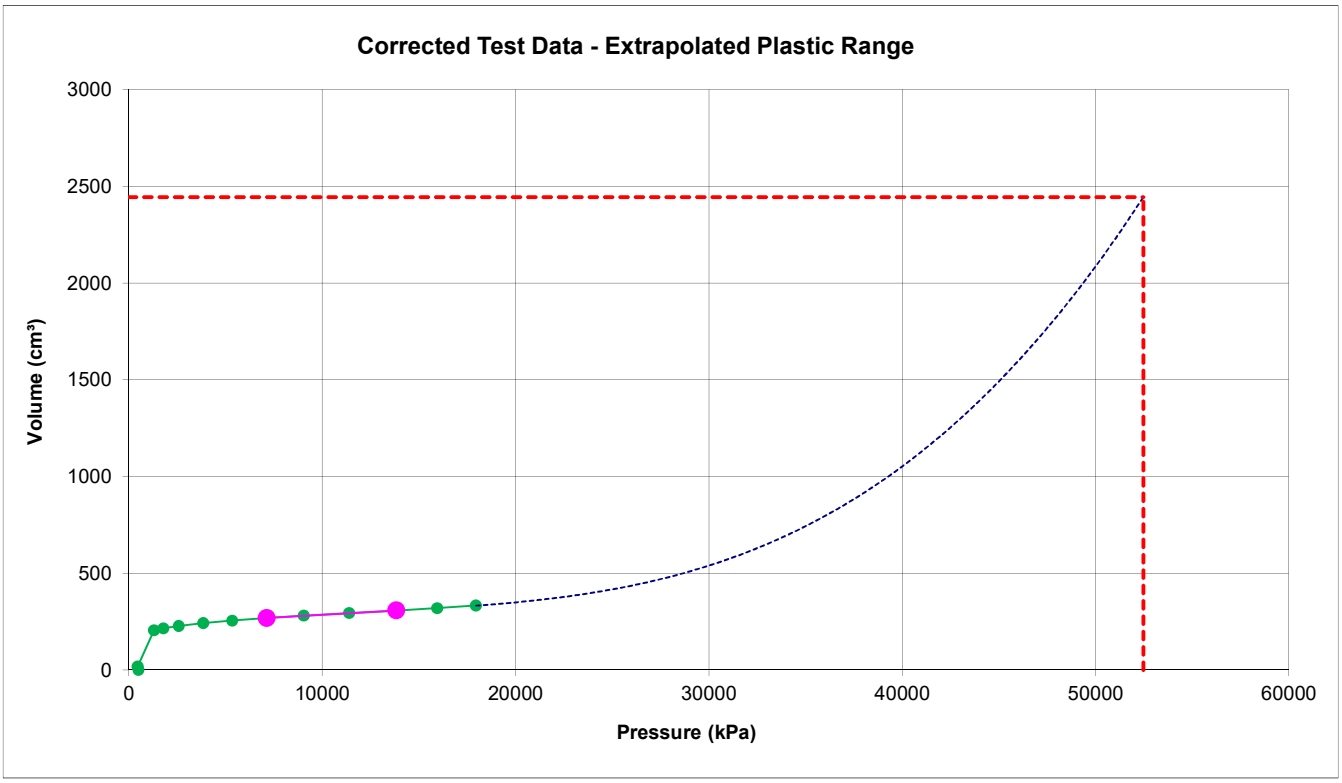
Test Data with Calibration Curves

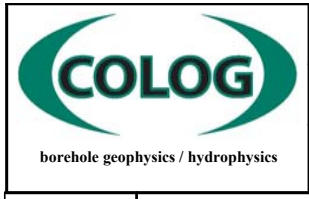


PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-16**	Test depth:	**294.00 ft**
Test date: (mm/dd/yyyy)	**6/30/2019**	C :	0.9546 cc/MPa
Test number:	1	Poisson's coefficient	0.20







Geophysical Summary Plot

COMPANY: WSP

PROJECT: L5RT Project

DATE LOGGED: 4 - 13 July 2019

WELL: BH19-17 - North Side

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN	Tadpoles - MN
1ft:100ft	0 CPS 200	0 OHMM 2000	0 m/s 4000	100 us/m 600	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	64" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 Inch 8	0 OHMM 1000	0 m/s 4000	0 us/m 2000			
	Temperature	Single-Point Resistance	Shear Velocity - Avg	Poisson's Ratio			
	0 deg C 50	0 OHM 1000	0 m/s 4000	-0.5 0.5			
	Fluid Conductivity		Compressive Velocity				
	0 uS/cm 1000		1000 m/s 6000				

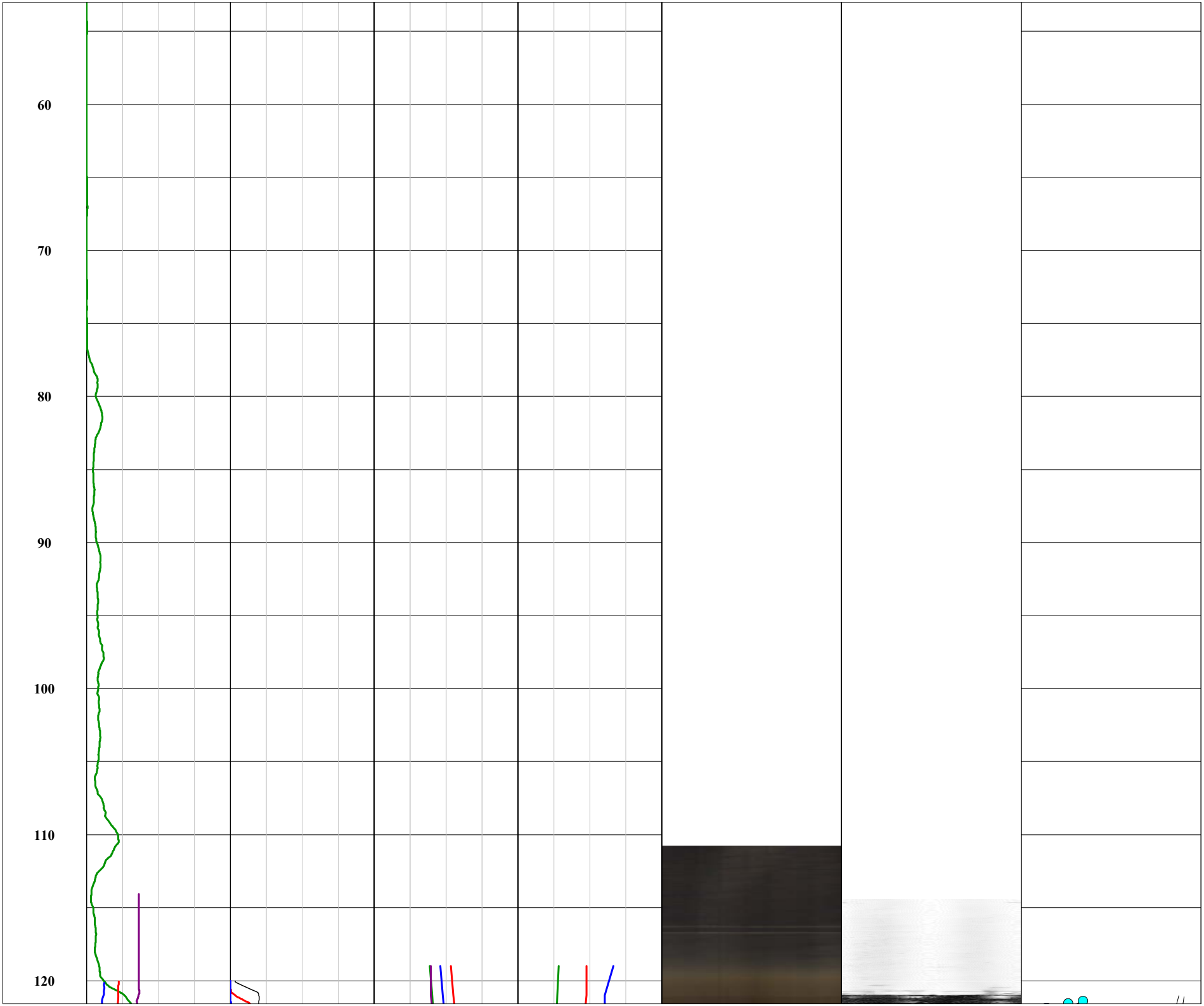
10

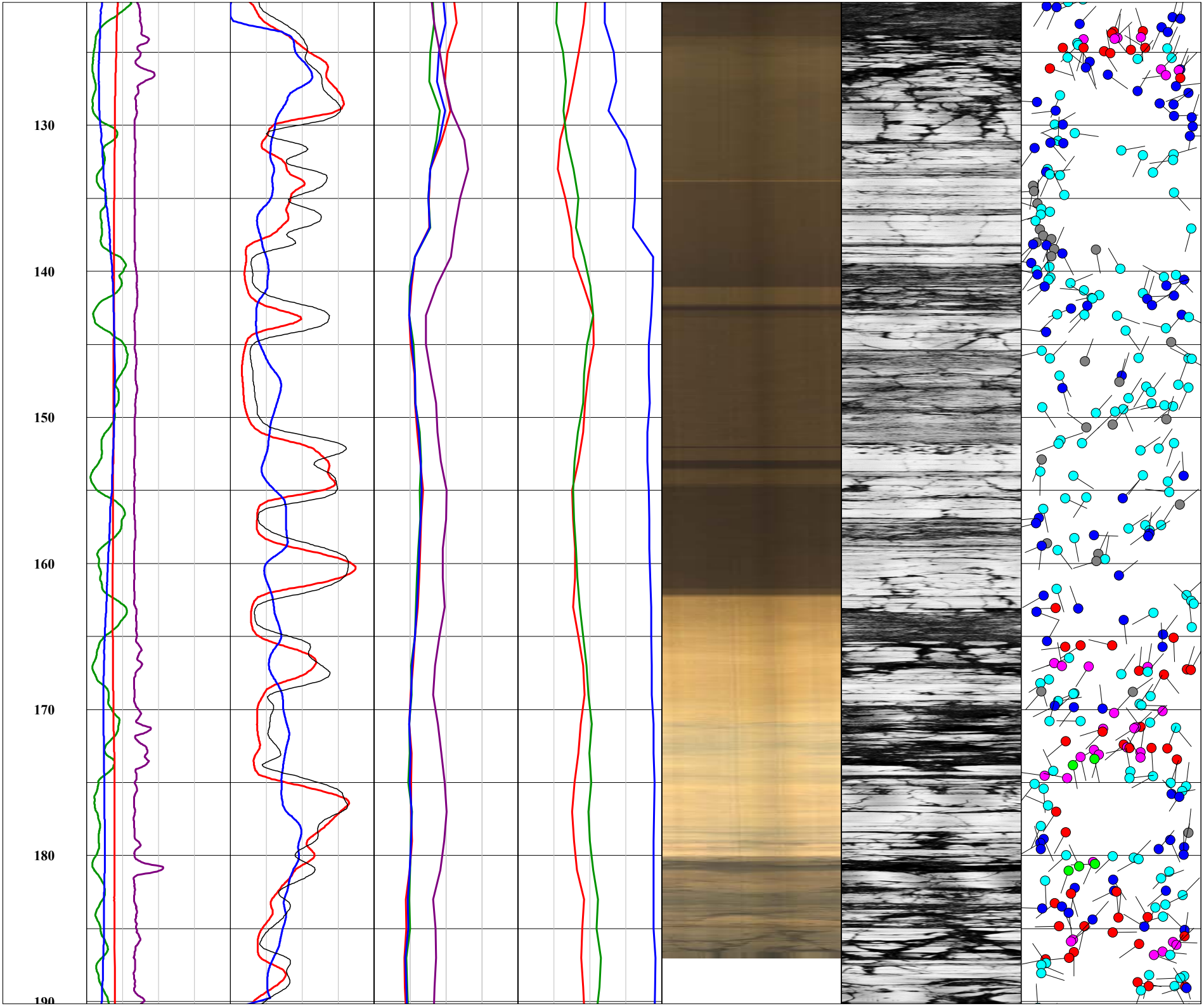
20

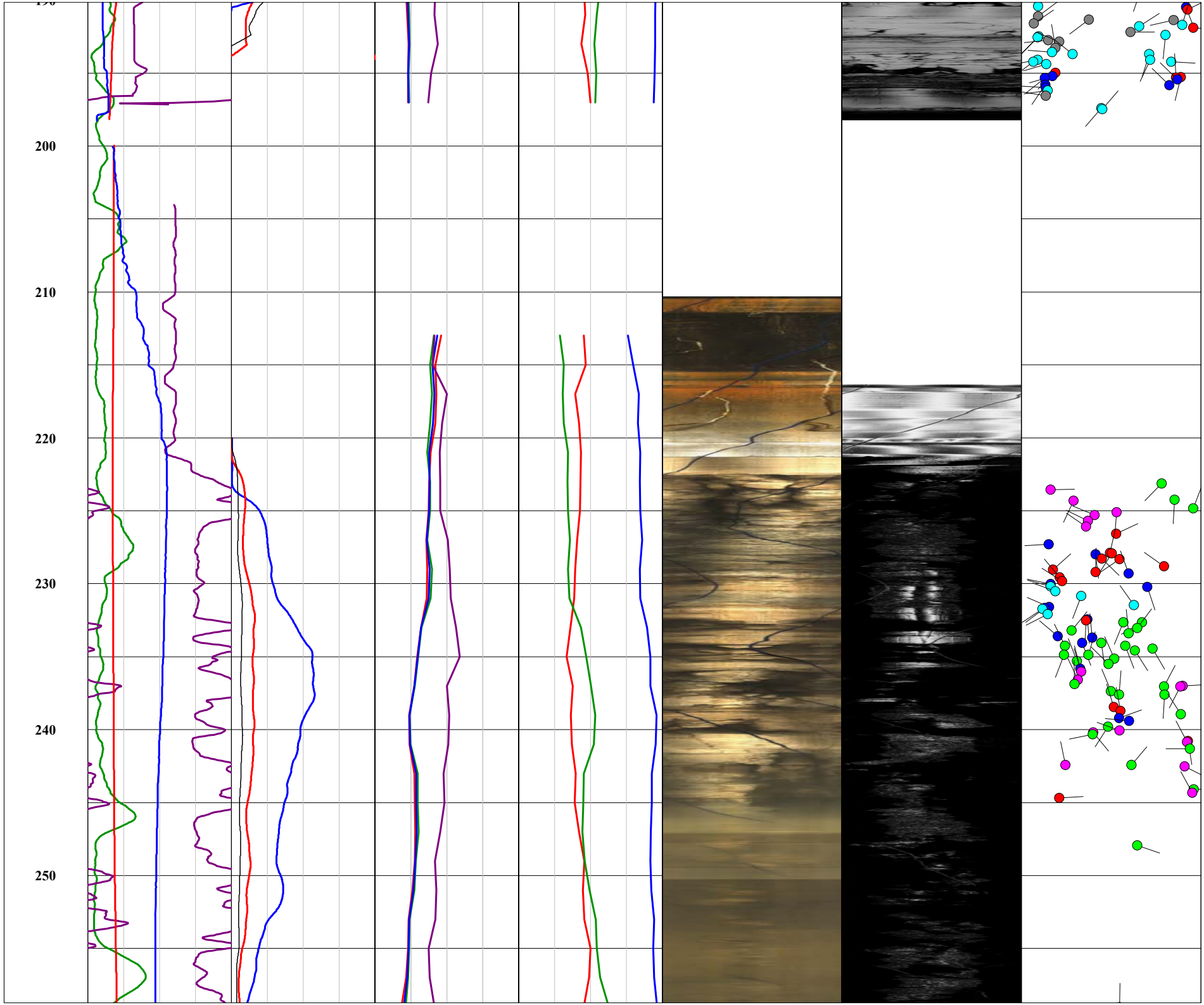
30

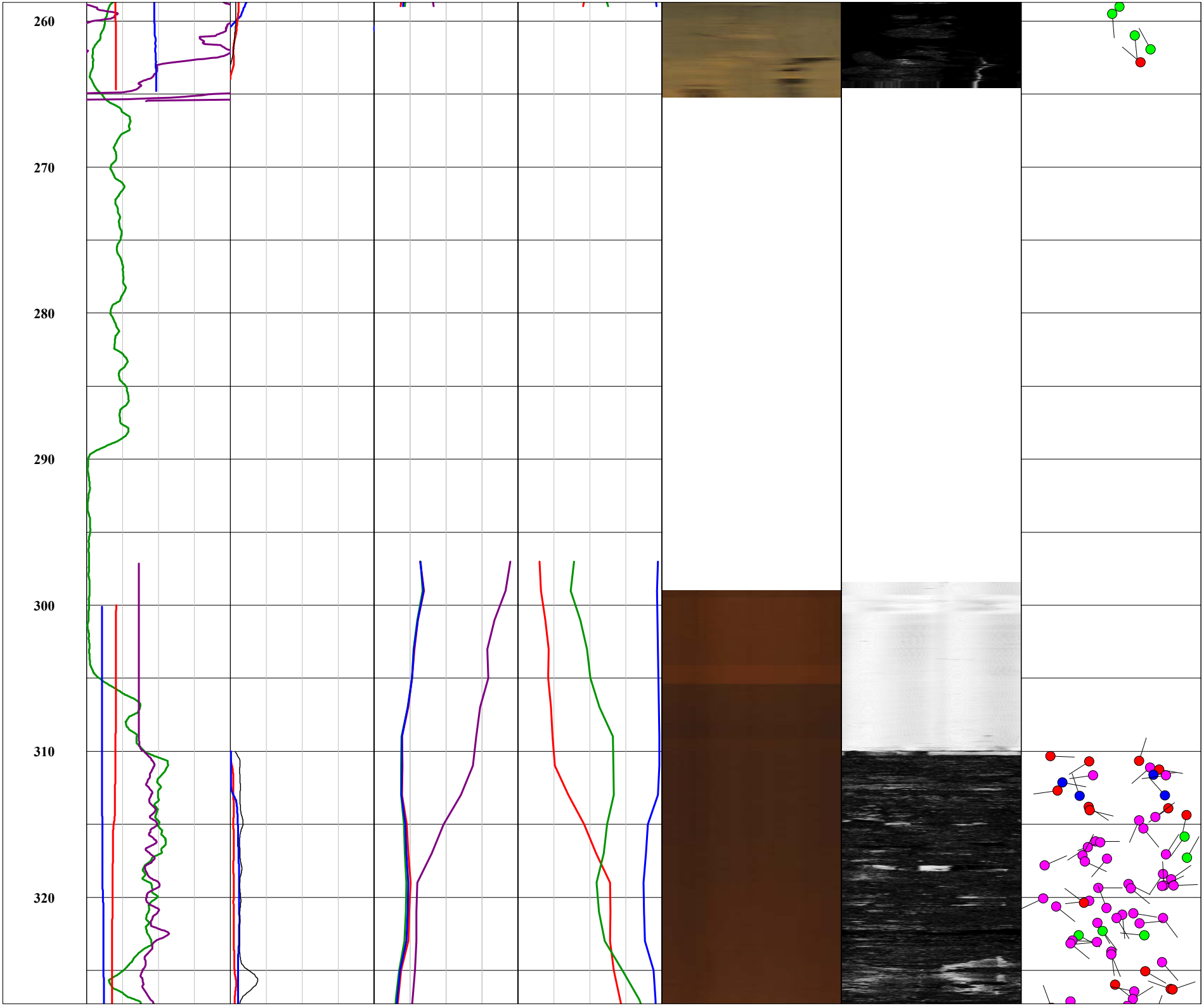
40

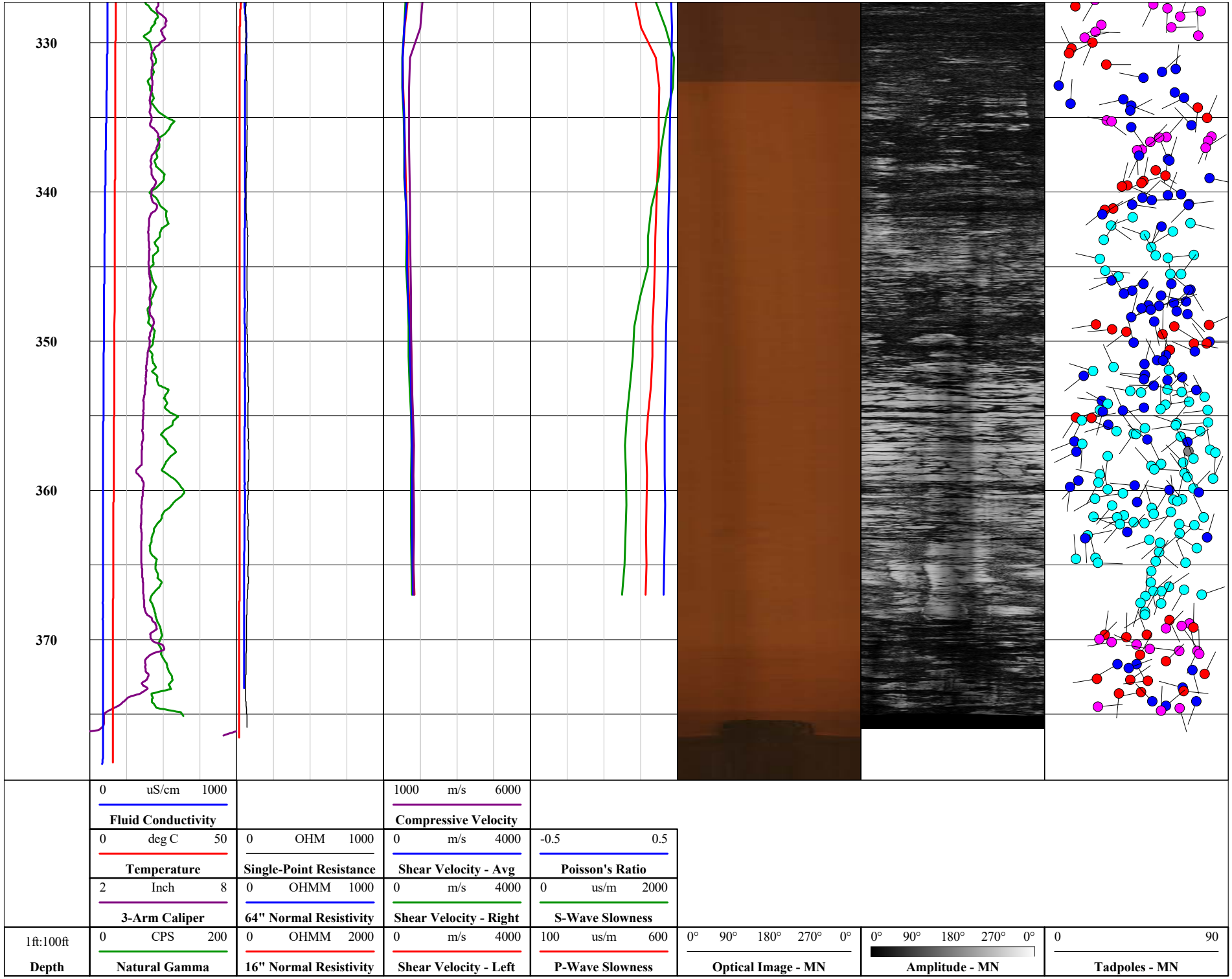
50


60
70
80
90
100
110
120


130
140
150
160
170
180
190


200
210
220
230
240
250


260
270
280
290
300
310
320


330
340
350
360
370
0 uS/cm 1000
Fluid Conductivity
1000 m/s 6000
Compressive Velocity
0 deg C 50
Temperature
0 OHM 1000
Single-Point Resistance
0 m/s 4000
Shear Velocity - Avg
-0.5 0.5
Poisson's Ratio
2 Inch 8
3-Arm Caliper
0 OHMM 1000
64" Normal Resistivity
0 m/s 4000
Shear Velocity - Right
0 us/m 2000
S-Wave Slowness
1ft:100ft
Depth
0 CPS 200
Natural Gamma
0 OHMM 2000
16" Normal Resistivity
0 m/s 4000
Shear Velocity - Left
100 us/m 600
P-Wave Slowness
0° 90° 180° 270° 0°
Optical Image - MN
0° 90° 180° 270° 0°
Amplitude - MN
0 90
Tadpoles - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-17
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-17
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.82875 N
Longitude: 84.76084 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 599.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	4-13 July 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	380'			
DEPTH-LOGGER	378'			
BTM LOG INTERVAL	376.8'			
TOP LOG INTERVAL	115'			
RECORDED BY	CKL,BEH,JBG			
WITNESSED BY				
PROBE TYPE, S/N	OBI LIM #1729			
LOGGING SPEED	4.5			
A.S.D.E. / Sample Interval	0.13' / 0.0024'			
Fluid Level / Fluid Type	16'/water			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	380'

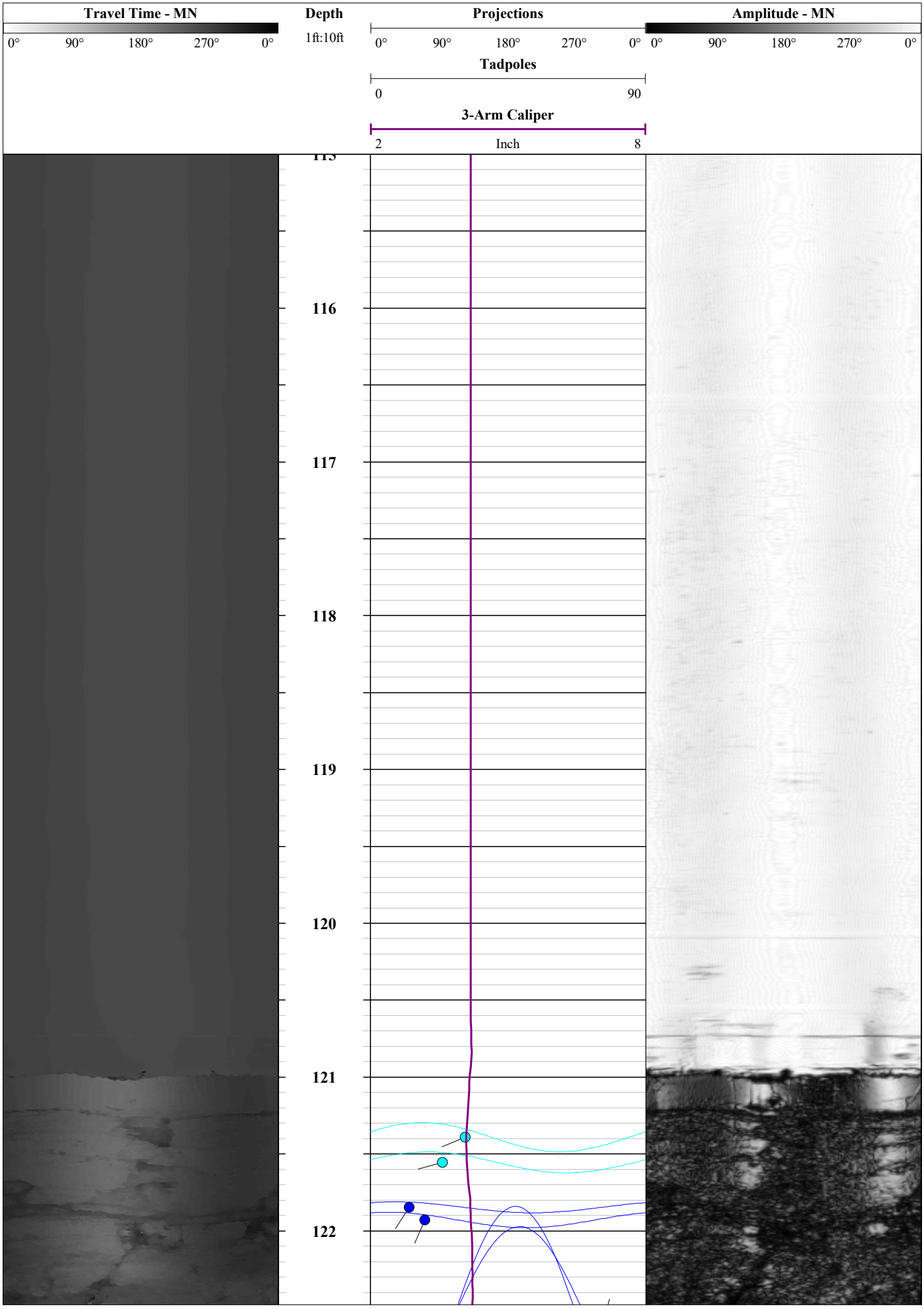
CASING RECORD

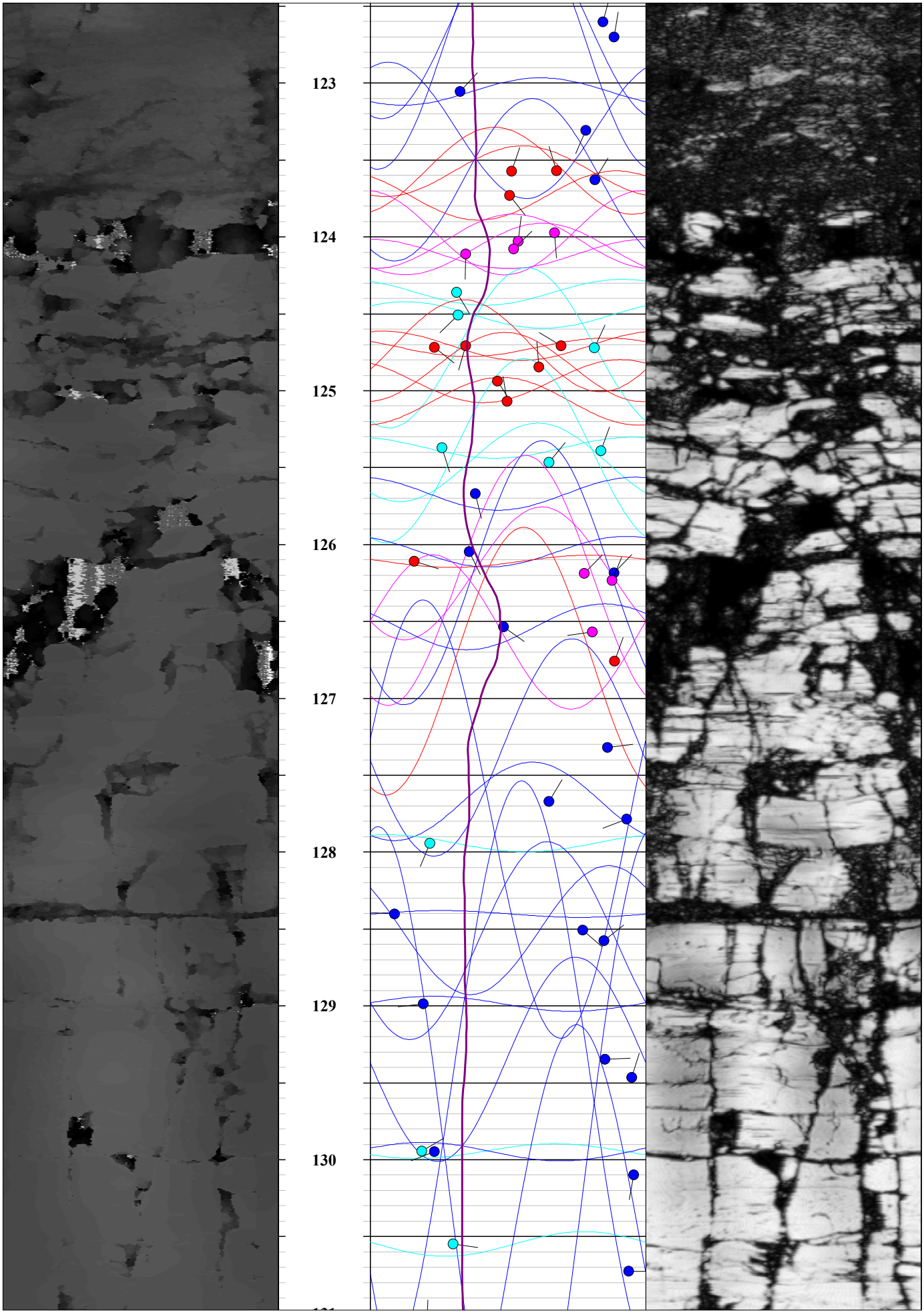
SIZE	WGT.	FROM	TO
PQ	Steel	0'	120'

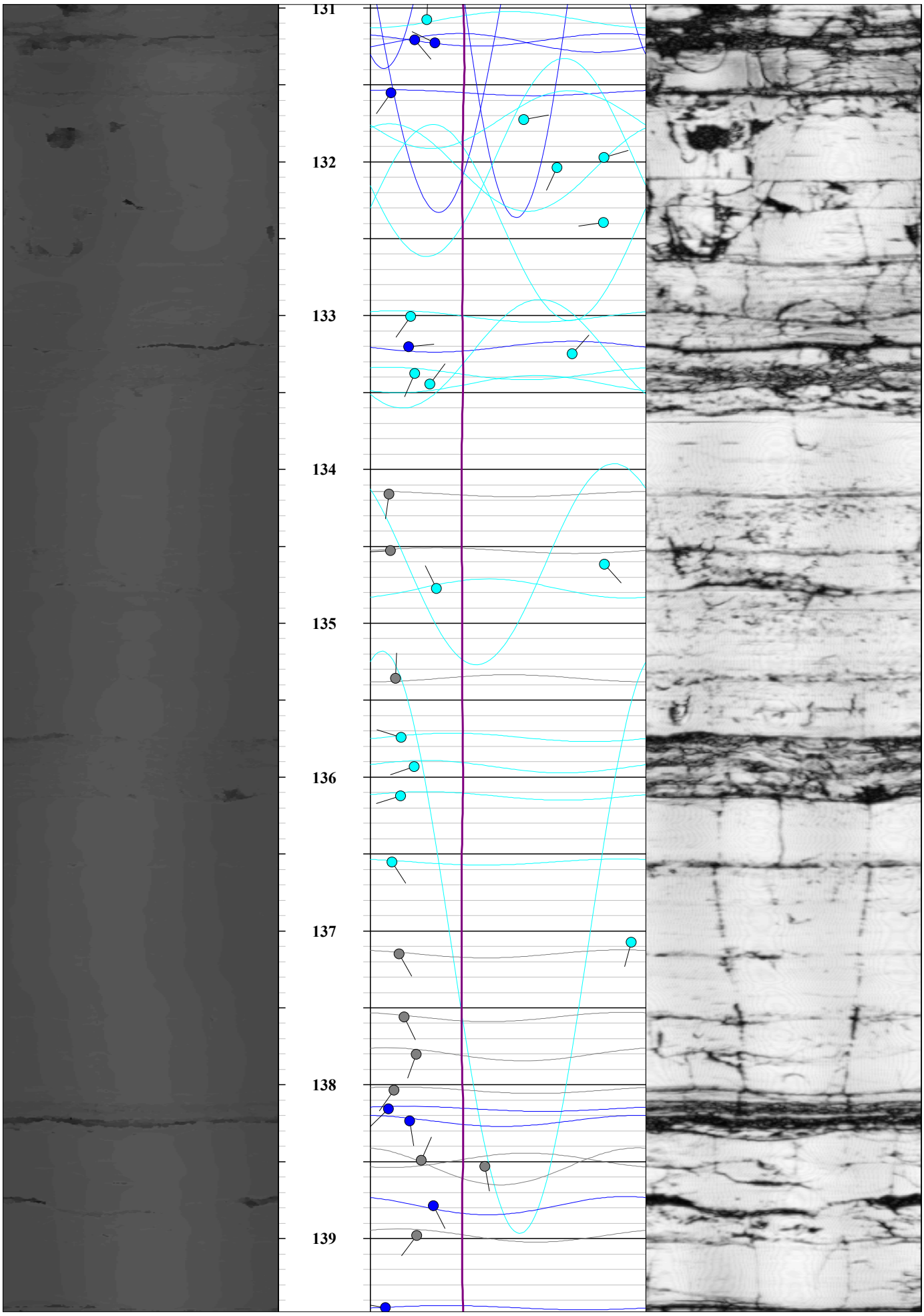
NA - Not Available, N/A - Not Applicable

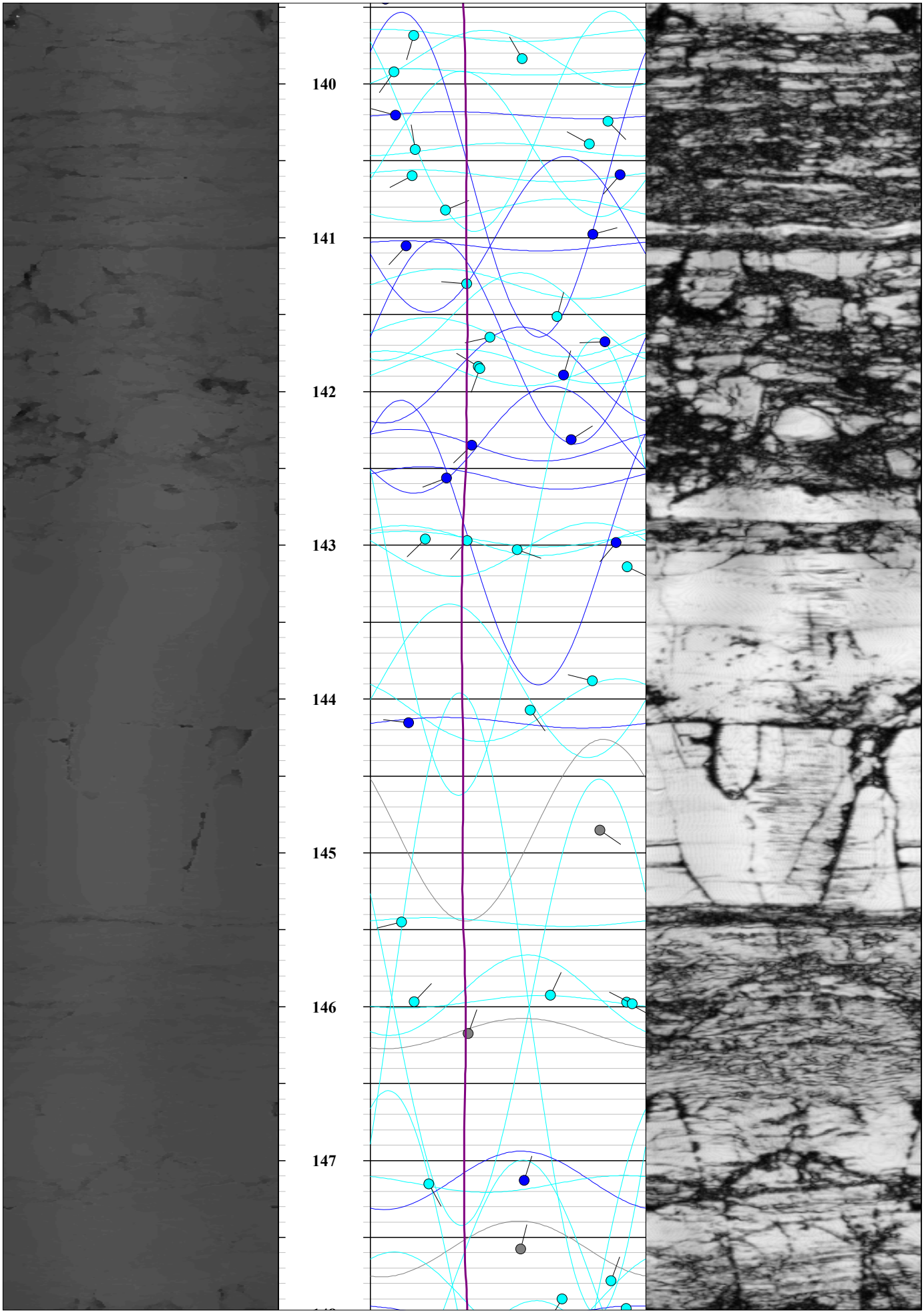
COMMENTS

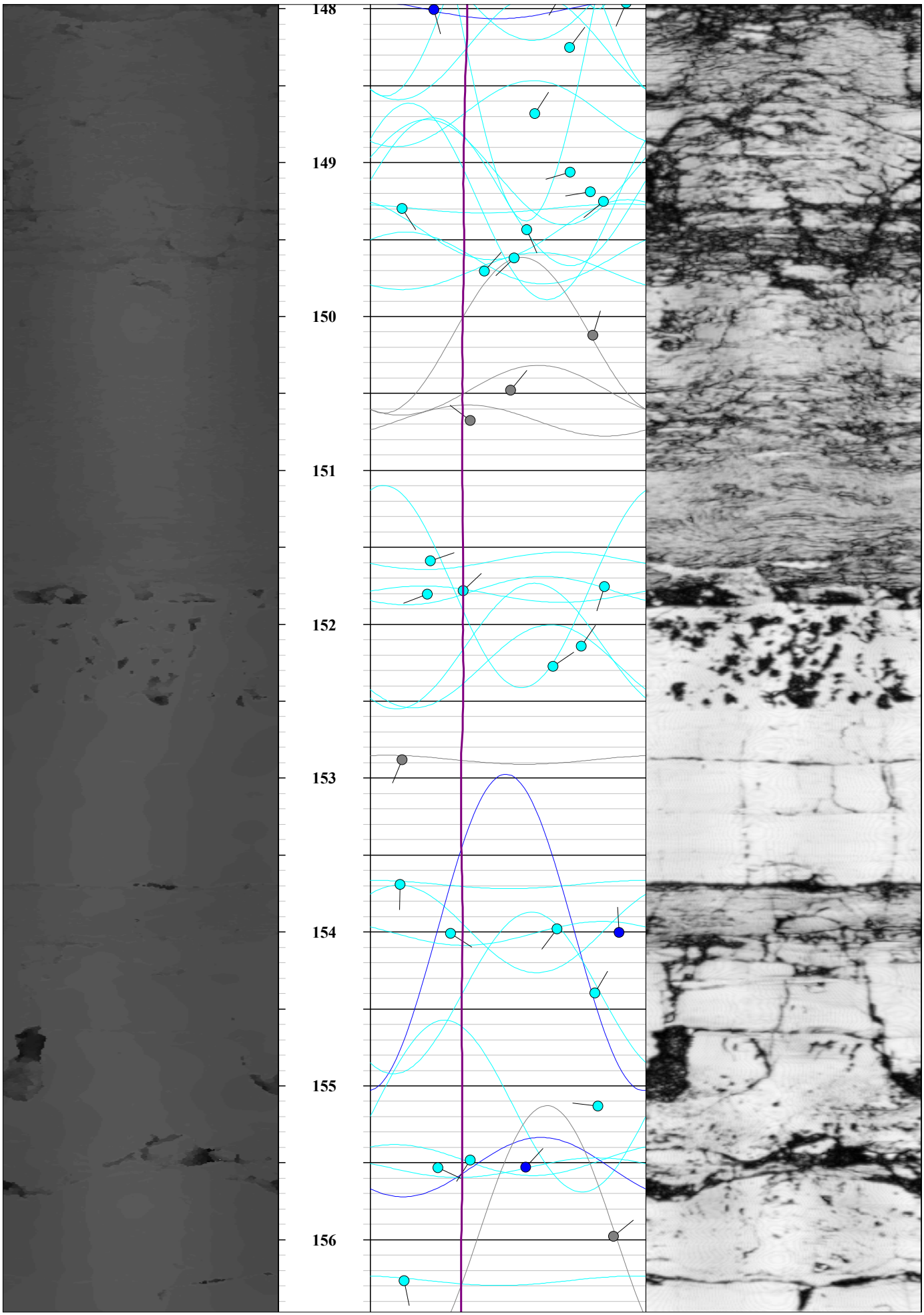
Hole severly damaged in center section due to collapse and dropped packer that is still in the hole, reason for missing areas of data.

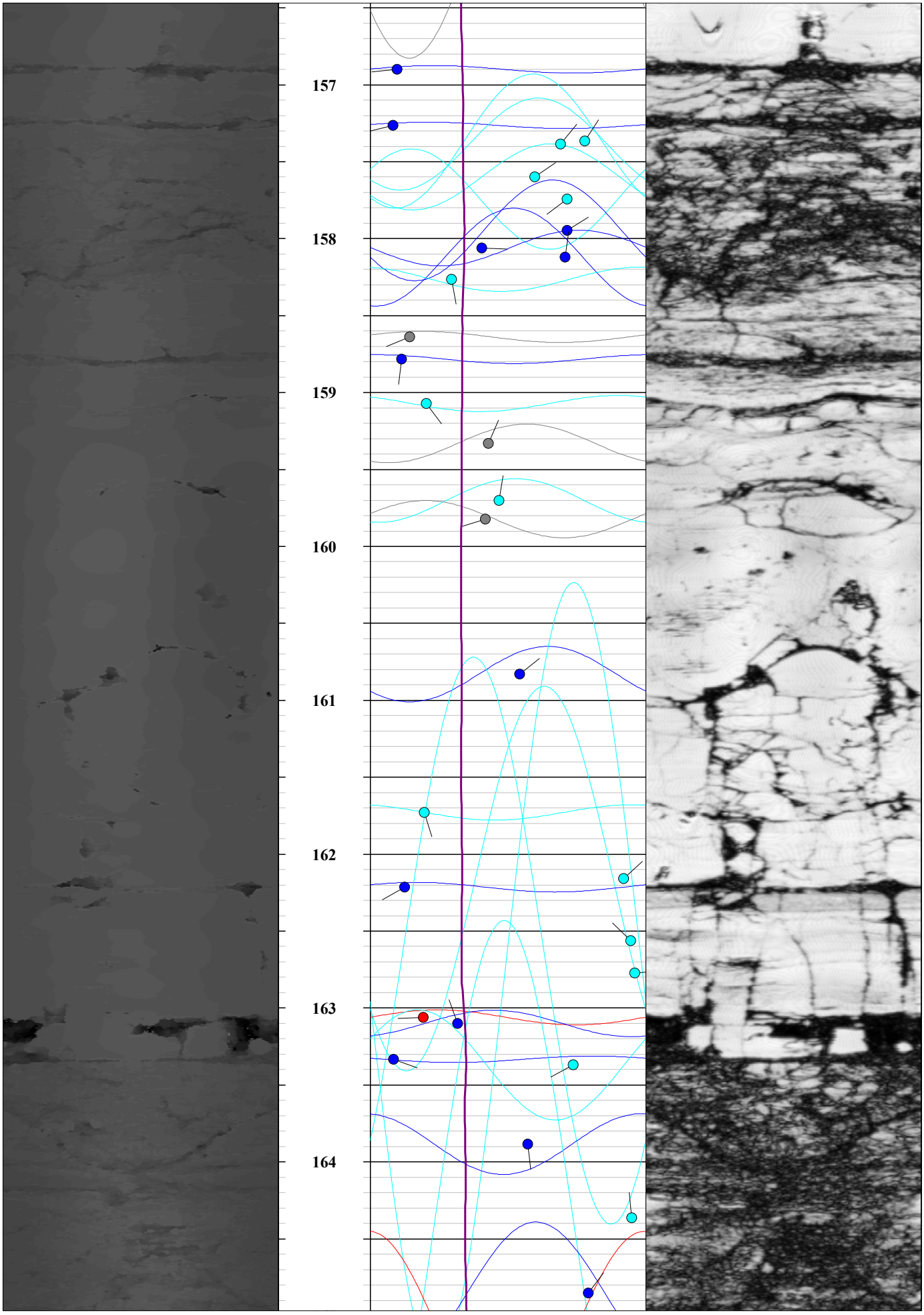

Travel Time - MN
0°
90°
180°
270°
0°
Depth
1ft:10ft
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
3-Arm Caliper
2
Inch
8
Amplitude - MN
0°
90°
180°
270°
0°
116
117
118
119
120
121
122

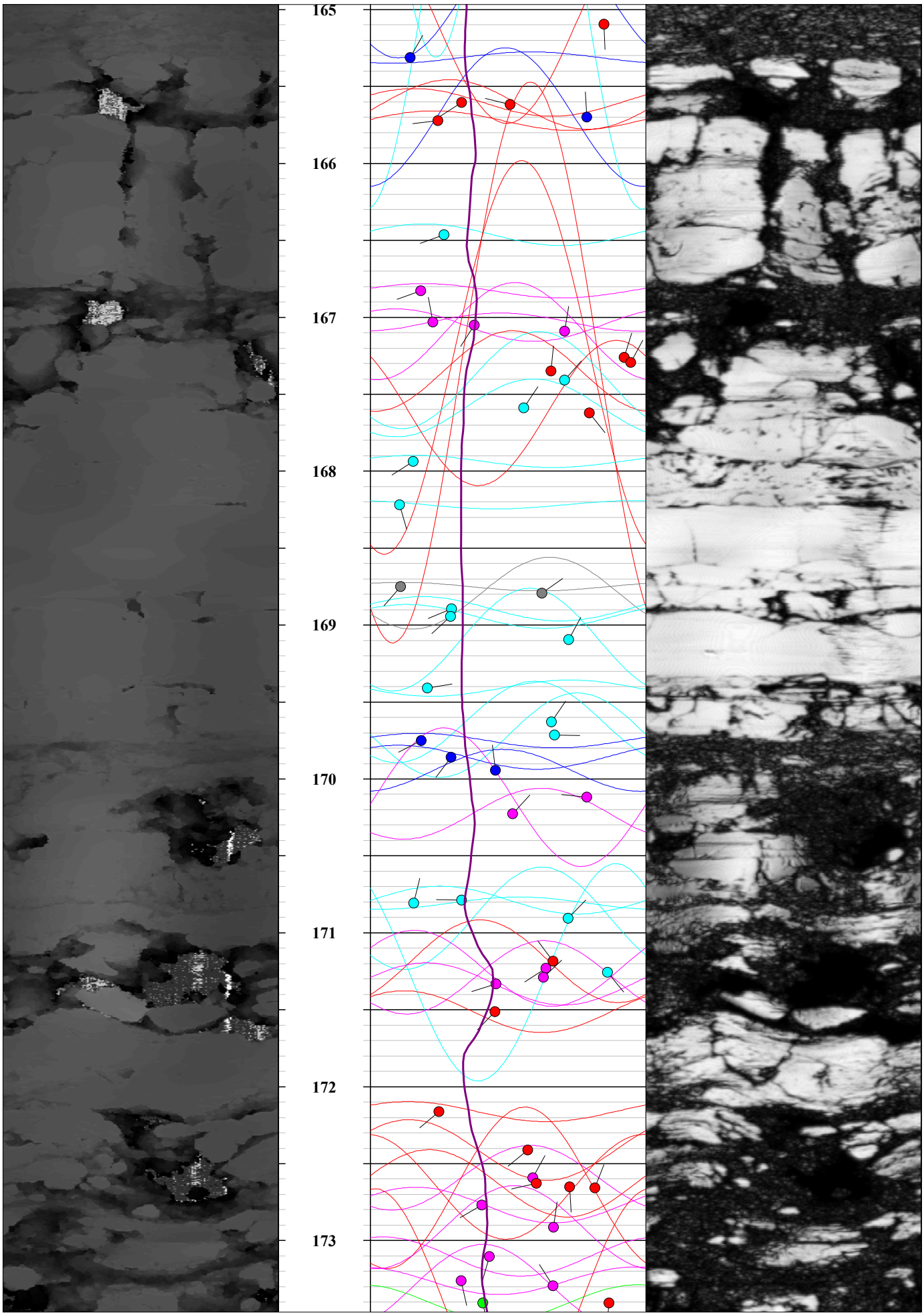

123
124
125
126
127
128
129
130

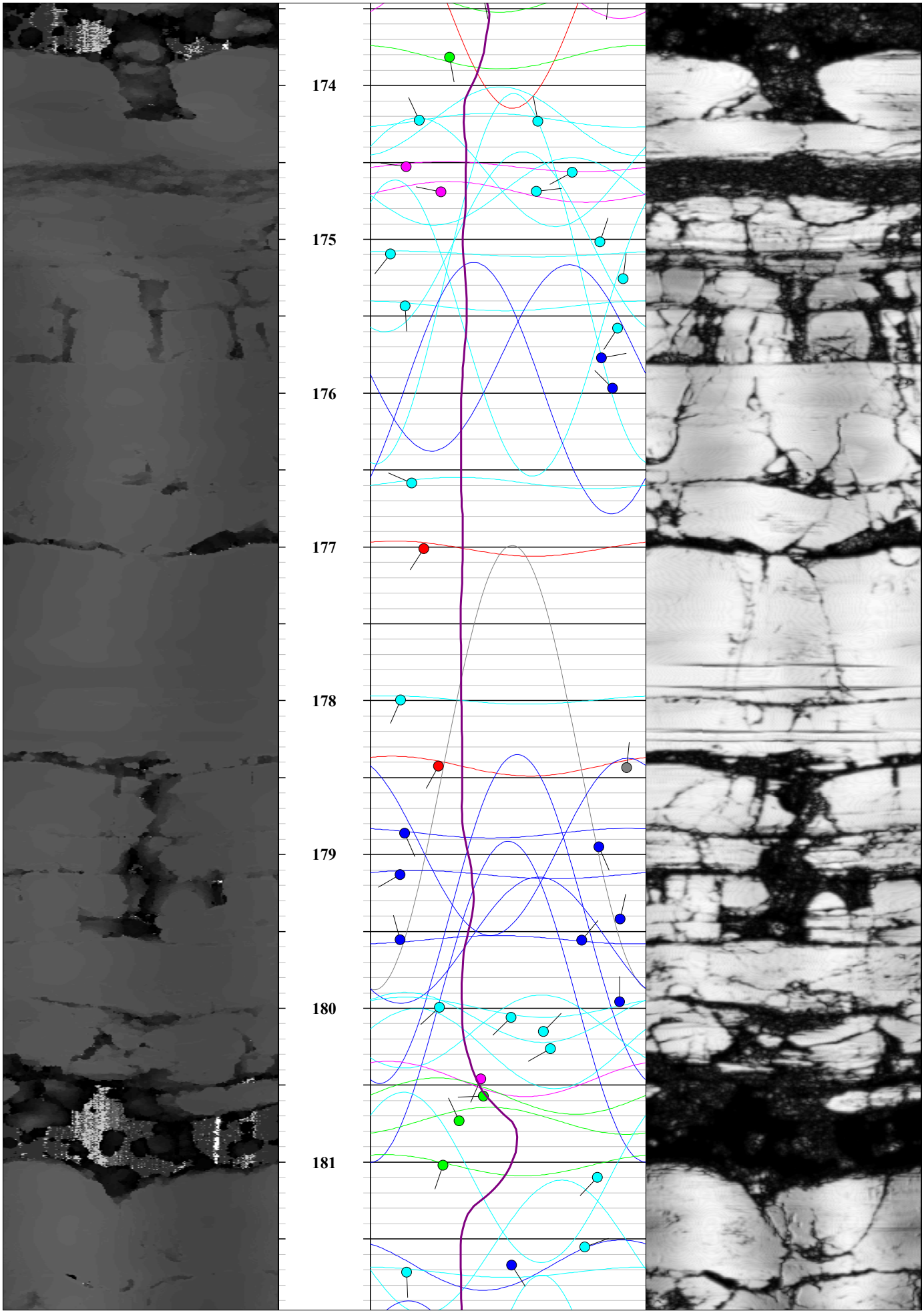

131
132
133
134
135
136
137
138
139

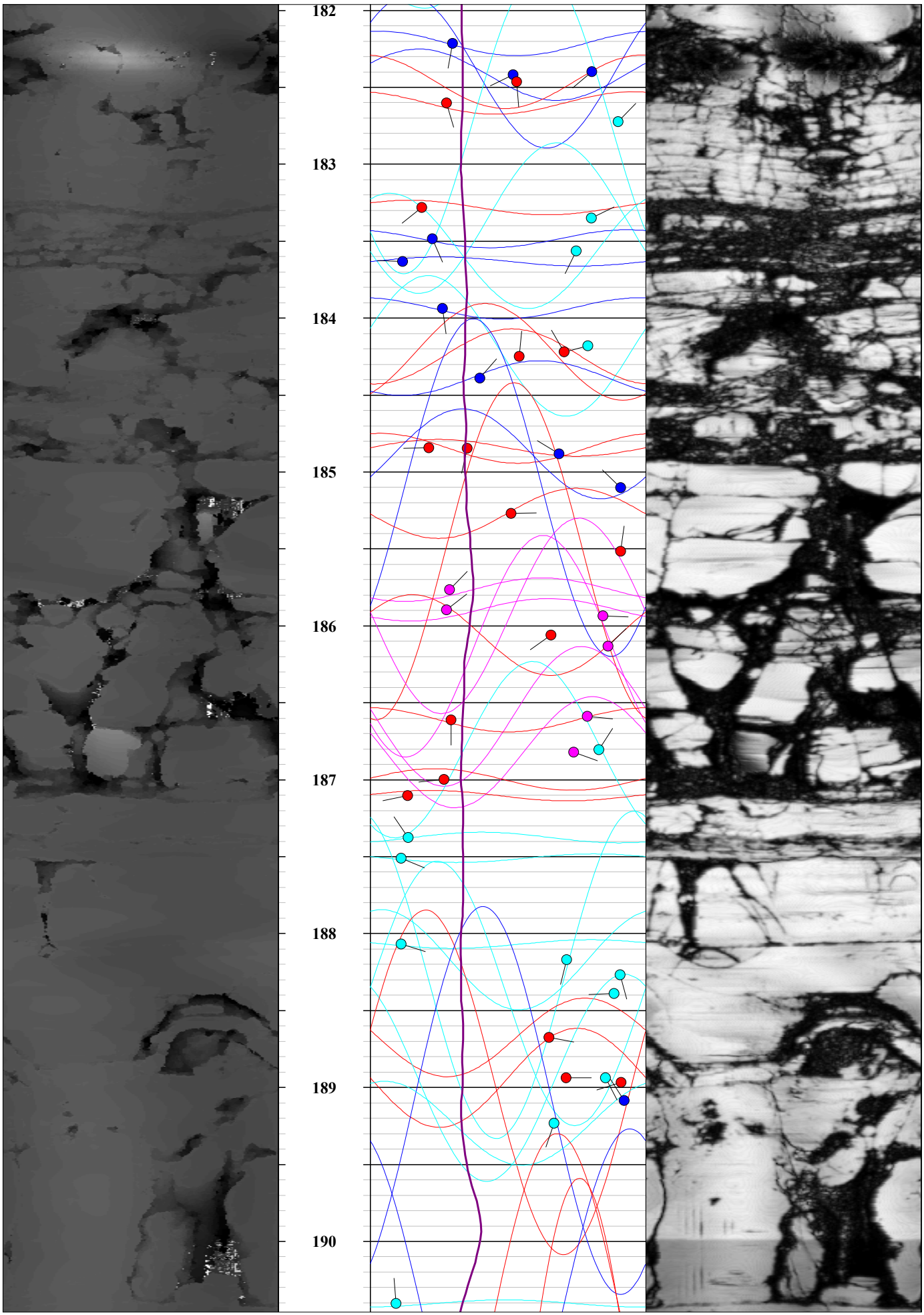

140
141
142
143
144
145
146
147

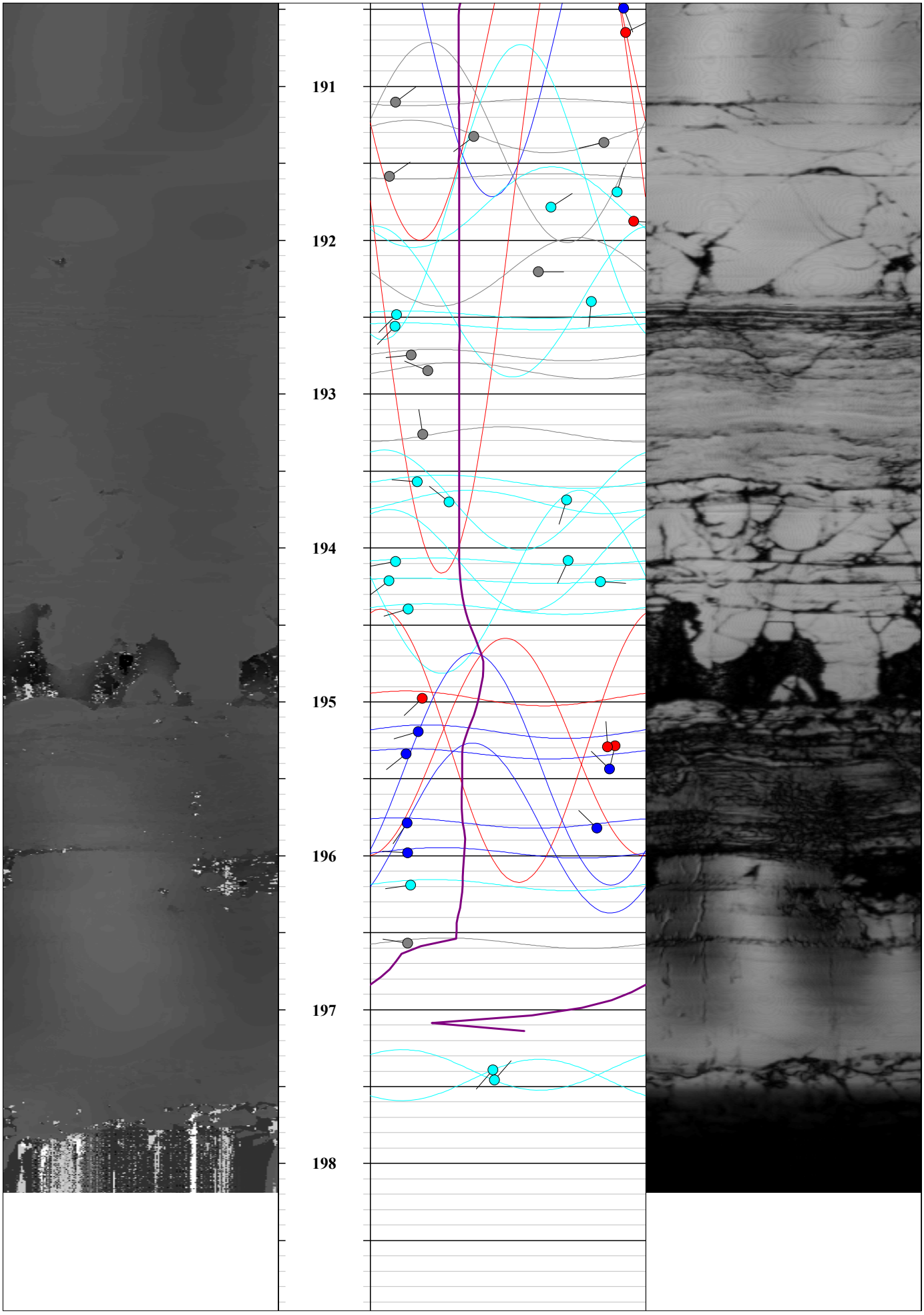

148
149
150
151
152
153
154
155
156

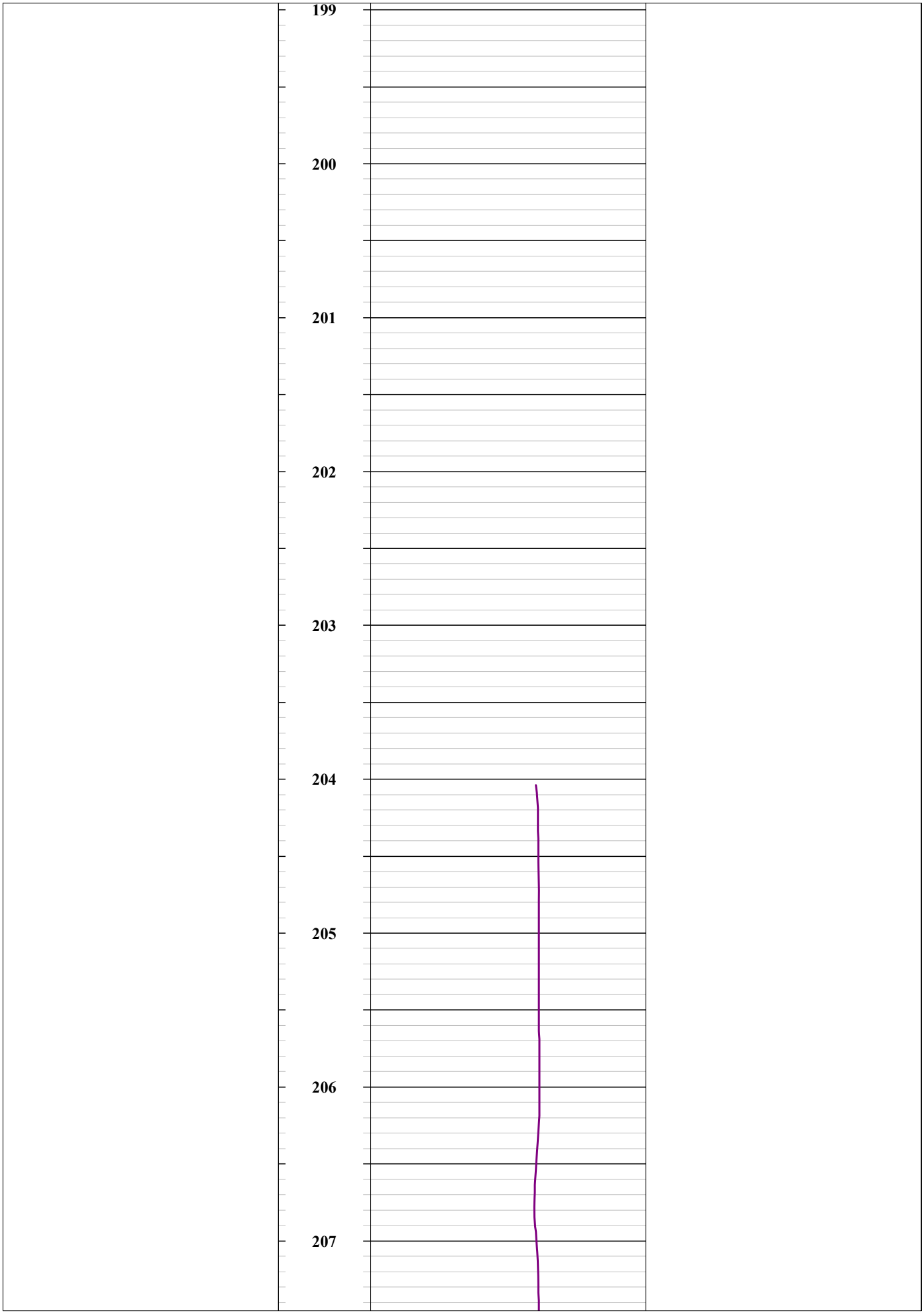

157
158
159
160
161
162
163
164

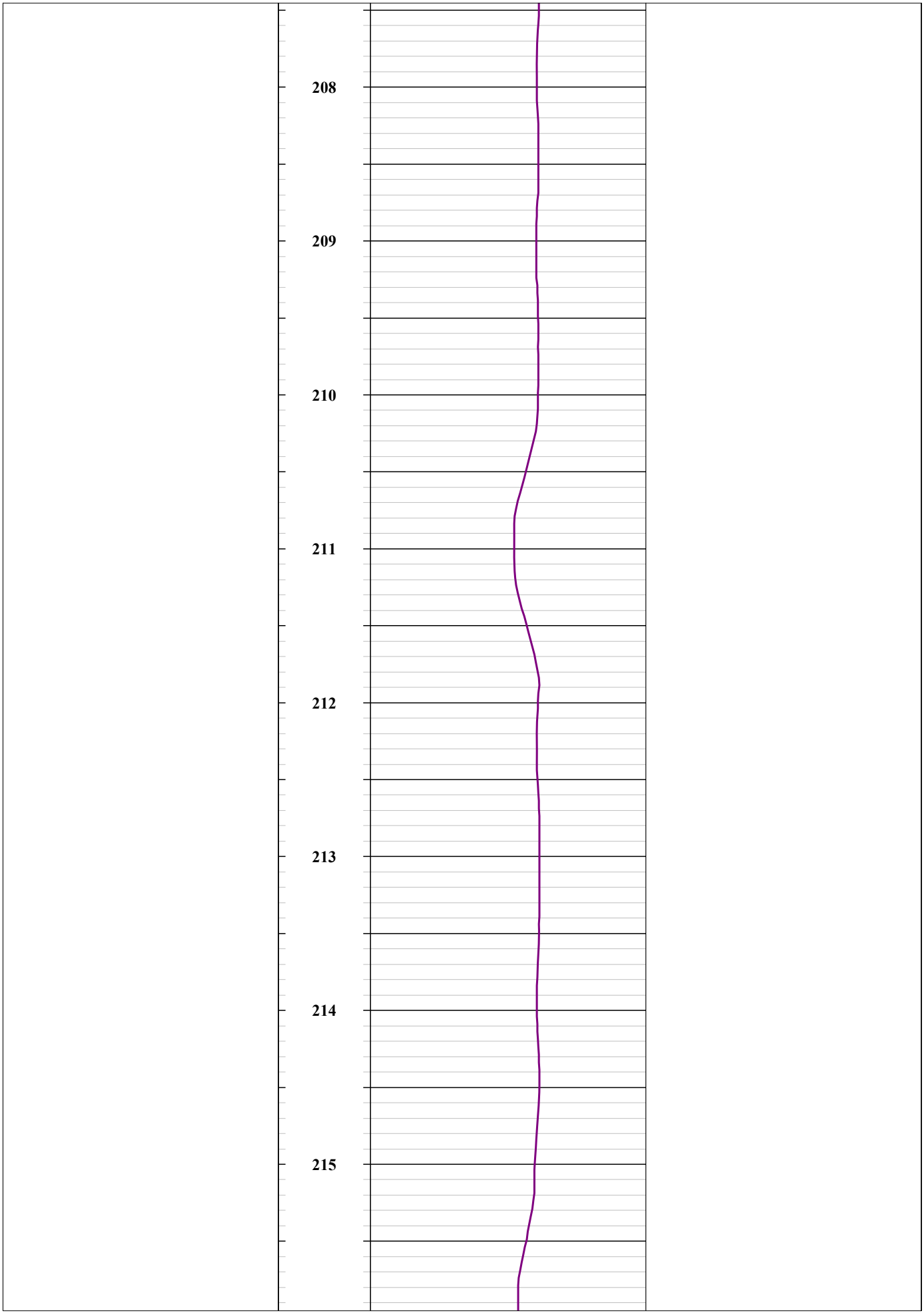

165
166
167
168
169
170
171
172
173

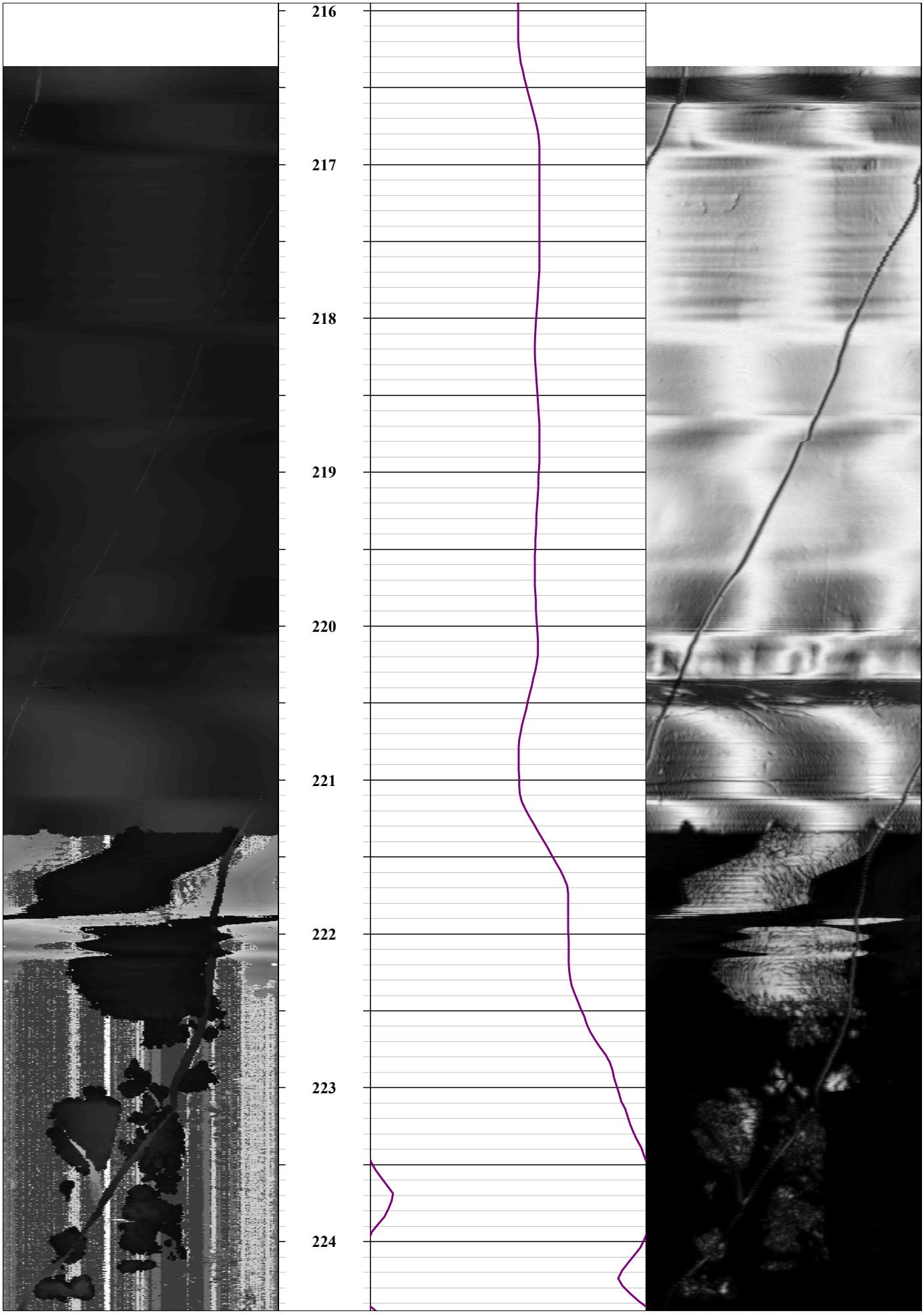

174
175
176
177
178
179
180
181

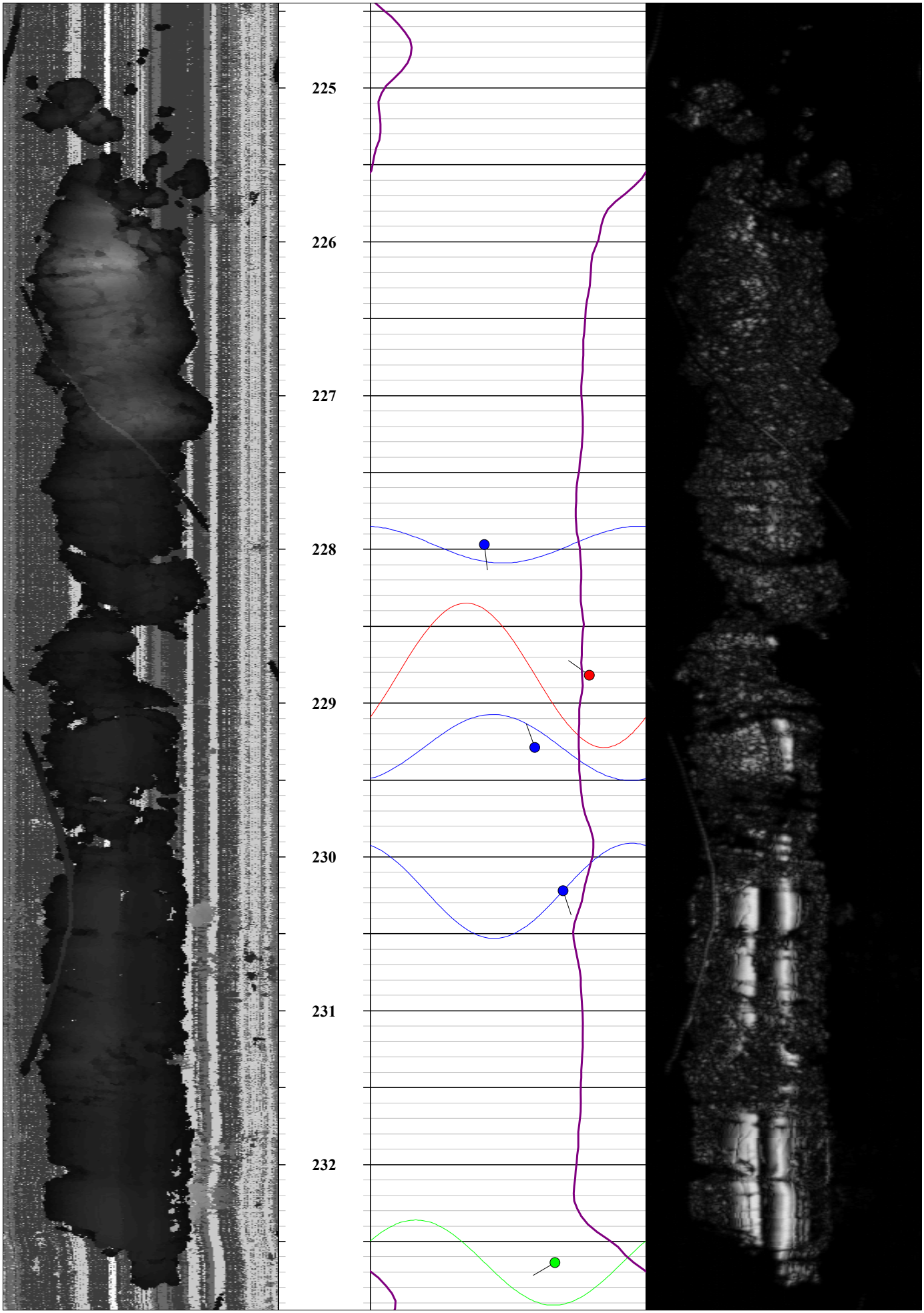

182
183
184
185
186
187
188
189
190

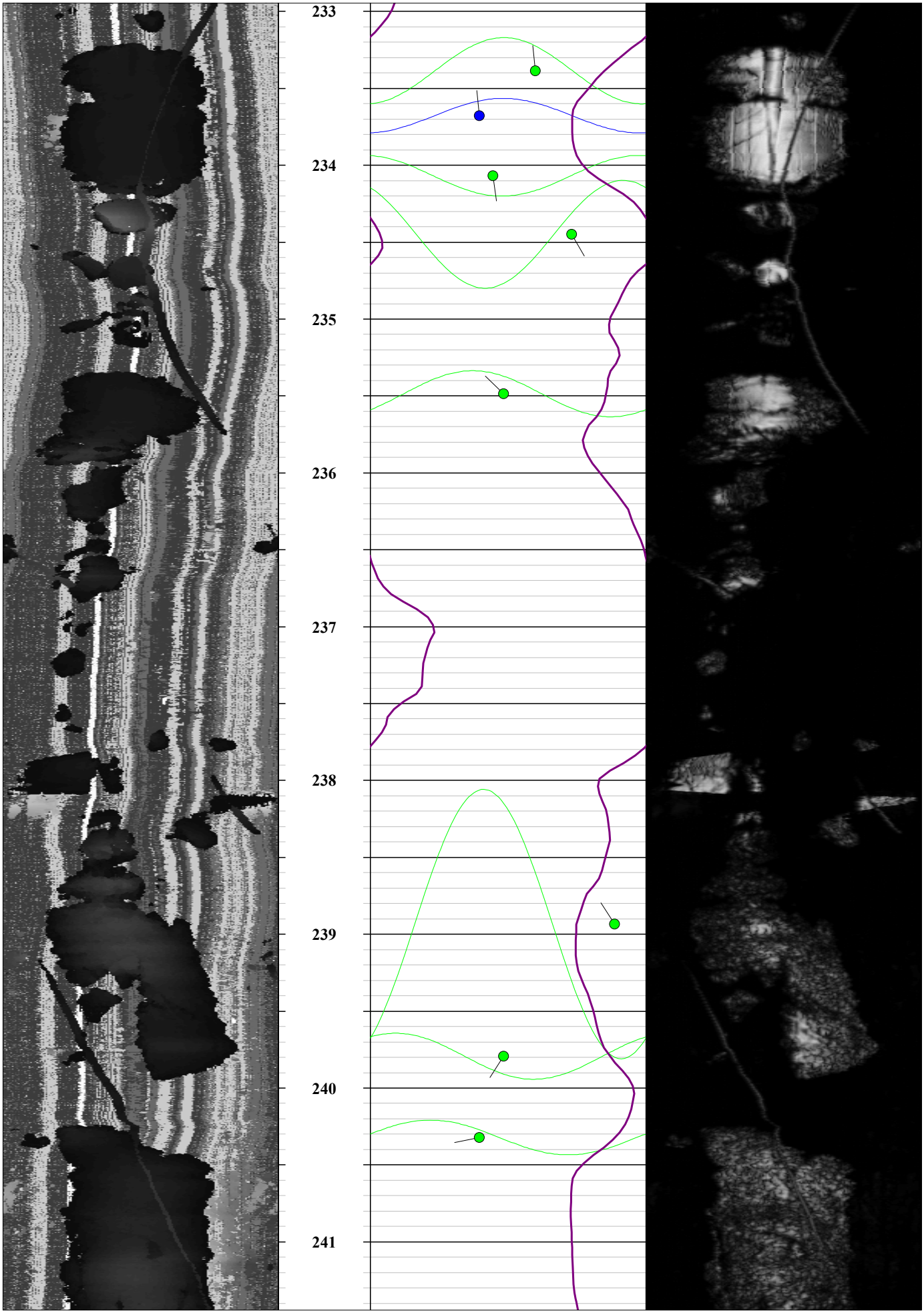

191
192
193
194
195
196
197
198

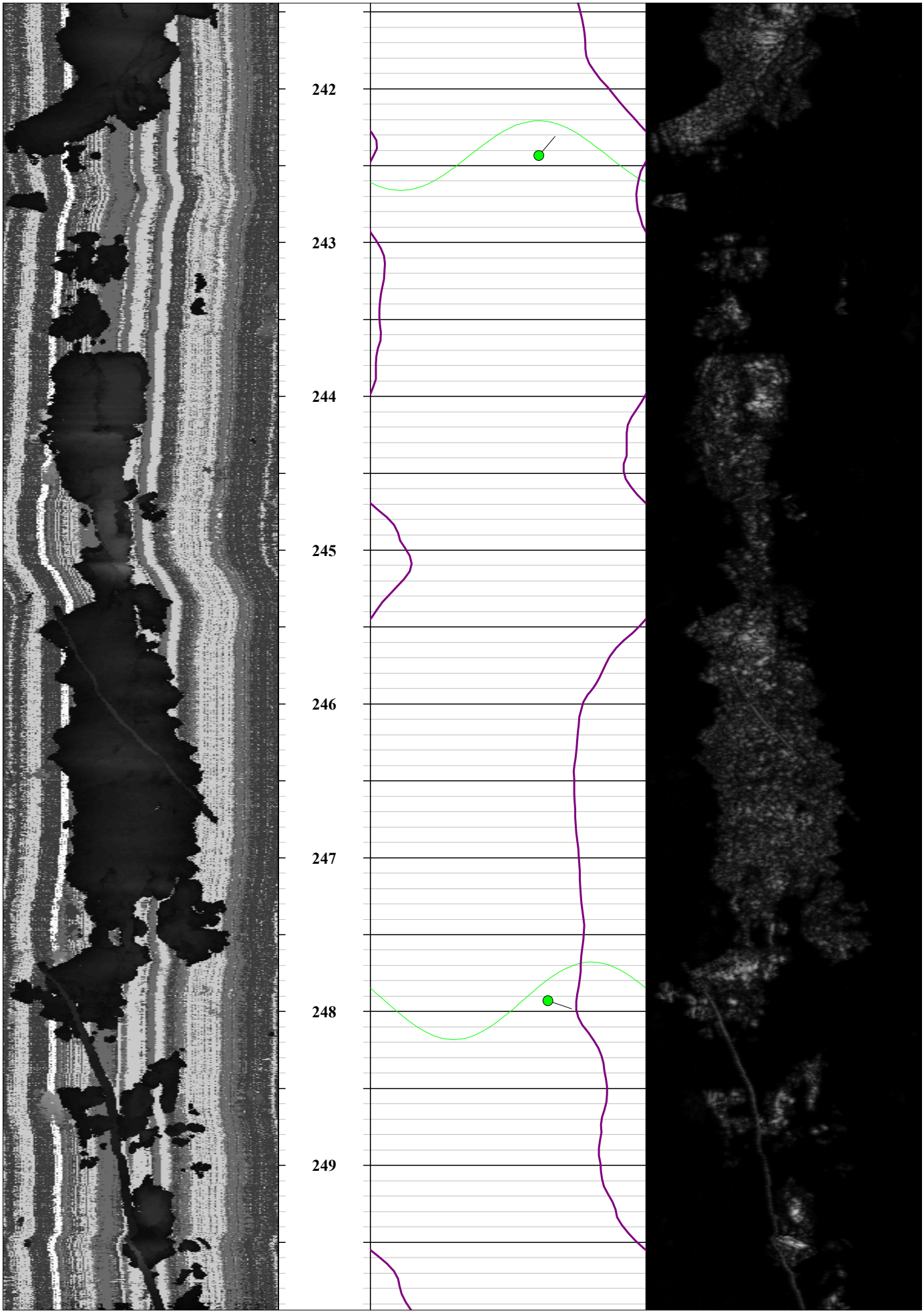

199
200
201
202
203
204
205
206
207

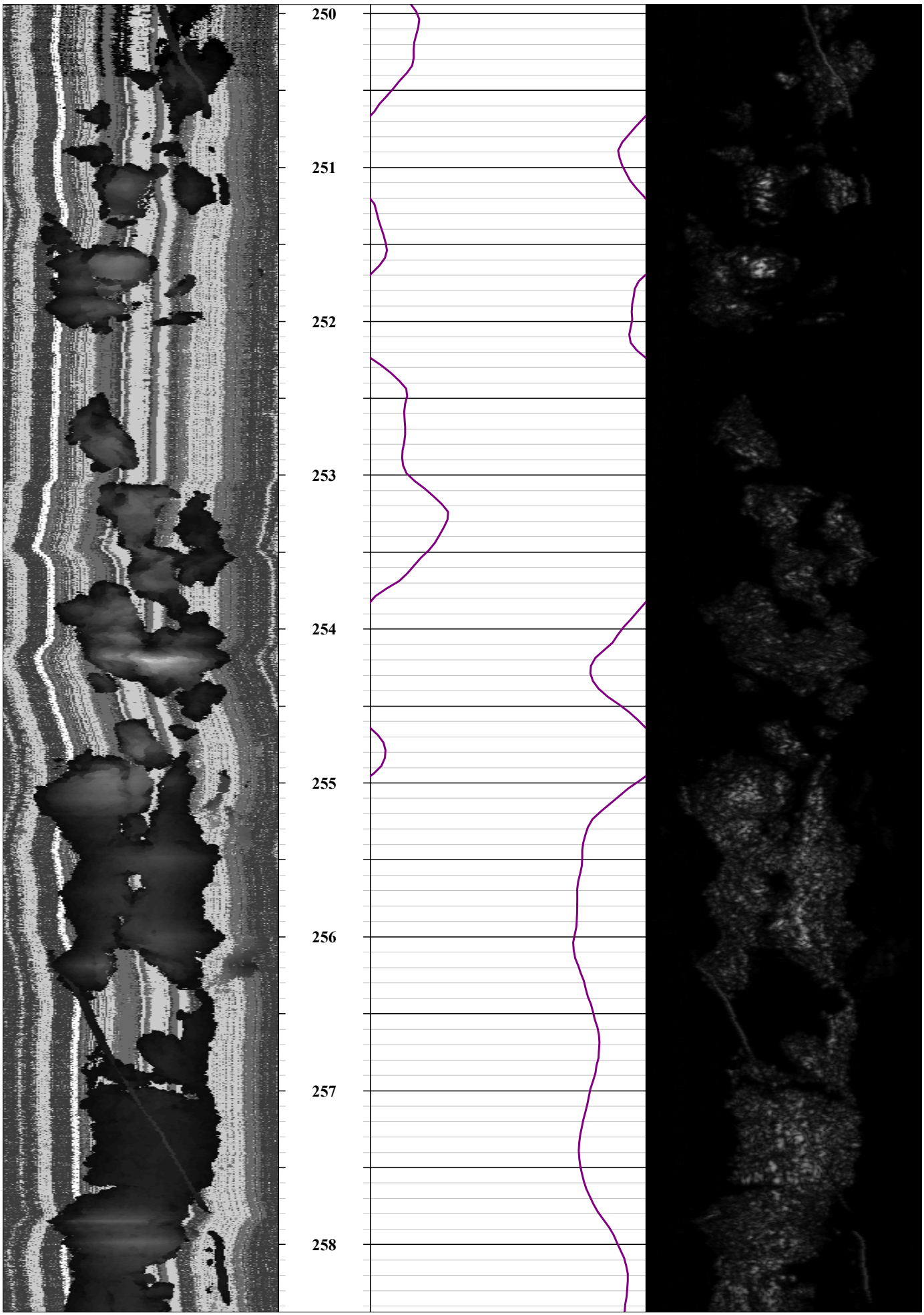

208
209
210
211
212
213
214
215

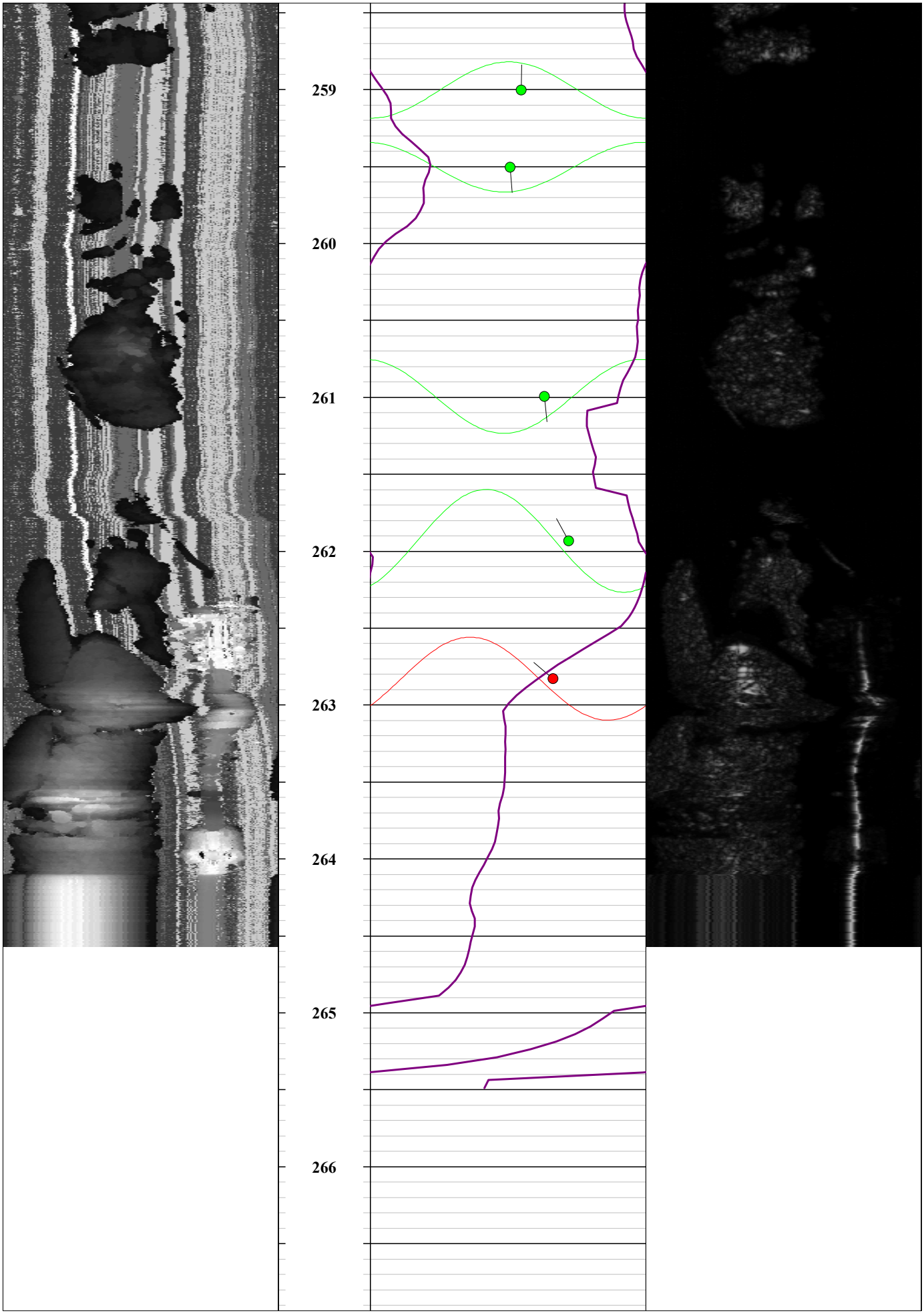

216
217
218
219
220
221
222
223
224


225
226
227
228
229
230
231
232


233
234
235
236
237
238
239
240
241


242
243
244
245
246
247
248
249


250
251
252
253
254
255
256
257
258


259
260
261
262
263
264
265
266

267

268

269

270

271

272

273

274

275

276

277

278

279

280

281

282

283

284

285

286

287

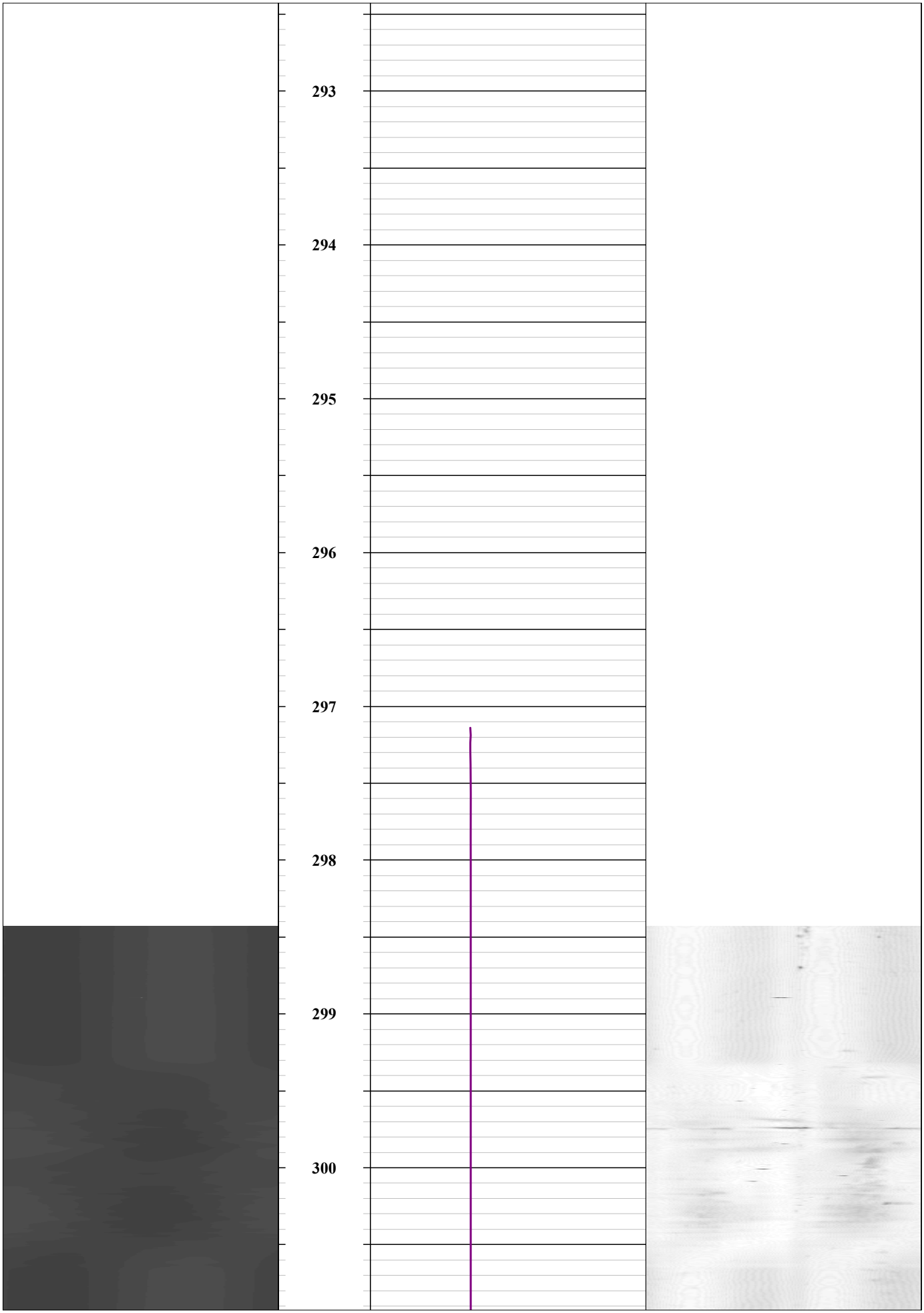
288

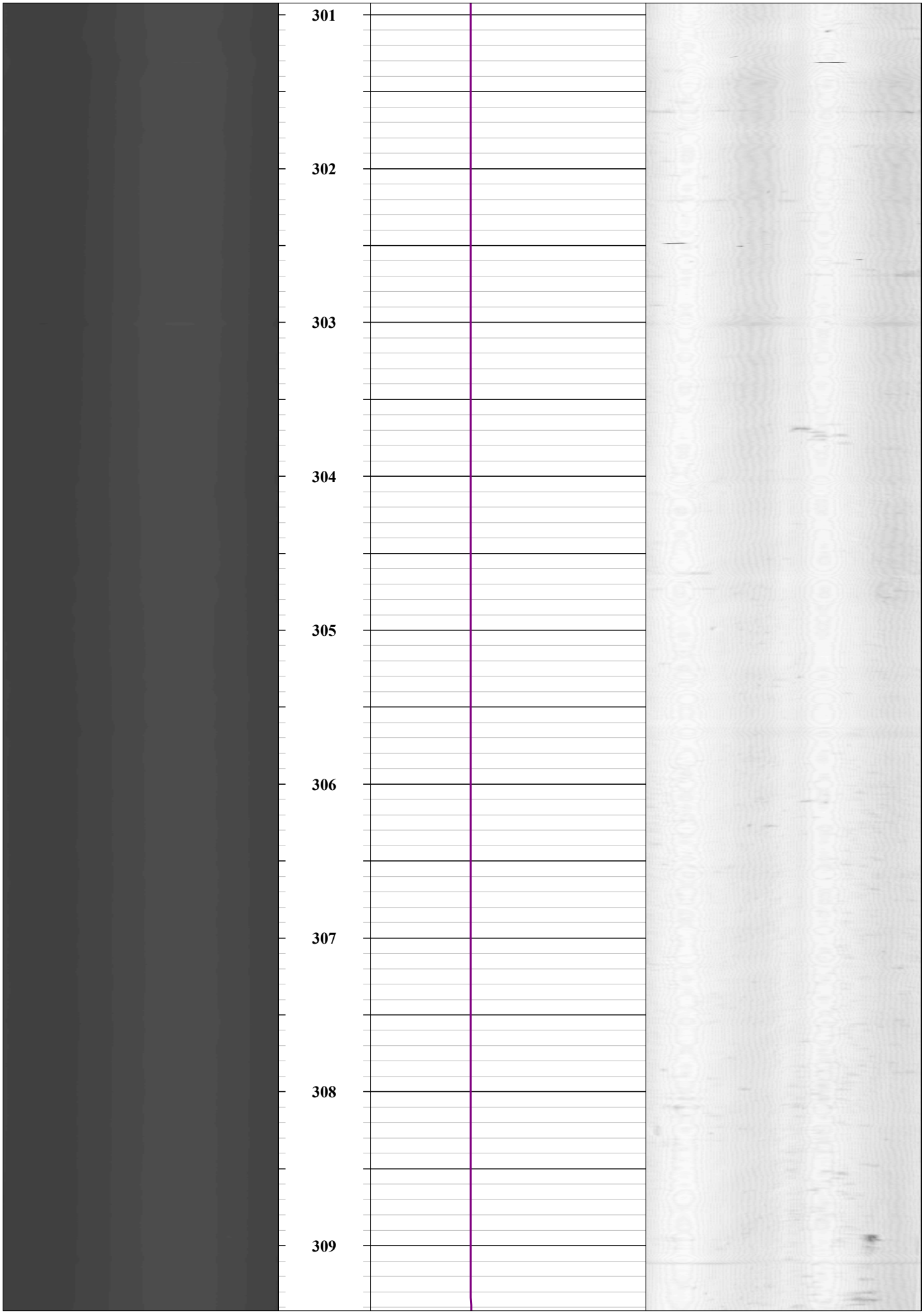
289

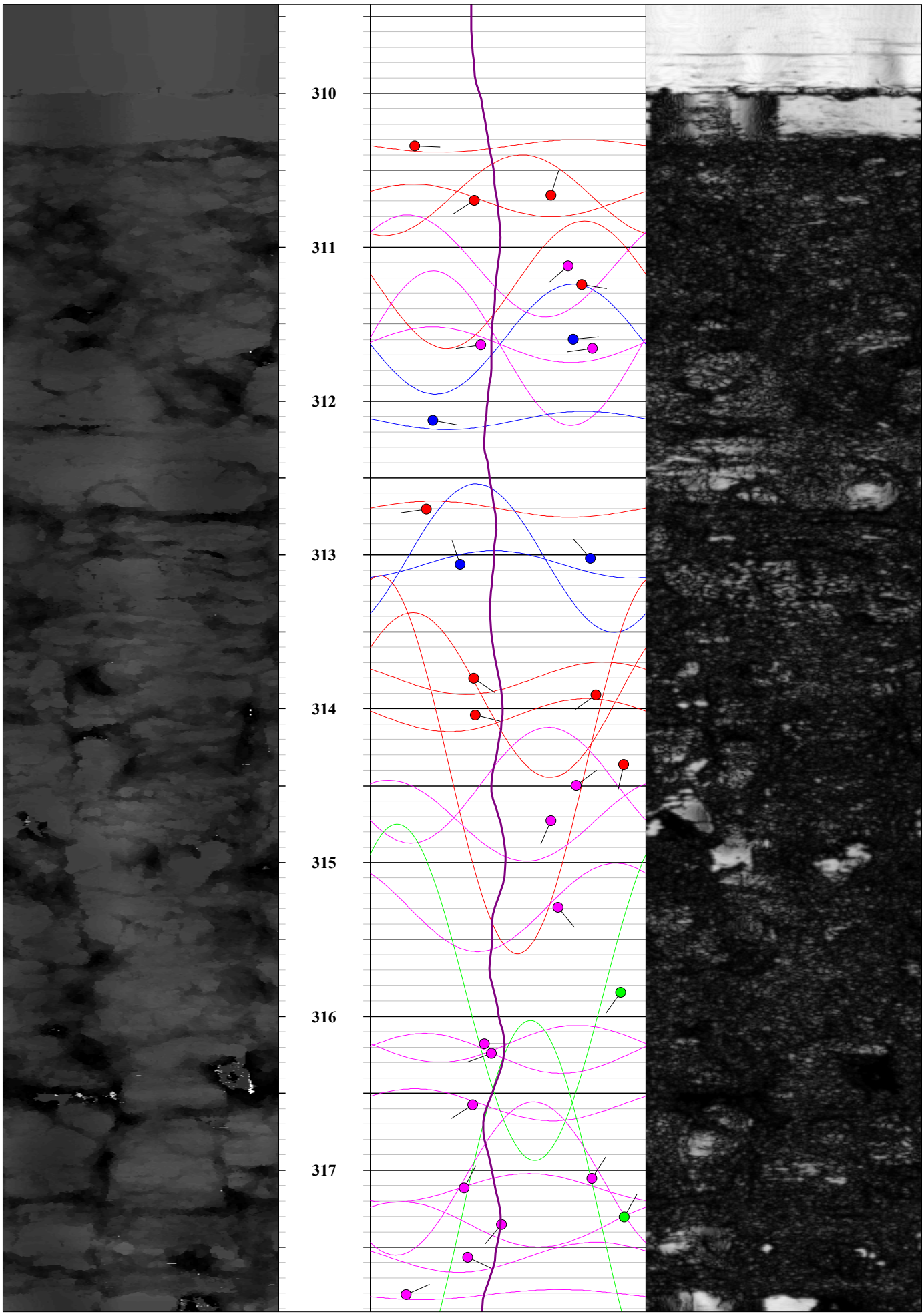
290

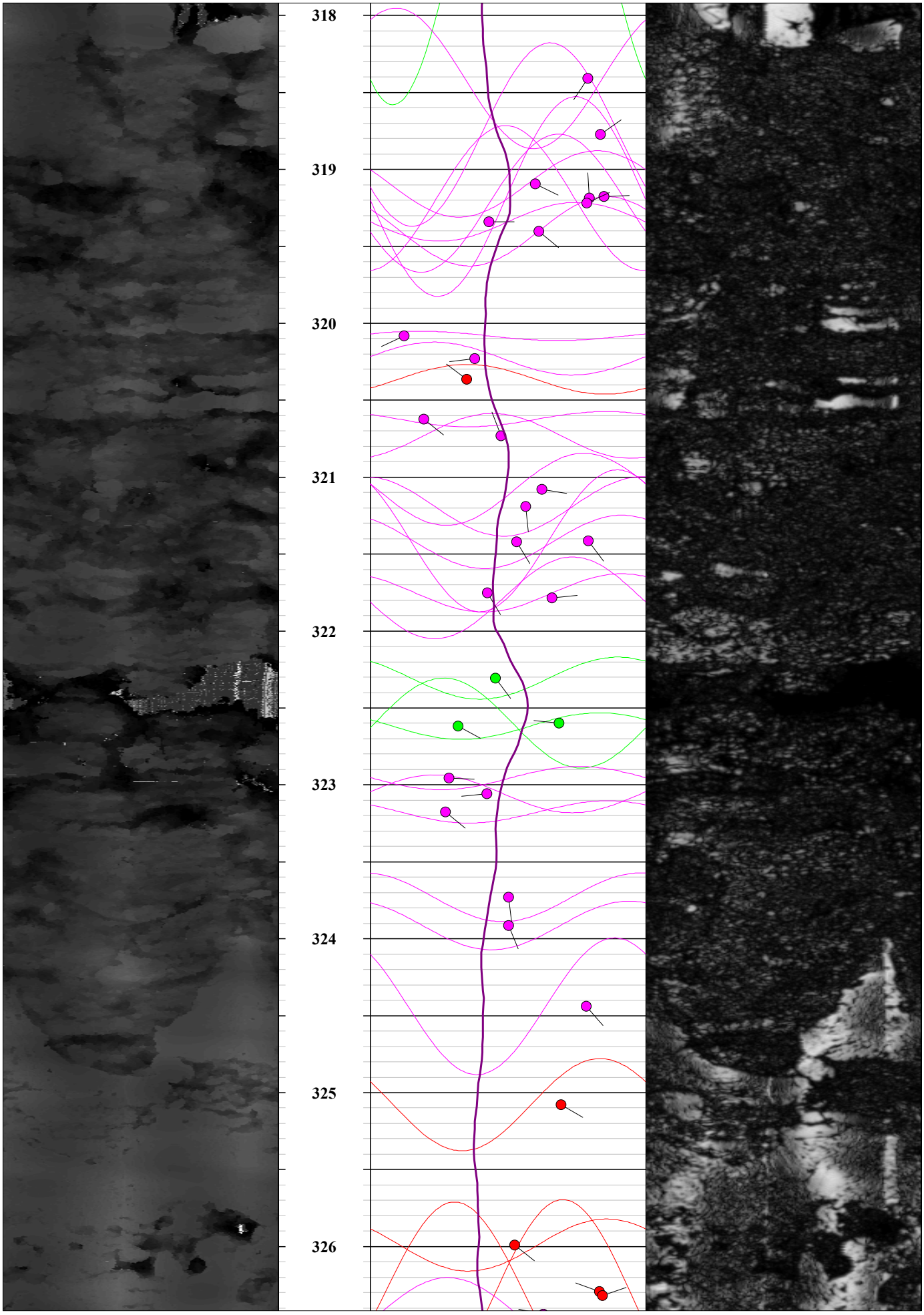
291

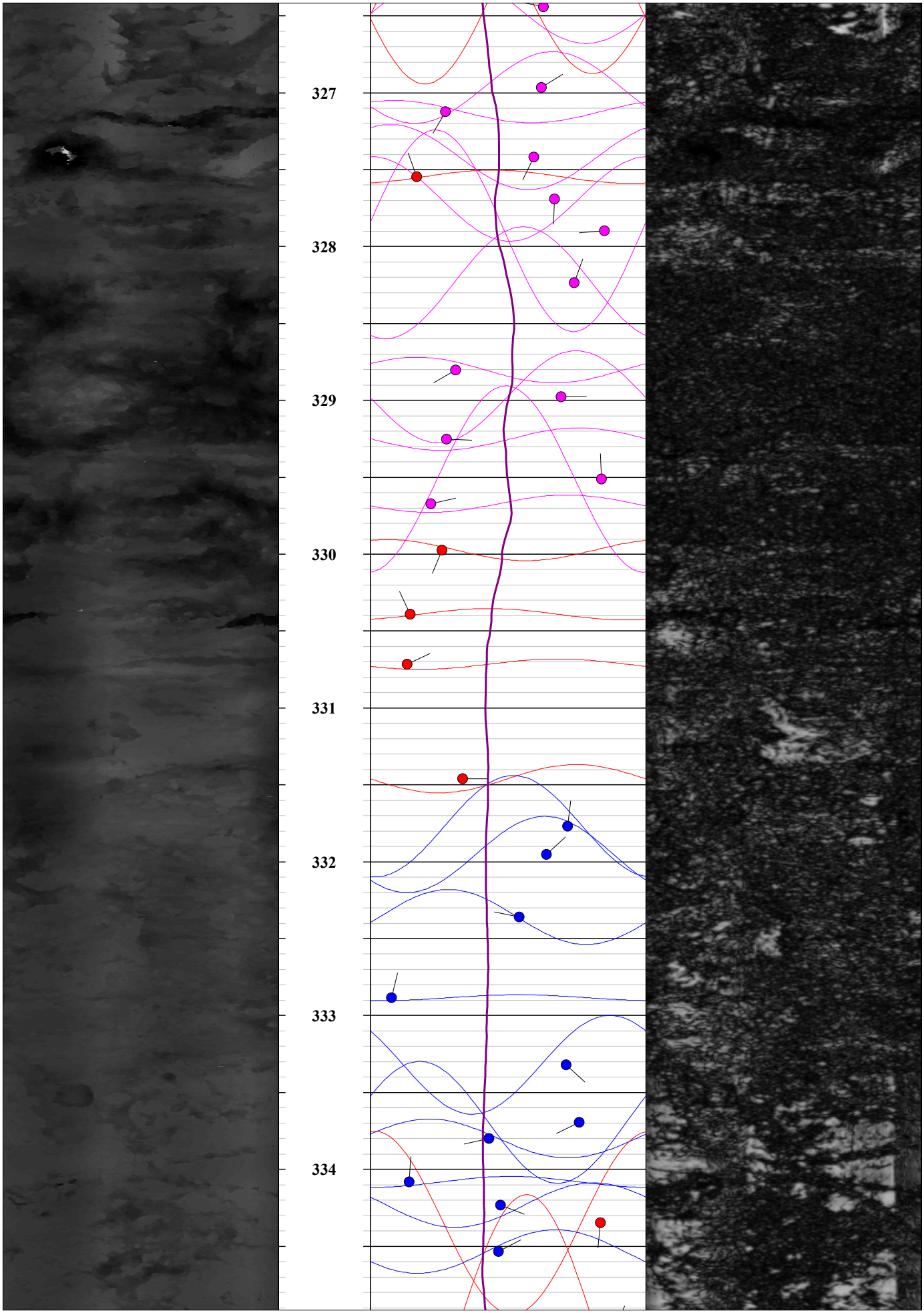
292

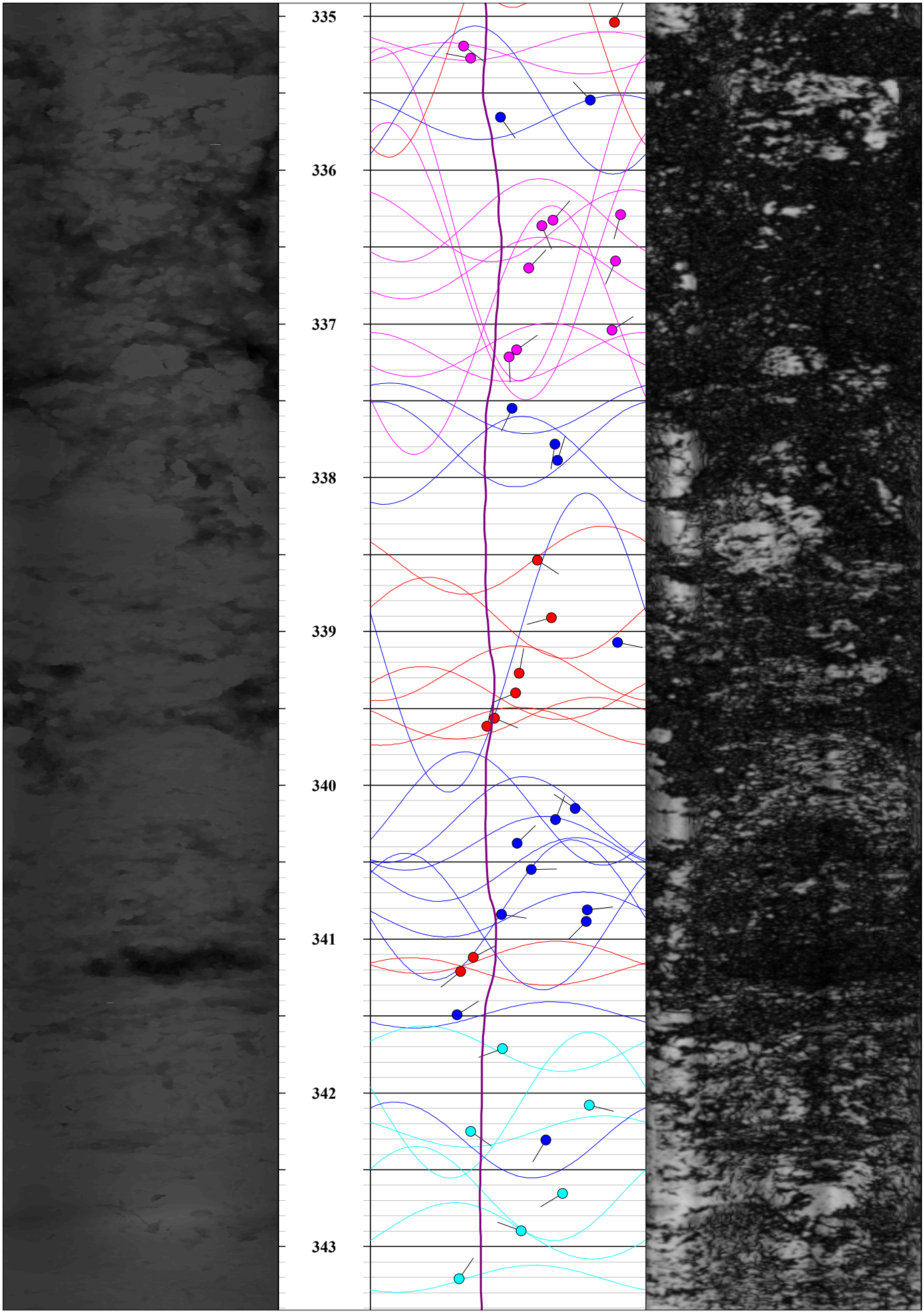

293
294
295
296
297
298
299
300

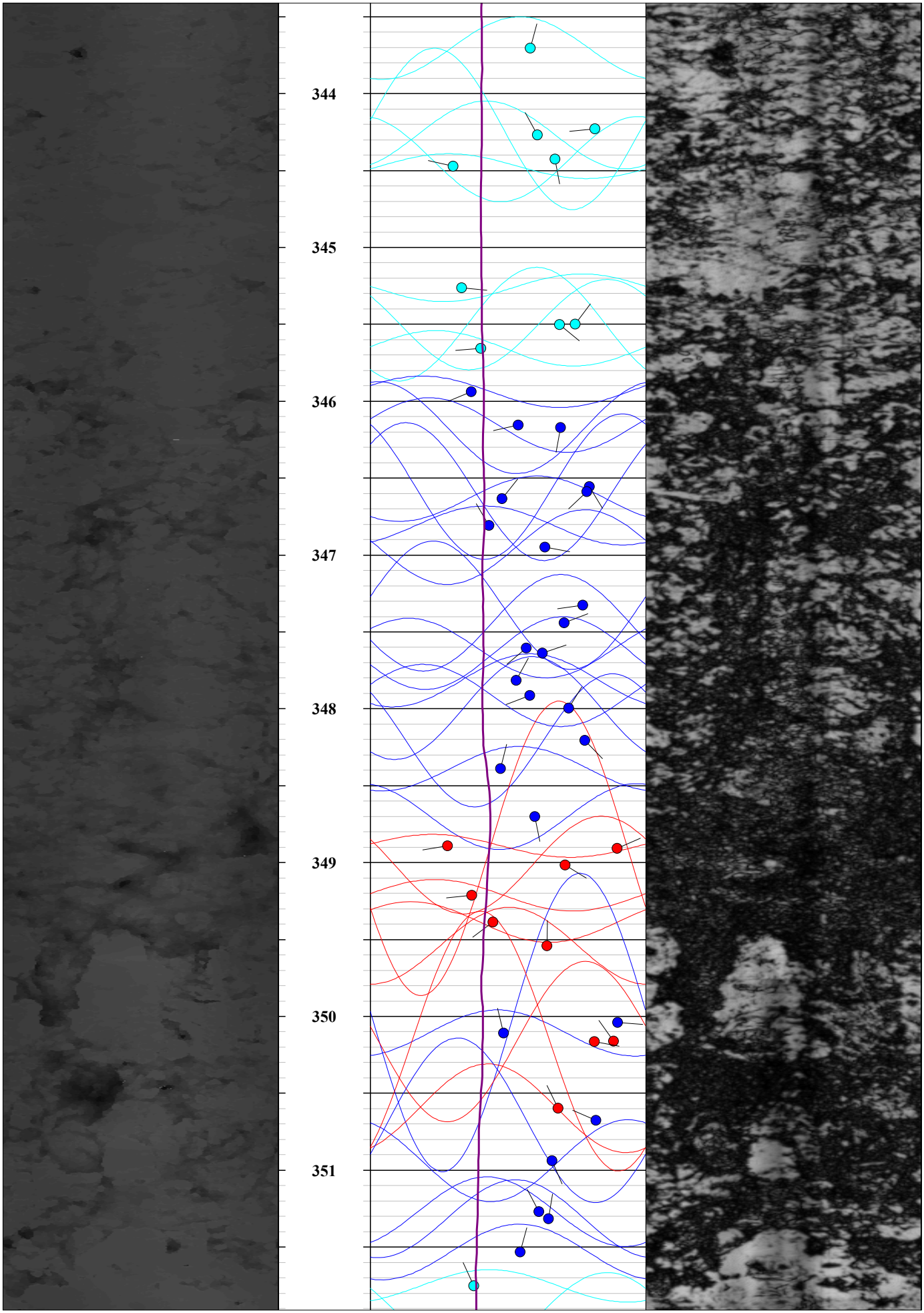

301
302
303
304
305
306
307
308
309

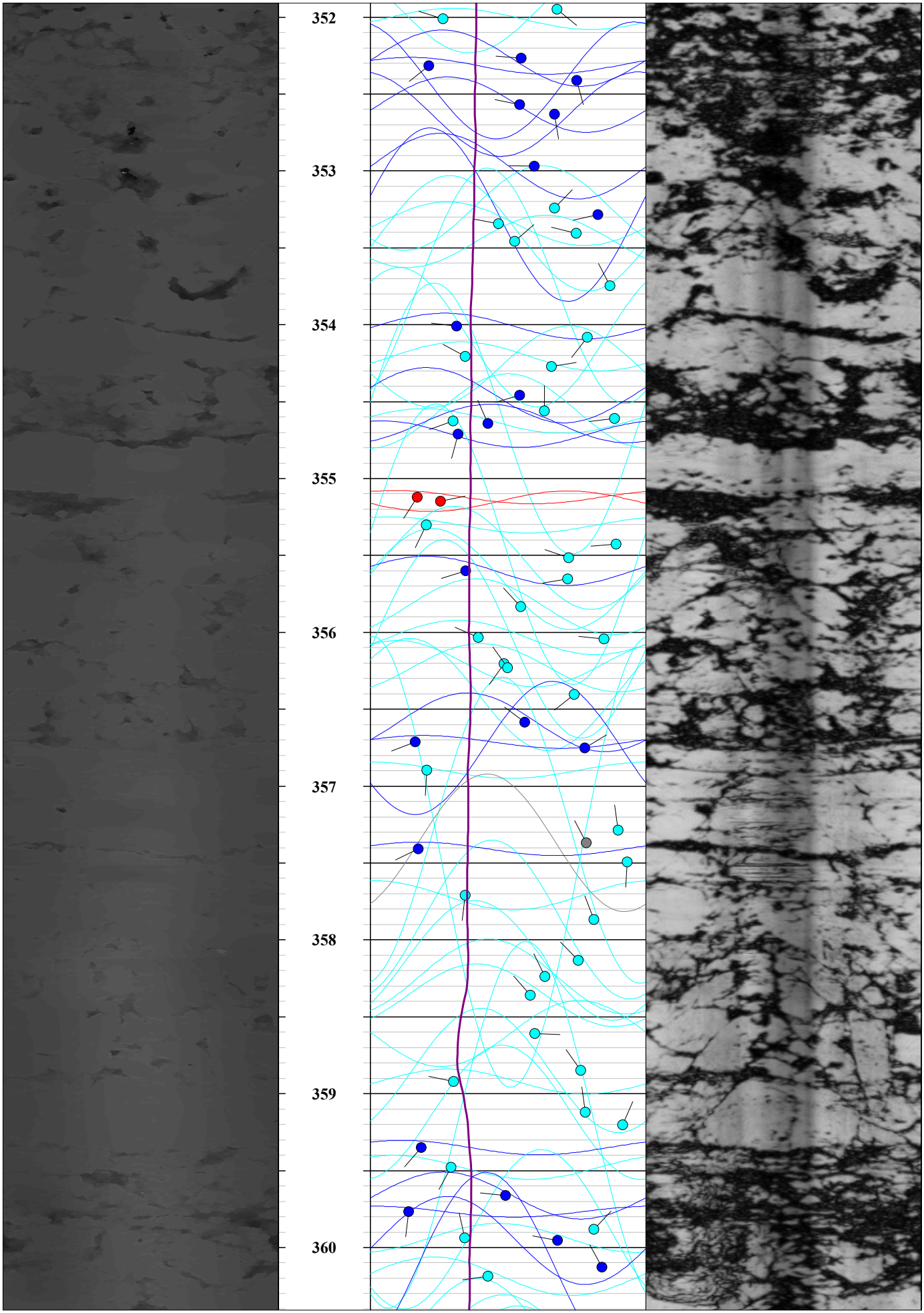

310
311
312
313
314
315
316
317

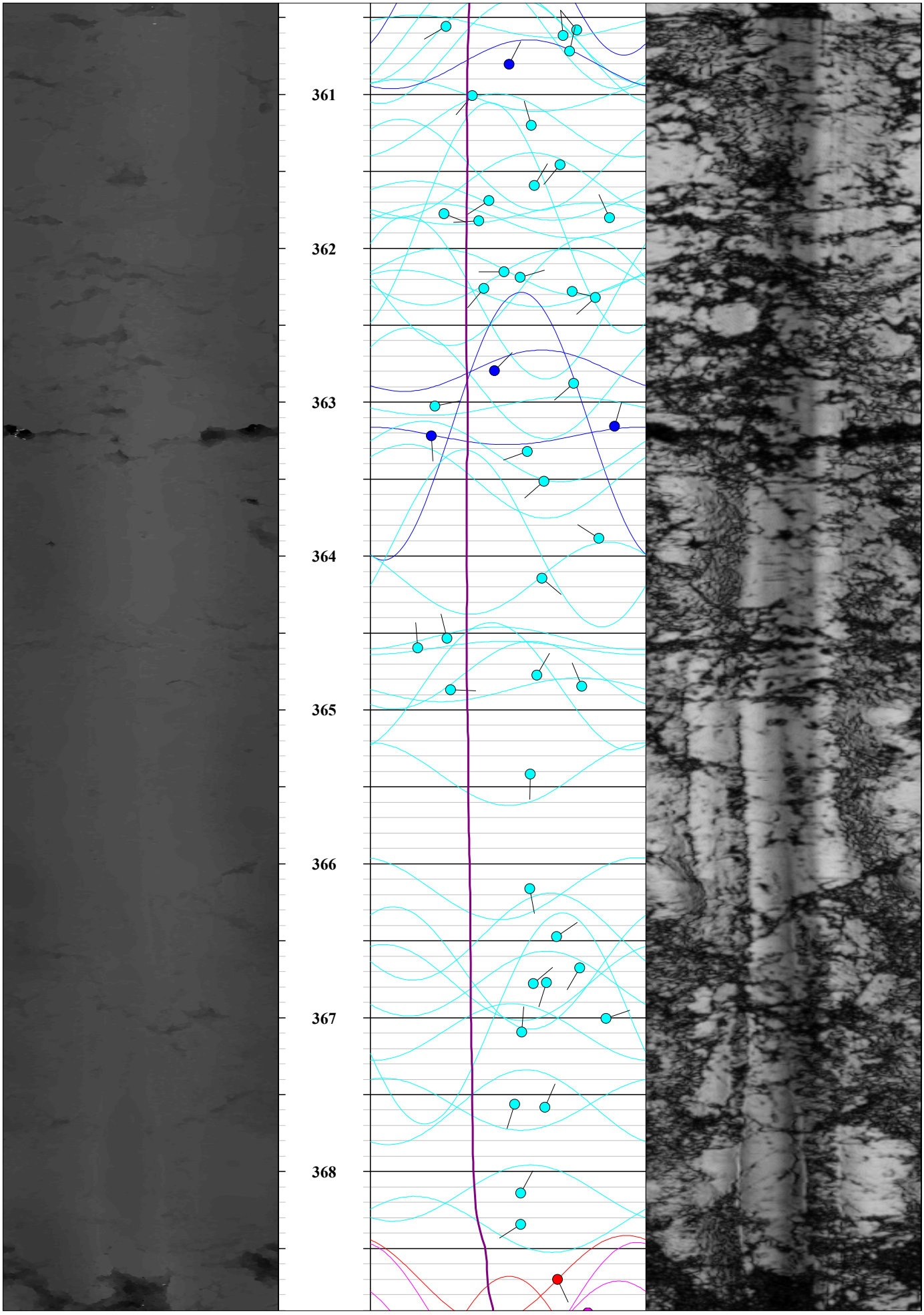

318
319
320
321
322
323
324
325
326

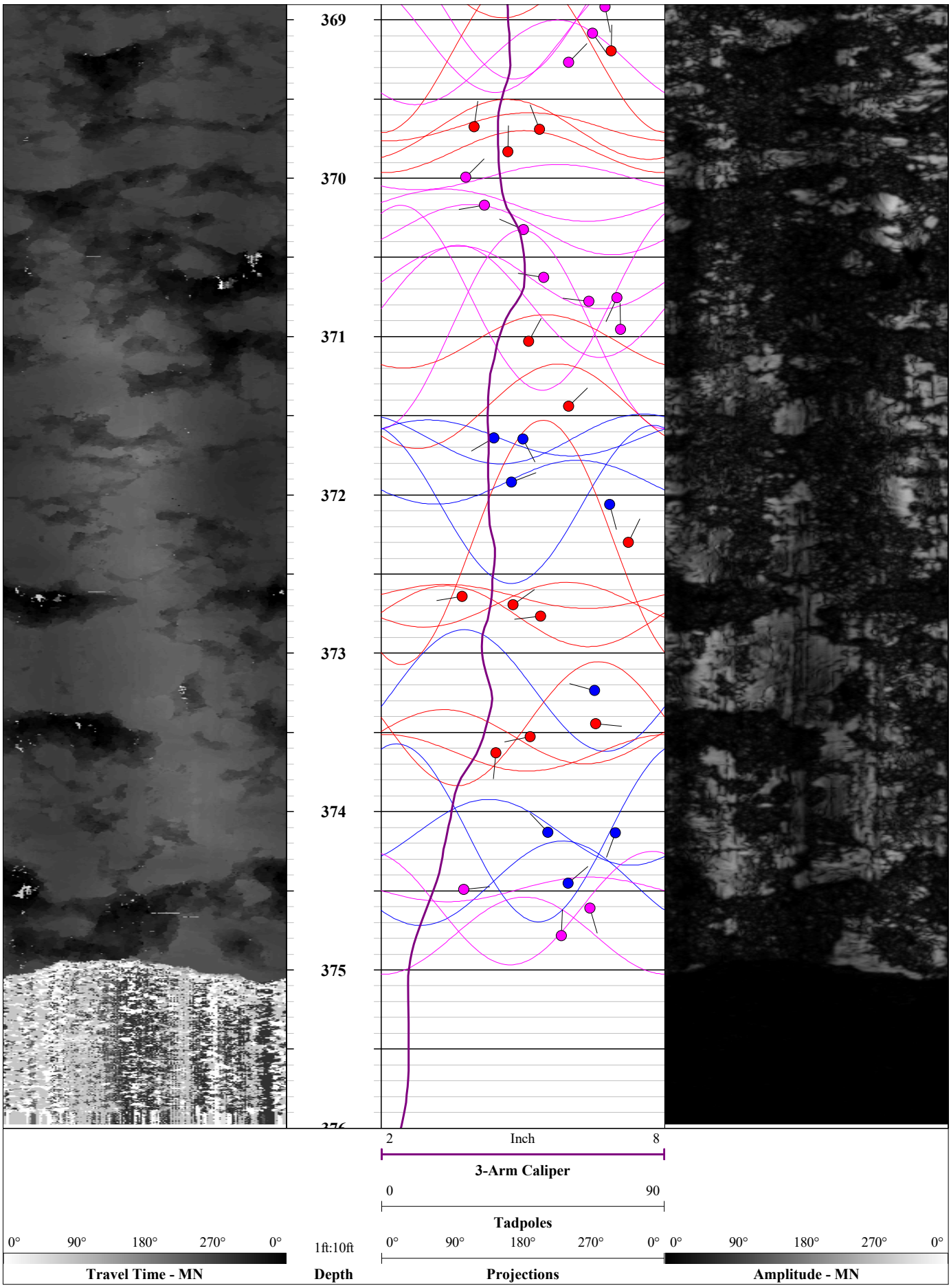

327
328
329
330
331
332
333
334


335
336
337
338
339
340
341
342
343


344
345
346
347
348
349
350
351


352
353
354
355
356
357
358
359
360


361
362
363
364
365
366
367
368


369
370
371
372
373
374
375
376
2
Inch
8
3-Arm Caliper
0
90
Tadpoles
0°
90°
180°
270°
0°
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
Travel Time - MN
Depth
Projections
Amplitude - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-17
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-17
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.82875 N
Longitude: 84.76084 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 599.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	5-13 July 2019			
RUN NUMBER	1			
LOG TYPE	Optical Televiewer			
DEPTH-DRILLER	380'			
DEPTH-LOGGER	378'			
BTM LOG INTERVAL	376'			
TOP LOG INTERVAL	115'			
RECORDED BY	CKL,BEH,JBG			
WITNESSED BY				
PROBE TYPE, S/N	OBI/LIM #1729			
LOGGING SPEED	4.5 fpm			
A.S.D.E. / Sample Interval	0.11' / 0.003'			
Fluid Level / Fluid Type	16'/water			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	380'

CASING RECORD

SIZE	WGT.	FROM	TO
PQ	Steel	0'	120'

NA - Not Available, N/A - Not Applicable

COMMENTS

Hole severly damaged in center section due to collapse and dropped packer that is still in the hole, reason for missing areas of data.

3-Arm Caliper	Depth	Projections	Optical Image - MN
2 Inch 8	1ft:10ft	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°
		Tadpoles: 0 90	

111

112

113

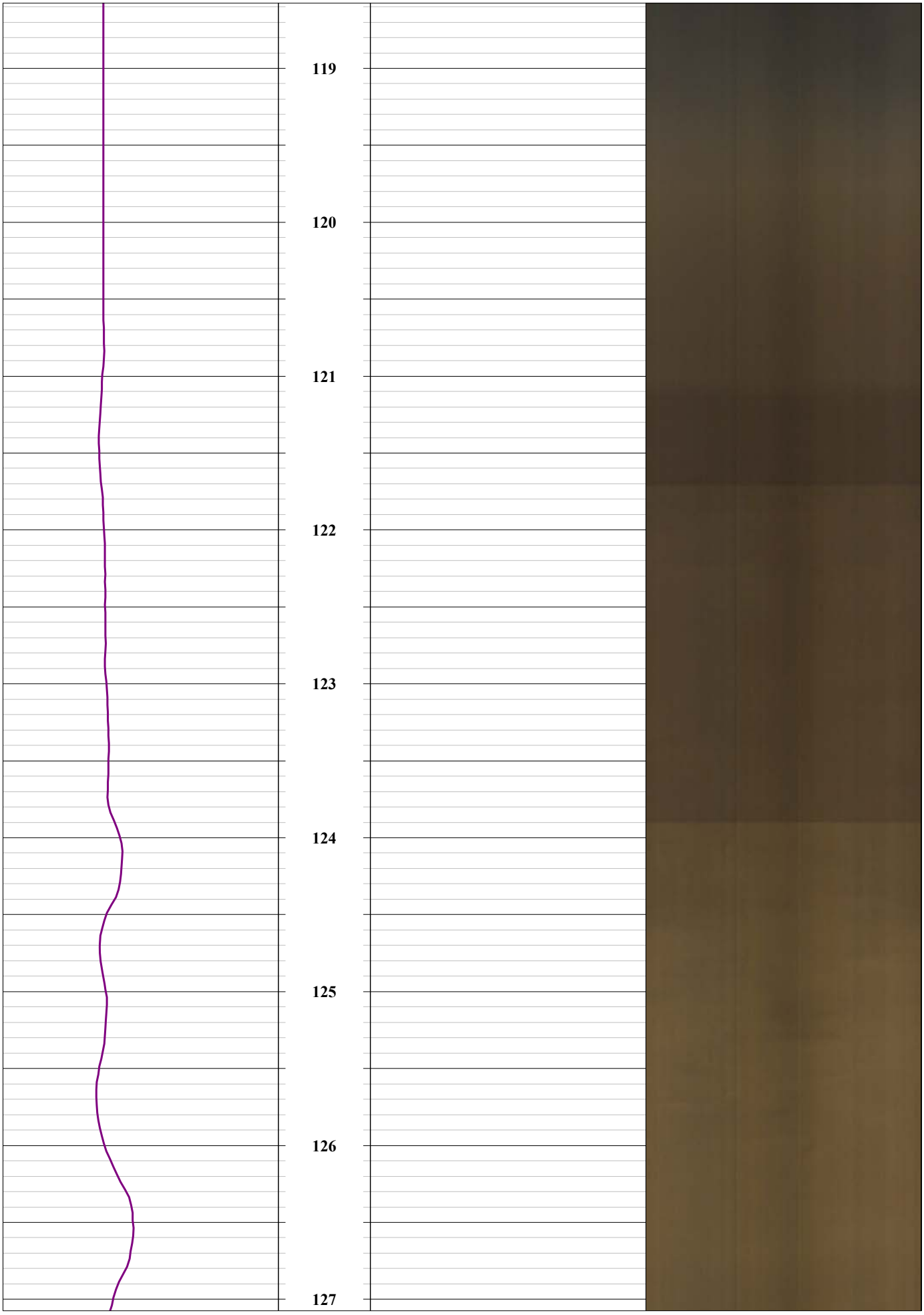
114

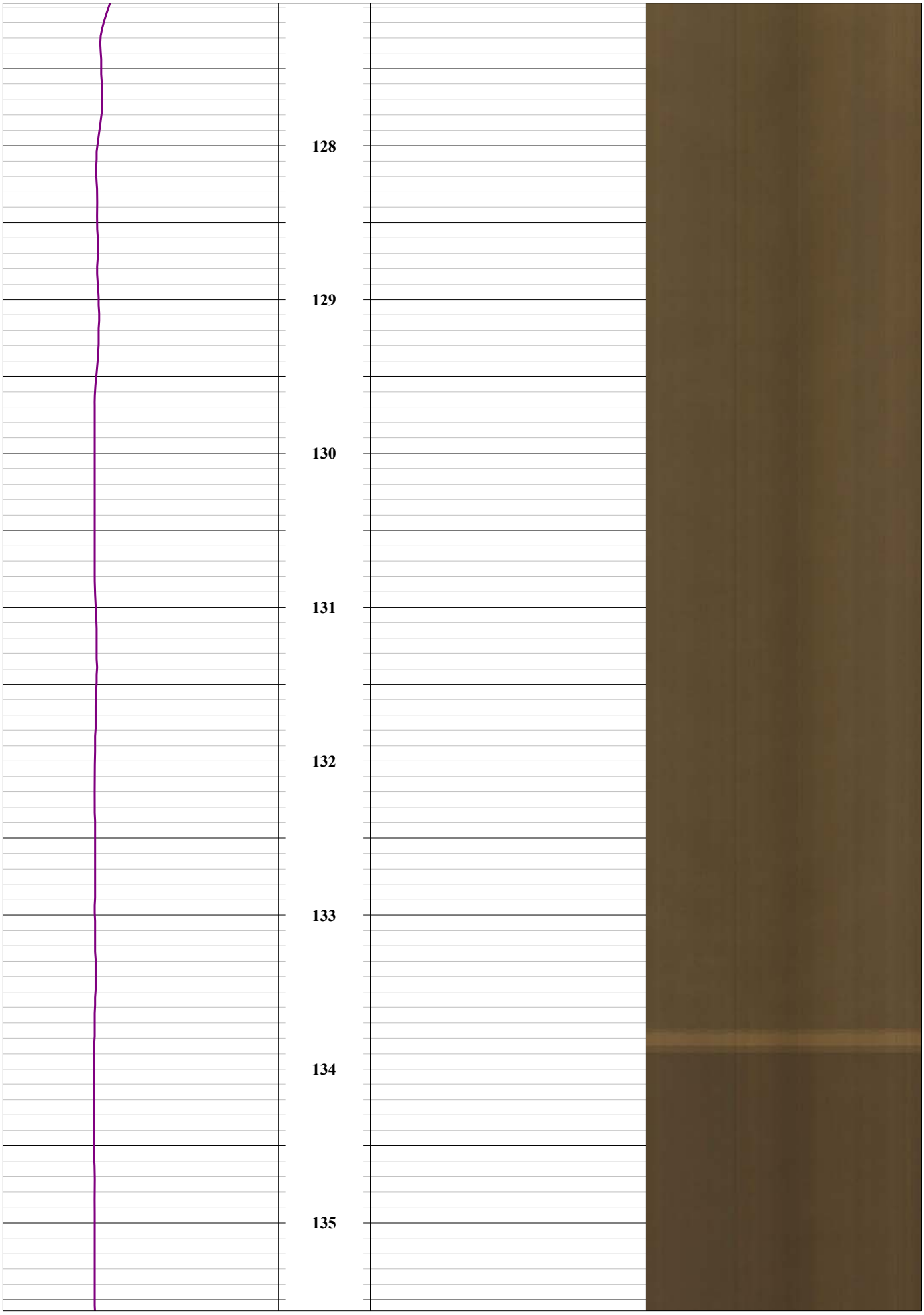
115

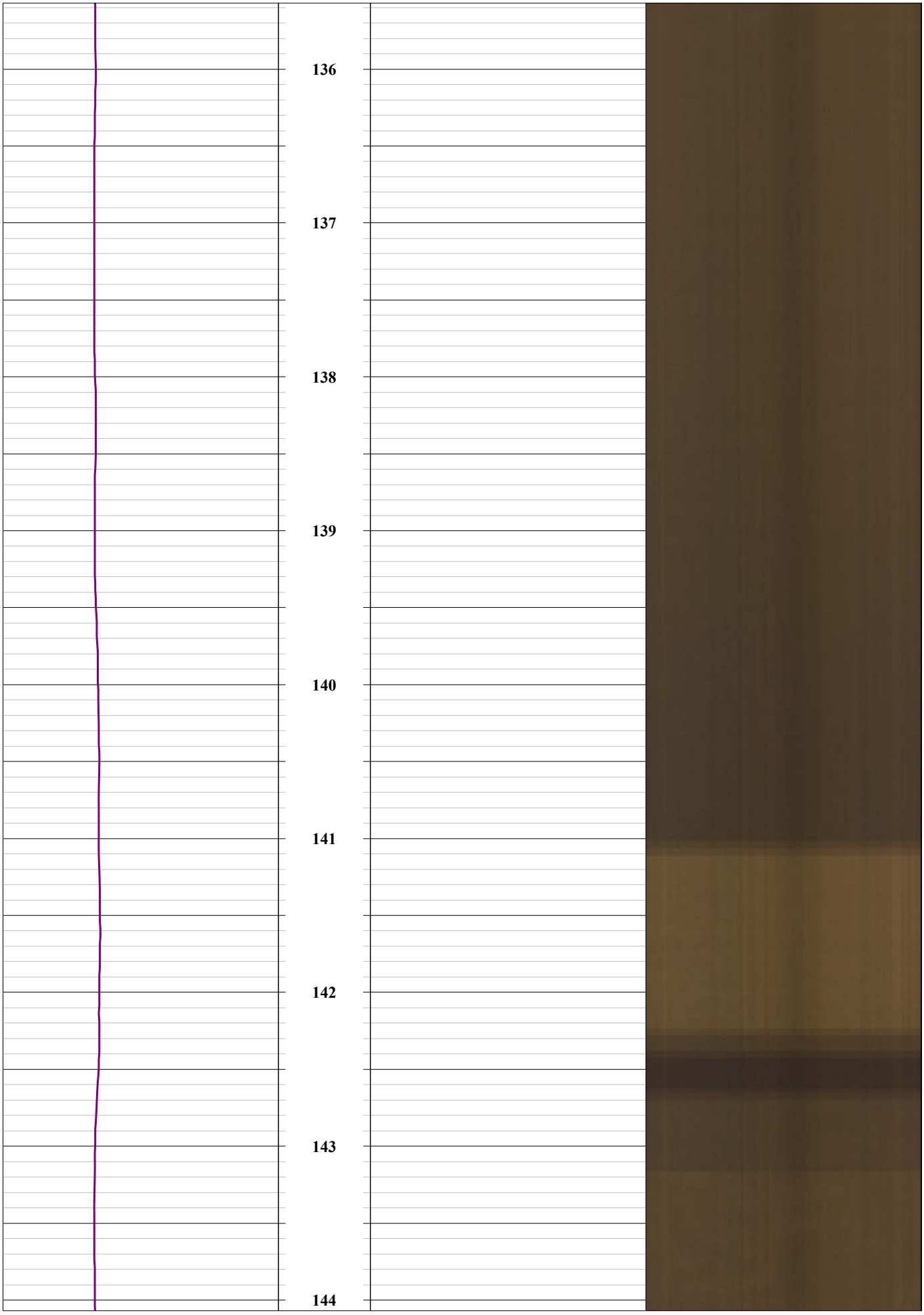
116

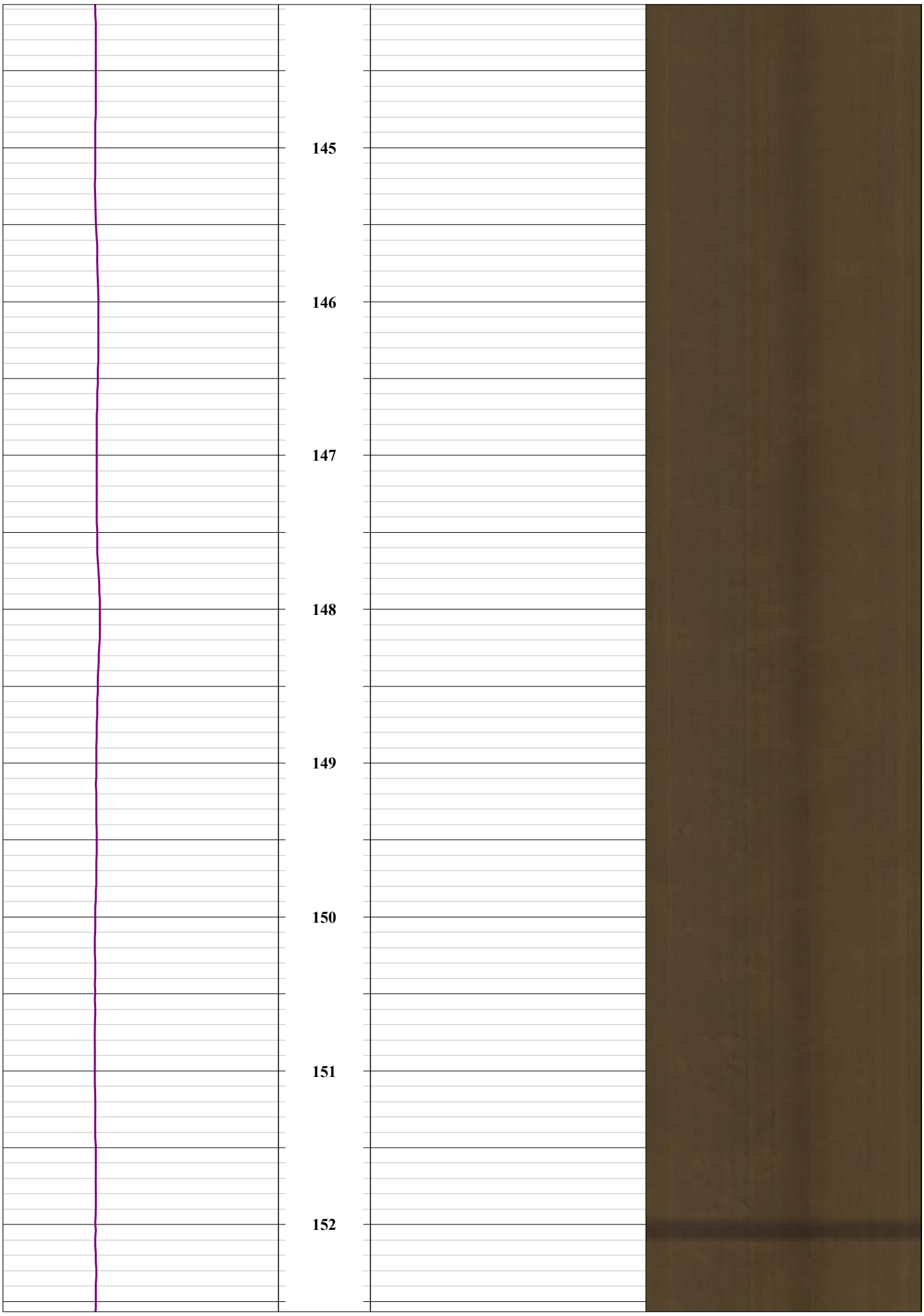
117

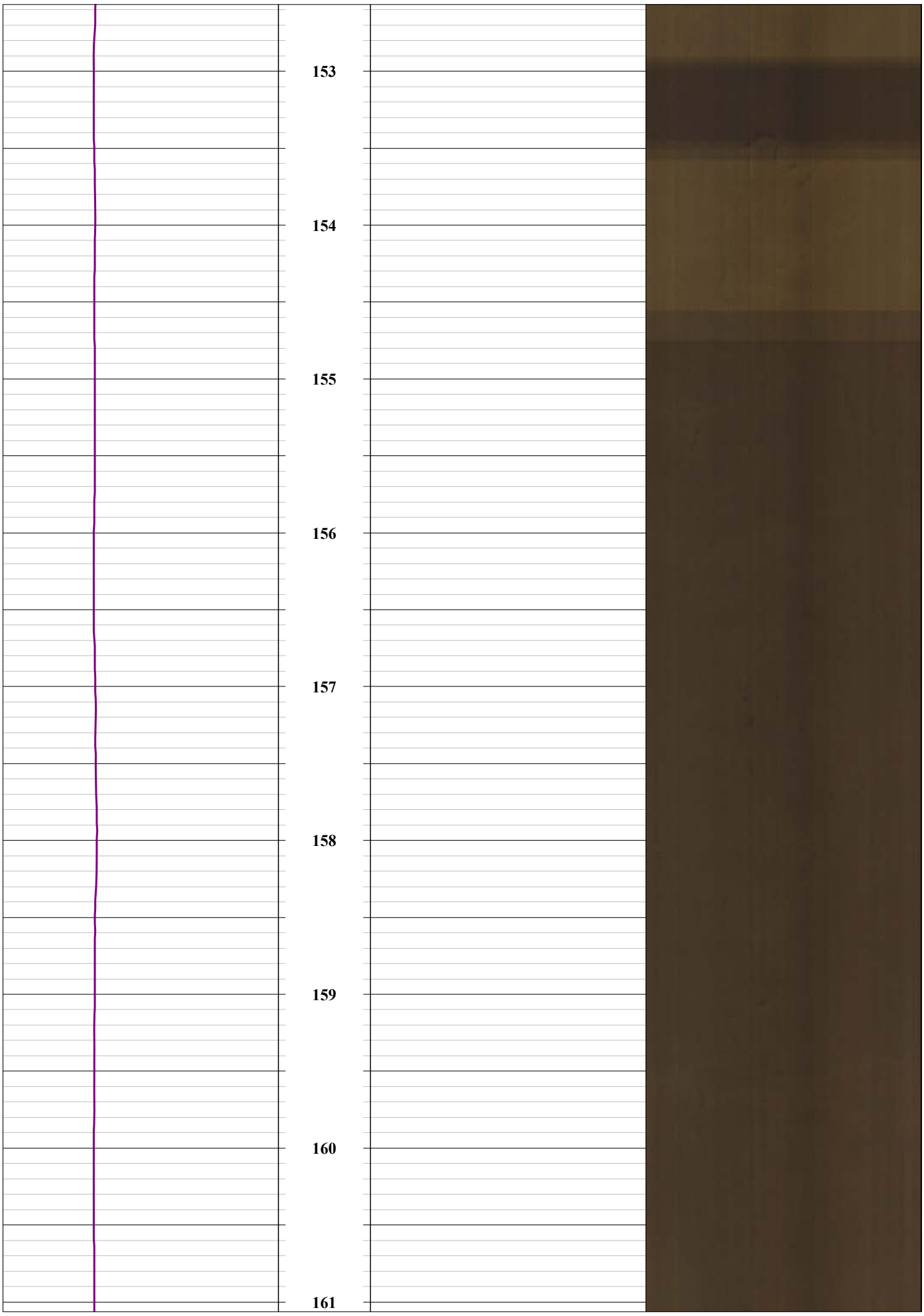
118

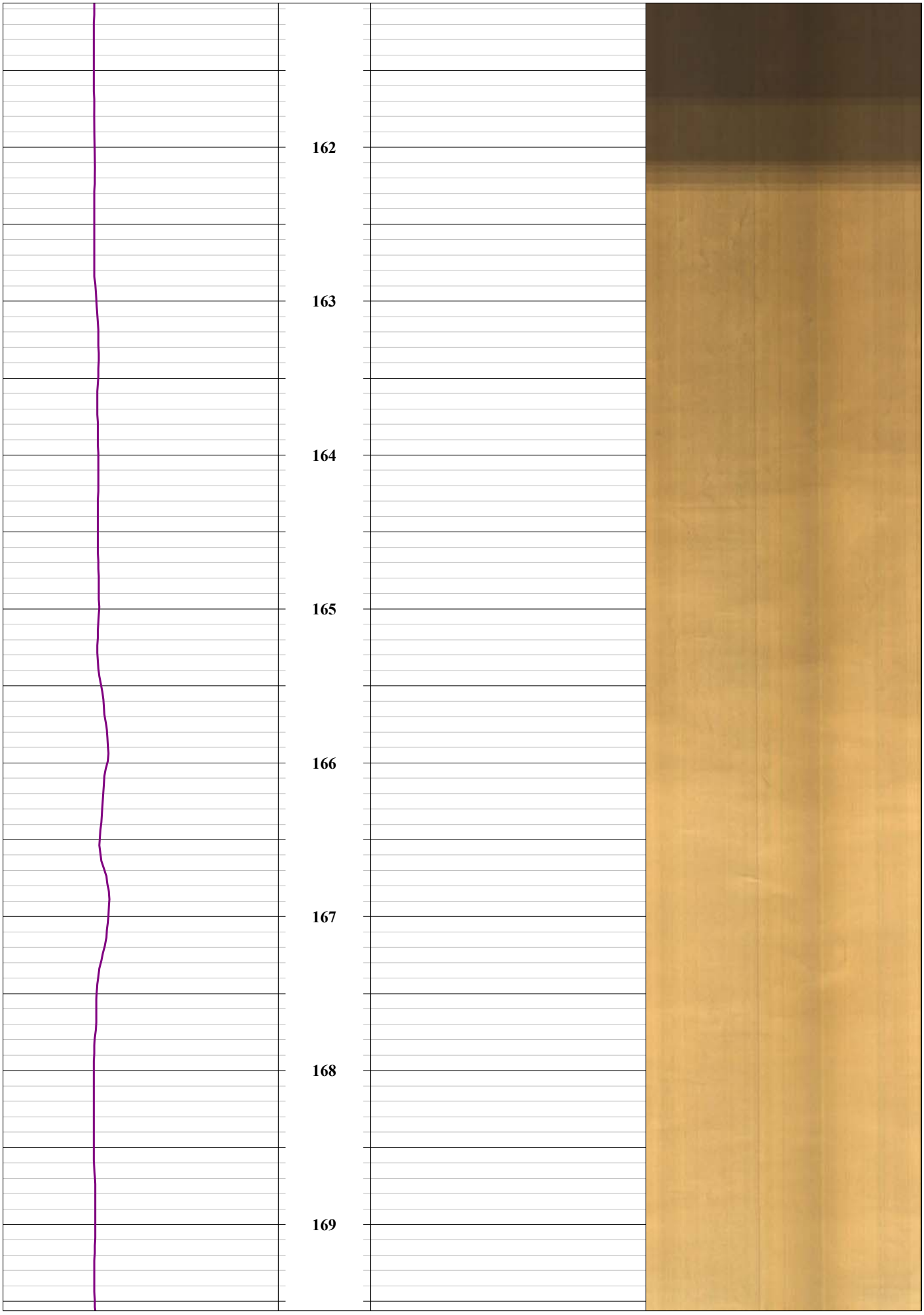

119
120
121
122
123
124
125
126
127

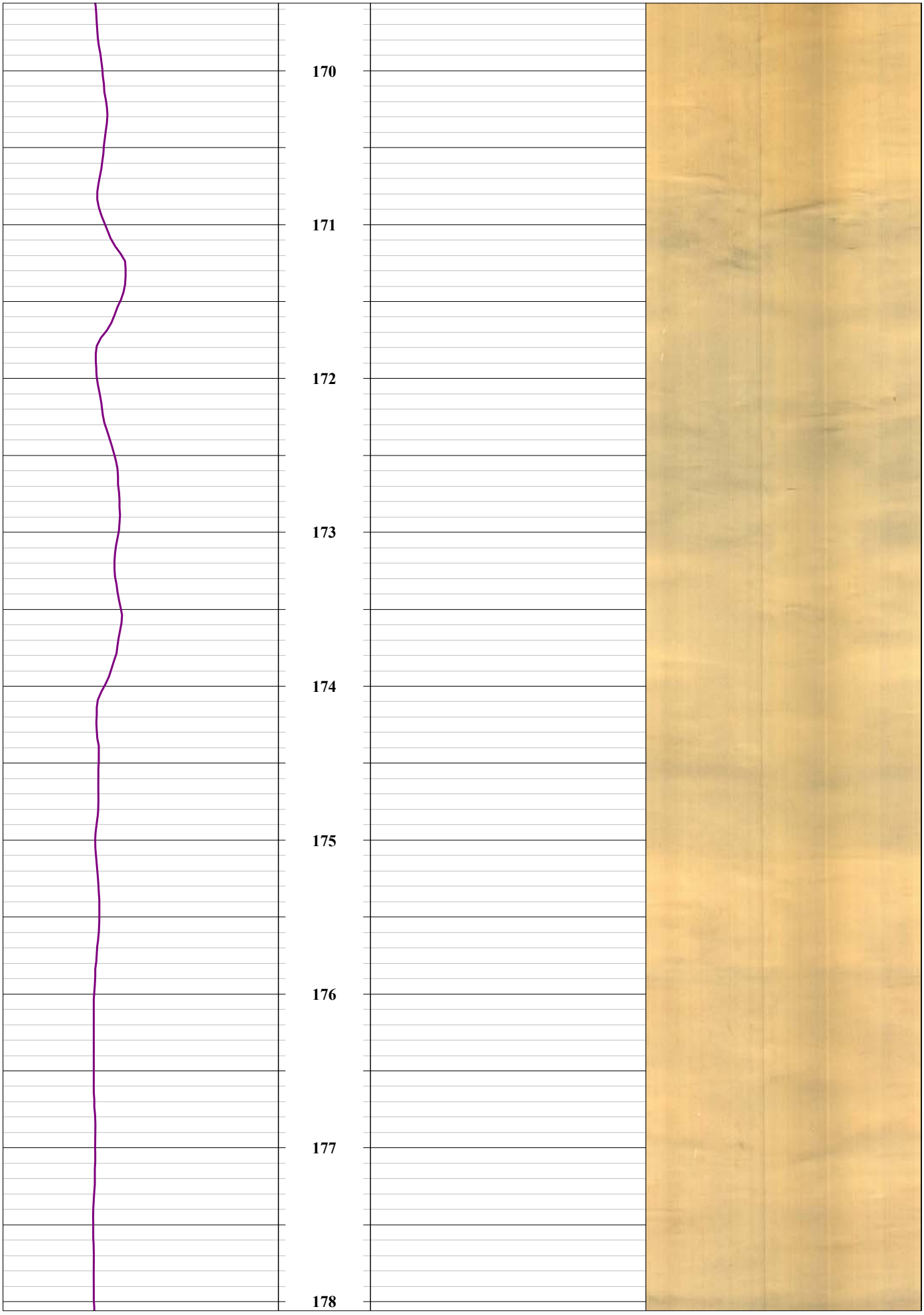

128
129
130
131
132
133
134
135

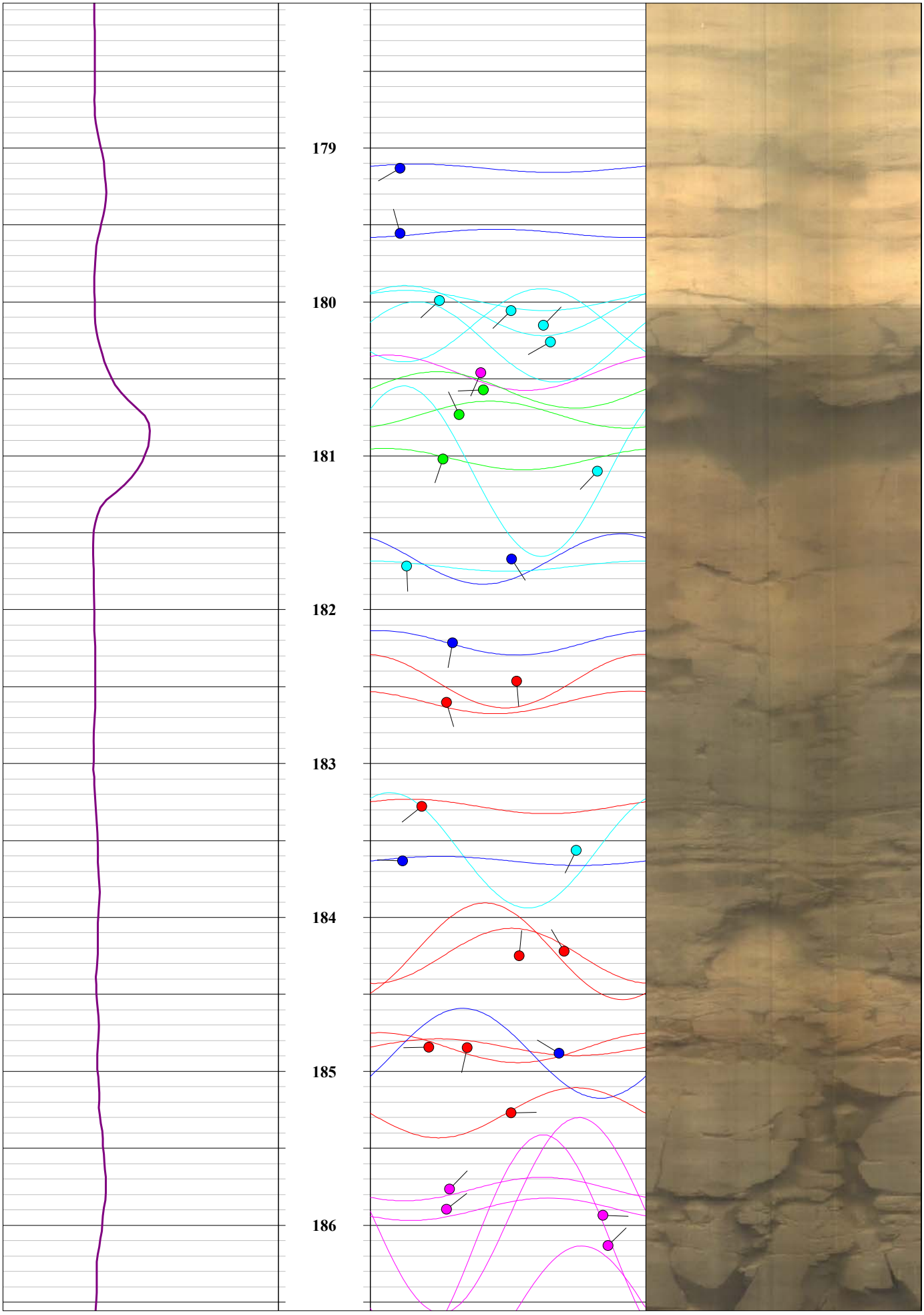

136
137
138
139
140
141
142
143
144


145
146
147
148
149
150
151
152


153
154
155
156
157
158
159
160
161


162
163
164
165
166
167
168
169


170
171
172
173
174
175
176
177
178


179
180
181
182
183
184
185
186

187

188

189

190

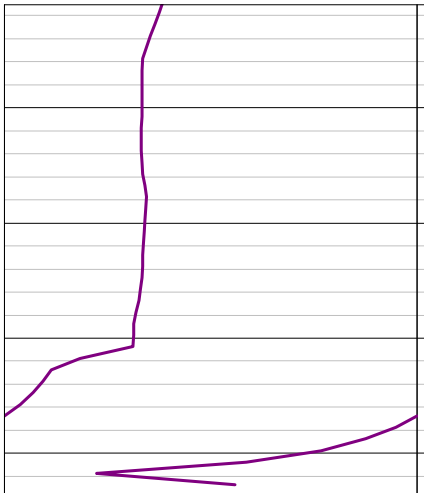
191

192

193

194

195



196

197

198

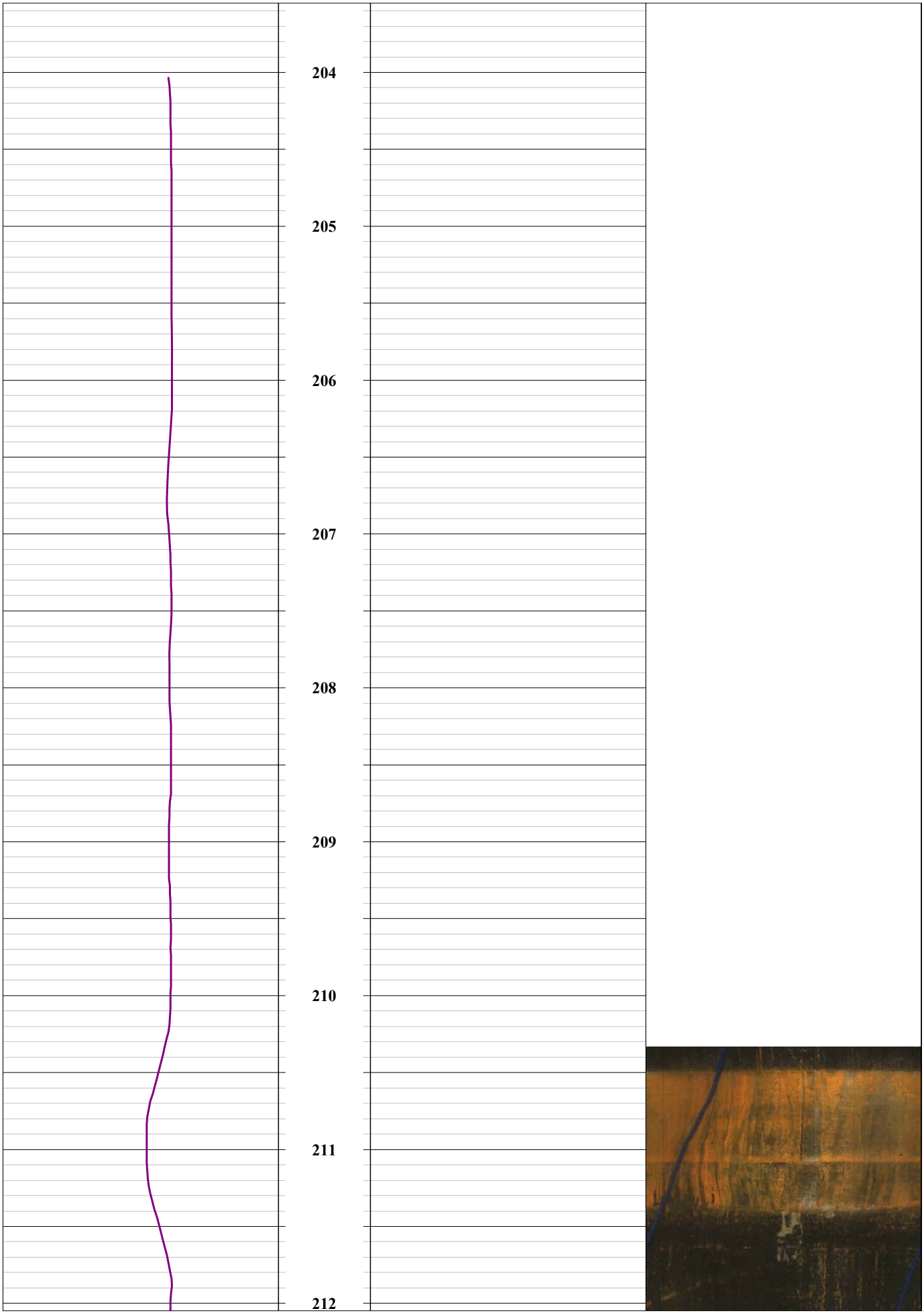
199

200

201

202

203


204
205
206
207
208
209
210
211
212

213

214

215

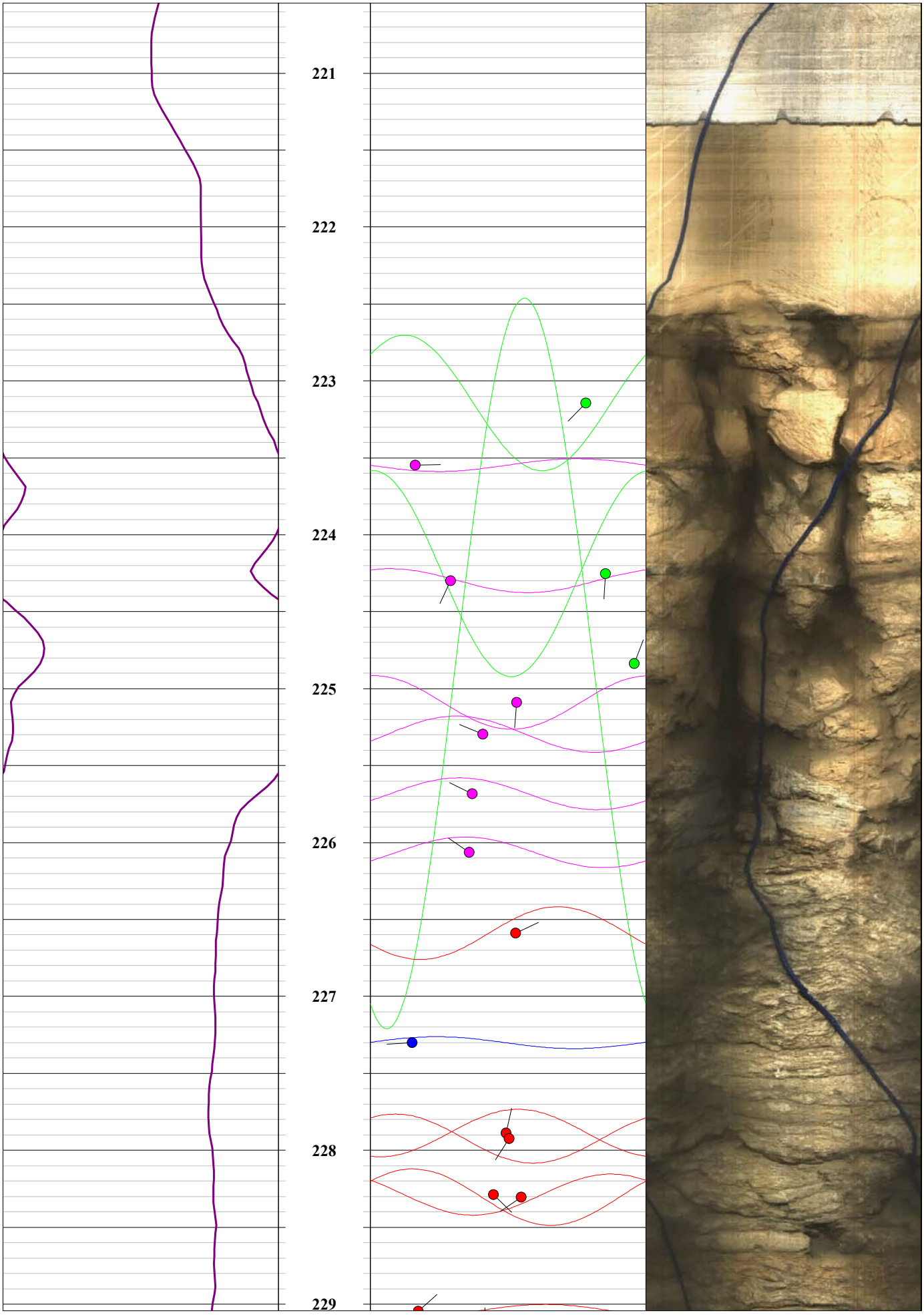
216

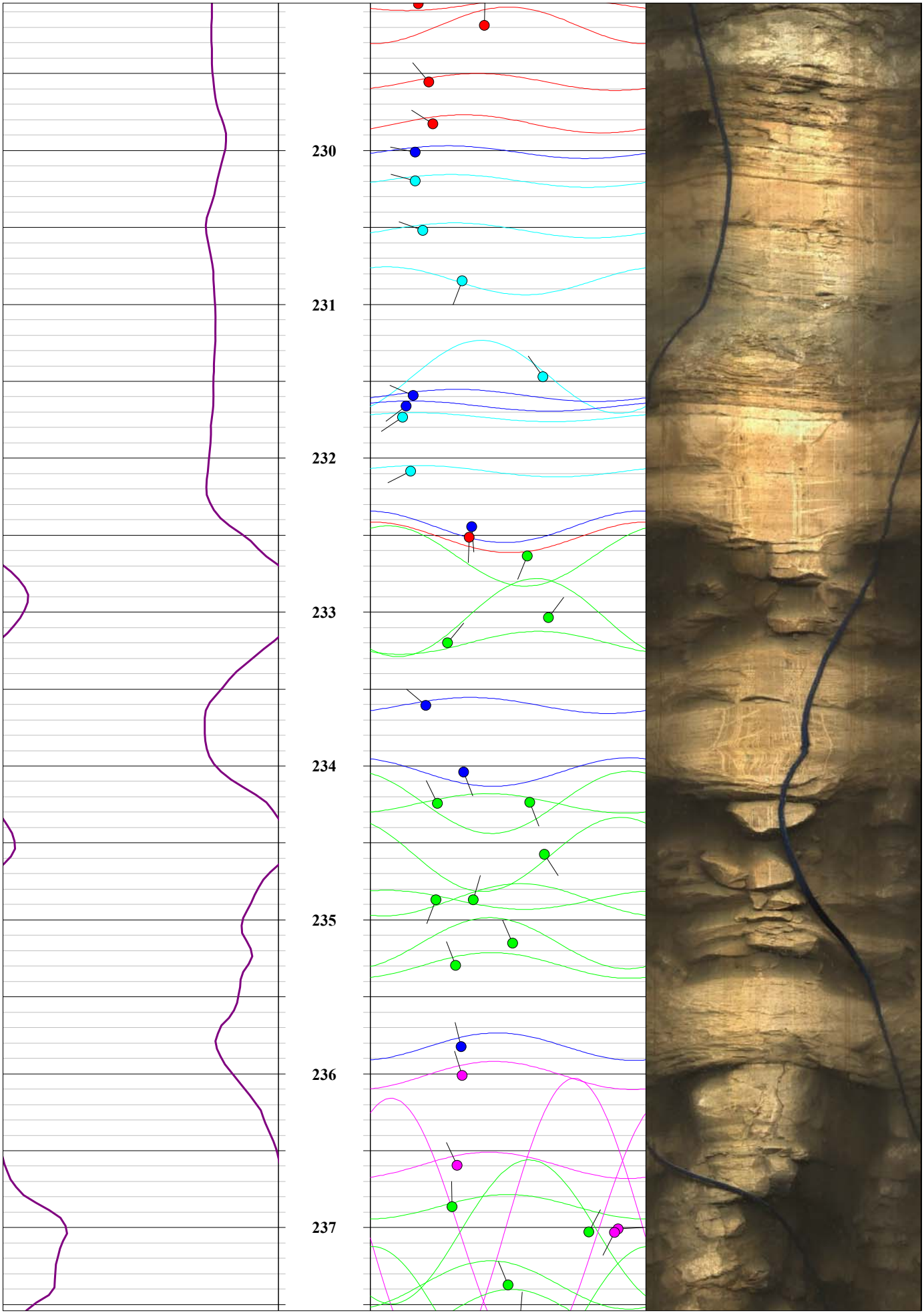
217

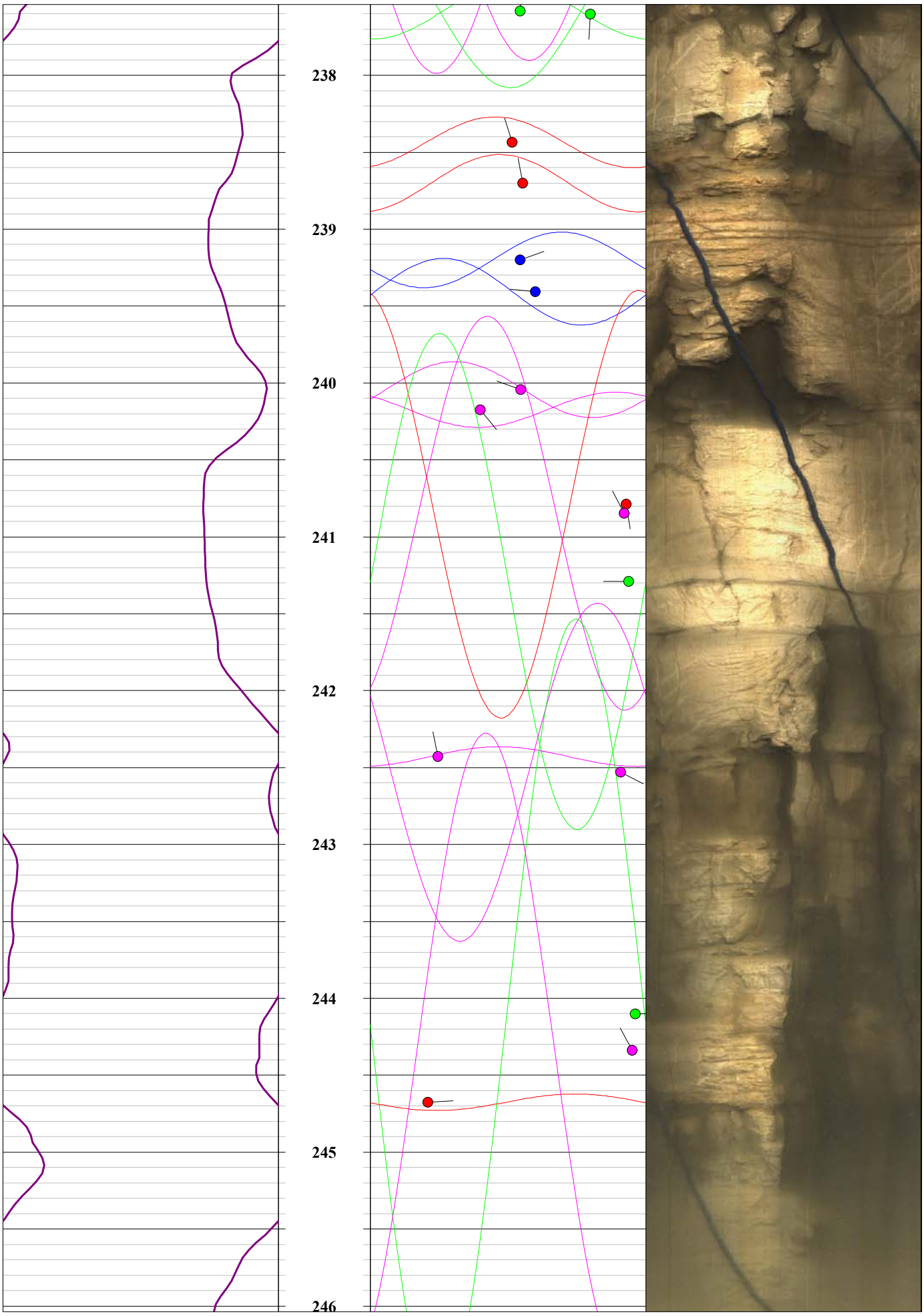
218

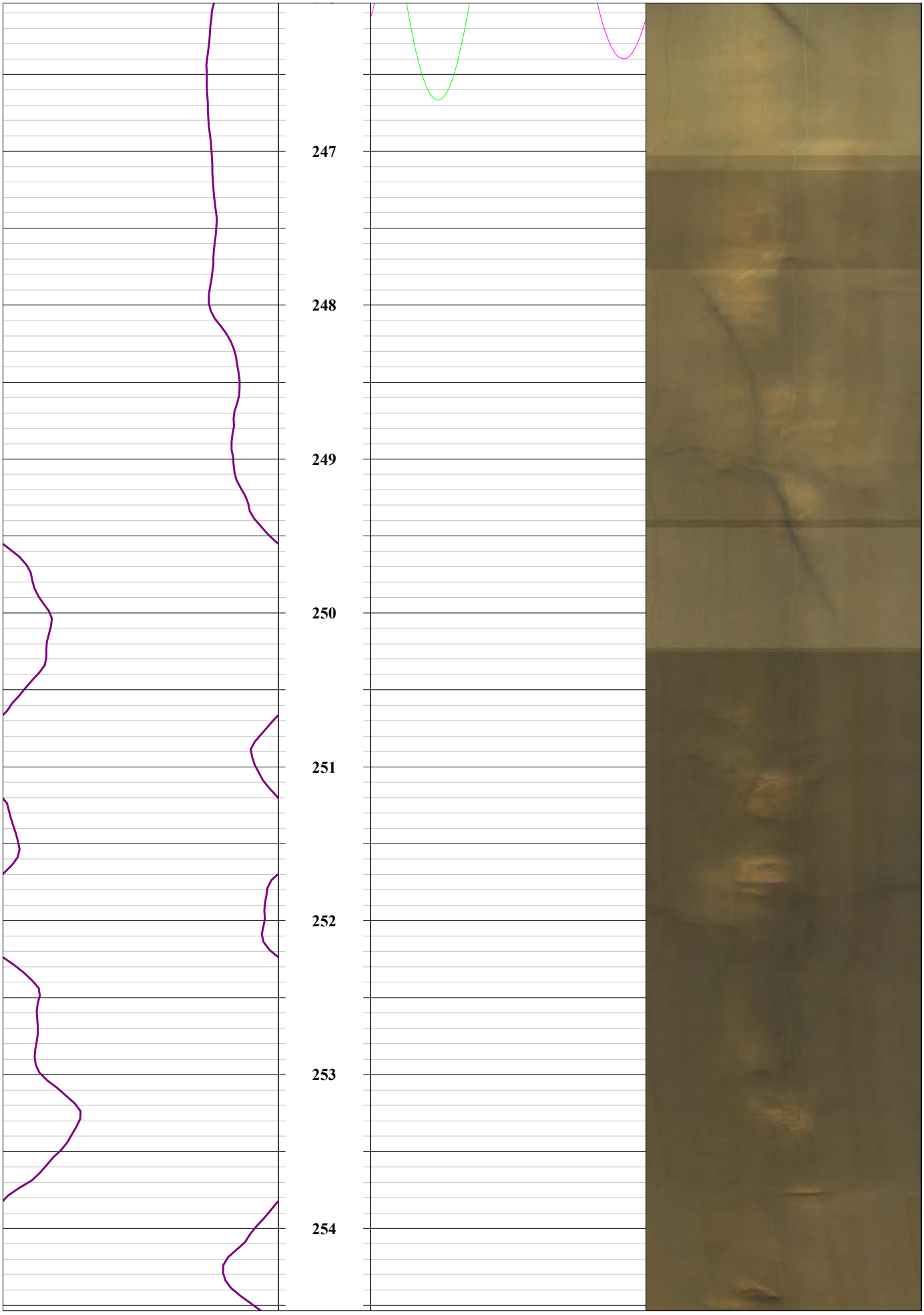
219

220

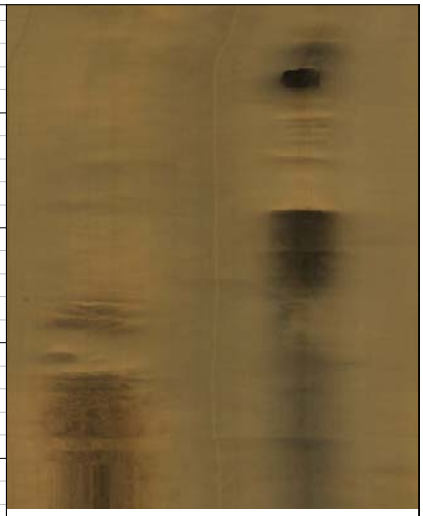

221
222
223
224
225
226
227
228
229


230
231
232
233
234
235
236
237


238
239
240
241
242
243
244
245
246


247
248
249
250
251
252
253
254

255
256
257
258
259
260
261
262
263



264

265

266

267

268

269

270

271

272

273

274

275

276

277

278

279

280

280

281

282

283

284

285

286

287

288

289

290

291

292

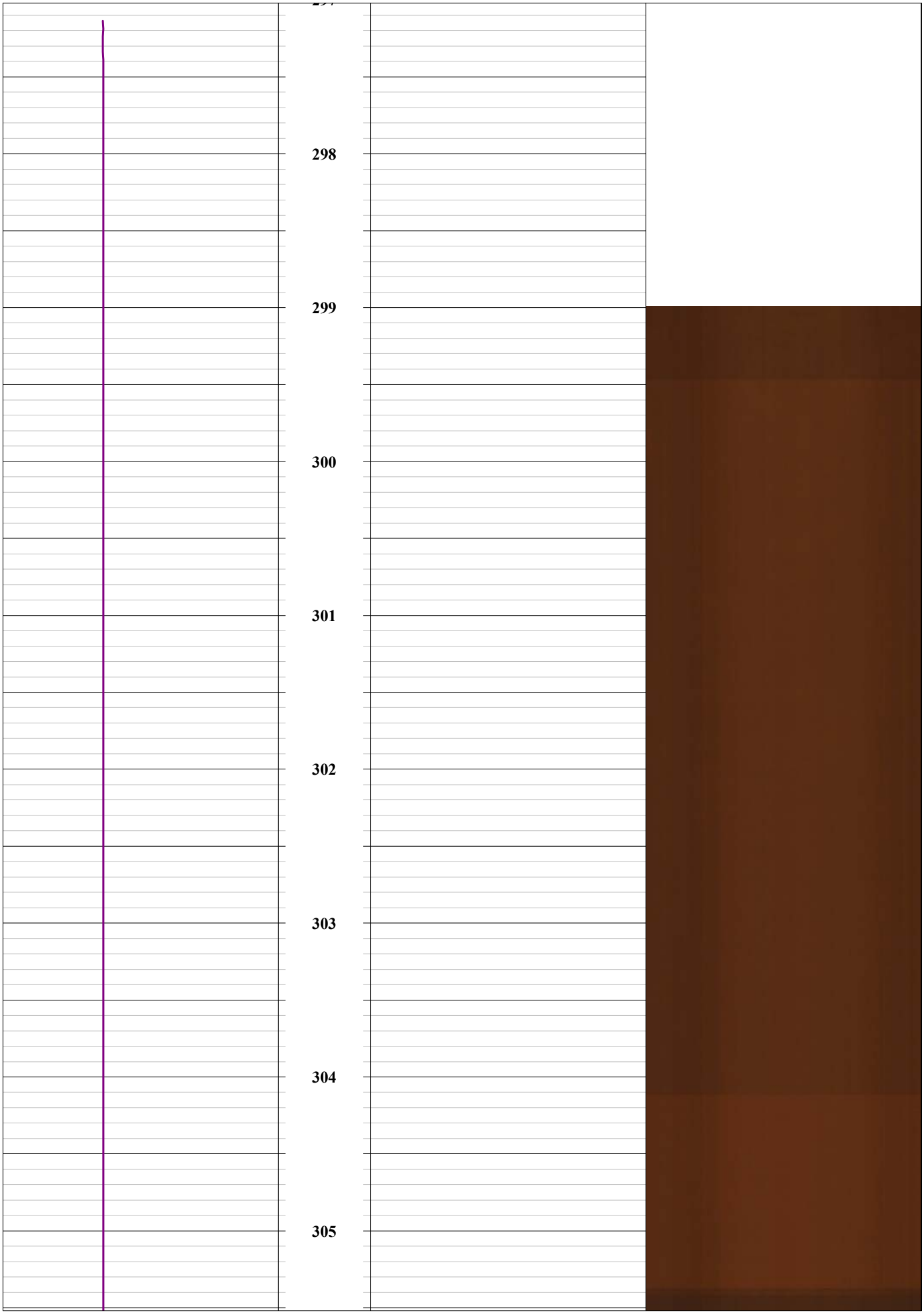
293

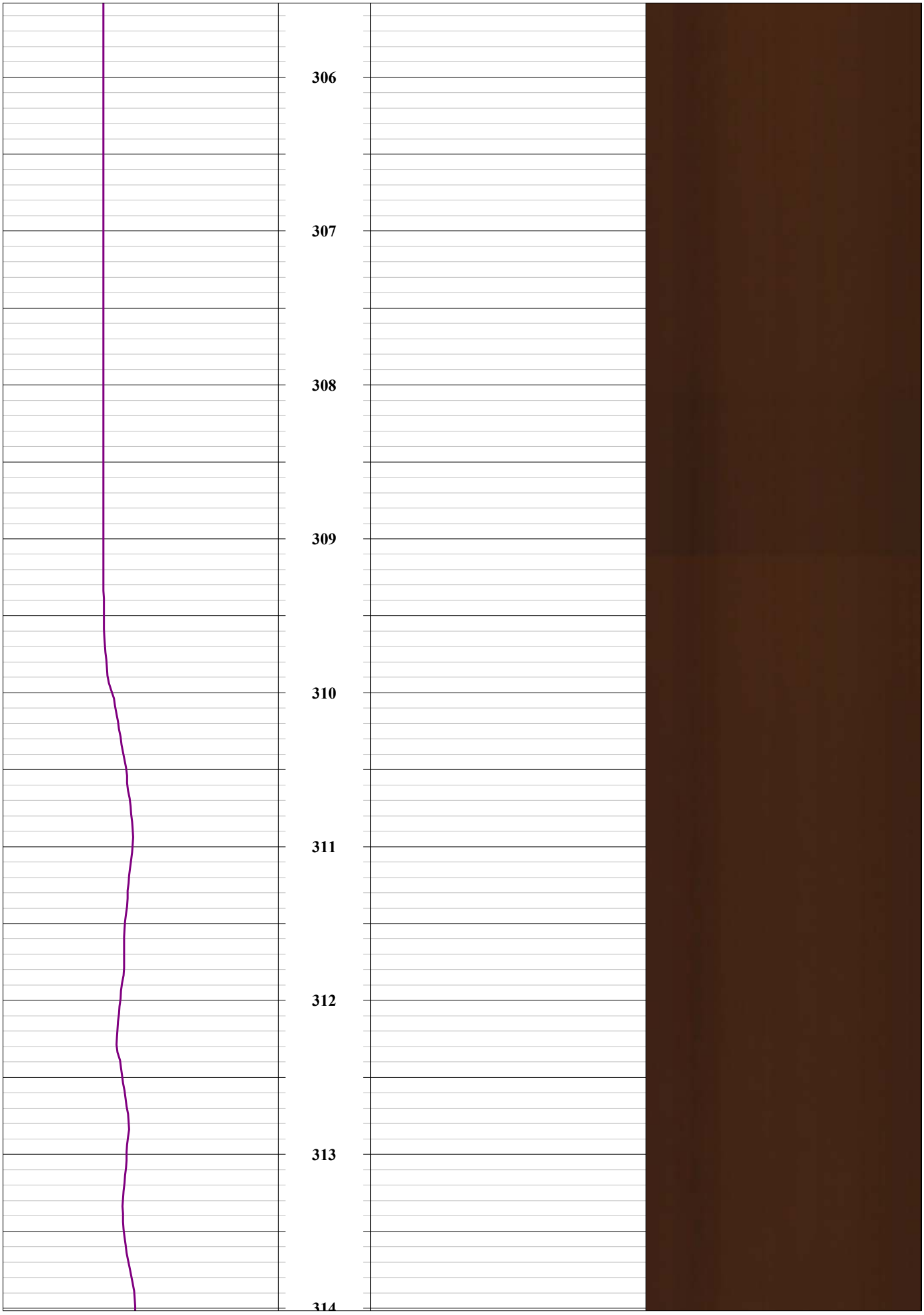
294

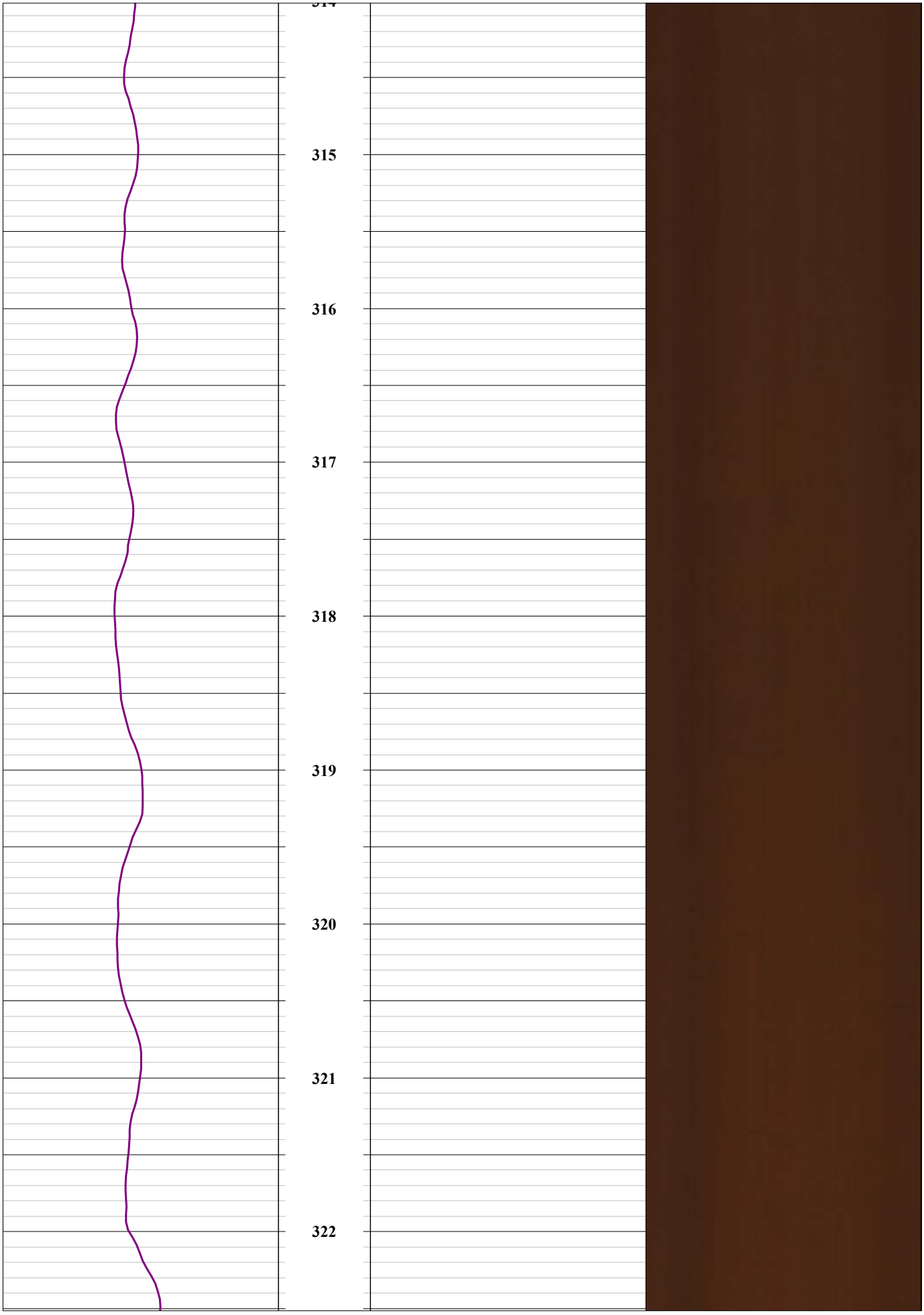
295

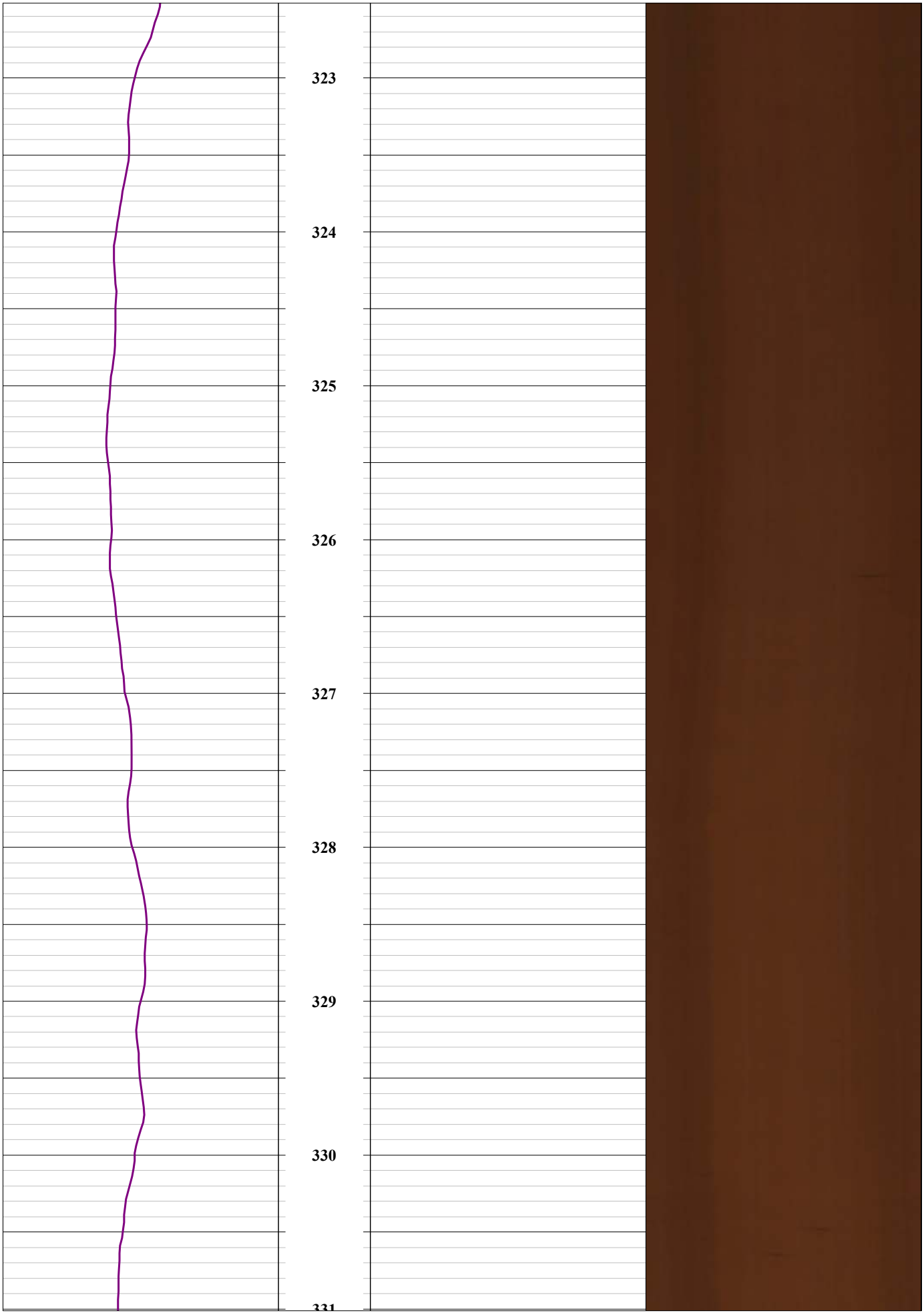
296

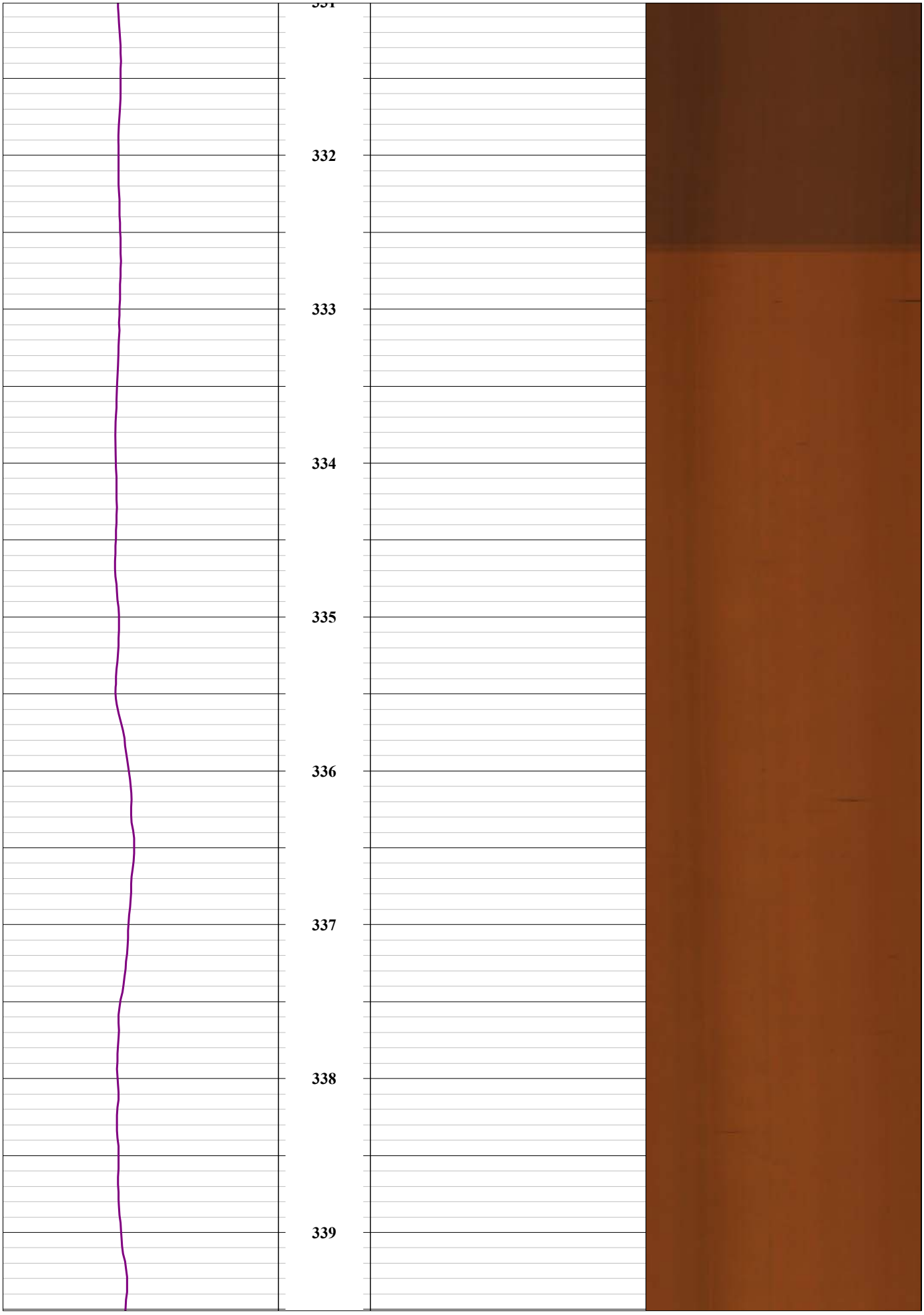
297

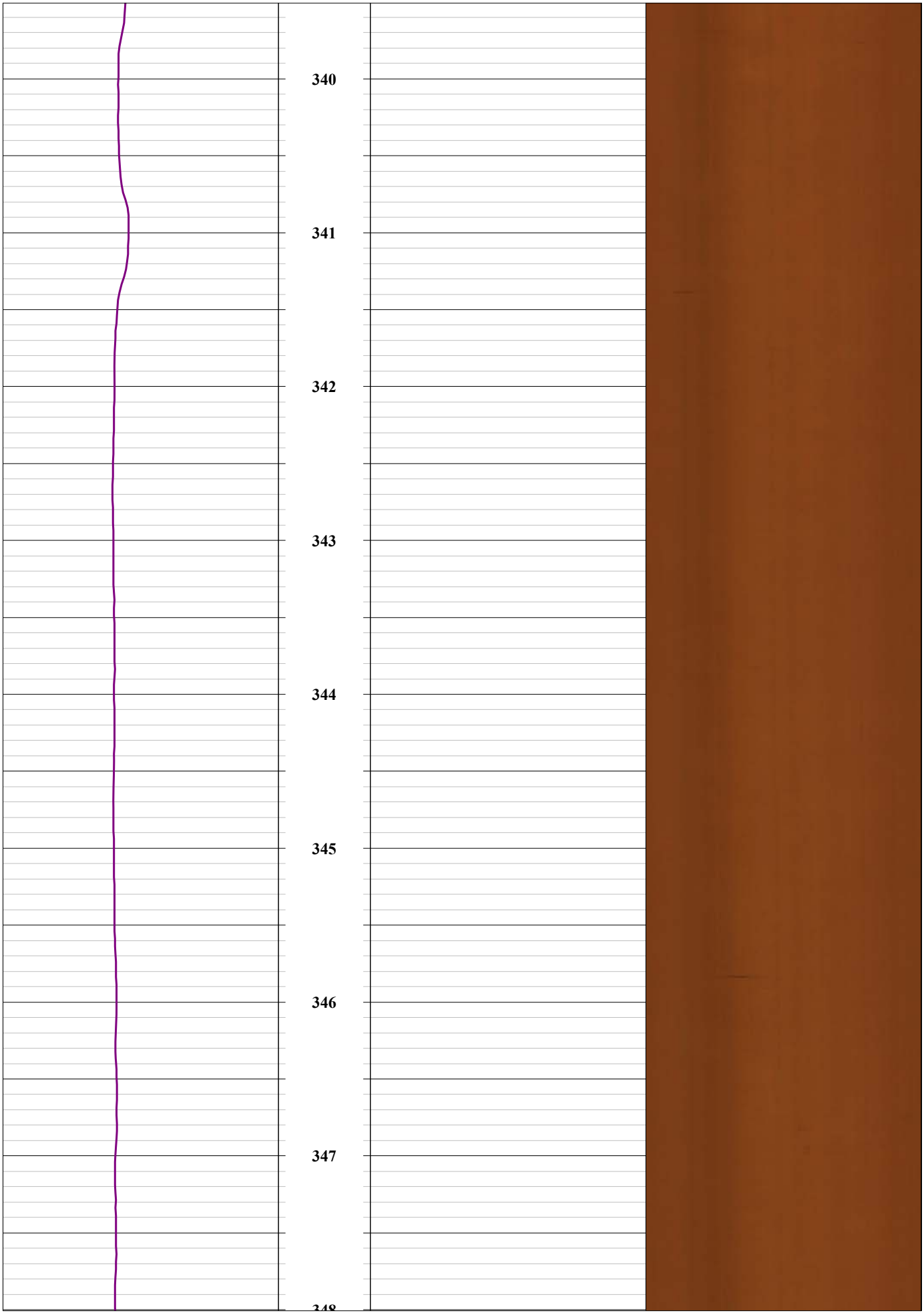

298
299
300
301
302
303
304
305

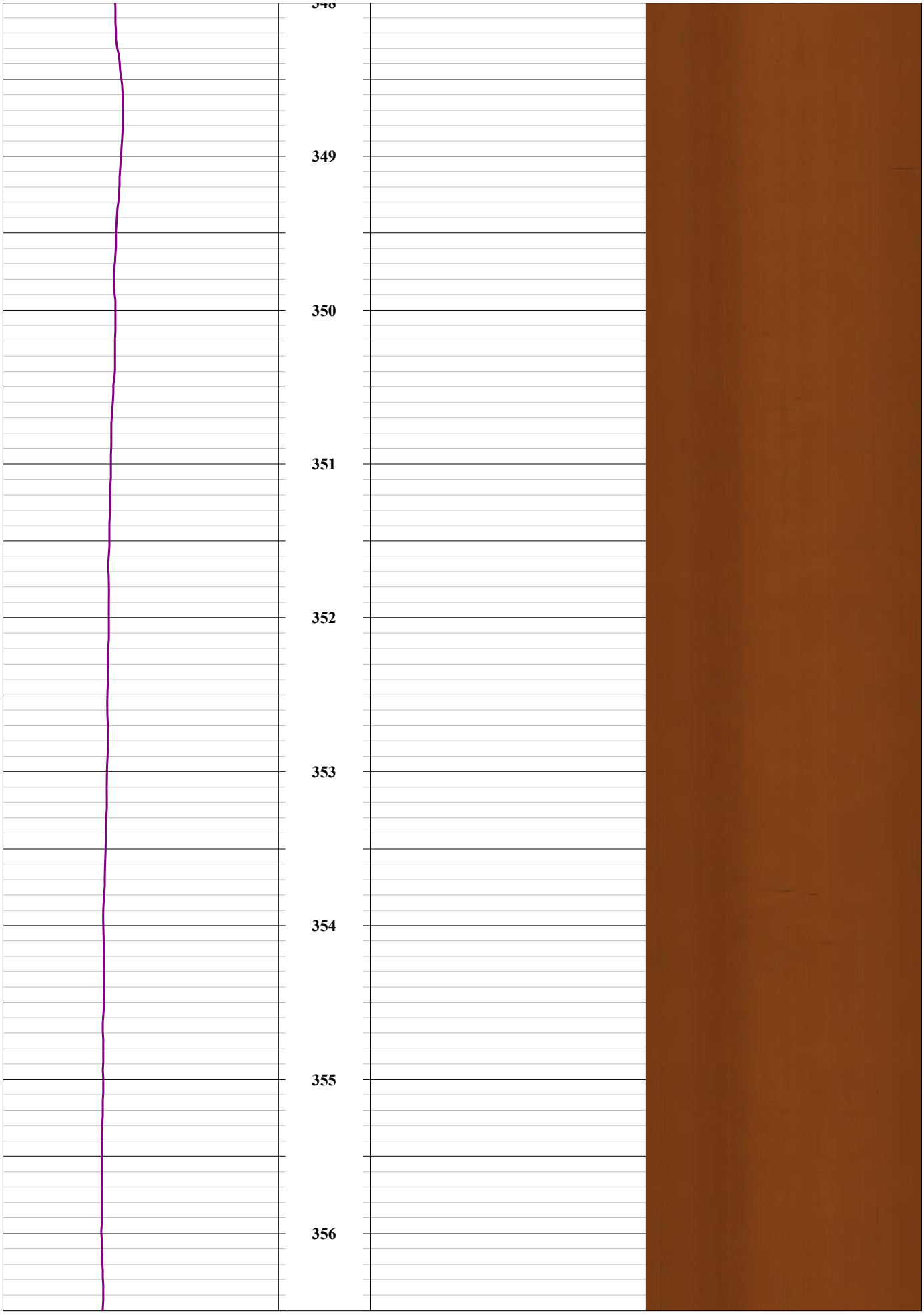

306
307
308
309
310
311
312
313
314

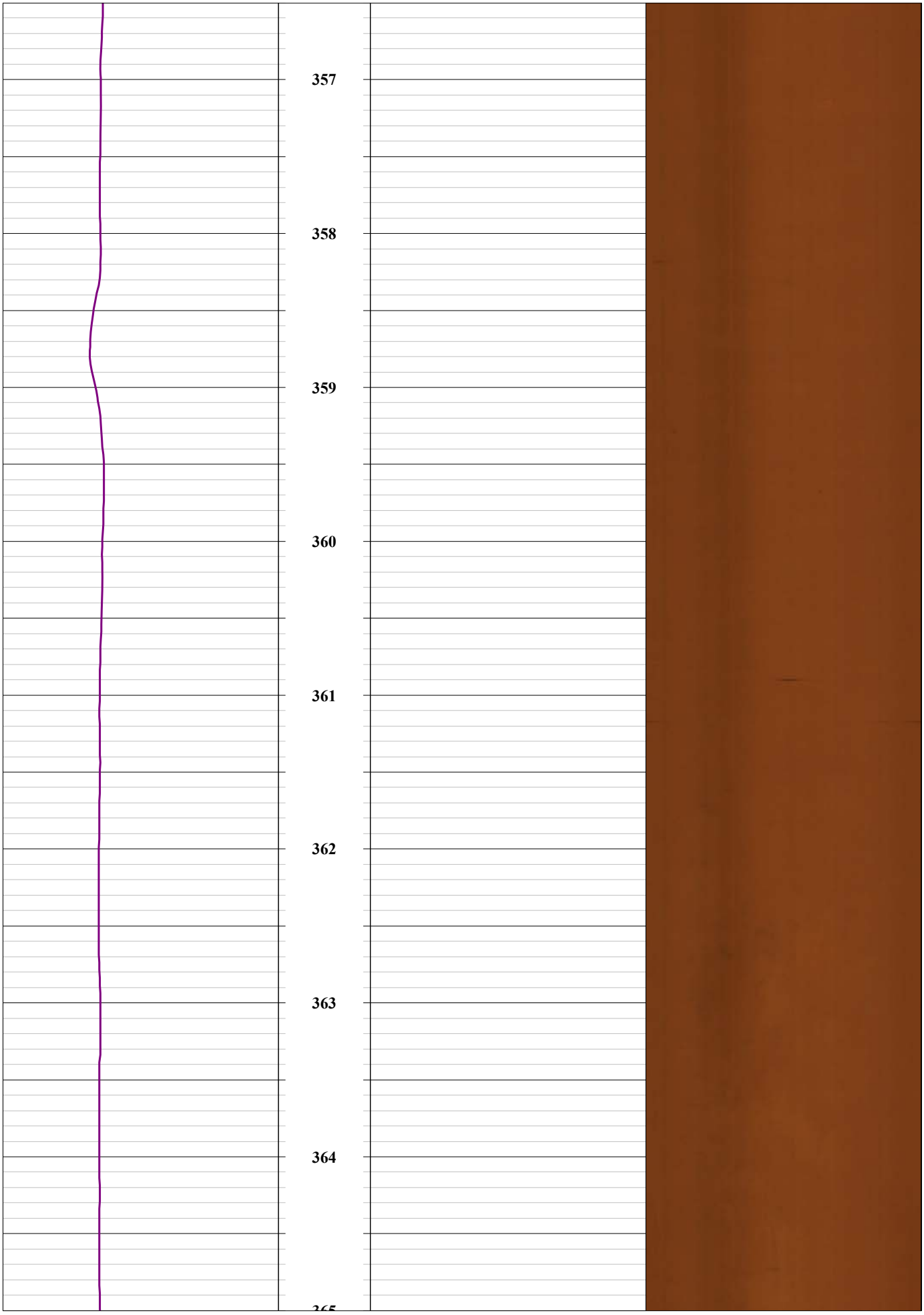

315
316
317
318
319
320
321
322

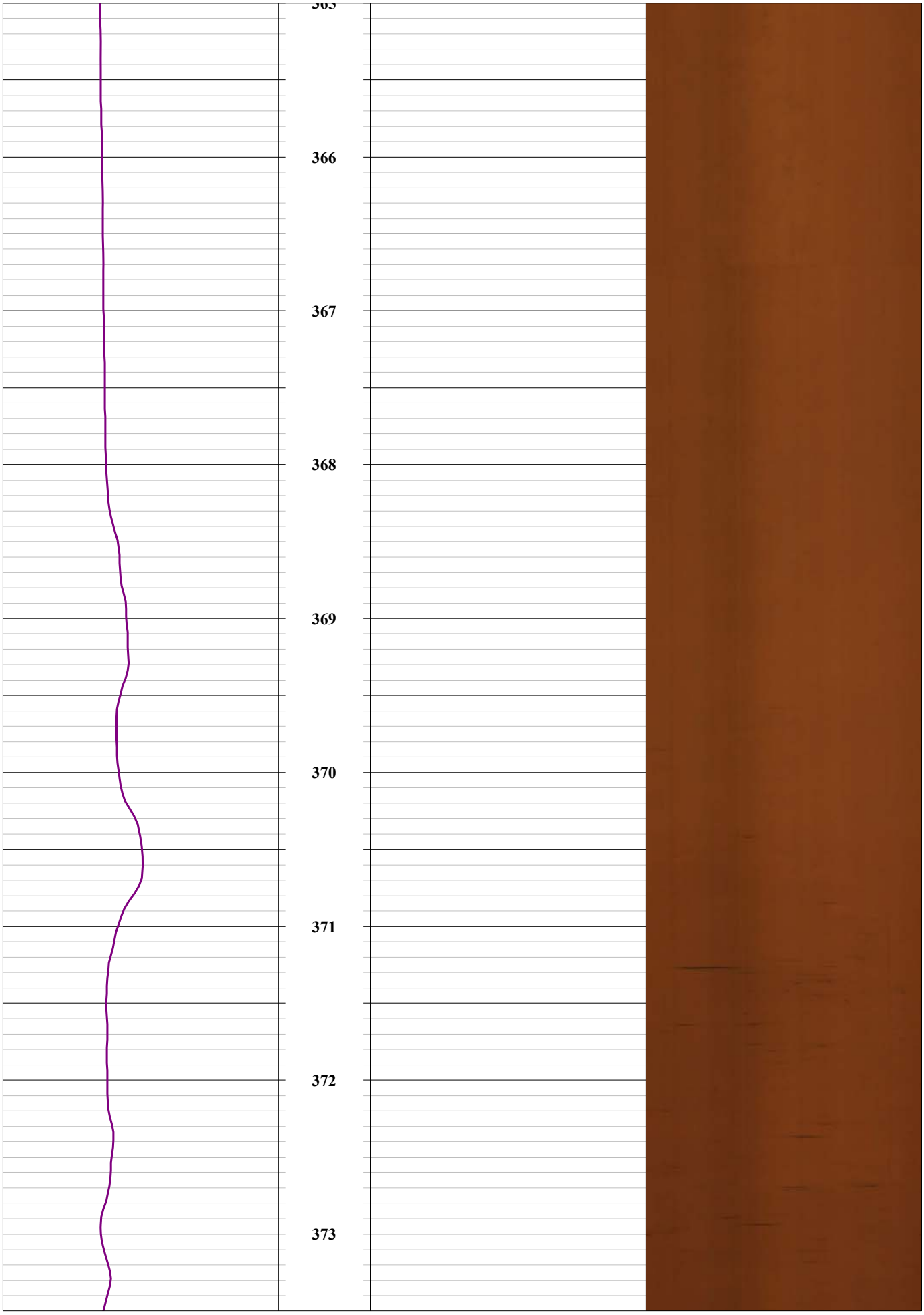

323
324
325
326
327
328
329
330
331

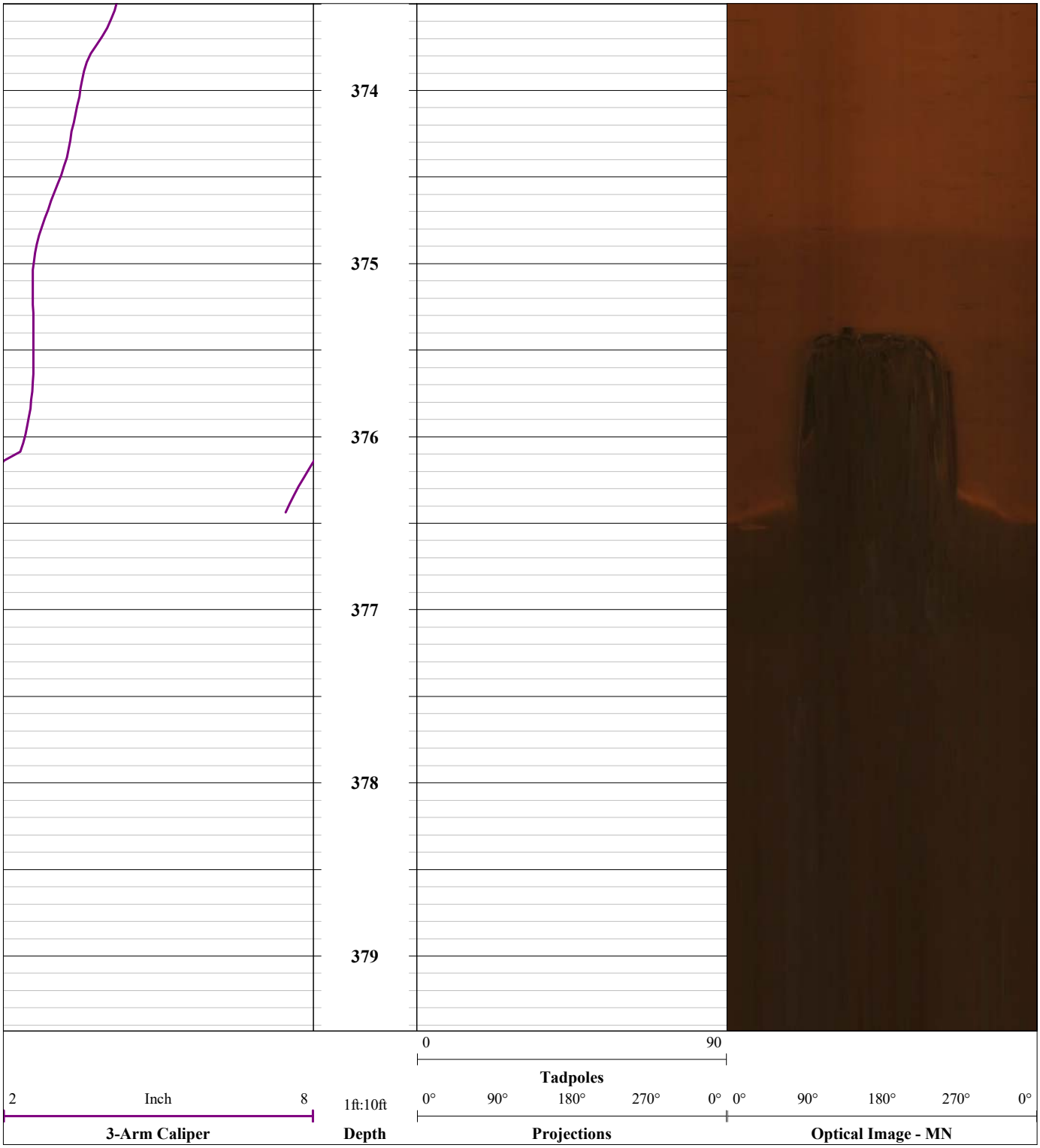

331
332
333
334
335
336
337
338
339


340
341
342
343
344
345
346
347
348

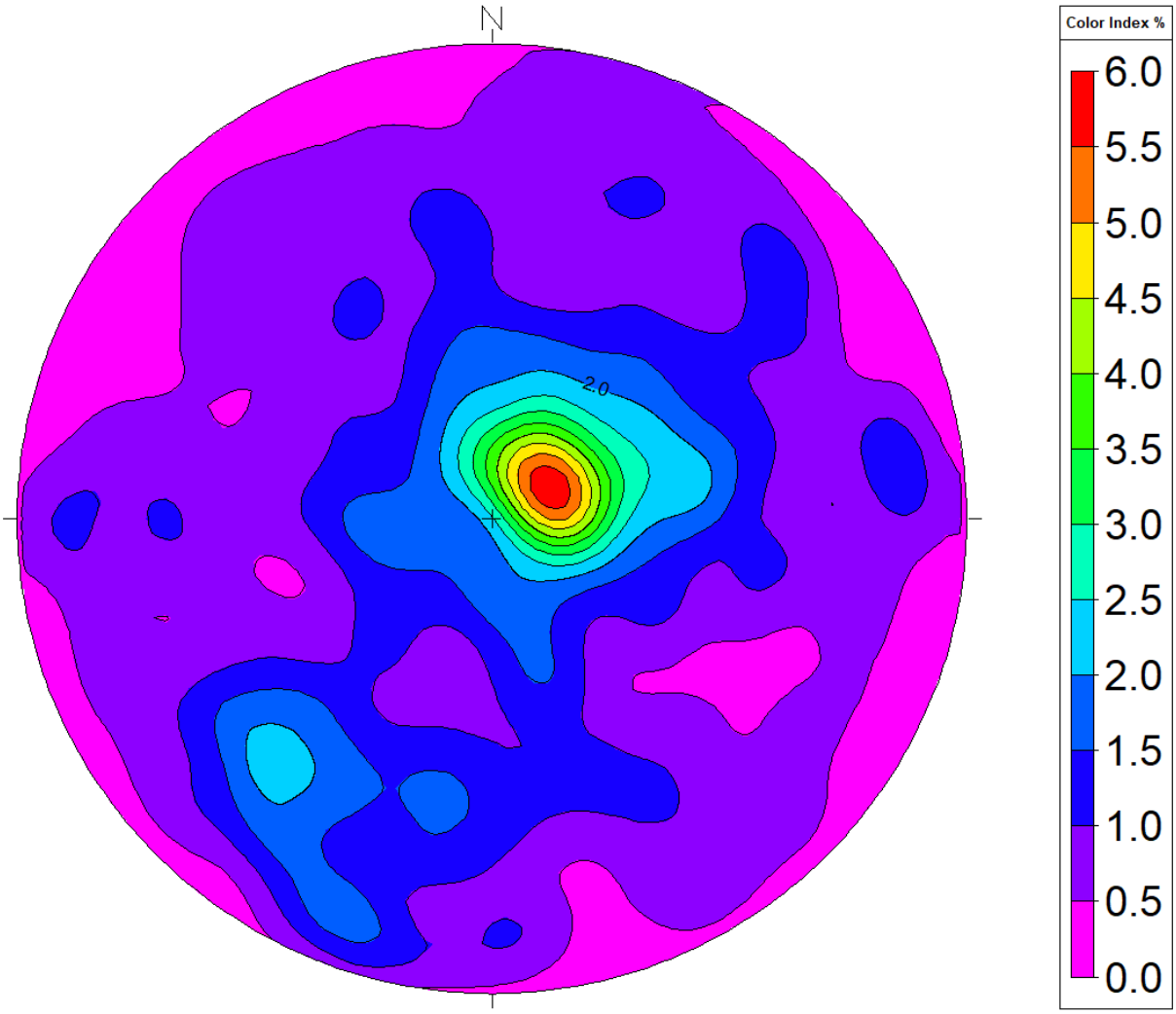

348
349
350
351
352
353
354
355
356


357
358
359
360
361
362
363
364
365


365
366
367
368
369
370
371
372
373

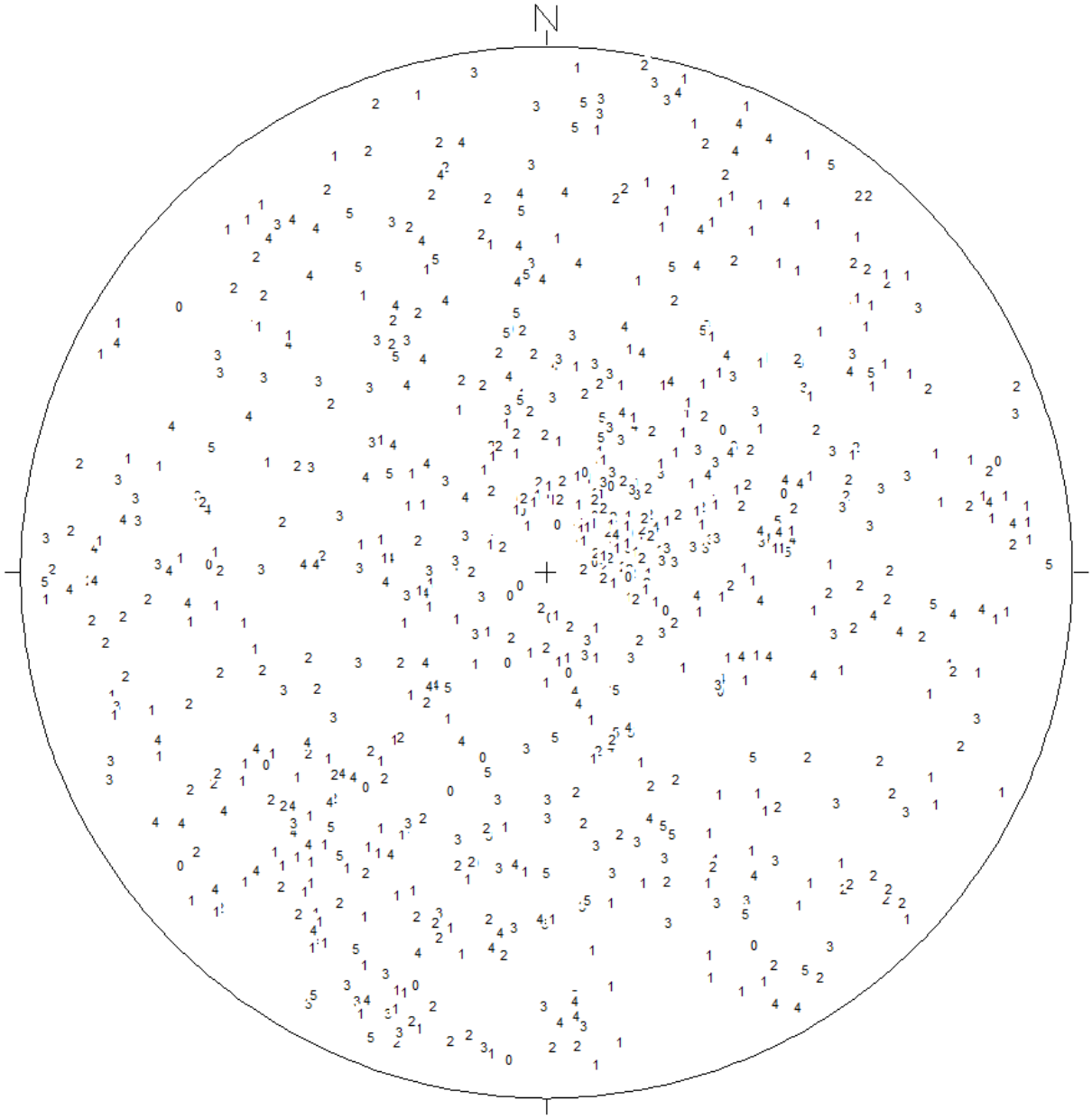

374
375
376
377
378
379
0
90
Tadpoles
2
Inch
8
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
Projections
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-17
4-13 July 2019



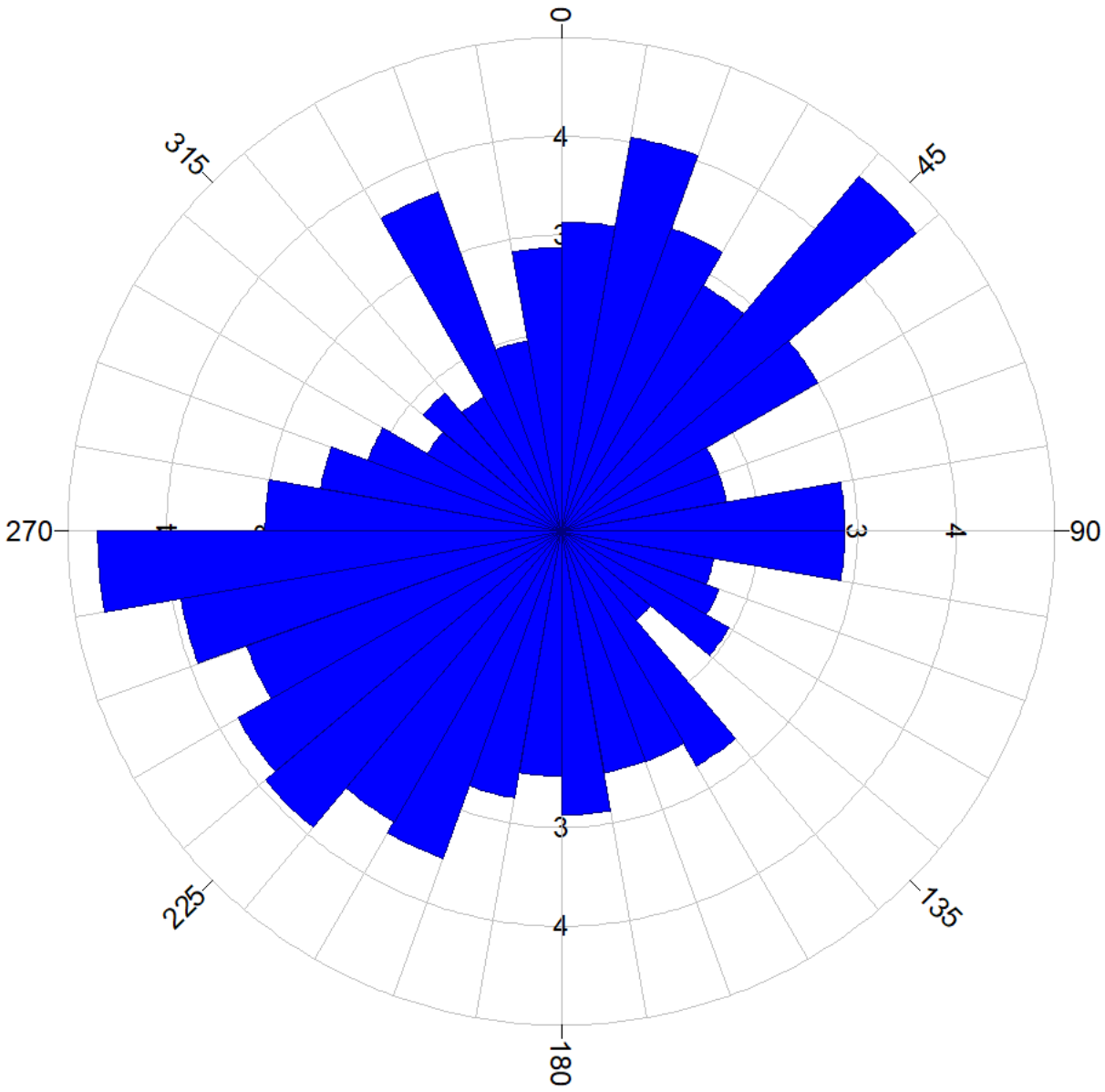
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-17
4-13 July 2019



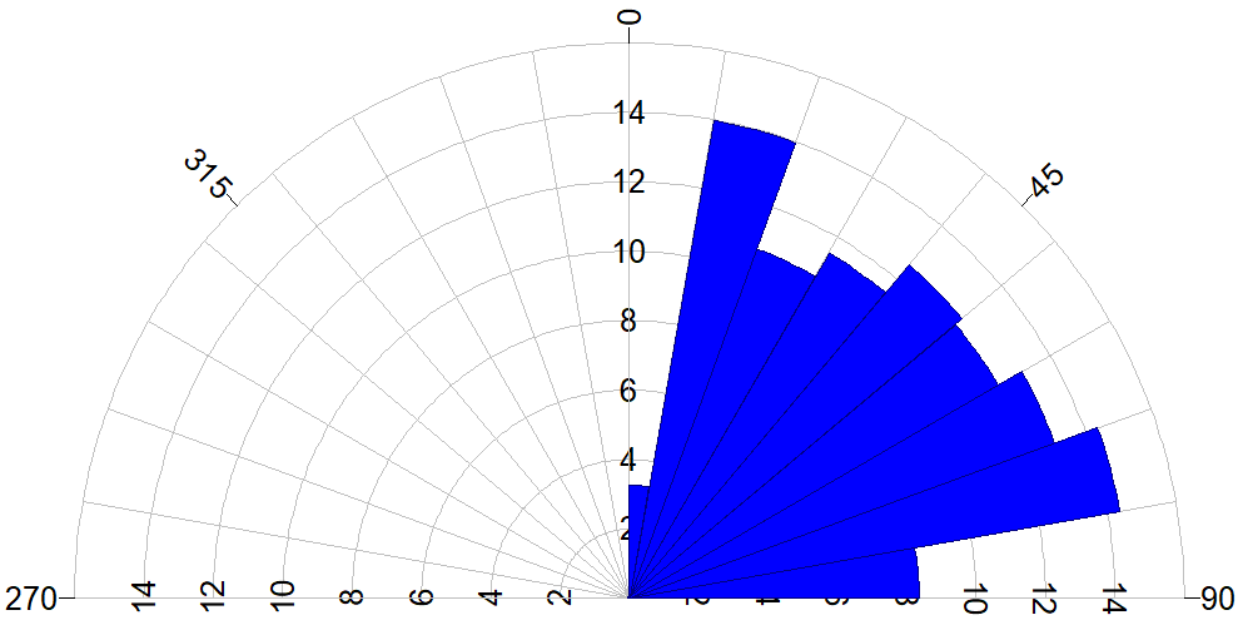
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-17
4-13 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-17
4-13 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	37.00	121.4	248	31	1
2	37.05	121.6	255	24	1
3	37.14	121.9	212	13	2
4	37.16	121.9	204	18	2
5	37.37	122.6	15	76	2
6	37.40	122.7	10	80	2
7	37.51	123.1	42	29	2
8	37.58	123.3	204	70	2
9	37.66	123.6	342	61	3
10	37.66	123.6	19	46	3
11	37.68	123.6	32	73	2
12	37.71	123.7	142	45	3
13	37.79	124.0	175	60	4
14	37.80	124.0	7	48	4
15	37.82	124.1	45	47	4
16	37.83	124.1	181	31	4
17	37.90	124.4	149	28	1
18	37.95	124.5	225	29	1
19	38.01	124.7	301	62	3
20	38.01	124.7	197	31	3
21	38.01	124.7	128	21	3
22	38.01	124.7	25	73	1
23	38.05	124.8	355	55	3
24	38.08	124.9	147	42	3
25	38.12	125.1	351	45	3
26	38.21	125.4	162	23	1
27	38.22	125.4	20	75	1
28	38.24	125.5	39	58	1
29	38.30	125.7	166	34	2
30	38.42	126.1	154	32	2
31	38.44	126.1	108	14	3
32	38.46	126.2	44	80	2
33	38.46	126.2	44	70	4
34	38.47	126.2	23	79	4
35	38.57	126.5	126	43	2
36	38.58	126.6	262	73	4
37	38.64	126.8	20	80	3
38	38.81	127.3	83	77	2
39	38.91	127.7	31	58	2
40	38.95	127.8	249	84	2
41	39.00	127.9	203	19	1
42	39.14	128.4	273	8	2
43	39.17	128.5	131	69	2
44	39.19	128.6	51	76	2
45	39.32	129.0	263	17	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	39.43	129.4	88	77	2
47	39.46	129.5	18	85	2
48	39.61	129.9	60	17	1
49	39.61	130.0	248.4	21.0	2
50	39.65	130.1	190.6	86.0	2
51	39.79	130.6	98.4	27.0	1
52	39.84	130.7	89.4	84.4	2
53	39.95	131.1	2.8	18.4	1
54	39.99	131.2	140.3	14.6	2
55	40.00	131.2	295.8	21.1	2
56	40.10	131.6	214.9	6.7	2
57	40.15	131.7	79.2	50.0	1
58	40.22	132.0	73.5	76.3	1
59	40.25	132.0	205.0	61.0	1
60	40.35	132.4	261.5	76.1	1
61	40.54	133.0	215.1	13.3	1
62	40.60	133.2	84.2	12.5	2
63	40.61	133.3	41.8	65.9	1
64	40.65	133.4	203.1	14.5	1
65	40.68	133.5	37.4	19.5	1
66	40.89	134.2	188.5	6.1	0
67	41.00	134.5	267.0	6.6	0
68	41.03	134.6	138.5	76.5	1
69	41.08	134.8	334.3	21.5	1
70	41.26	135.4	2.2	8.3	0
71	41.37	135.7	287.0	10.0	1
72	41.43	135.9	251.6	14.4	1
73	41.49	136.1	252.4	9.8	1
74	41.62	136.6	147.7	7.1	1
75	41.78	137.1	195.3	85.2	1
76	41.80	137.2	150.6	9.4	0
77	41.93	137.6	153.9	11.0	0
78	42.00	137.8	199.8	15.1	0
79	42.07	138.0	215.6	7.7	0
80	42.11	138.2	225.9	5.9	2
81	42.13	138.2	171.3	12.8	2
82	42.21	138.5	24.2	16.6	0
83	42.22	138.5	169.9	37.4	0
84	42.30	138.8	152.9	20.6	2
85	42.36	139.0	216.7	15.2	0
86	42.50	139.5	279.0	5.0	2
87	42.58	139.7	195.8	14.1	1
88	42.62	139.8	329.6	49.6	1
89	42.65	139.9	215.0	7.7	1
90	42.73	140.2	285.5	8.2	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	42.75	140.2	135.9	77.6	1
92	42.79	140.4	299.3	71.6	1
93	42.80	140.4	350.6	14.7	1
94	42.85	140.6	220.7	81.5	2
95	42.85	140.6	242.3	13.7	1
96	42.92	140.8	68.1	24.6	1
97	42.97	141.0	75.2	72.7	2
98	42.99	141.1	222.7	11.7	2
99	43.07	141.3	274.8	31.4	1
100	43.13	141.5	15.6	61.0	1
101	43.17	141.7	257.2	39.1	1
102	43.18	141.7	267.5	76.7	2
103	43.23	141.8	301.0	35.4	1
104	43.24	141.9	200.0	35.8	1
105	43.25	141.9	16.8	63.2	2
106	43.38	142.3	57.1	65.6	2
107	43.39	142.4	225.8	33.1	2
108	43.45	142.6	249.1	25.0	2
109	43.57	143.0	225.8	18.0	1
110	43.58	143.0	221.7	31.7	1
111	43.58	143.0	219.7	80.3	2
112	43.60	143.0	109.6	48.0	1
113	43.63	143.1	115.0	84.0	1
114	43.85	143.9	284.2	72.5	1
115	43.91	144.1	144.9	52.3	1
116	43.94	144.2	276.5	12.5	2
117	44.15	144.9	124.6	75.1	0
118	44.33	145.5	255.9	10.3	1
119	44.48	145.9	25.1	58.9	1
120	44.49	146.0	43.5	14.4	1
121	44.49	146.0	119.1	83.8	1
122	44.49	146.0	296.8	85.5	1
123	44.55	146.2	19.6	32.0	0
124	44.85	147.1	17.4	50.3	2
125	44.85	147.2	151.6	19.1	1
126	44.98	147.6	14.4	49.1	0
127	45.04	147.8	19.4	78.7	1
128	45.08	147.9	211	63	1
129	45.10	148.0	203	84	1
130	45.11	148.0	165	21	2
131	45.19	148.3	37	65	1
132	45.32	148.7	33	54	1
133	45.43	149.1	254	65	1
134	45.47	149.2	261	72	1
135	45.49	149.3	231	76	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	45.51	149.3	147	10	1
137	45.55	149.4	157	51	1
138	45.60	149.6	226	47	1
139	45.63	149.7	42	37	1
140	45.76	150.1	18	73	0
141	45.87	150.5	40	46	0
142	45.93	150.7	307	33	0
143	46.20	151.6	71	20	1
144	46.26	151.8	198	77	1
145	46.26	151.8	47	30	1
146	46.27	151.8	249	19	1
147	46.37	152.1	34	69	1
148	46.41	152.3	56	60	1
149	46.60	152.9	202	10	0
150	46.84	153.7	181	10	1
151	46.93	154.0	217	61	1
152	46.94	154.0	357	81	2
153	46.94	154.0	123	26	1
154	47.06	154.4	31	73	1
155	47.28	155.1	277	74	1
156	47.39	155.5	212	33	1
157	47.41	155.5	43	51	2
158	47.41	155.5	115	22	1
159	47.54	156.0	51	80	0
160	47.63	156.3	168	11	1
161	47.82	156.9	264	9	2
162	47.93	157.3	256	7	2
163	47.97	157.4	33	70	1
164	47.97	157.4	39	62	1
165	48.04	157.6	56	54	1
166	48.08	157.7	233	64	1
167	48.14	158.0	58	64	2
168	48.18	158.1	92	36	2
169	48.19	158.1	7	64	2
170	48.24	158.3	170	27	1
171	48.35	158.6	248	13	0
172	48.40	158.8	187	10	2
173	48.48	159.1	144	18	1
174	48.56	159.3	24	39	0
175	48.68	159.7	10	42	1
176	48.71	159.8	253	38	0
177	49.02	160.8	52	49	2
178	49.30	161.7	162	18	1
179	49.43	162.2	47	83	1
180	49.44	162.2	241	11	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	49.55	162.6	315	85	1
182	49.61	162.8	86	86	1
183	49.70	163.1	268	17	3
184	49.71	163.1	341	29	2
185	49.78	163.3	110	8	2
186	49.80	163.4	242	66	1
187	49.95	163.9	174	51	2
188	50.10	164.4	355	85	1
189	50.25	164.9	36	71	2
190	50.32	165.1	178	76	3
191	50.39	165.3	29	13	2
192	50.47	165.6	238	30	3
193	50.48	165.6	284	46	3
194	50.51	165.7	357	71	2
195	50.51	165.7	263	22	3
196	50.74	166.5	250	24	1
197	50.85	166.8	250	17	4
198	50.91	167.0	350	20	4
199	50.92	167.1	213	34	4
200	50.93	167.1	9	63	4
201	50.98	167.3	18	83	3
202	50.99	167.3	29	85	3
203	51.01	167.4	6	59	3
204	51.03	167.4	41	63	1
205	51.08	167.6	33	50	1
206	51.09	167.6	141	72	3
207	51.19	167.9	238	14	1
208	51.27	168.2	164	10	1
209	51.44	168.8	221	10	0
210	51.45	168.8	55	56	0
211	51.48	168.9	248	27	1
212	51.49	168.9	228	26	1
213	51.54	169.1	28	65	1
214	51.64	169.4	81	19	1
215	51.70	169.6	34	59	1
216	51.73	169.7	91	60	1
217	51.74	169.8	243	17	2
218	51.77	169.9	217	26	2
219	51.80	169.9	353	41	2
220	51.85	170.1	276	71	4
221	51.89	170.2	43	46	4
222	52.06	170.8	271	30	1
223	52.06	170.8	14	14	1
224	52.09	170.9	44	65	1
225	52.18	171.2	323	60	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	52.19	171.2	237	57	4
227	52.20	171.3	141	77	1
228	52.21	171.3	47	57	4
229	52.22	171.3	252	41	4
230	52.28	171.5	224	41	3
231	52.47	172.2	230	22	3
232	52.55	172.4	231	51	3
233	52.61	172.6	29	53	4
234	52.62	172.6	257	54	3
235	52.62	172.7	177	65	3
236	52.63	172.7	22	73	3
237	52.66	172.8	239	36	4
238	52.70	172.9	8	60	4
239	52.76	173.1	197	39	4
240	52.81	173.3	167	30	4
241	52.82	173.3	327	60	4
242	52.86	173.4	169	37	5
243	52.86	173.4	186	78	3
244	52.98	173.8	169	26	5
245	53.11	174.2	335	16	1
246	53.11	174.2	350	55	1
247	53.20	174.5	278	12	4
248	53.21	174.6	242	66	1
249	53.25	174.7	83	54	1
250	53.25	174.7	282	23	4
251	53.35	175.0	19	75	1
252	53.37	175.1	219	7	1
253	53.42	175.3	7	83	1
254	53.47	175.4	176	11	1
255	53.52	175.6	212	81	1
256	53.57	175.8	80	75	2
257	53.64	176.0	315	79	2
258	53.82	176.6	293	13	1
259	53.95	177.0	213	17	3
260	54.25	178.0	204	10	1
261	54.39	178.4	209	22	3
262	54.39	178.4	5	84	0
263	54.52	178.9	157	11	2
264	54.54	179.0	156	75	2
265	54.60	179.1	240	10	2
266	54.69	179.4	12	82	2
267	54.73	179.6	344	10	2
268	54.73	179.6	40	69	2
269	54.85	180.0	0	81	2
270	54.86	180.0	227	23	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	54.88	180.1	226	46	1
272	54.91	180.2	44	56	1
273	54.94	180.3	241	59	1
274	55.00	180.5	203	36	4
275	55.04	180.6	267	37	5
276	55.09	180.7	335	29	5
277	55.17	181.0	199	24	5
278	55.20	181.1	223	74	1
279	55.34	181.6	70	70	1
280	55.37	181.7	147	46	2
281	55.39	181.7	178	12	1
282	55.54	182.2	191	27	2
283	55.60	182.4	230	72	2
284	55.60	182.4	243	47	2
285	55.62	182.5	176	48	3
286	55.66	182.6	164	25	3
287	55.69	182.7	44	81	1
288	55.86	183.3	231	17	3
289	55.89	183.4	64	72	1
290	55.92	183.5	156	20	2
291	55.95	183.6	206	67	1
292	55.97	183.6	272	11	2
293	56.06	183.9	172	24	2
294	56.14	184.2	256	71	1
295	56.15	184.2	330	63	3
296	56.16	184.3	5	49	3
297	56.20	184.4	41	36	2
298	56.34	184.8	269	19	3
299	56.34	184.9	192	32	3
300	56.35	184.9	301	62	2
301	56.42	185.1	314	82	2
302	56.47	185.3	89	46	3
303	56.54	185.5	8	82	3
304	56.62	185.8	44	26	4
305	56.66	185.9	52	25	4
306	56.67	185.9	92	76	4
307	56.71	186.1	235	59	3
308	56.73	186.1	46	78	4
309	56.87	186.6	96	71	4
310	56.88	186.6	180	26	3
311	56.94	186.8	32	75	1
312	56.94	186.8	110	66	4
313	57.00	187.0	264	24	3
314	57.03	187.1	258	12	3
315	57.11	187.4	325	12	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
316	57.15	187.5	112	10	1
317	57.32	188.1	108	10	1
318	57.35	188.2	194	64	1
319	57.38	188.3	164	82	1
320	57.42	188.4	267	80	1
321	57.51	188.7	101	58	3
322	57.59	188.9	90	64	3
323	57.59	188.9	152	77	1
324	57.60	189.0	252	82	3
325	57.63	189.1	327	83	2
326	57.68	189.2	198	60	1
327	58.03	190.4	355	8	1
328	58.06	190.5	159	83	2
329	58.11	190.7	64	83	3
330	58.25	191.1	53	8	0
331	58.32	191.3	232	34	0
332	58.33	191.4	257	76	0
333	58.39	191.6	56	6	0
334	58.43	191.7	16	81	1
335	58.46	191.8	57	59	1
336	58.49	191.9	93	86	3
337	58.58	192.2	90	55	0
338	58.64	192.4	186	72	1
339	58.67	192.5	225	9	1
340	58.69	192.6	224	8	1
341	58.75	192.7	264	13	0
342	58.78	192.9	292	19	0
343	58.91	193.3	351	17	0
344	59.00	193.6	275	15	1
345	59.04	193.7	198	64	1
346	59.04	193.7	308	26	1
347	59.16	194.1	205	65	1
348	59.16	194.1	260	8	1
349	59.20	194.2	233	6	1
350	59.20	194.2	93	75	1
351	59.25	194.4	254	12	1
352	59.43	195.0	227	17	3
353	59.49	195.2	254	16	2
354	59.52	195.3	194	80	3
355	59.52	195.3	356	77	3
356	59.54	195.3	232	12	2
357	59.57	195.4	314	78	2
358	59.68	195.8	214	12	2
359	59.69	195.8	314	74	2
360	59.73	196.0	274	12	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
361	59.80	196.2	262	13	1
362	59.91	196.6	279	12	0
363	60.16	197.4	221	40	1
364	60.19	197.5	41	41	1
365	68.01	223.1	225	70	5
366	68.14	223.6	89	15	4
367	68.35	224.3	184	77	5
368	68.37	224.3	205	26	4
369	68.53	224.8	21	86	5
370	68.61	225.1	185	48	4
371	68.67	225.3	293	37	4
372	68.79	225.7	296	33	4
373	68.90	226.1	304	32	4
374	69.06	226.6	65	47	3
375	69.28	227.3	266	14	2
376	69.46	227.9	13	44	3
377	69.47	227.9	213	45	3
378	69.49	228.0	173	37	2
379	69.58	228.3	134	40	3
380	69.59	228.3	235	49	3
381	69.74	228.8	305	71	3
382	69.81	229.1	48	16	3
383	69.86	229.2	1	37	3
384	69.89	229.3	340	54	2
385	69.97	229.6	320	19	3
386	70.05	229.8	302	20	3
387	70.11	230.0	281	15	2
388	70.16	230.2	285	15	1
389	70.17	230.2	162	63	2
390	70.26	230.5	290	17	1
391	70.36	230.9	201	30	1
392	70.55	231.5	325	56	1
393	70.59	231.6	293	14	2
394	70.61	231.7	233	12	2
395	70.63	231.7	236	11	1
396	70.74	232.1	243	13	1
397	70.85	232.5	175	33	2
398	70.87	232.5	182	32	3
399	70.91	232.6	202	51	5
400	70.91	232.6	239	60	5
401	71.03	233.0	36	58	5
402	71.08	233.2	40	25	5
403	71.14	233.4	354	54	5
404	71.20	233.6	311	18	2
405	71.23	233.7	354	36	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
406	71.34	234.0	159	30	2
407	71.34	234.1	172	40	5
408	71.40	234.2	159	52	5
409	71.40	234.2	333	22	5
410	71.46	234.5	150	66	5
411	71.50	234.6	147	57	5
412	71.59	234.9	17	34	5
413	71.59	234.9	201	21	5
414	71.67	235.2	336	47	5
415	71.72	235.3	339	28	5
416	71.77	235.5	314	44	5
417	71.88	235.8	346	30	2
418	71.94	236.0	342	30	4
419	72.11	236.6	335	28	4
420	72.19	236.9	359	27	5
421	72.24	237.0	87	81	4
422	72.25	237.0	27	71	5
423	72.25	237.0	207	80	4
424	72.35	237.4	337	45	5
425	72.41	237.6	5	49	5
426	72.42	237.6	183	72	5
427	72.68	238.4	343	46	3
428	72.76	238.7	349	50	3
429	72.83	238.9	328	80	5
430	72.91	239.2	70	49	2
431	72.97	239.4	276	54	2
432	73.09	239.8	213	44	5
433	73.16	240.0	290	49	4
434	73.20	240.2	141	36	4
435	73.25	240.3	259	36	5
436	73.39	240.8	171	84	3
437	73.41	240.9	333	83	4
438	73.55	241.3	270	84	5
439	73.89	242.4	349	22	4
440	73.89	242.4	40	55	5
441	73.92	242.5	117	82	4
442	74.40	244.1	88	86	5
443	74.47	244.3	331	86	4
444	74.58	244.7	87	19	3
445	75.57	247.9	109	58	5
446	78.94	259.0	1	49	5
447	79.10	259.5	175	46	5
448	79.55	261.0	175	57	5
449	79.84	261.9	331	65	5
450	80.11	262.8	310	60	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
451	94.59	310.3	92	15	3
452	94.69	310.7	18	59	3
453	94.70	310.7	237	34	3
454	94.83	311.1	229	65	4
455	94.87	311.2	99	69	3
456	94.98	311.6	85	66	2
457	94.99	311.6	262	36	4
458	94.99	311.7	262	73	4
459	95.14	312.1	100	21	2
460	95.31	312.7	262	18	3
461	95.41	313.0	318	72	2
462	95.42	313.1	341	29	2
463	95.65	313.8	124	34	3
464	95.68	313.9	235	74	3
465	95.72	314.0	103	34	3
466	95.82	314.4	192	83	3
467	95.86	314.5	53	67	4
468	95.93	314.7	204	59	4
469	96.10	315.3	140	61	4
470	96.27	315.8	215	82	5
471	96.37	316.2	90	37	4
472	96.39	316.2	250	39	4
473	96.49	316.6	238	33	4
474	96.64	317.1	33	72	4
475	96.66	317.1	27	31	4
476	96.71	317.3	29	83	5
477	96.73	317.4	220	43	4
478	96.80	317.6	115	32	4
479	96.87	317.8	66	12	4
480	97.05	318.4	213	71	4
481	97.16	318.8	55	75	4
482	97.26	319.1	116	54	4
483	97.29	319.2	88	76	4
484	97.29	319.2	357	72	4
485	97.30	319.2	66	71	4
486	97.33	319.3	90	39	4
487	97.35	319.4	130	55	4
488	97.56	320.1	245	11	4
489	97.61	320.2	263	34	4
490	97.65	320.4	306	32	3
491	97.72	320.6	128	17	4
492	97.76	320.7	339	43	4
493	97.87	321.1	99	56	4
494	97.90	321.2	174	51	4
495	97.97	321.4	143	71	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
496	97.97	321.4	149	48	4
497	98.07	321.8	148	38	4
498	98.08	321.8	84	59	4
499	98.24	322.3	143	41	5
500	98.33	322.6	276	62	5
501	98.33	322.6	119	29	5
502	98.44	323.0	92	26	4
503	98.47	323.1	264	38	4
504	98.51	323.2	129	25	4
505	98.67	323.7	173	45	4
506	98.73	323.9	158	45	4
507	98.89	324.4	139	71	4
508	99.08	325.1	120	62	3
509	99.36	326.0	128	47	3
510	99.45	326.3	290	75	3
511	99.46	326.3	72	76	3
512	99.50	326.4	281	57	4
513	99.66	327.0	58	56	4
514	99.71	327.1	211	25	4
515	99.80	327.4	206	53	4
516	99.84	327.6	340	15	3
517	99.88	327.7	182	60	4
518	99.94	327.9	265	77	4
519	100.05	328.2	19	67	4
520	100.22	328.8	240	28	4
521	100.27	329.0	89	62	4
522	100.36	329.3	92	25	4
523	100.43	329.5	357	75	4
524	100.48	329.7	77	20	4
525	100.57	330.0	203	23	3
526	100.70	330.4	335	13	3
527	100.80	330.7	65	12	3
528	101.03	331.5	89	30	3
529	101.12	331.8	7	64	2
530	101.18	332.0	48	58	2
531	101.30	332.4	282	49	2
532	101.46	332.9	14	7	2
533	101.60	333.3	133	64	2
534	101.71	333.7	245	68	2
535	101.74	333.8	257	39	2
536	101.83	334.1	4	13	2
537	101.87	334.2	111	43	2
538	101.91	334.4	186	75	3
539	101.96	334.5	62	42	2
540	102.12	335.0	24	80	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
541	102.17	335.2	127	31	4
542	102.19	335.3	280	33	4
543	102.27	335.5	317	72	2
544	102.31	335.7	144	43	2
545	102.50	336.3	195	82	4
546	102.51	336.3	41	60	4
547	102.52	336.4	158	56	4
548	102.59	336.6	203	80	4
549	102.61	336.6	43	52	4
550	102.73	337.0	57	79	4
551	102.77	337.2	54	48	4
552	102.78	337.2	178	45	4
553	102.89	337.6	205	46	2
554	102.96	337.8	190	60	2
555	102.99	337.9	18	61	2
556	103.19	338.5	123	55	3
557	103.30	338.9	256	59	3
558	103.35	339.1	102	81	2
559	103.41	339.3	10	49	3
560	103.45	339.4	248	48	3
561	103.50	339.6	112	41	3
562	103.52	339.6	13	38	3
563	103.68	340.2	304	67	2
564	103.70	340.2	21	61	2
565	103.75	340.4	46	48	2
566	103.80	340.6	89	53	2
567	103.88	340.8	83	71	2
568	103.89	340.8	99	43	2
569	103.90	340.9	225	70	2
570	103.97	341.1	63	34	3
571	104.00	341.2	232	29	3
572	104.09	341.5	57	28	2
573	104.15	341.7	251	43	1
574	104.27	342.1	104	72	1
575	104.32	342.3	126	33	1
576	104.34	342.3	211	57	2
577	104.44	342.7	239	63	1
578	104.52	342.9	290	49	1
579	104.61	343.2	34	29	1
580	104.76	343.7	15	52	1
581	104.92	344.2	264	73	1
582	104.93	344.3	331	54	1
583	104.98	344.4	170	60	1
584	104.99	344.5	282	27	1
585	105.24	345.3	96	30	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
586	105.31	345.5	37	67	1
587	105.31	345.5	129	62	1
588	105.36	345.7	266	36	1
589	105.44	345.9	248	33	2
590	105.51	346.2	257	48	2
591	105.51	346.2	191	62	2
592	105.63	346.6	149	72	2
593	105.64	346.6	227	71	2
594	105.65	346.6	38	43	2
595	105.71	346.8	330	39	2
596	105.75	347.0	100	57	2
597	105.87	347.3	262	69	2
598	105.90	347.4	69	63	2
599	105.95	347.6	230	51	2
600	105.96	347.6	72	56	2
601	106.01	347.8	29	48	2
602	106.04	347.9	249	52	2
603	106.07	348.0	32	65	2
604	106.13	348.2	136	70	2
605	106.19	348.4	14	43	2
606	106.28	348.7	168	54	2
607	106.34	348.9	261	25	3
608	106.35	348.9	66	81	3
609	106.38	349.0	122	64	3
610	106.44	349.2	264	33	3
611	106.49	349.4	233	40	3
612	106.54	349.5	1	58	3
613	106.69	350.0	94	81	2
614	106.71	350.1	346	44	2
615	106.73	350.2	324	79	3
616	106.73	350.2	101	73	3
617	106.86	350.6	334	61	3
618	106.89	350.7	294	74	2
619	106.97	350.9	157	59	2
620	107.07	351.3	332	55	2
621	107.08	351.3	10	58	2
622	107.15	351.5	15	49	2
623	107.21	351.8	336	34	1
624	107.27	352.0	129	61	1
625	107.29	352.0	288	24	1
626	107.37	352.3	274	49	2
627	107.39	352.3	232	19	2
628	107.41	352.4	165	67	2
629	107.46	352.6	282	49	2
630	107.48	352.6	170	60	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
631	107.59	353.0	271	54	2
632	107.67	353.2	44	60	1
633	107.68	353.3	258	74	2
634	107.70	353.3	280	42	1
635	107.72	353.4	284	67	1
636	107.73	353.5	49	47	1
637	107.82	353.8	333	78	1
638	107.90	354.0	277	28	2
639	107.92	354.1	218	71	1
640	107.96	354.2	298	31	1
641	107.98	354.3	81	59	1
642	108.04	354.5	254	49	2
643	108.07	354.6	0	57	1
644	108.09	354.6	263	80	1
645	108.09	354.6	250	27	1
646	108.09	354.6	336	38	2
647	108.12	354.7	195	29	2
648	108.24	355.1	212	15	3
649	108.25	355.2	78	23	3
650	108.30	355.3	206	18	1
651	108.34	355.4	265	80	1
652	108.36	355.5	289	65	1
653	108.39	355.6	253	31	2
654	108.40	355.7	261	64	1
655	108.46	355.8	318	49	1
656	108.52	356.0	294	35	1
657	108.52	356.0	276	76	1
658	108.57	356.2	215	44	1
659	108.58	356.2	324	45	1
660	108.63	356.4	231	67	1
661	108.69	356.6	307	51	2
662	108.73	356.7	249	15	2
663	108.74	356.8	58	70	2
664	108.78	356.9	183	19	1
665	108.90	357.3	352	81	1
666	108.93	357.4	332	71	0
667	108.94	357.4	244	16	2
668	108.96	357.5	183	84	1
669	109.03	357.7	187	31	1
670	109.08	357.9	339	73	1
671	109.16	358.1	316	68	1
672	109.19	358.2	334	57	1
673	109.23	358.4	319	52	1
674	109.30	358.6	92	54	1
675	109.38	358.9	324	69	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
676	109.40	358.9	281	27	1
677	109.46	359.1	352	70	1
678	109.48	359.2	23	82	1
679	109.53	359.4	221	17	2
680	109.57	359.5	209	26	1
681	109.62	359.7	276	44	2
682	109.66	359.8	187	13	2
683	109.69	359.9	44	73	1
684	109.71	359.9	348	31	1
685	109.72	360.0	281	61	2
686	109.77	360.1	331	76	2
687	109.79	360.2	262	38	1
688	109.90	360.6	240	25	1
689	109.90	360.6	321	67	1
690	109.92	360.6	354	63	1
691	109.95	360.7	13	65	1
692	109.97	360.8	27	45	2
693	110.04	361.0	220	33	1
694	110.09	361.2	344	53	1
695	110.17	361.5	220	62	1
696	110.21	361.6	31	54	1
697	110.24	361.7	237	39	1
698	110.27	361.8	112	24	1
699	110.28	361.8	336	78	1
700	110.28	361.8	266	35	1
701	110.38	362.2	270	44	1
702	110.40	362.2	74	49	1
703	110.42	362.3	220	37	1
704	110.42	362.3	104	66	1
705	110.44	362.3	229	73	1
706	110.58	362.8	44	41	2
707	110.61	362.9	229	66	1
708	110.65	363.0	79	21	1
709	110.69	363.2	17	80	2
710	110.71	363.2	177	20	2
711	110.74	363.3	250	51	1
712	110.80	363.5	229	57	1
713	110.91	363.9	302	75	1
714	110.99	364.1	131	56	1
715	111.11	364.5	346	25	1
716	111.13	364.6	356	15	1
717	111.18	364.8	31	54	1
718	111.21	364.9	338	69	1
719	111.21	364.9	92	26	1
720	111.38	365.4	181	52	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
721	111.61	366.2	169	52	1
722	111.70	366.5	55	61	1
723	111.76	366.7	210	68	1
724	111.79	366.8	198	57	1
725	111.79	366.8	50	53	1
726	111.86	367.0	71	77	1
727	111.89	367.1	5	49	1
728	112.03	367.6	197	47	1
729	112.04	367.6	23	57	1
730	112.21	368.1	29	49	1
731	112.27	368.3	237	49	1
732	112.38	368.7	155	61	3
733	112.45	368.9	168	71	4
734	112.50	369.1	145	67	4
735	112.53	369.2	1	73	3
736	112.55	369.3	44	60	4
737	112.68	369.7	8	29	3
738	112.68	369.7	339	50	3
739	112.72	369.8	1	40	3
740	112.77	370.0	45	27	4
741	112.83	370.2	261	33	4
742	112.87	370.3	293	45	4
743	112.97	370.6	279	52	4
744	113.01	370.8	204	75	4
745	113.01	370.8	277	66	4
746	113.07	371.0	359	76	4
747	113.09	371.0	29	47	3
748	113.21	371.4	45	59	3
749	113.28	371.6	240	36	2
750	113.28	371.7	152	45	2
751	113.36	371.9	69	41	2
752	113.40	372.1	165	72	2
753	113.48	372.3	26	78	3
754	113.58	372.6	261	26	3
755	113.60	372.7	55	42	3
756	113.62	372.8	263	51	3
757	113.76	373.2	285	68	2
758	113.83	373.5	96	68	3
759	113.85	373.5	259	47	3
760	113.88	373.6	185	36	3
761	114.03	374.1	317	53	2
762	114.03	374.1	200	74	2
763	114.13	374.5	50	59	2
764	114.14	374.5	84	26	4
765	114.18	374.6	164	66	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-17

4-13 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
766	114.23	374.8	2	57	4

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-17
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-17
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.82875 N
Longitude: 84.76084 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 599.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	5-13 July 2019	5-13 July 2019		
RUN NUMBER	1	1		
LOG TYPE	Fluid Temp & Cond	Caliper & Gamma		
DEPTH-DRILLER	380'	380'		
DEPTH-LOGGER	378'	378'		
BTM LOG INTERVAL	377'	377'		
TOP LOG INTERVAL	120'	120'		
RECORDED BY	CKL,BEH,JBG	CKL,BEH,JBG		
WITNESSED BY				
PROBE TYPE, S/N	2PFA #5969	3ACS #6011		
LOGGING SPEED	15 fpm	10 fpm		
A.S.D.E. / Sample Interval	.0.06' / 0.10'	0.11' / 0.10'		
Fluid Level / Fluid Type	18'/water	18'/water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	380'

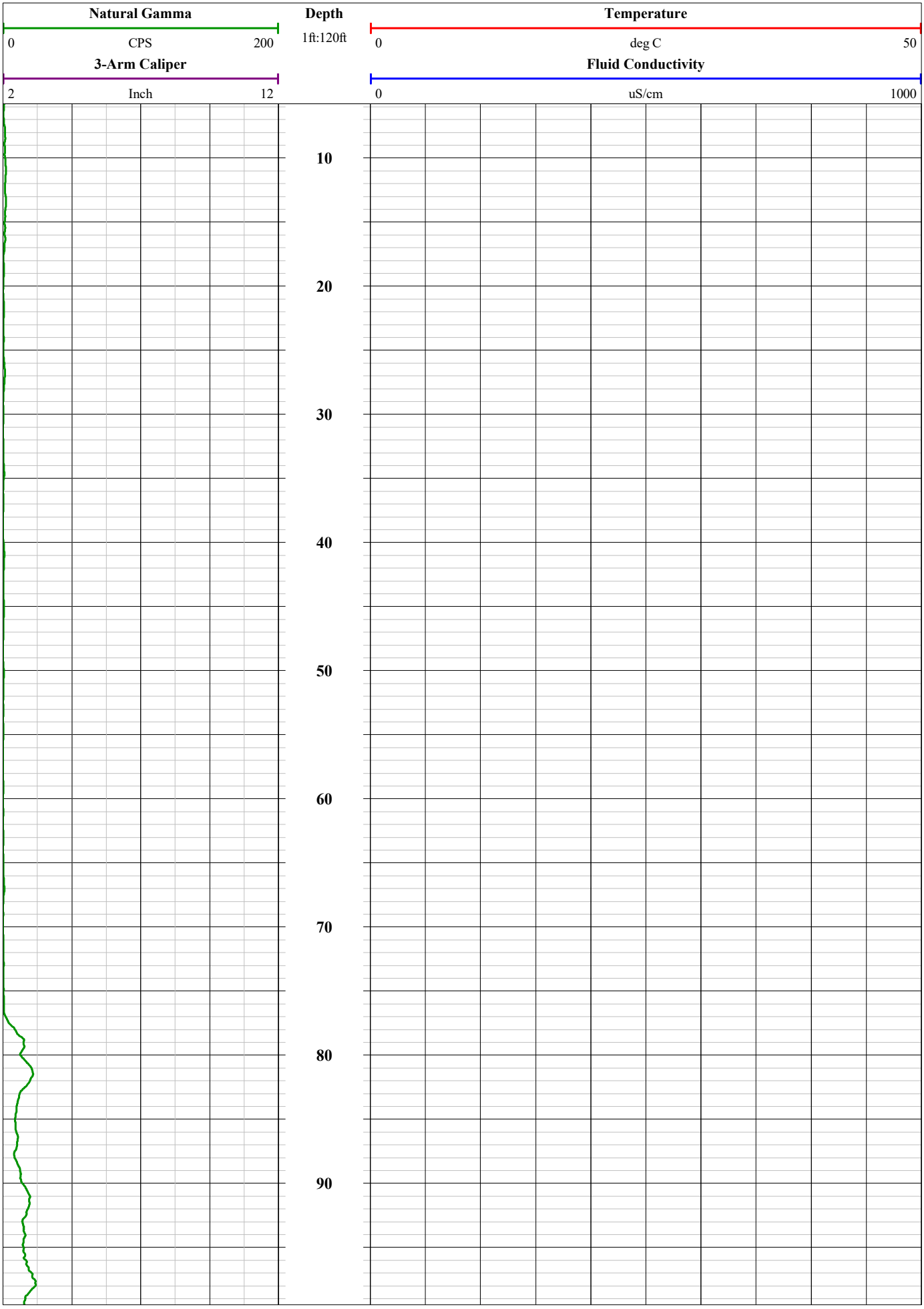
CASING RECORD

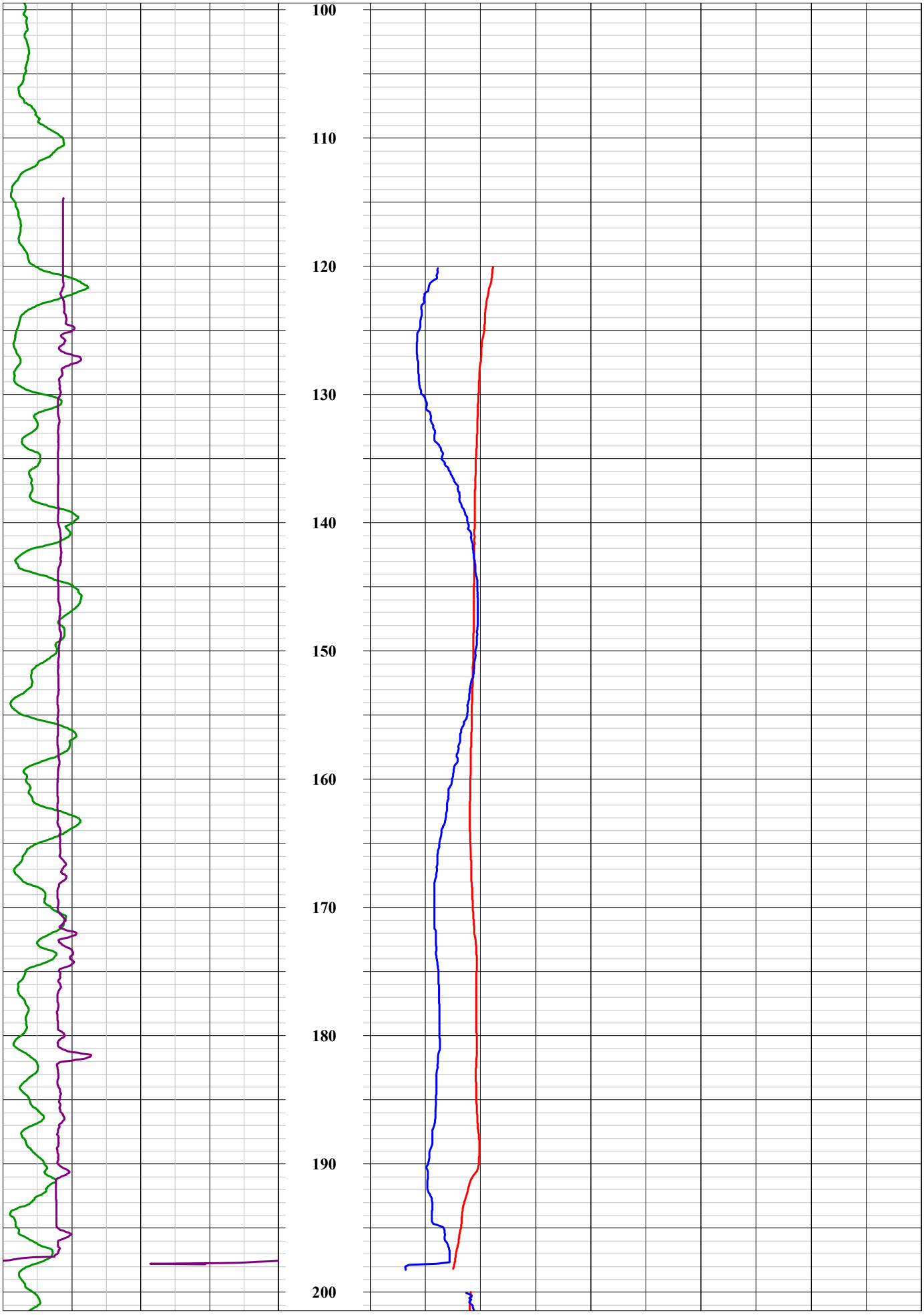
SIZE	WGT.	FROM	TO
1	Steel	0'	120'

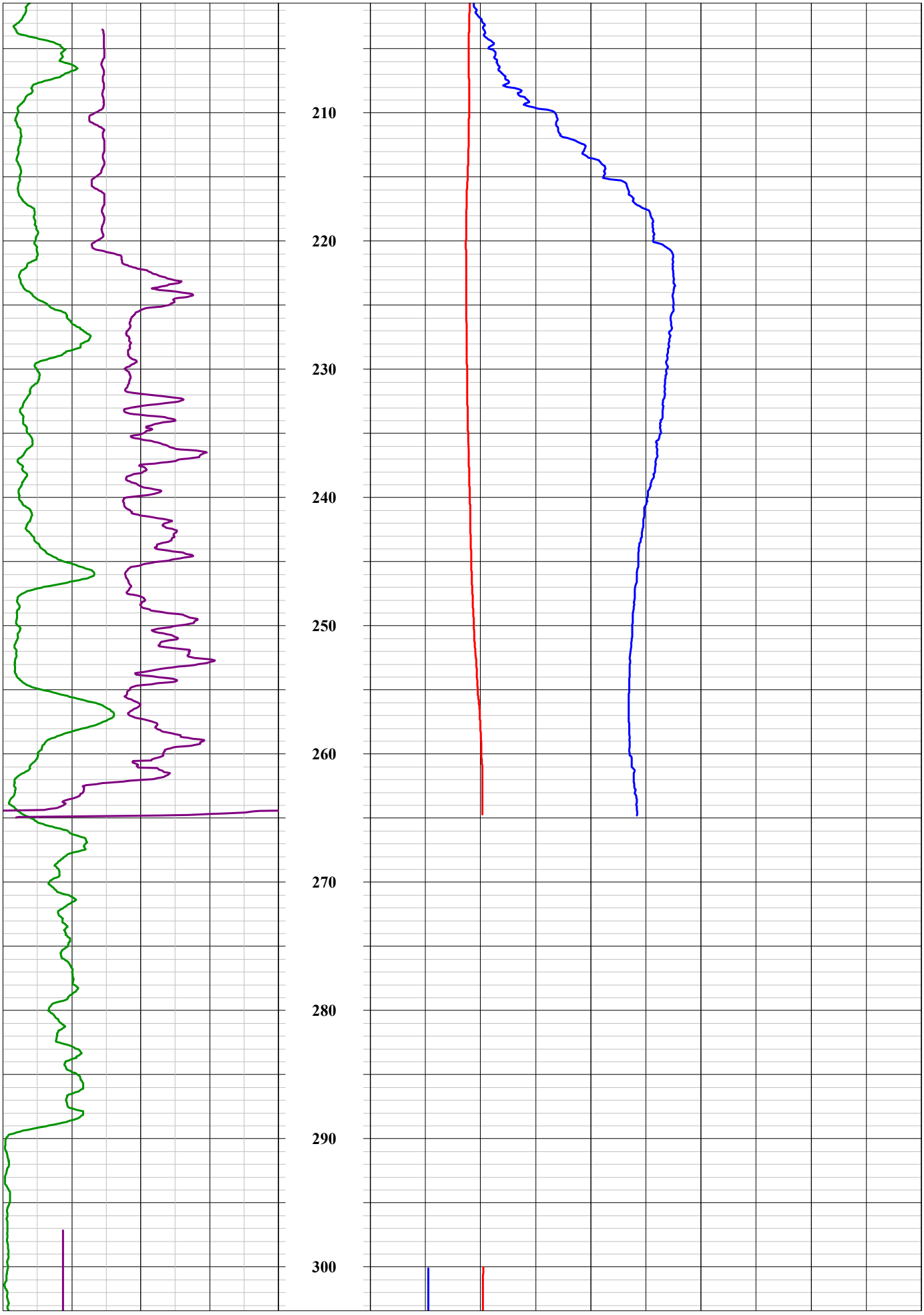
NA - Not Available, N/A - Not Applicable

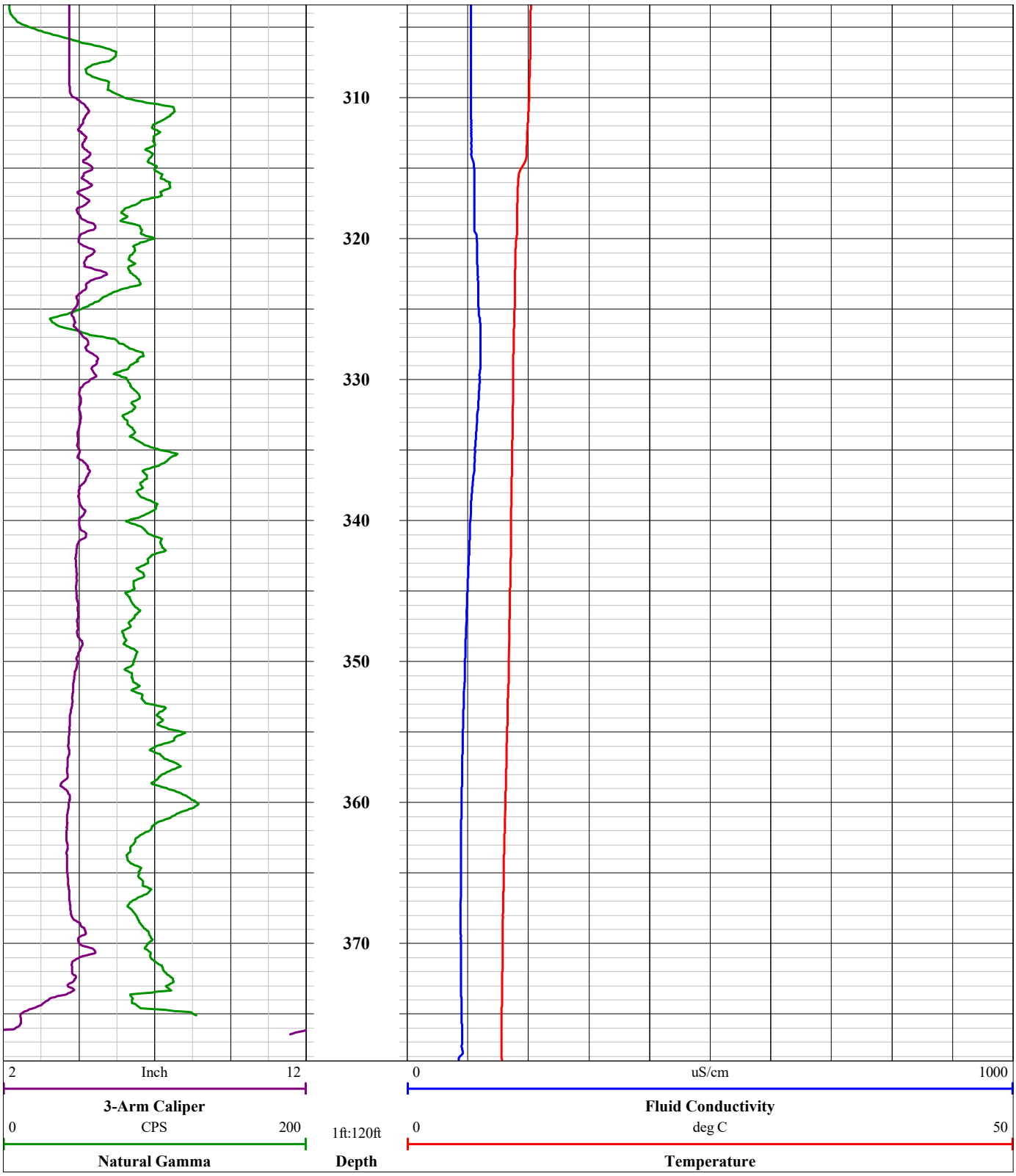
COMMENTS

Gaps in data due to poor borehole conditions during logging.
Natural Gamma collected through rods and casing to get data through entire borehole.


Natural Gamma
0
CPS
200
3-Arm Caliper
2
Inch
12
Depth
1ft:120ft
10
20
30
40
50
60
70
80
90
Temperature
0
deg C
50
Fluid Conductivity
0
uS/cm
1000


100
110
120
130
140
150
160
170
180
190
200


210
220
230
240
250
260
270
280
290
300


310
320
330
340
350
360
370
2
Inch
12
3-Arm Caliper
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
0
deg C
50
Temperature

Borehole Deviation

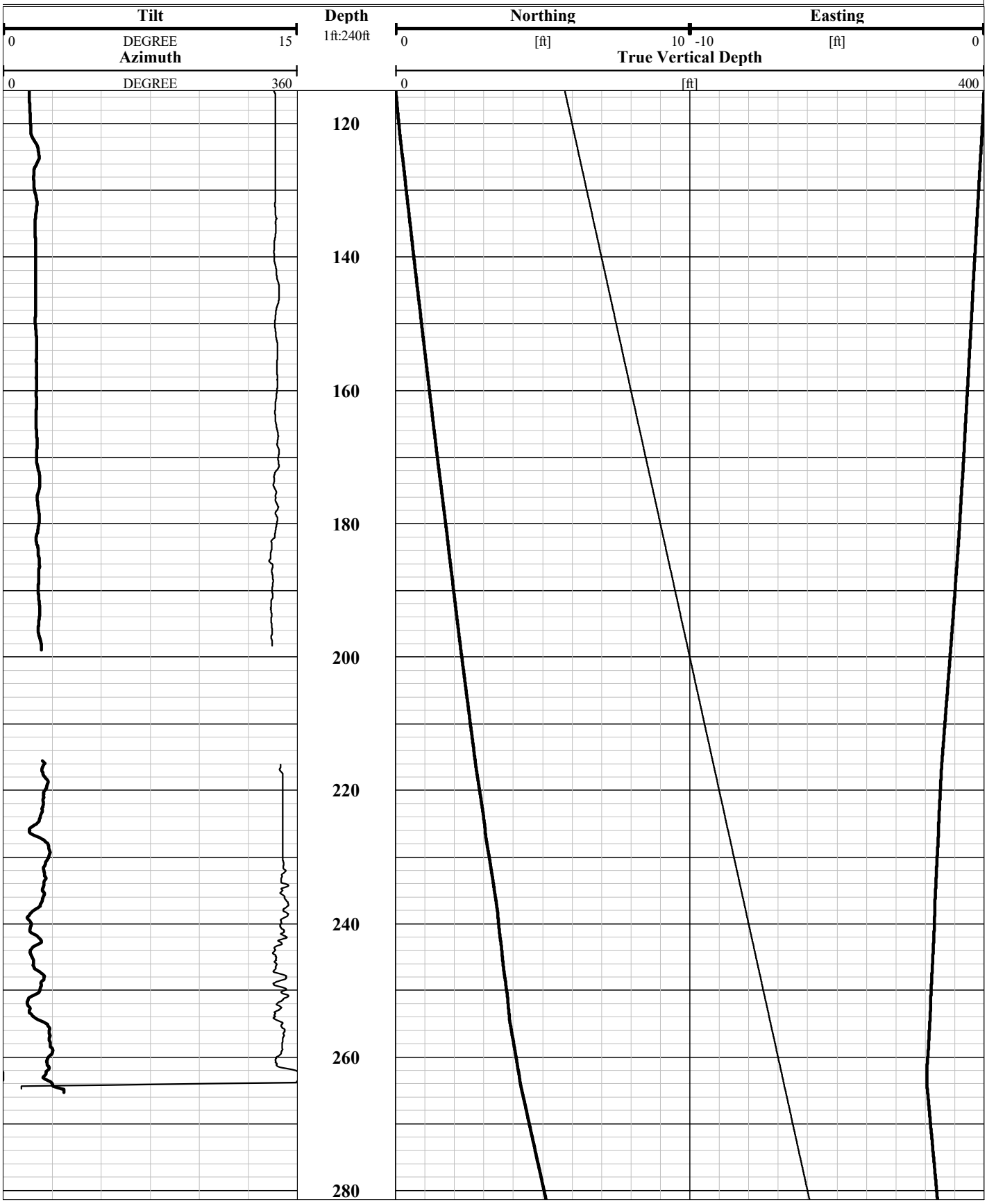
COLOG
borehole geophysics / hydrophysics

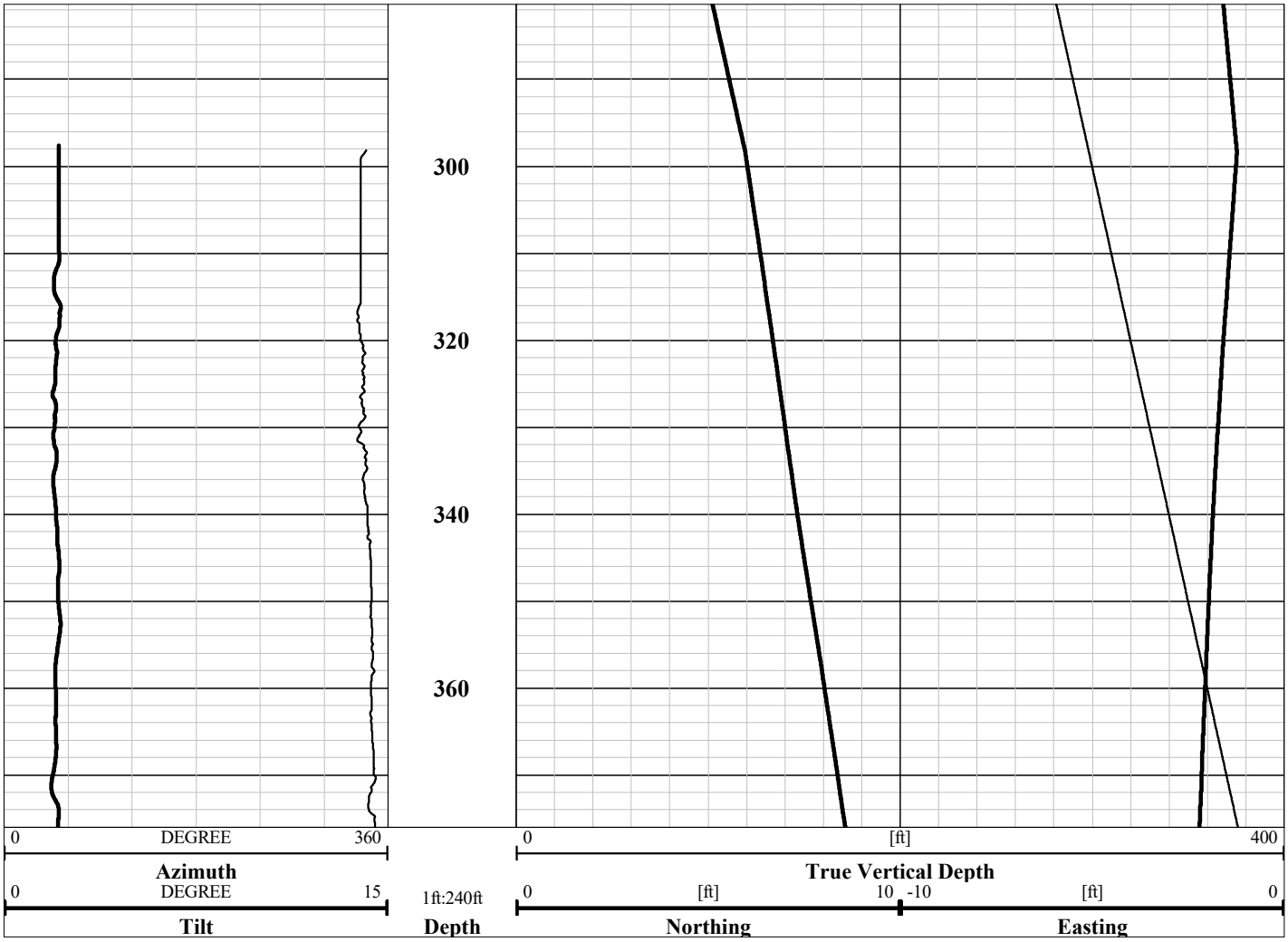
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 5-13 July 2019	WELL: BH19-17 - North Side

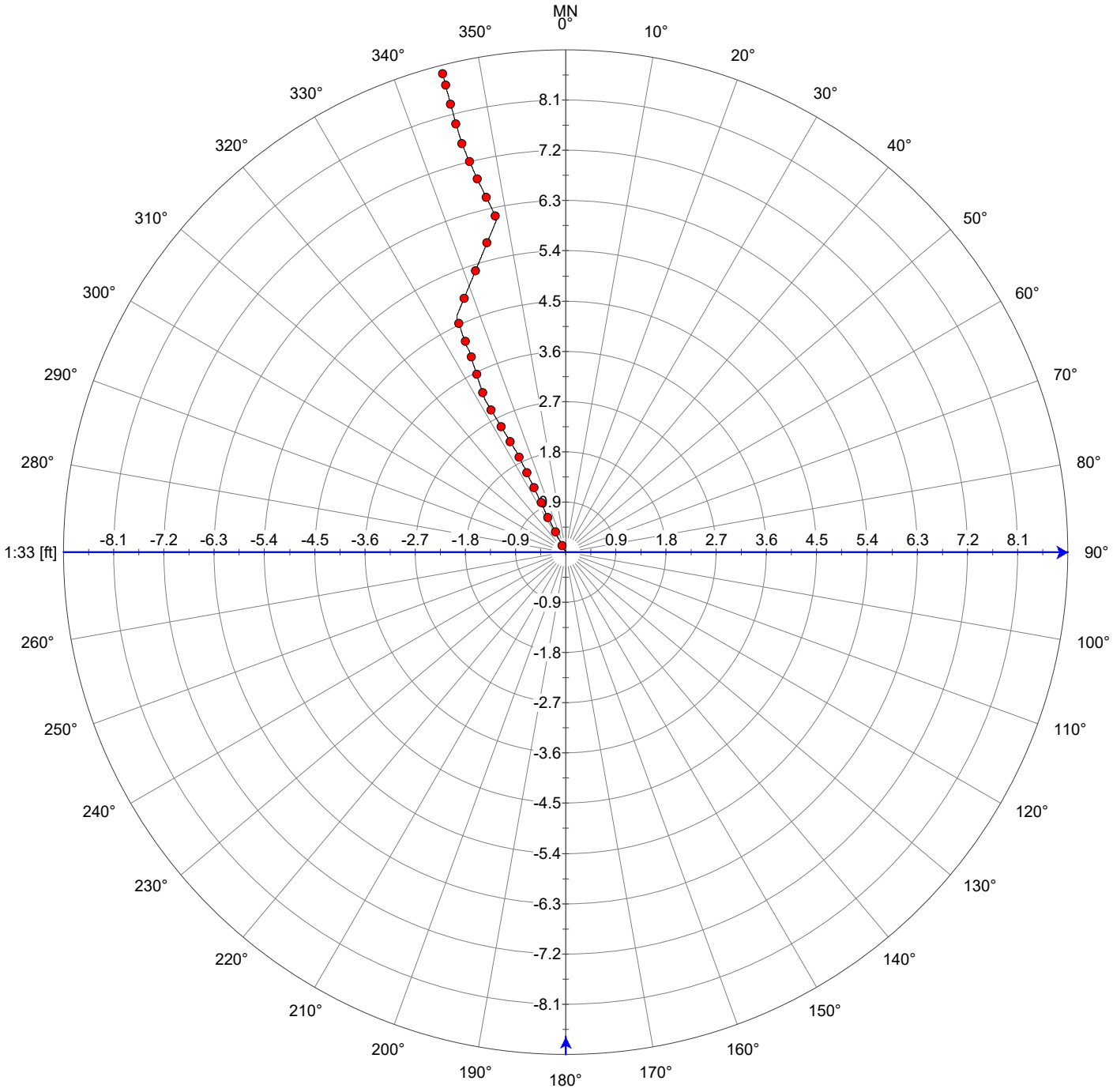
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 599.7'** **Latitude: 45.82875 N** **Longitude: 84.76084 W**




300
320
340
360
0
DEGREE
360
Azimuth
0
DEGREE
15
Tilt
1ft:240ft
Depth
0
[ft]
400
True Vertical Depth
0
[ft]
10
-10
[ft]
0
Northing
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
8.1
7.2
6.3
5.4
4.5
3.6
2.7
1.8
0.9
-0.9
-1.8
-2.7
-3.6
-4.5
-5.4
-6.3
-7.2
-8.1
1:33 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-17
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-17
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.82875 N
Longitude: 84.76084 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 599.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	6-13 July 2019	6-13 July 2019		
RUN NUMBER	1	Multiple		
LOG TYPE	Natural Gamma	Eletcric Log		
DEPTH-DRILLER	380'	380'		
DEPTH-LOGGER	377'	377'		
BTM LOG INTERVAL	375.1'	375.1'		
TOP LOG INTERVAL	5.8'	120'		
RECORDED BY	CKL,BEH,JBG	CKL,BEH,JBG		
WITNESSED BY				
PROBE TYPE, S/N	ELXG #4248	ELXG #4248		
LOGGING SPEED	15 fpm	15 fpm		
A.S.D.E. / Sample Interval	0.05' / 0.25'	0.05' / 0.25'		
Fluid Level / Fluid Type	19'/water	19'/water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	380'

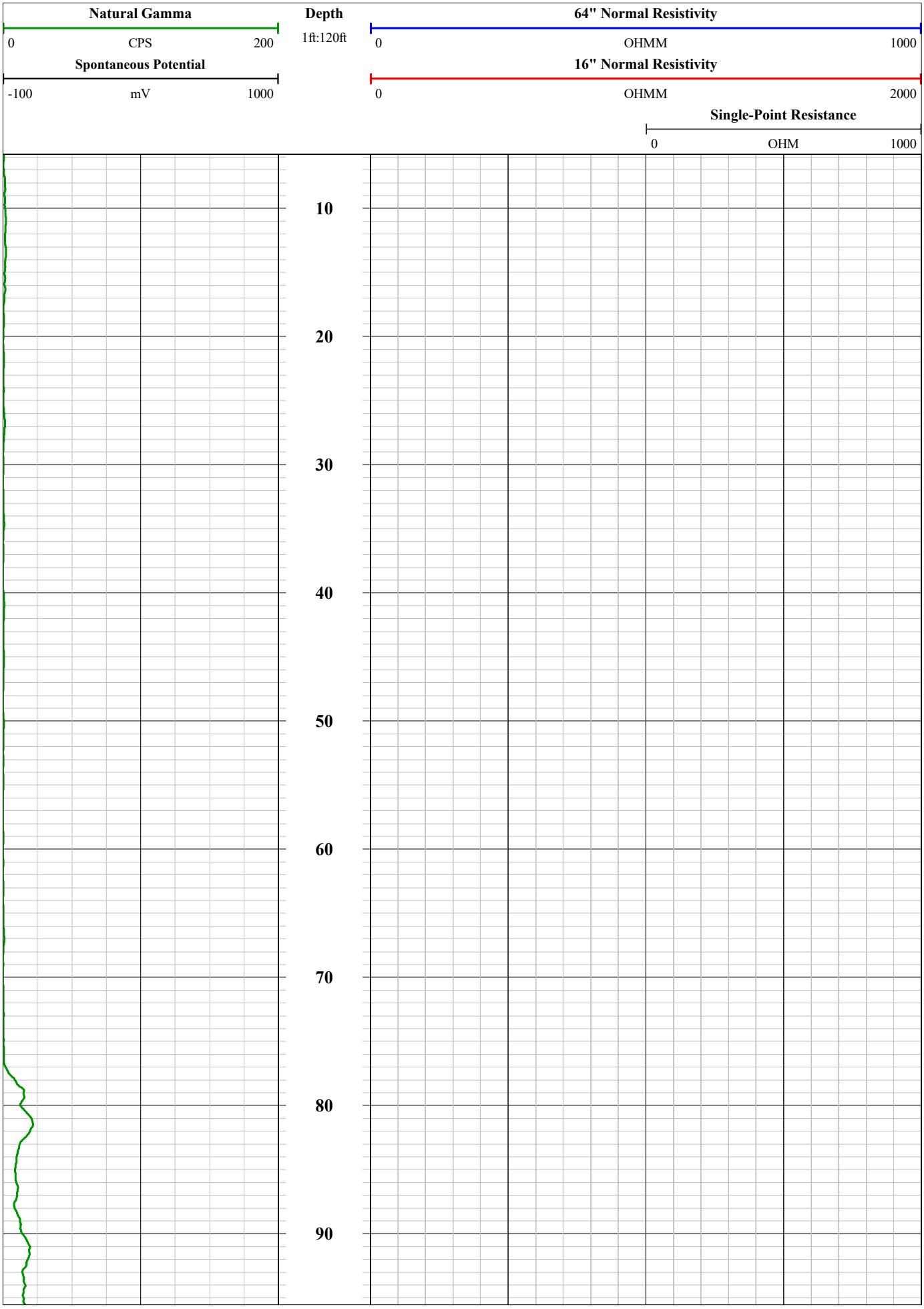
CASING RECORD

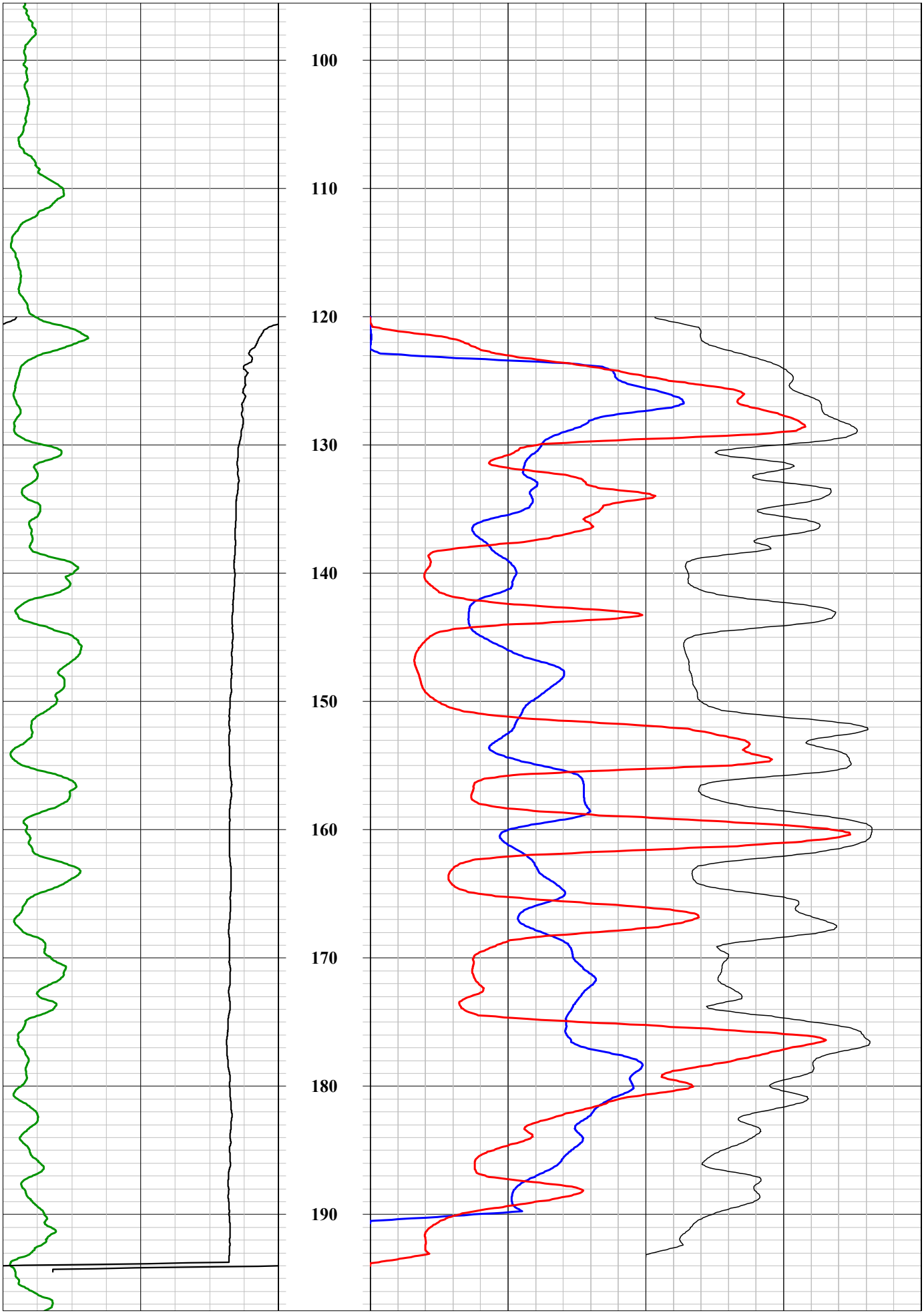
SIZE	WGT.	FROM	TO
PQ	Steel	0'	120'

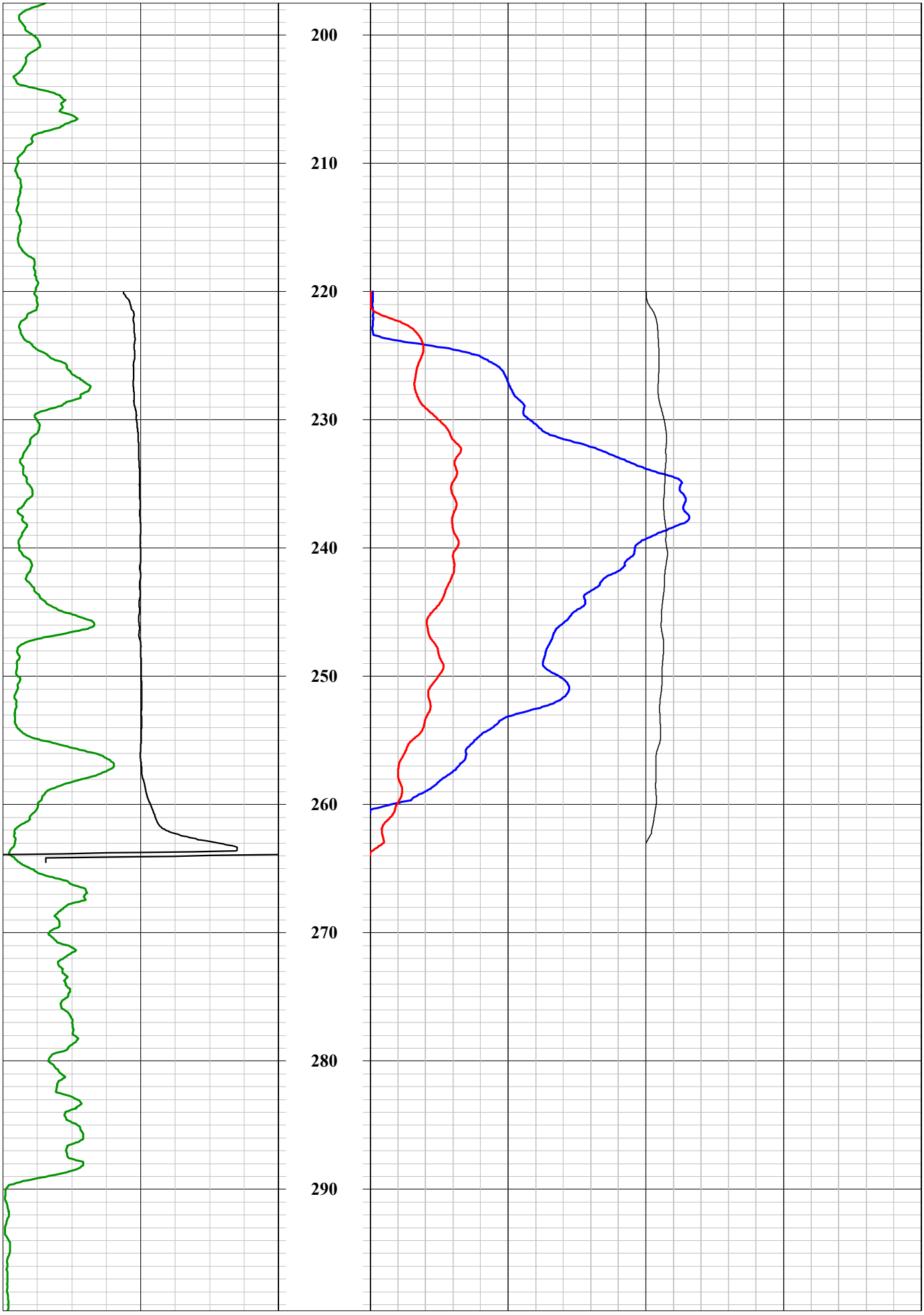
NA - Not Available, N/A - Not Applicable

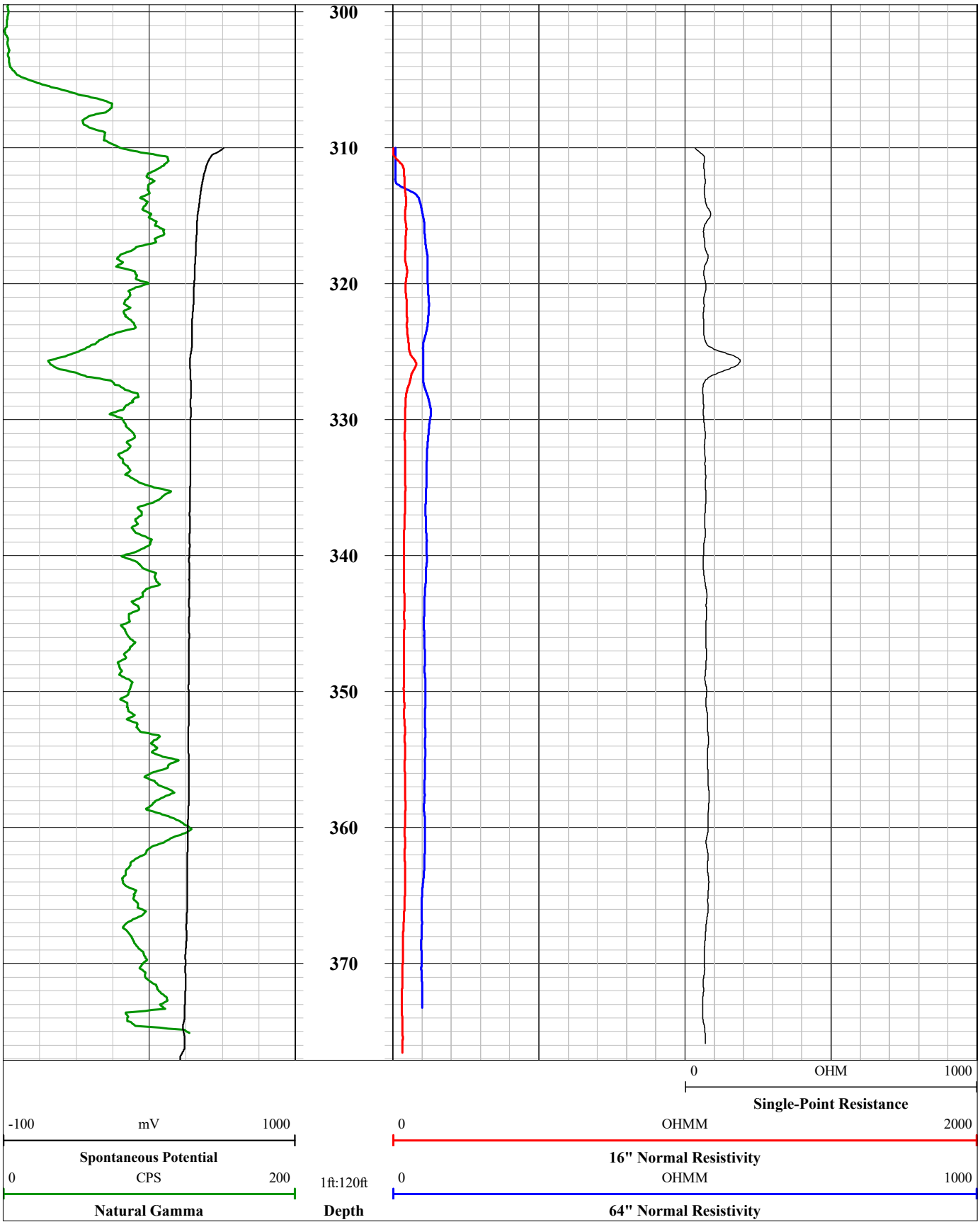
COMMENTS

Electrical Resistivities collected in multiple runs due to borehole conditions and instability.
Natural Gamma collected through rods and casing to get data through entire borehole.


Natural Gamma
0
CPS
200
Spontaneous Potential
-100
mV
1000
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
1000
16" Normal Resistivity
0
OHMM
2000
Single-Point Resistance
0
OHM
1000
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
320
330
340
350
360
370
0
OHM
1000
Single-Point Resistance
-100
mV
1000
Spontaneous Potential
0
OHMM
2000
16" Normal Resistivity
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
OHMM
1000
64" Normal Resistivity

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-17
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-17
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - North Side
Latitude: 45.82875 N
Longitude: 84.76084 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond.
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 599.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	5-13 July 2019			
RUN NUMBER	1			
LOG TYPE	PSLog			
DEPTH-DRILLER	380'			
DEPTH-LOGGER	378'			
BTM LOG INTERVAL	367'			
TOP LOG INTERVAL	120'			
RECORDED BY	CKL/JBG/BEH			
WITNESSED BY				
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	16'/Water			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	380'

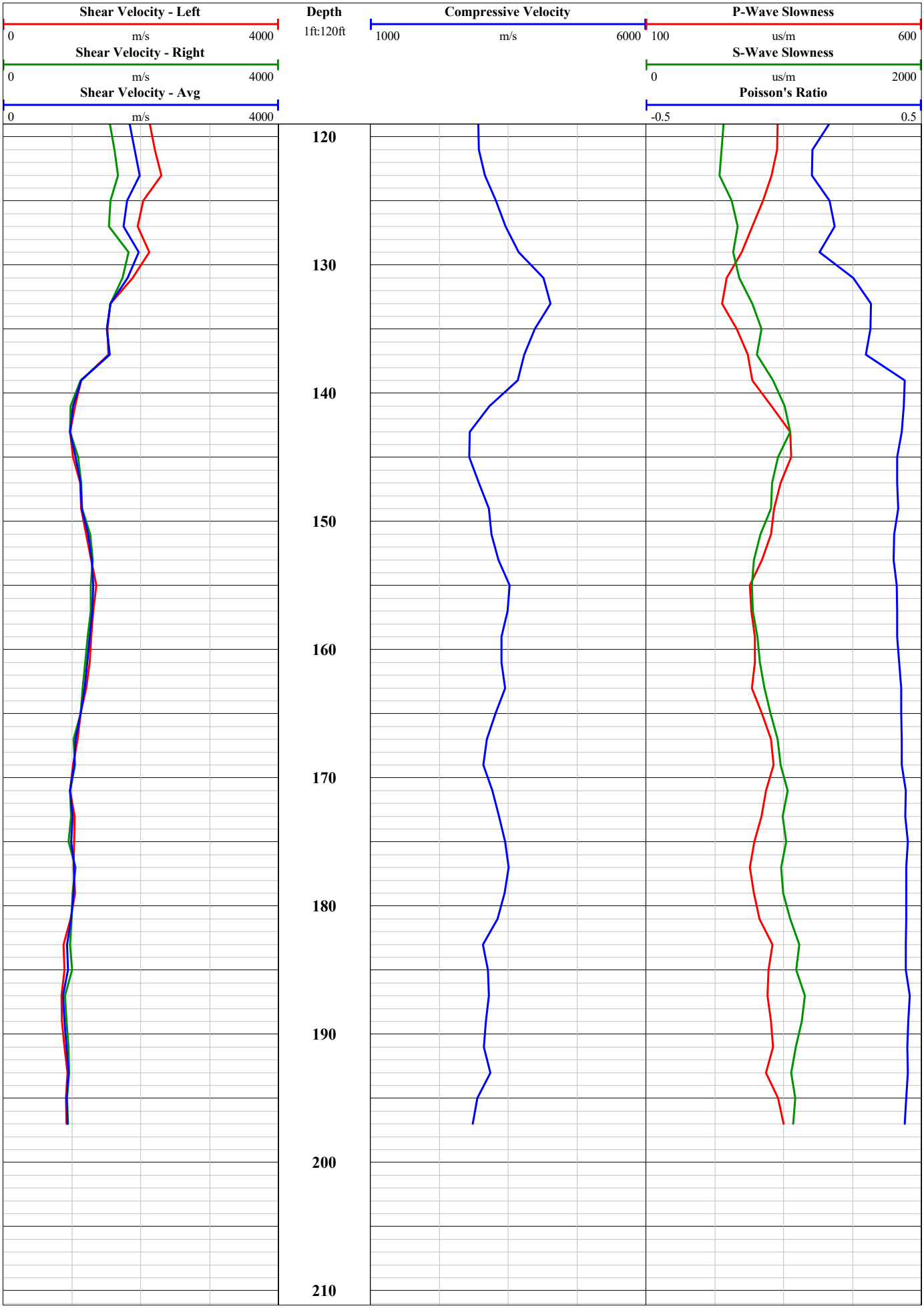
CASING RECORD

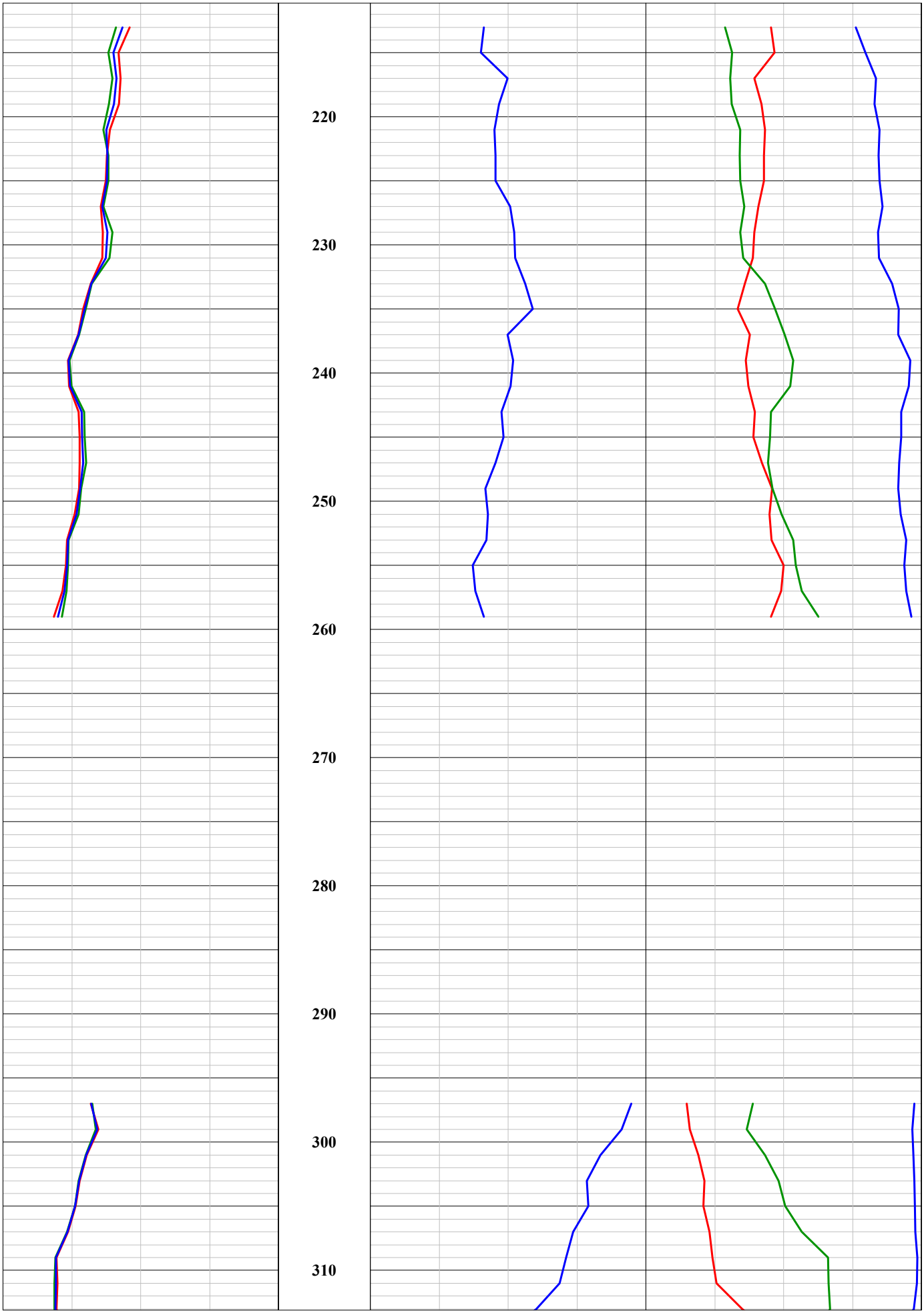
SIZE	WGT.	FROM	TO
PQ	Steel	0'	120'

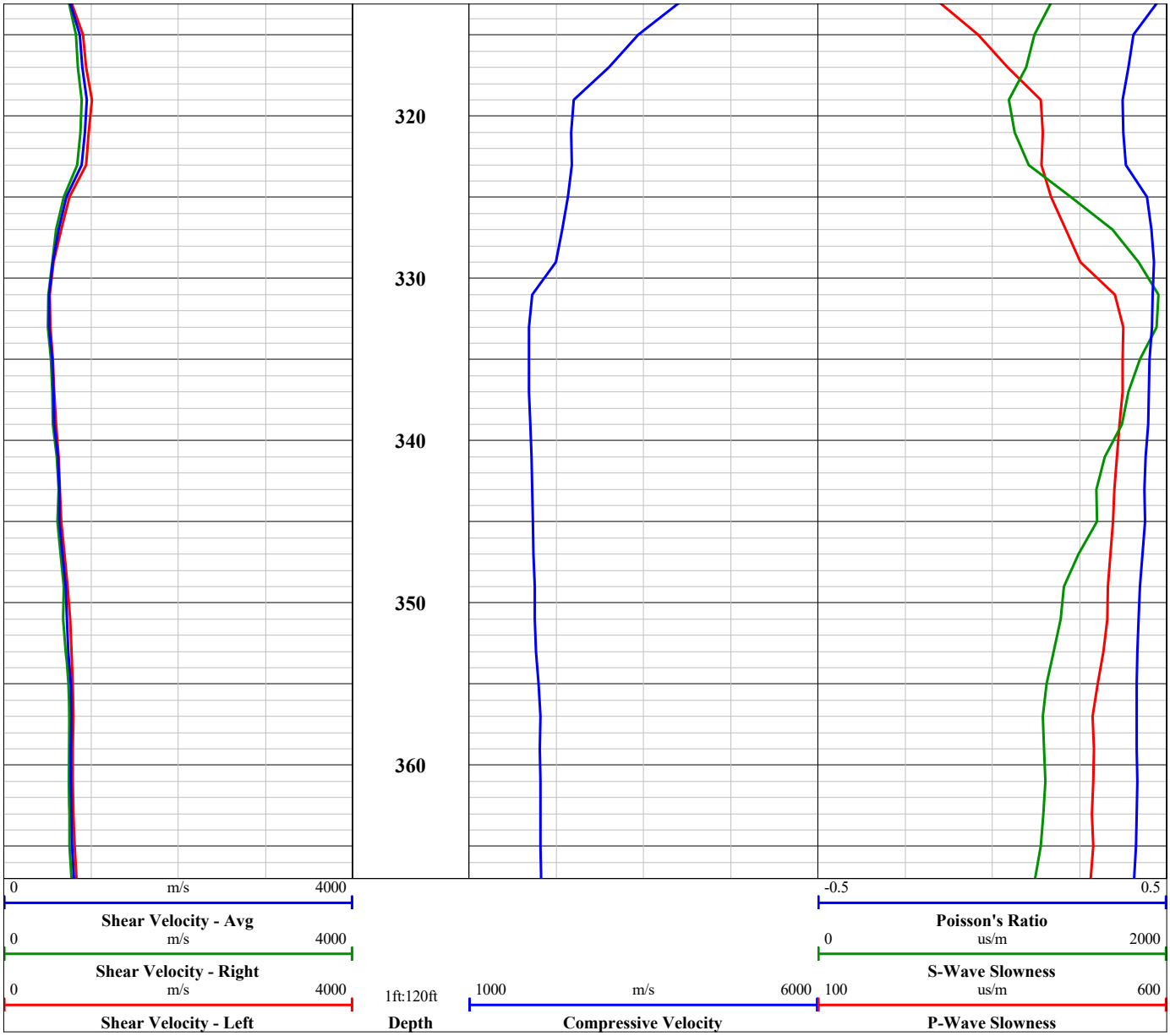
NA - Not Available, N/A - Not Applicable

COMMENTS

Gaps in data due to poor borehole conditions during logging.


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
1000
m/s
6000
P-Wave Slowness
100
us/m
600
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-0.5
0.5
120
130
140
150
160
170
180
190
200
210


220
230
240
250
260
270
280
290
300
310


320
330
340
350
360
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
1000
m/s
6000
Compressive Velocity
-0.5
0.5
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
100
us/m
600
P-Wave Slowness

COLOG
borehole geophysics / hydrophysics

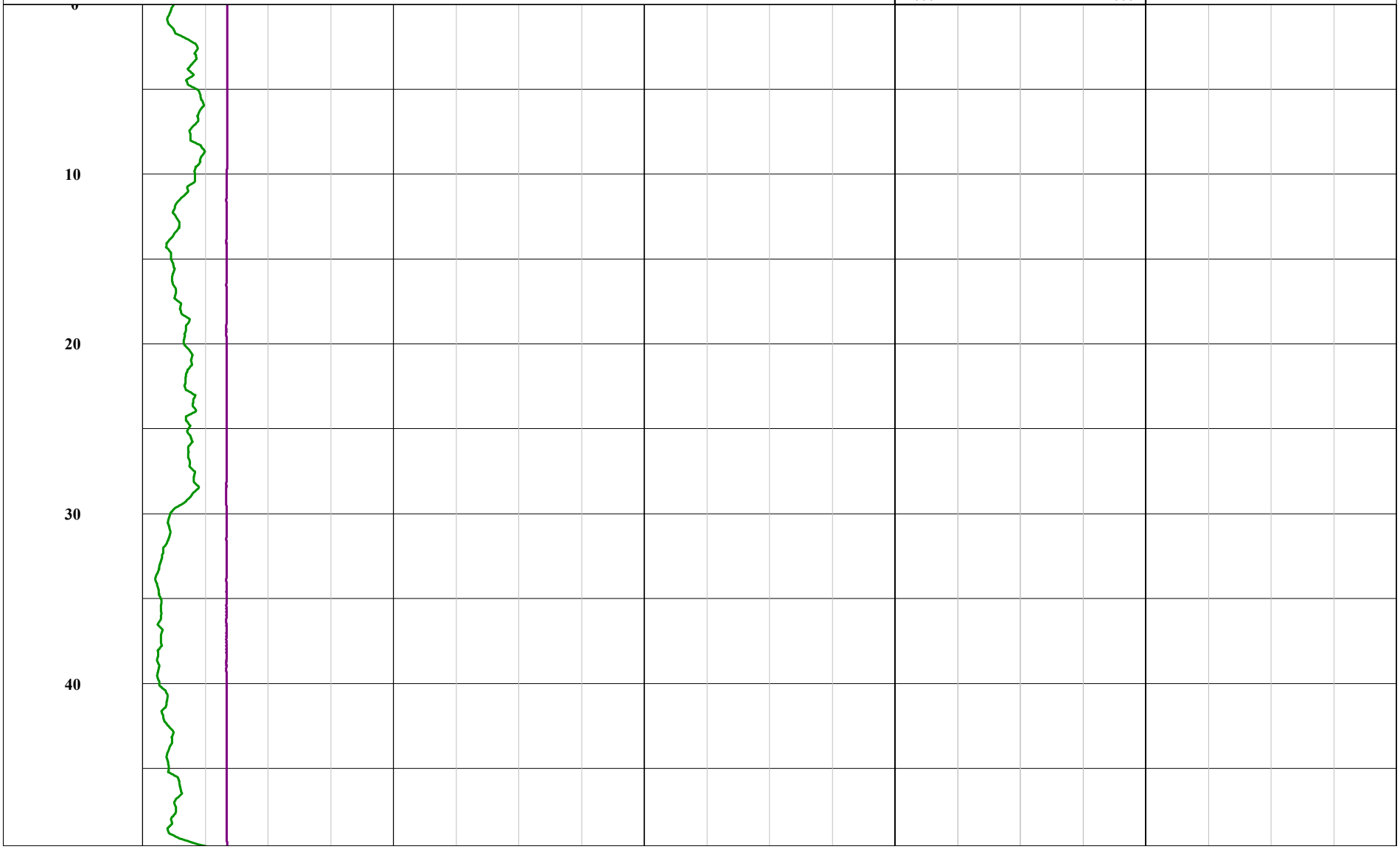
Geophysical Summary Plot

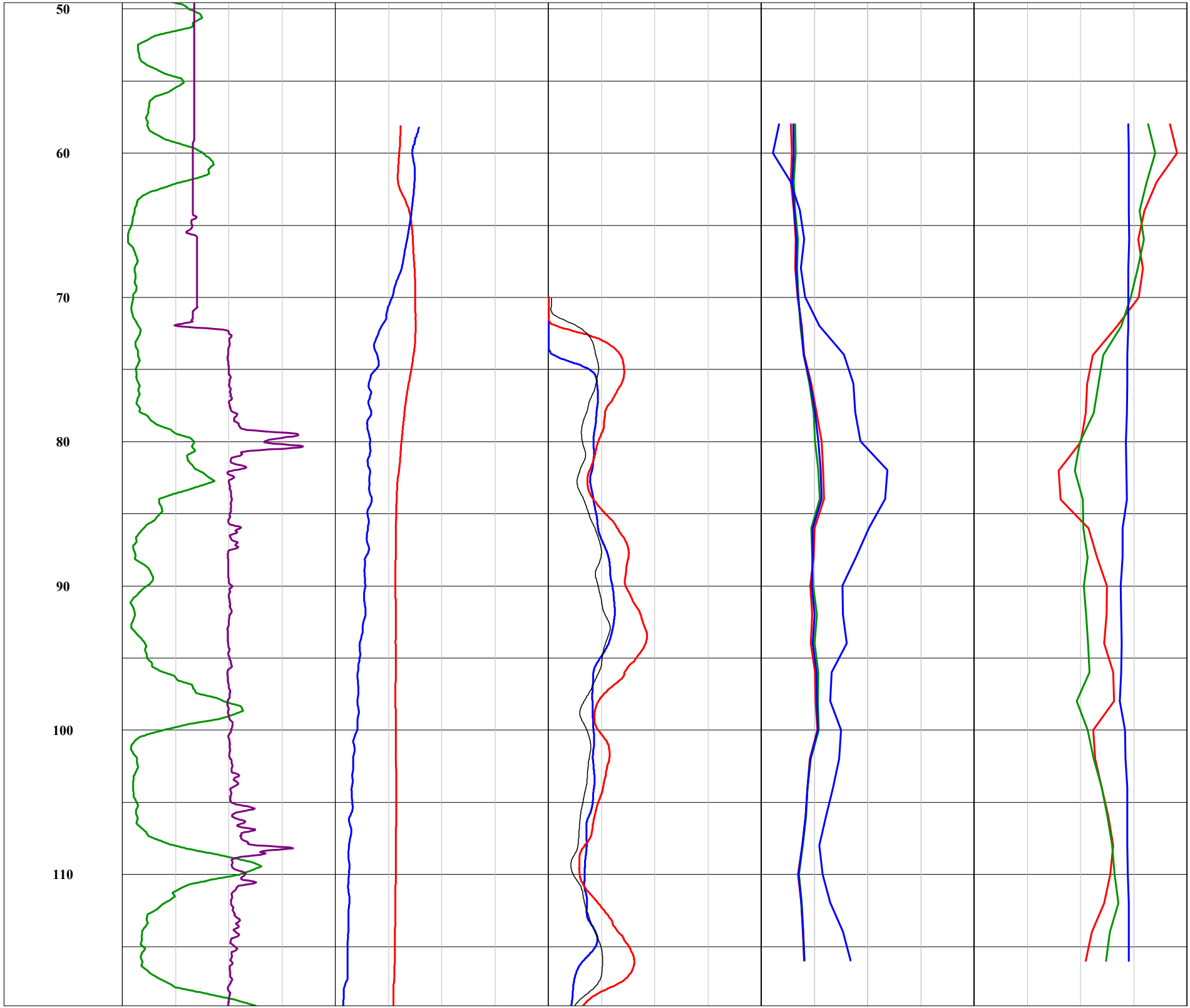
COMPANY: WSP | **PROJECT:** L5RT Project

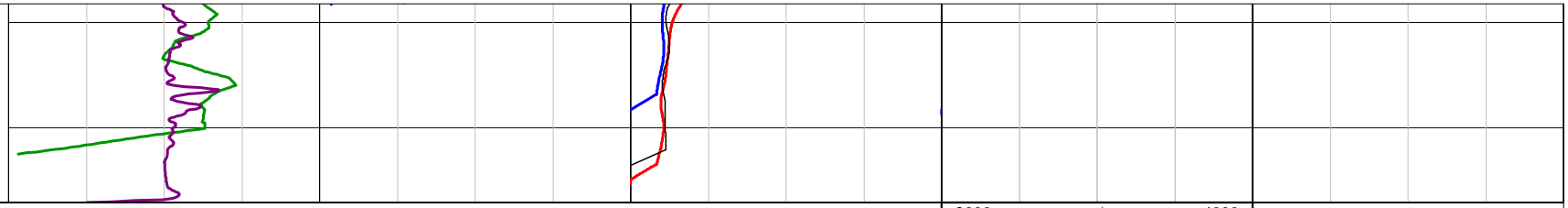
DATE LOGGED: 26 October 2019 | **WELL:** BH19-19 - Mid Strait

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	Temperature	64" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness
1ft:100ft	0 CPS 100	10 deg C 20	0 OHMM 1000	0 m/s 4000	200 us/m 500
	3-Arm Caliper	**Fluid Conductivity**	**16" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**
	3 Inch 9	1000 uS/cm 2000	0 OHMM 1000	0 m/s 4000	0 us/m 2000
			Single-Point Resistance	**Shear Velocity - Avg**	**Poisson's Ratio**
			0 OHM 500	0 m/s 4000	-1 1
				Compressive Velocity	
				2000 m/s 4000	




50
60
70
80
90
100
110

120						
					2000 m/s 4000 **Compressive Velocity**	
			0 OHM 500 **Single-Point Resistance**		0 m/s 4000 **Shear Velocity - Avg**	-1 1 **Poisson's Ratio**
	3 Inch 9 **3-Arm Caliper**	1000 uS/cm 2000 **Fluid Conductivity**	0 OHMM 1000 **16" Normal Resistivity**		0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**
1ft:100ft **Depth**	0 CPS 100 **Natural Gamma**	10 deg C 20 **Temperature**	0 OHMM 1000 **64" Normal Resistivity**		0 m/s 4000 **Shear Velocity - Left**	200 us/m 500 **P-Wave Slowness**

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-19
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-19
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.82346 N
Longitude: 84.76282 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electrical Log
P&S Logger

PERMANENT DATUM Mudline **ELEVATION** 446.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	26 October 2019	26 October 2019	26 October 2019	
RUN NUMBER	1	3	2	
LOG TYPE	Fluid Temp & Cond	3-Armed Caliper	Natural Gamma	
DEPTH-DRILLER	128.8'	128.8'	128.8'	
DEPTH-LOGGER	119.1'	128.4'	126.3'	
BTM LOG INTERVAL	119.1'	128.4'	126.3'	
TOP LOG INTERVAL	58.1'	0.0'	0.0'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	WSP	WSP	WSP	
PROBE TYPE, S/N	2PFA #5969	3ACS #3596	ELXG #4314	
LOGGING SPEED	15 ft/min	15 ft/min	15 ft/min	
A.S.D.E. / Sample Interval	0.05' / 0.10'	0.6' / 0.10'	0.85' / 0.25'	
Fluid Level / Fluid Type	2' / water	2' / water	2' / water	

BOREHOLE RECORD

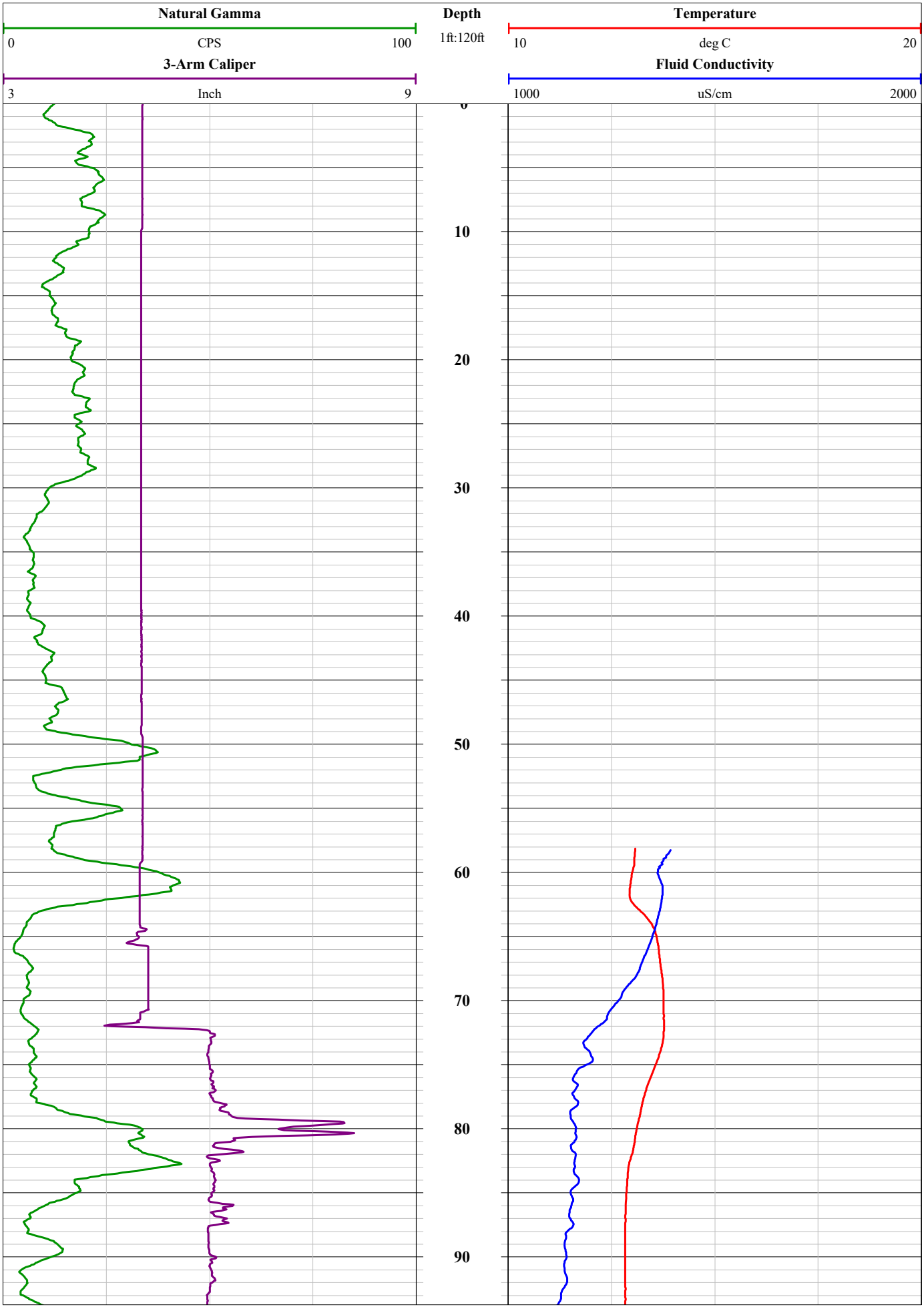
RUN No.	BIT	FROM	TO
1	7"	Mudline	41.6'
2	6"	Mudline	128.8'

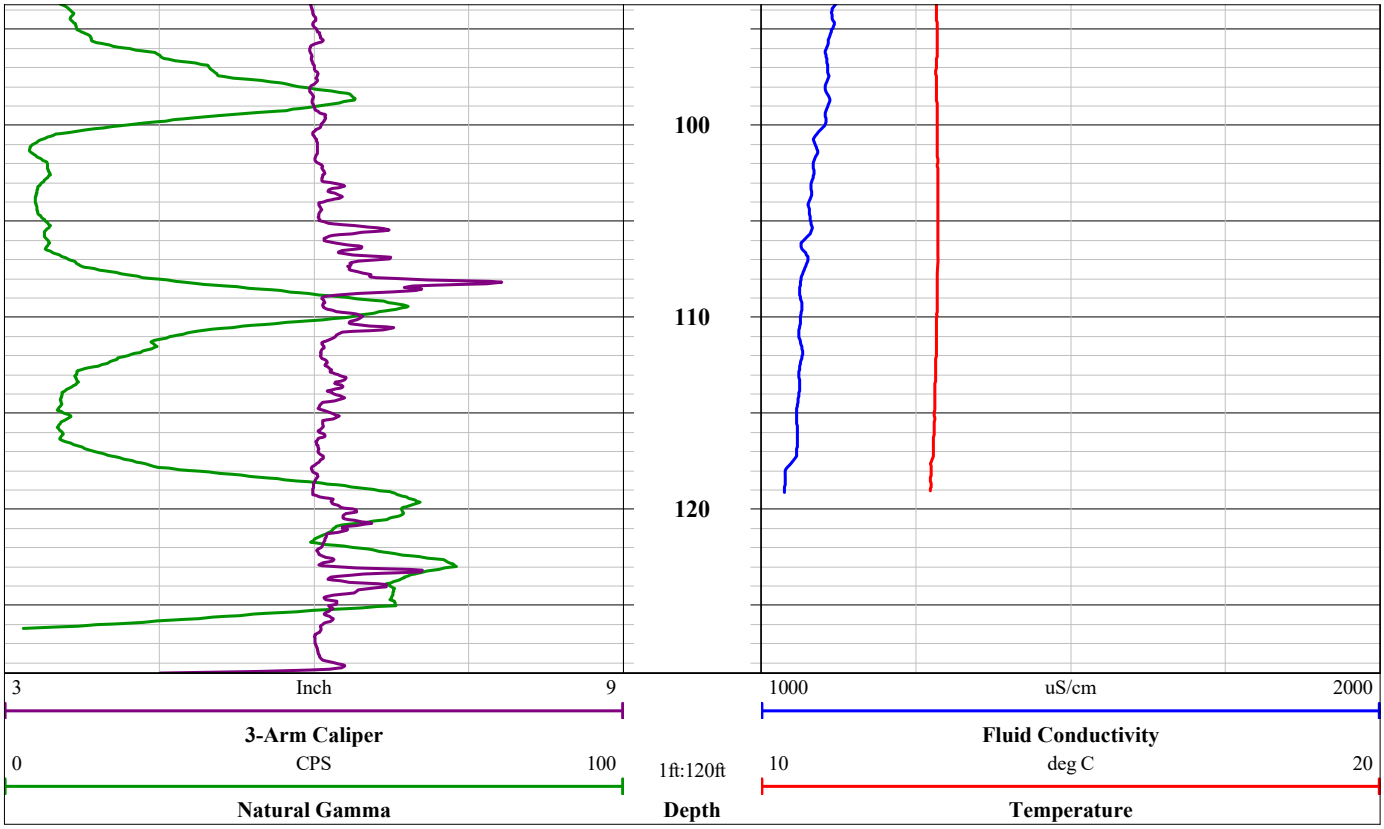
CASING RECORD

SIZE	WGT.	FROM	TO
7"	Steel	TOC	41.6'
GSX	Steel	TOC	71.5'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
3
Inch
9
Depth
1ft:120ft
Temperature
10
deg C
20
Fluid Conductivity
1000
uS/cm
2000
10
20
30
40
50
60
70
80
90


100
110
120
3
Inch
9
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
1000
uS/cm
2000
Fluid Conductivity
10
deg C
20
Temperature

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-19
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-19
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.82346 N
Longitude: 84.76282 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Fluid Temp. & Cond.
P&S Logger

PERMANENT DATUM Mudline **ELEVATION** 446.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	26 October 2019	26 October 2019		
RUN NUMBER	2	2		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	128.8'	128.8'		
DEPTH-LOGGER	126.3'	128'		
BTM LOG INTERVAL	126.3'	127.7'		
TOP LOG INTERVAL	0.0'	70.0'		
RECORDED BY	JBG	JBG		
WITNESSED BY	WSP	WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	15 ft/min	15 ft/min		
A.S.D.E. / Sample Interval	0.85' / 0.25'	0.85' / 0.25'		
Fluid Level / Fluid Type	2' / water	2' / water		

BOREHOLE RECORD

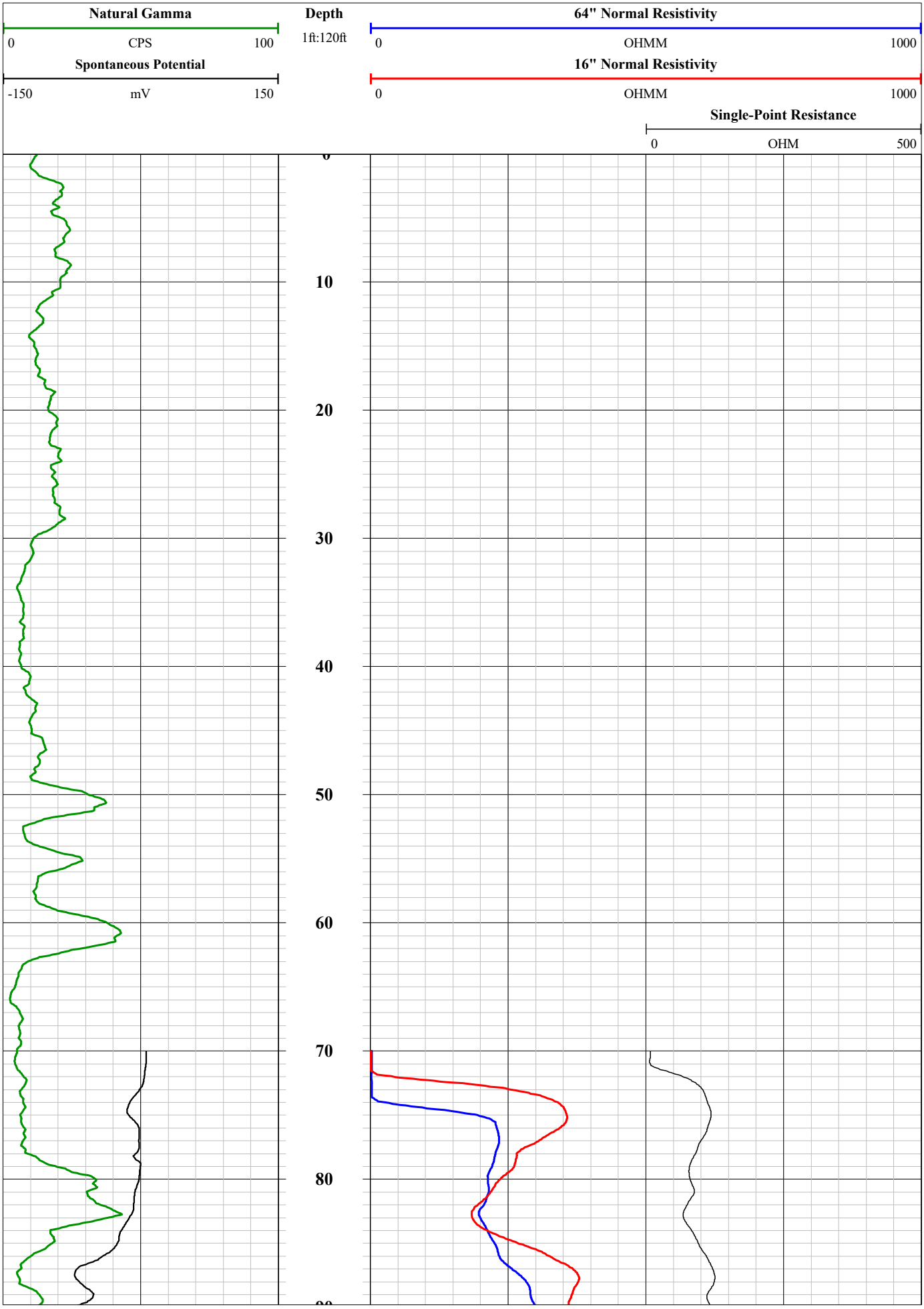
RUN No.	BIT	FROM	TO
1	7"	Mudline	41.6'
2	6"	Mudline	128.8'

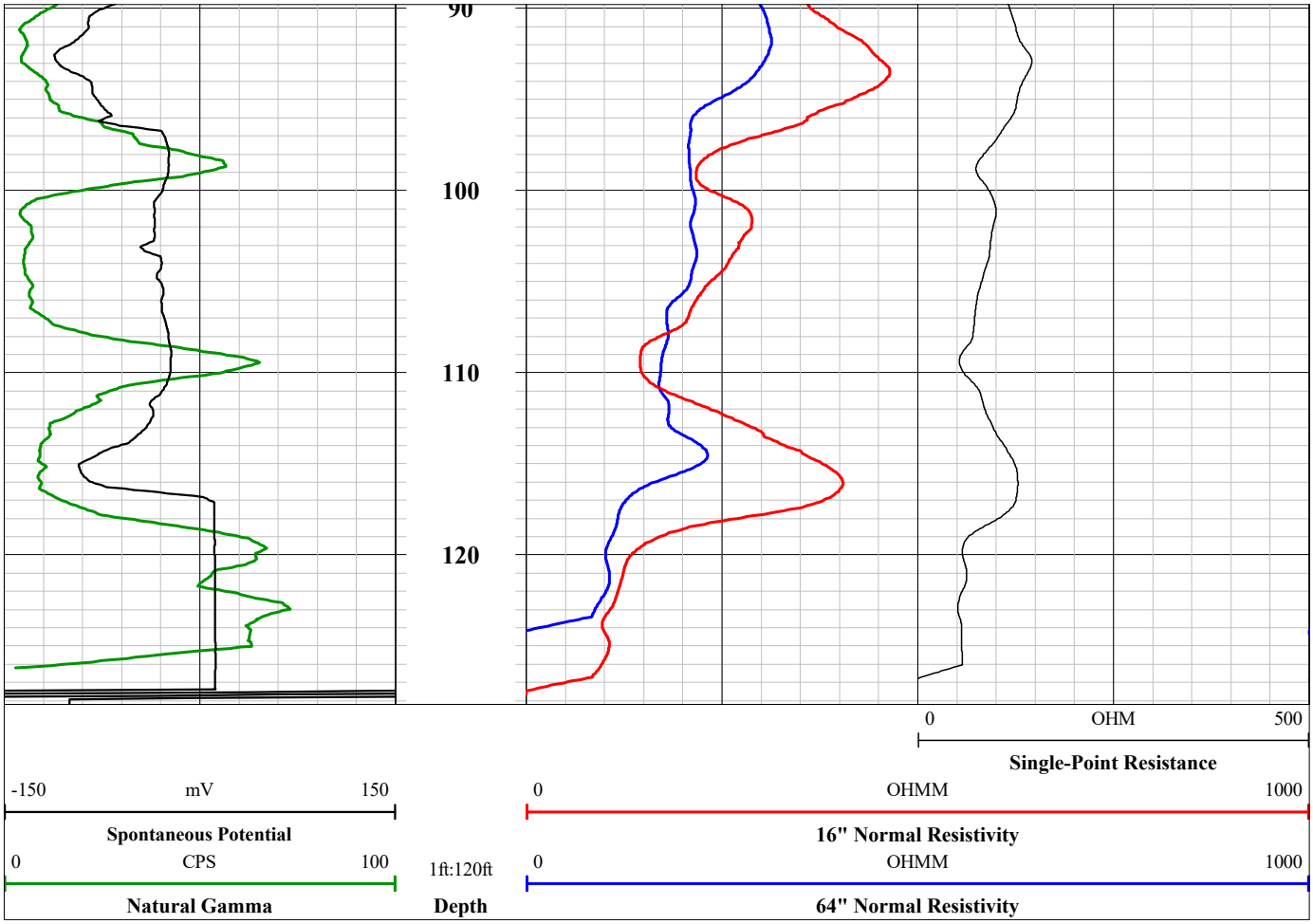
CASING RECORD

SIZE	WGT.	FROM	TO
7"	Steel	TOC	41.6'
GSX	Steel	TOC	71.5'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-150
mV
150
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
1000
16" Normal Resistivity
0
OHMM
1000
Single-Point Resistance
0
OHM
500
10
20
30
40
50
60
70
80


90
100
110
120
0
OHM
500
Single-Point Resistance
-150
mV
150
Spontaneous Potential
0
OHMM
1000
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
OHMM
1000
64" Normal Resistivity

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-19
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-19
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.82346 N
Longitude: 84.76282 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electrical Log
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 446.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	26 October 2019			
RUN NUMBER	4			
LOG TYPE	PSLog			
DEPTH-DRILLER	128.8'			
DEPTH-LOGGER	116'			
BTM LOG INTERVAL	116'			
TOP LOG INTERVAL	58'			
RECORDED BY	JBG			
WITNESSED BY	WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	6.5'/2.0'			
Fluid Level / Fluid Type	2'/Water			

BOREHOLE RECORD

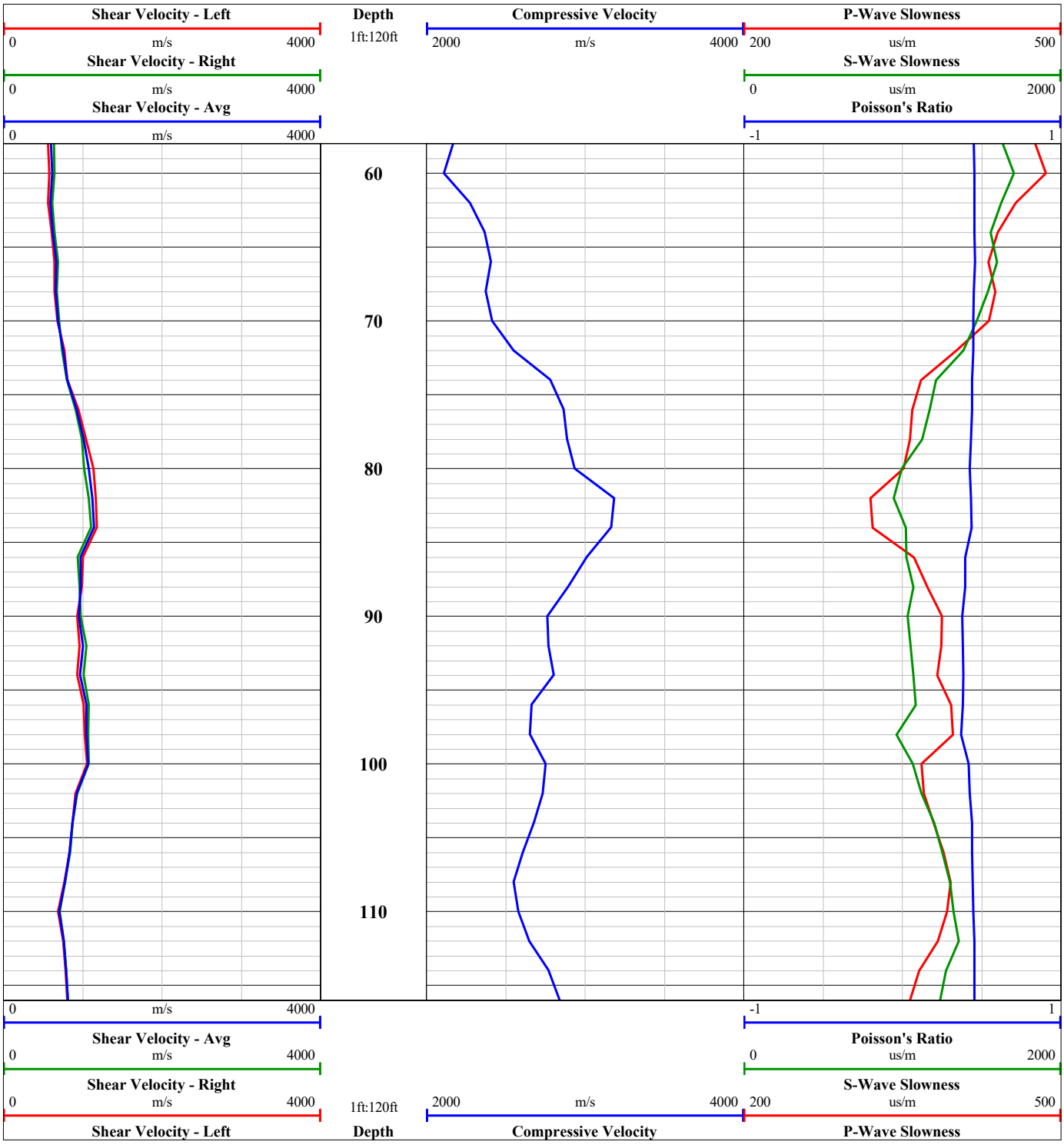
RUN No.	BIT	FROM	TO
1	7"	Mudline	41.6'
2	6"	Mudline	128.8'

CASING RECORD

SIZE	WGT.	FROM	TO
7"	Steel	TOC	41.6'
GSX	Steel	TOC	71.5'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
60
70
80
90
100
110
Compressive Velocity
2000
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
2000
m/s
4000
Compressive Velocity
-1
1
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness

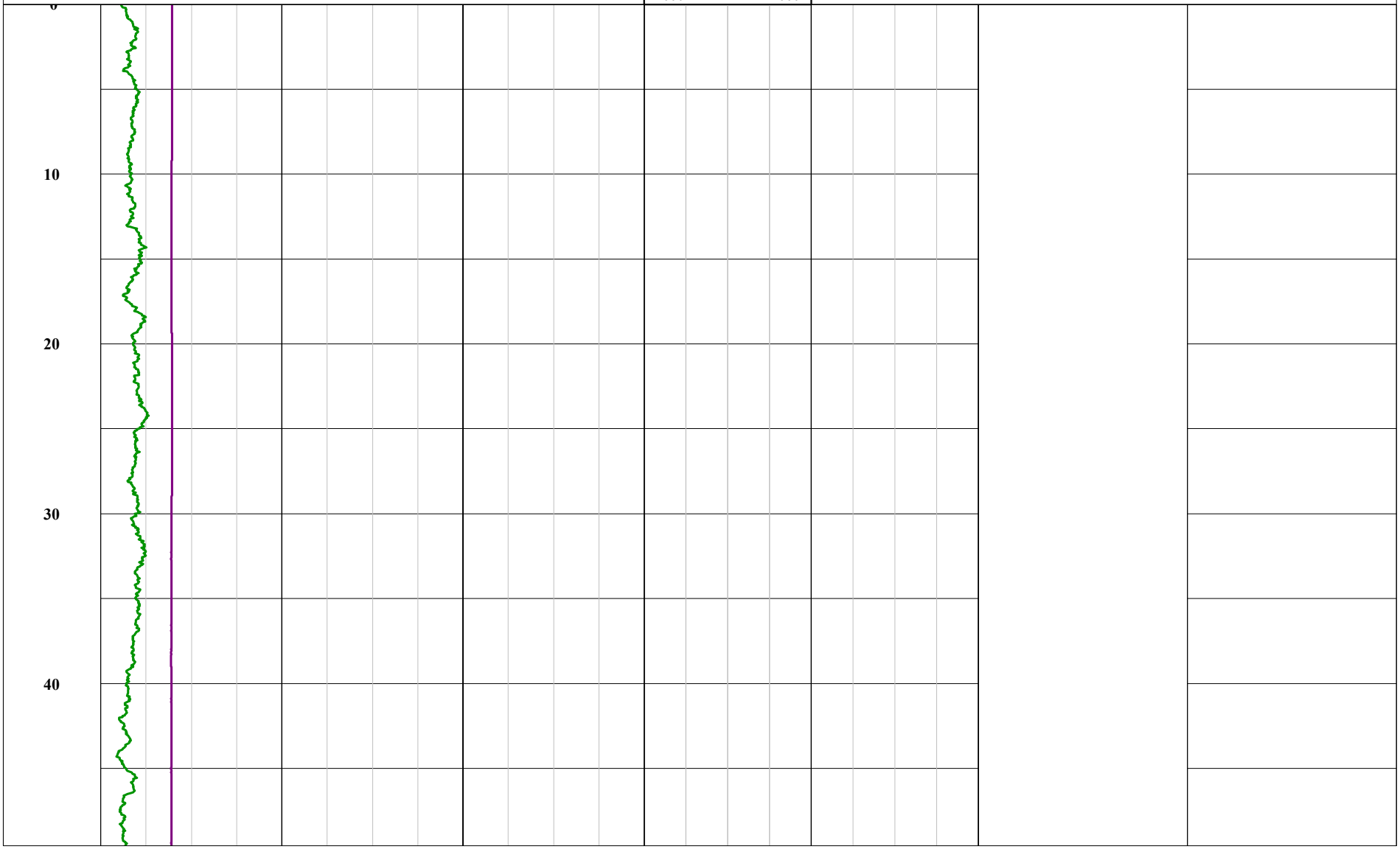
Geophysical Summary Plot

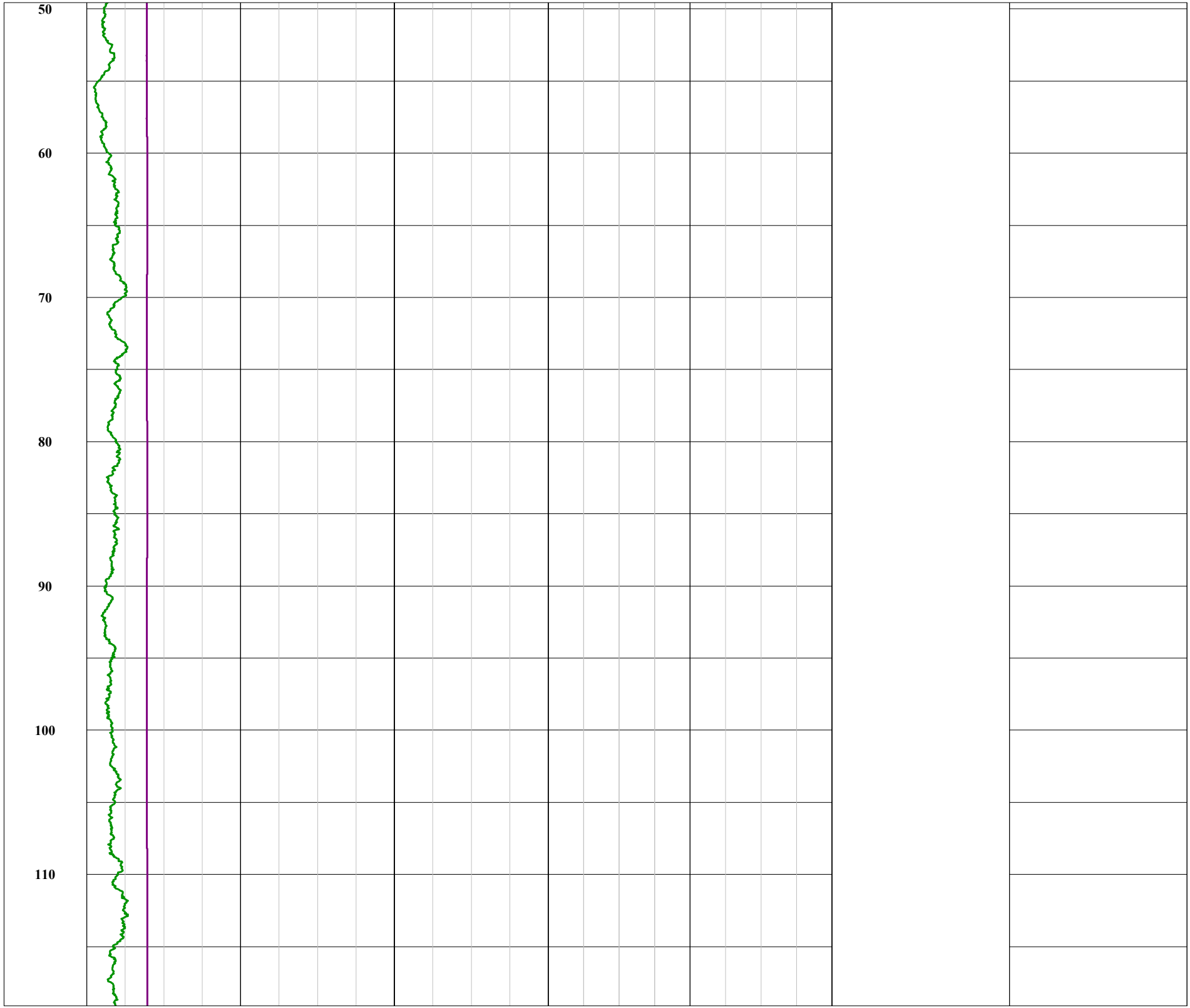
COLOG
borehole geophysics / hydrophysics

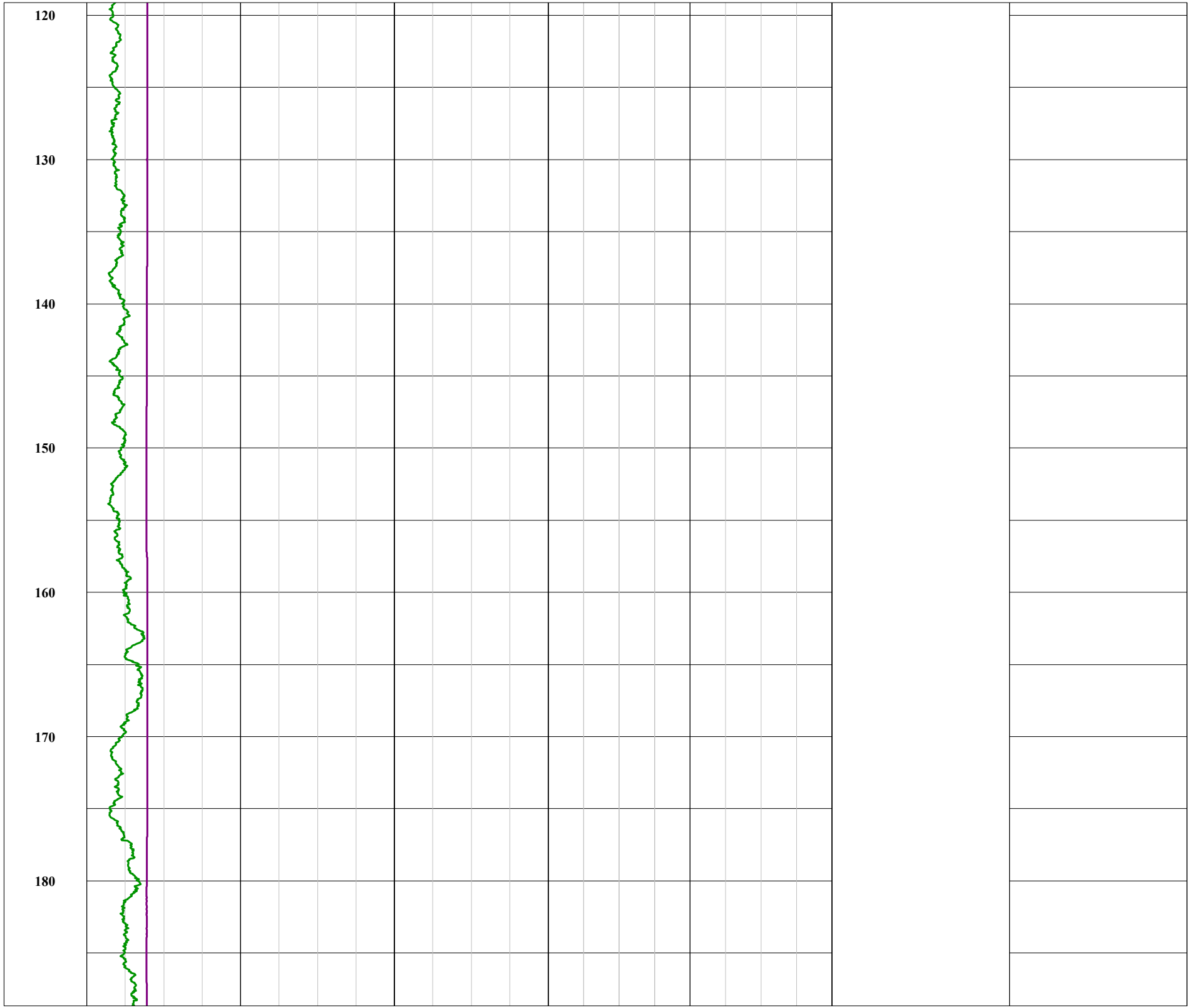
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 10-11 September 2019
WELL: BH19-24A - Mid Strait

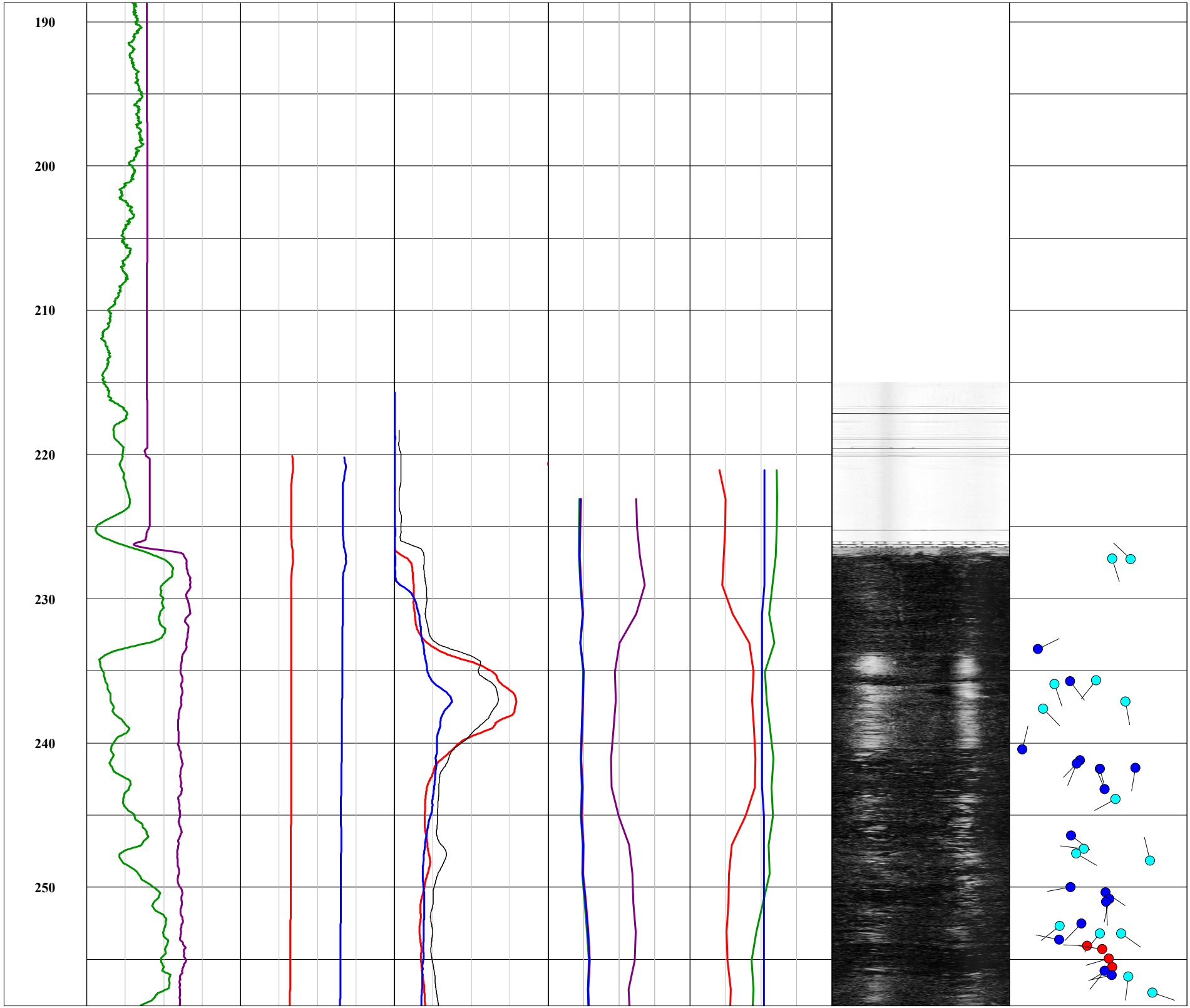
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

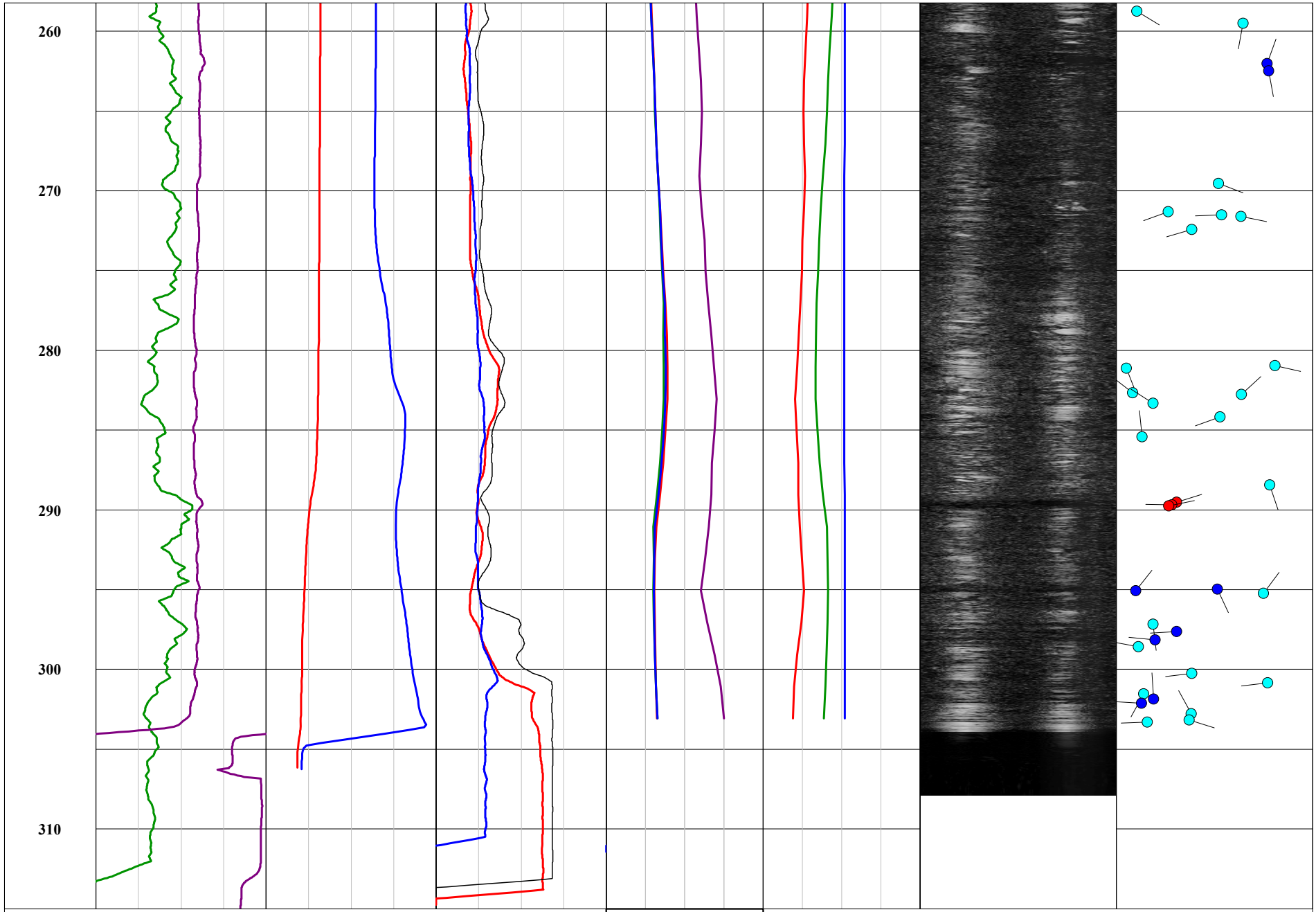
Depth	Natural Gamma	Temperature	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Amplitude - MN	Tadpoles
1ft:100ft	0 CPS 100	10 deg C 20	0 Ohm-m 500	0 m/s 4000	200 us/m 800	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	**Fluid Conductivity**	**64" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**		
	3 Inch 8	0 uS/cm 1000	0 Ohm-m 500	0 m/s 4000	0 us/m 2000		
			Single-Point Resistance	**Shear Velocity - Avg**	**Poisson's Ratio**		
			0 Ohm 200	0 m/s 4000	-10 10		
				Compressive Velocity			
				1000 m/s 4000			




50
60
70
80
90
100
110


120
130
140
150
160
170
180


190
200
210
220
230
240
250



					1000 m/s 4000 **Compressive Velocity**			
				0 Ohm 200 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-10 10 **Poisson's Ratio**		
	3 Inch 8 **3-Arm Caliper**	0 uS/cm 1000 **Fluid Conductivity**		0 Ohm-m 500 **64" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**		
1ft:100ft	0 CPS 100	10 deg C 20		0 Ohm-m 500	0 m/s 4000	200 us/m 800	0° 90° 180° 270° 0°	0 90
Depth	**Natural Gamma**	**Temperature**		**16" Normal Resistivity**	**Shear Velocity - Left**	**P-Wave Slowness**	**Amplitude - MN**	**Tadpoles**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-24A
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-24A
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81814 N
Longitude: 84.76479 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 356.7'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	10-11 Sept. 2019			
RUN NUMBER	3,4			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	316'			
DEPTH-LOGGER	315'			
BTM LOG INTERVAL	305.7'			
TOP LOG INTERVAL	215'			
RECORDED BY	JBG/DRE			
WITNESSED BY	A. Hesse			
PROBE TYPE, S/N	ALT ABI/#111018			
LOGGING SPEED	5 fpm			
A.S.D.E. / Sample Interval	0.39'/.008			
Fluid Level / Fluid Type	NA/water			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	6"	225'	316'

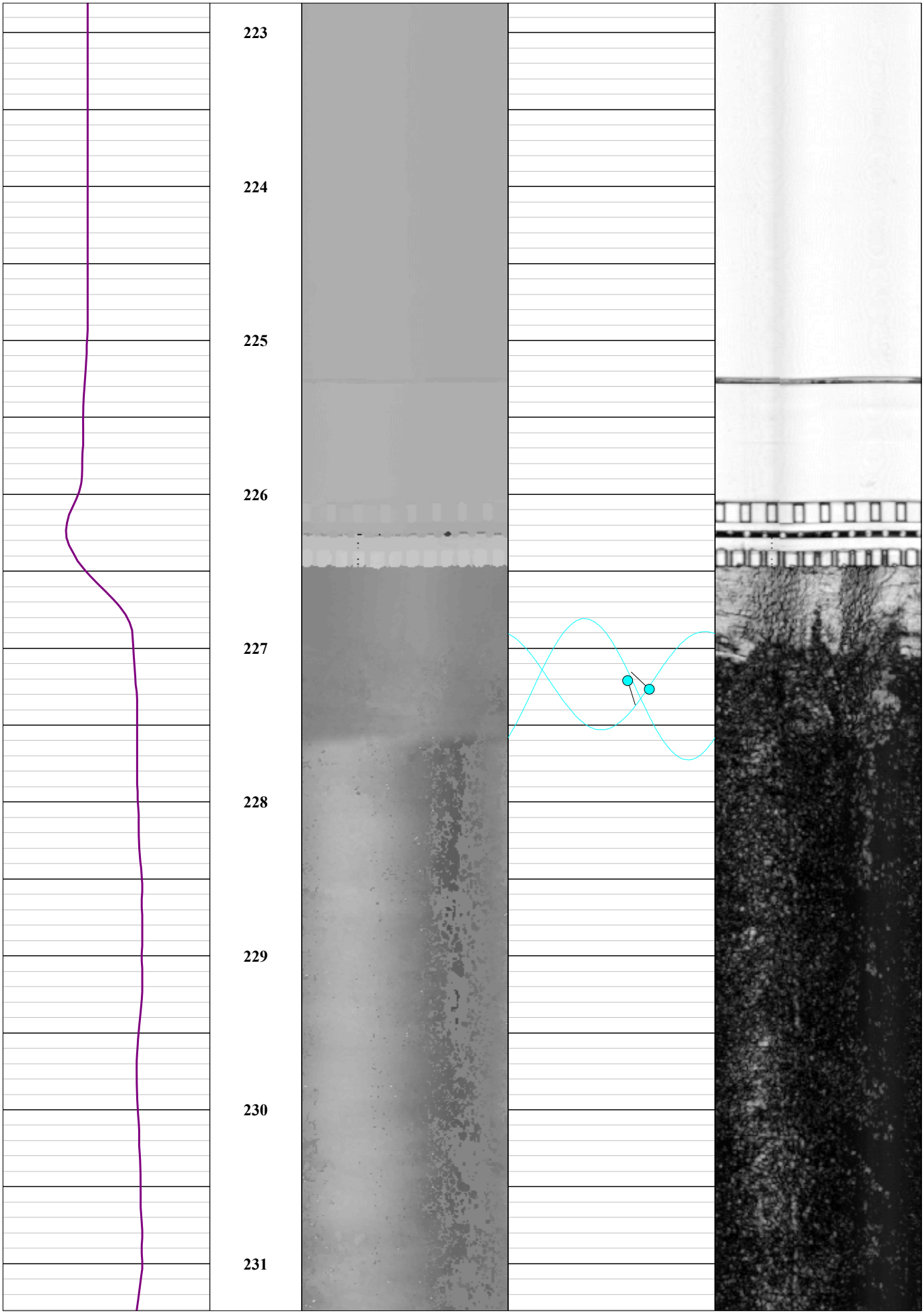
CASING RECORD

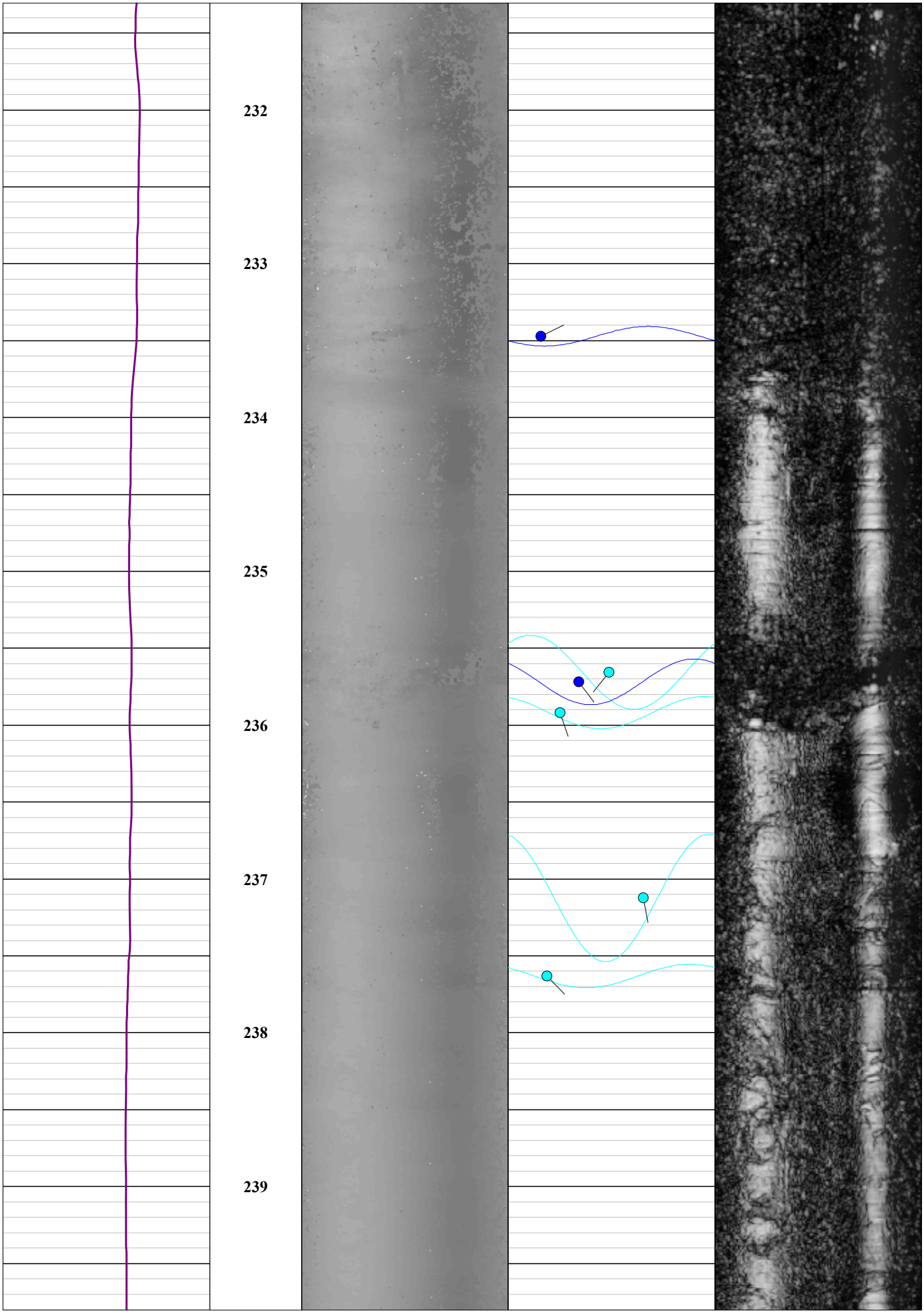
SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	225'

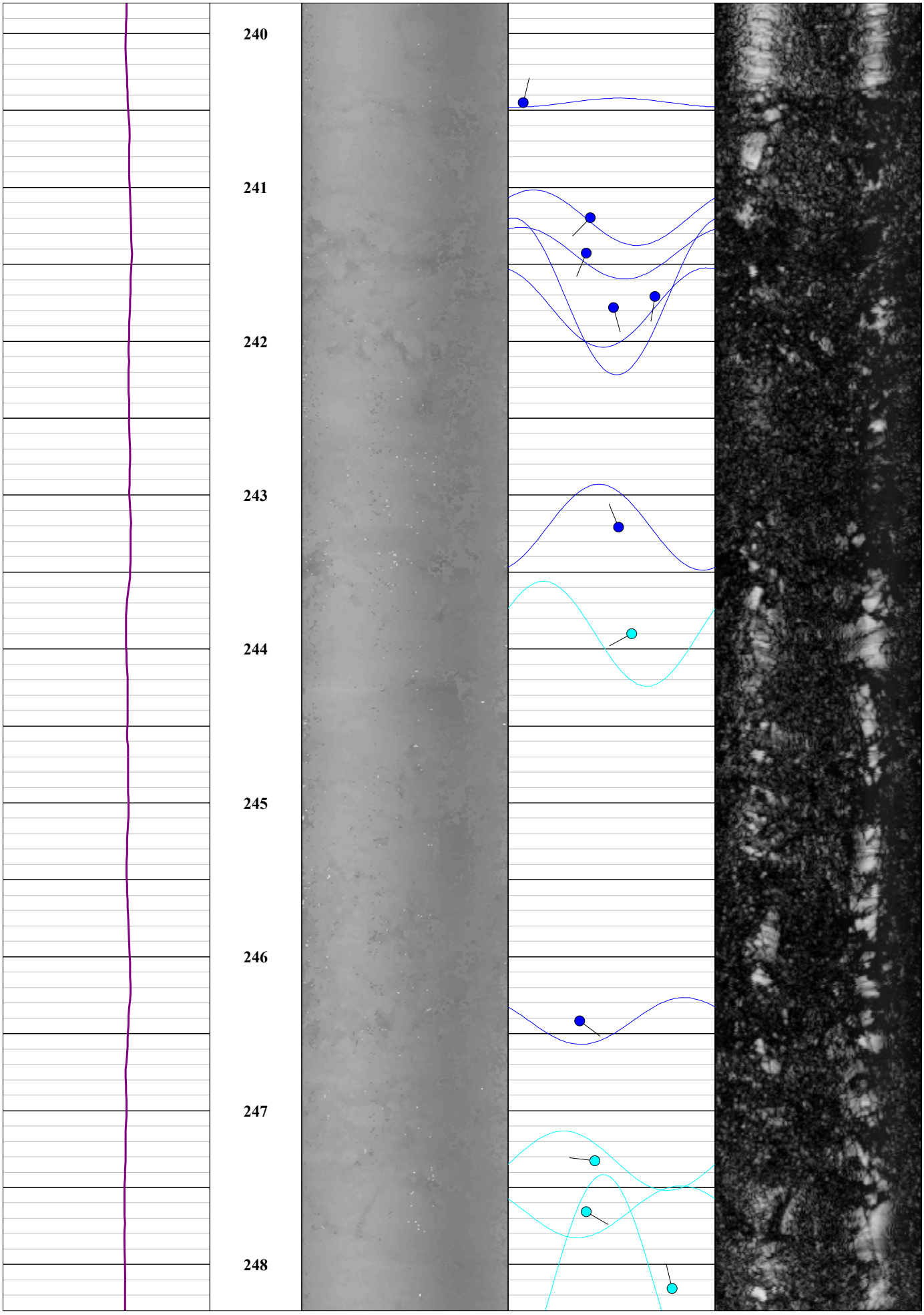
NA - Not Available, N/A - Not Applicable

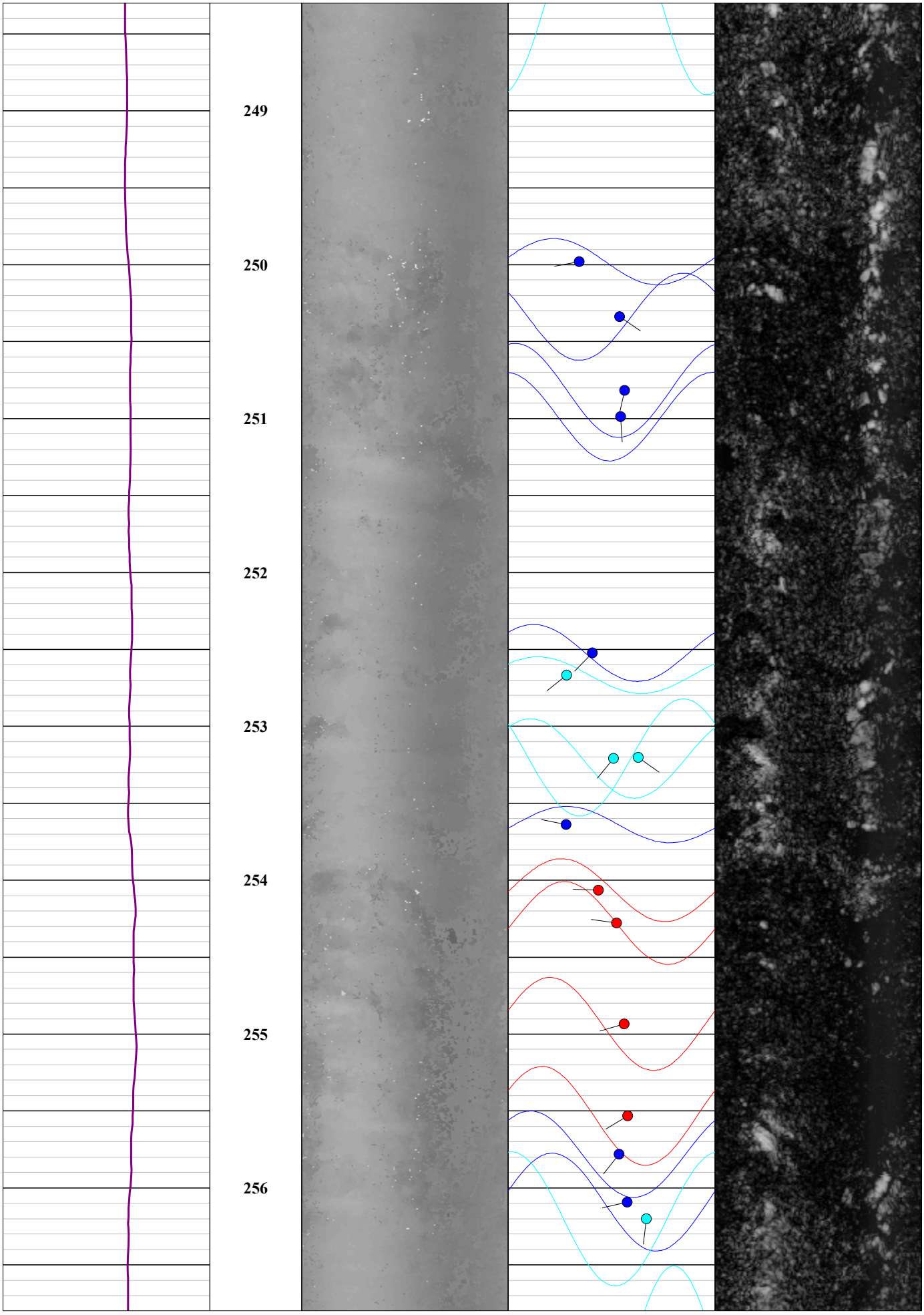
COMMENTS

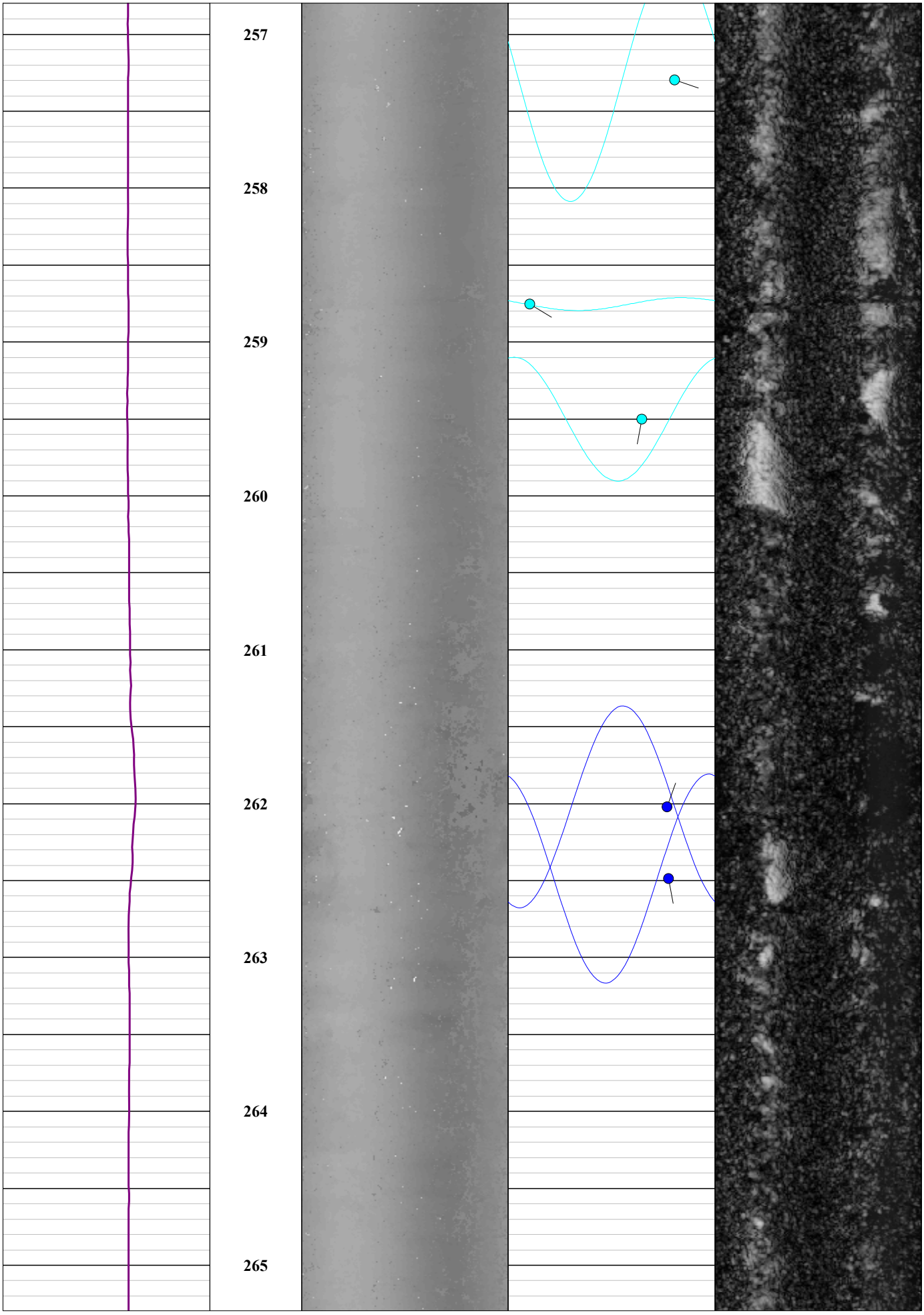
3-Arm Caliper
3
Inch
8
Depth
1ft:10ft
Travel Time - MN
0° 90° 180° 270° 0°
Projections
0° 90° 180° 270° 0°
Tadpoles
0
90
Amplitude - MN
0° 90° 180° 270° 0°
216
217
218
219
220
221
222

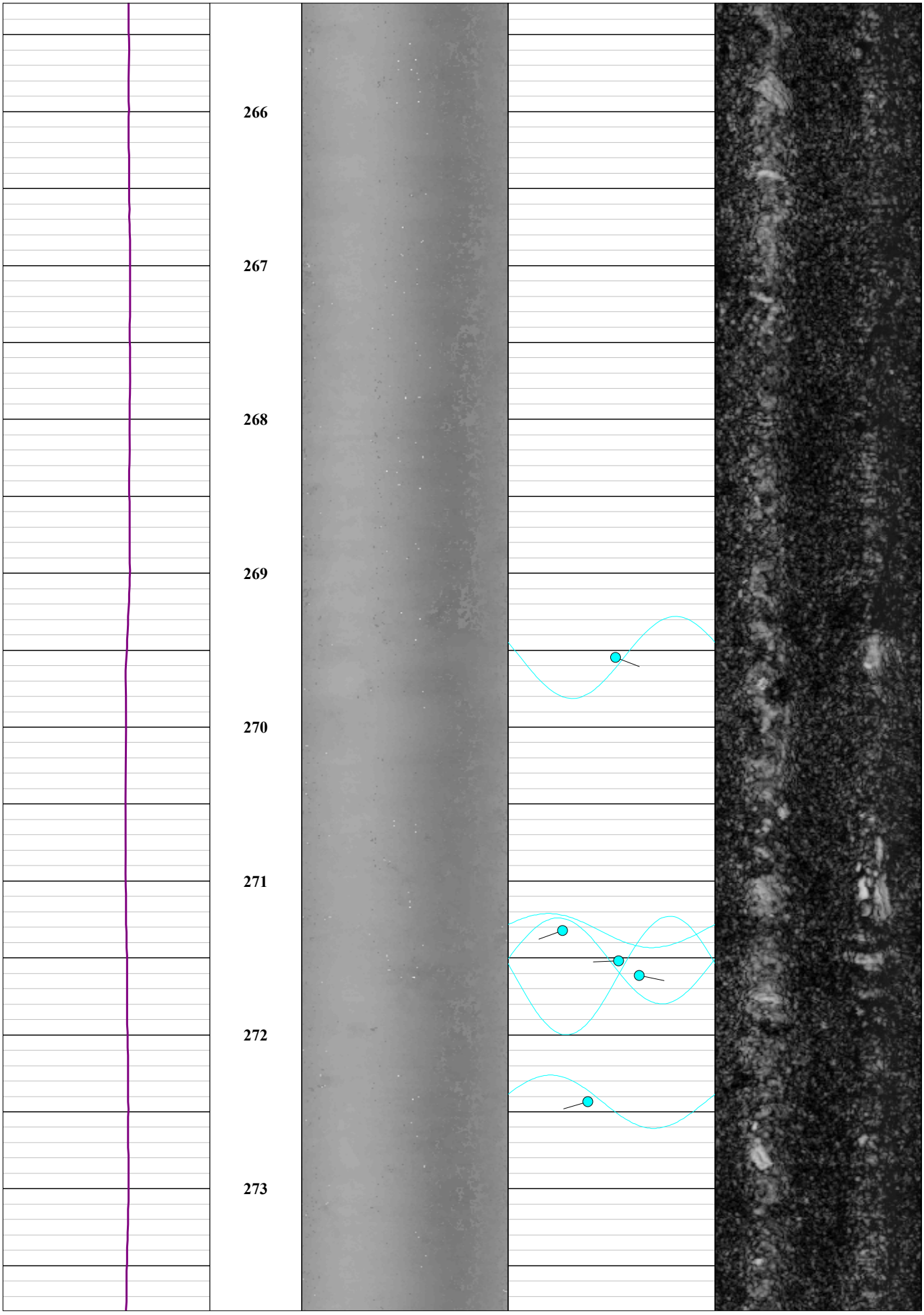

223
224
225
226
227
228
229
230
231

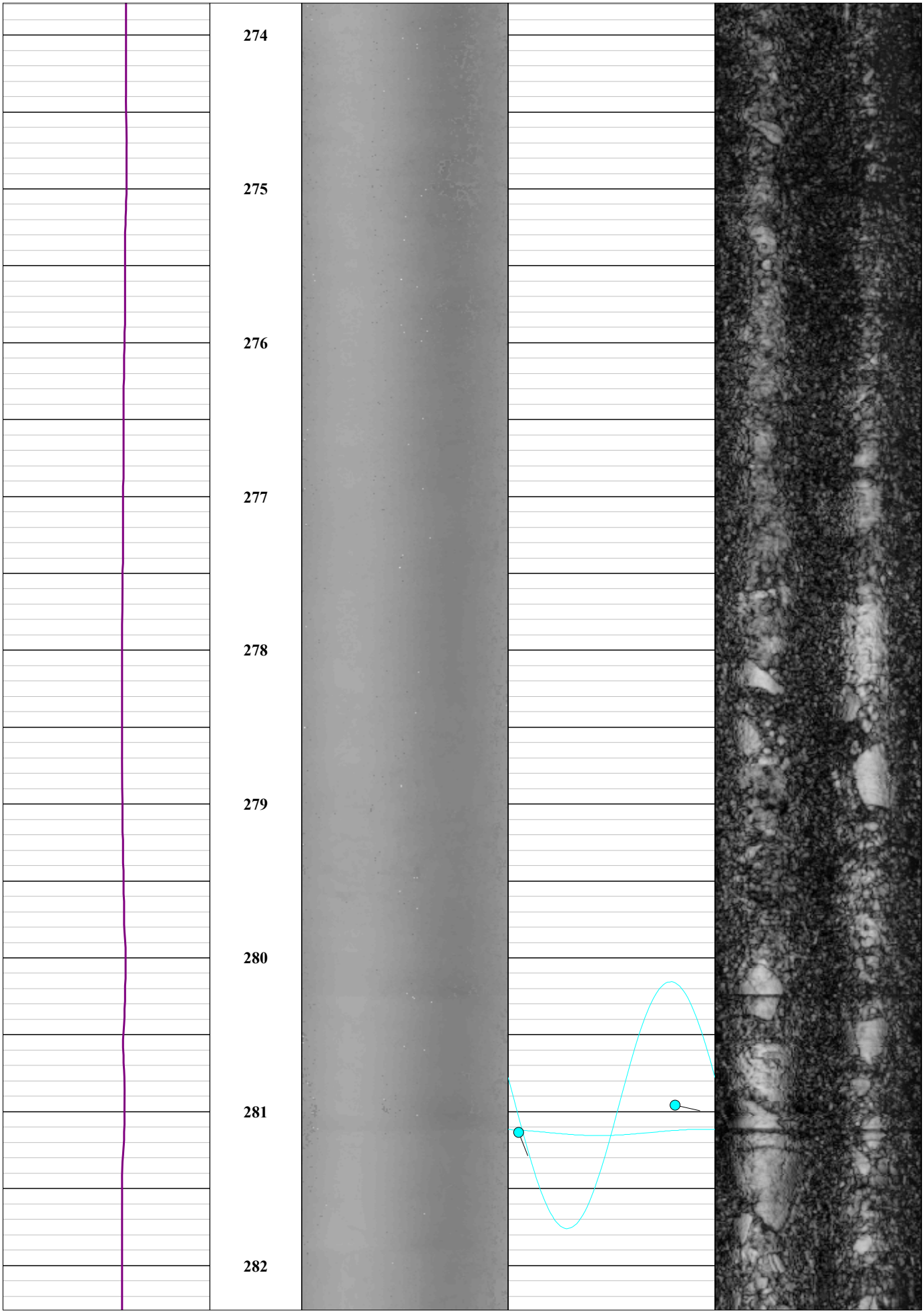

232
233
234
235
236
237
238
239

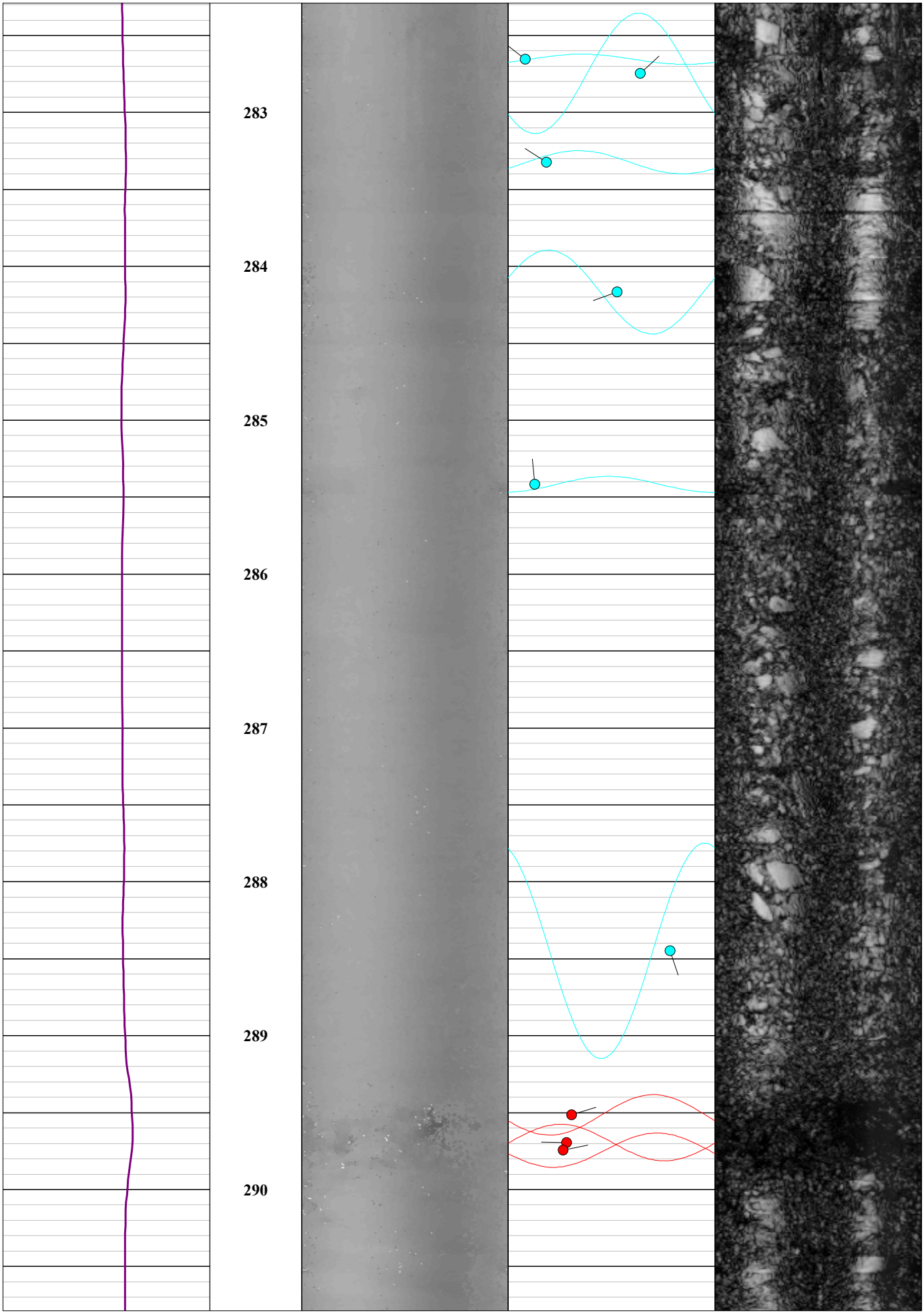

240
241
242
243
244
245
246
247
248

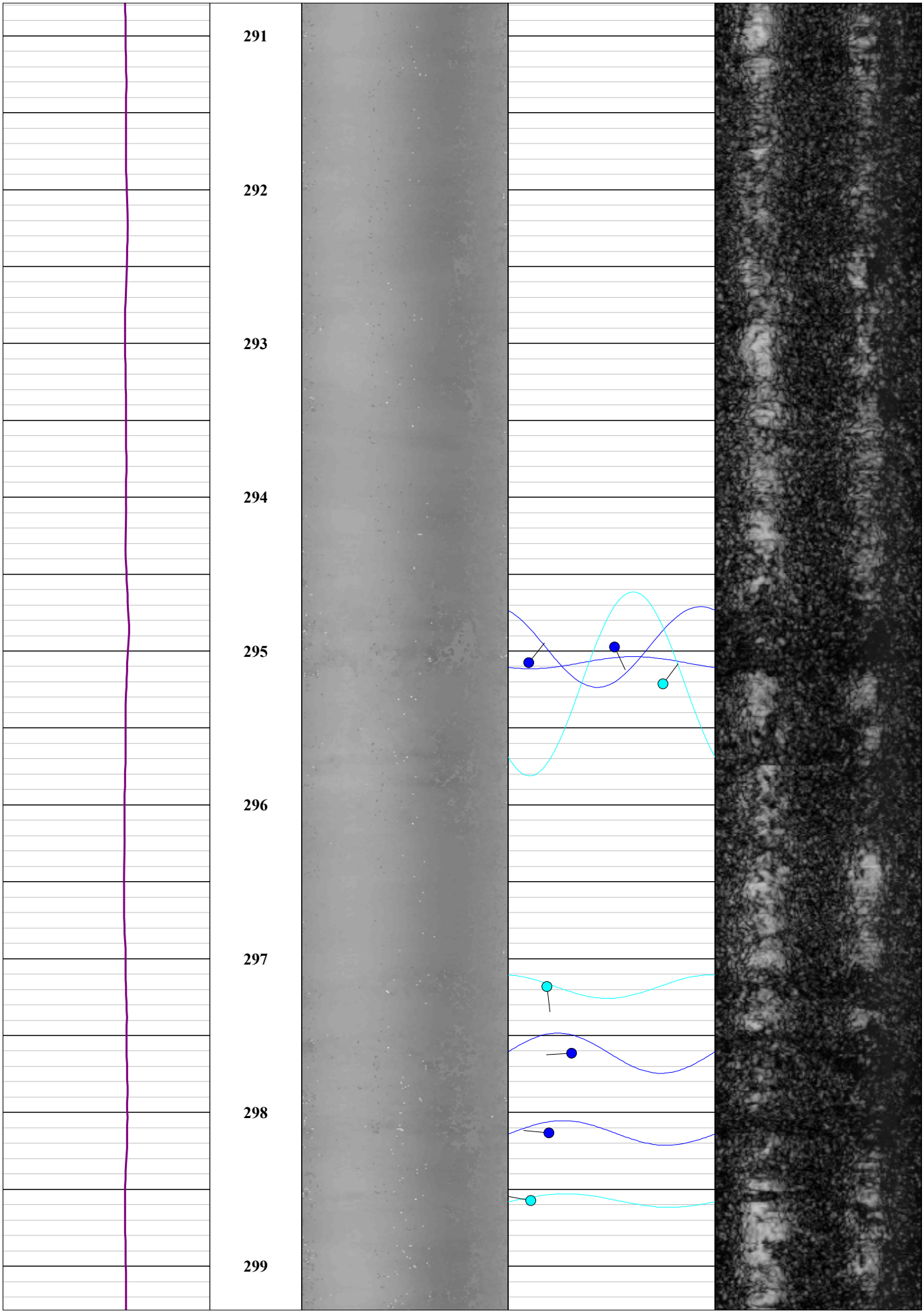

249
250
251
252
253
254
255
256

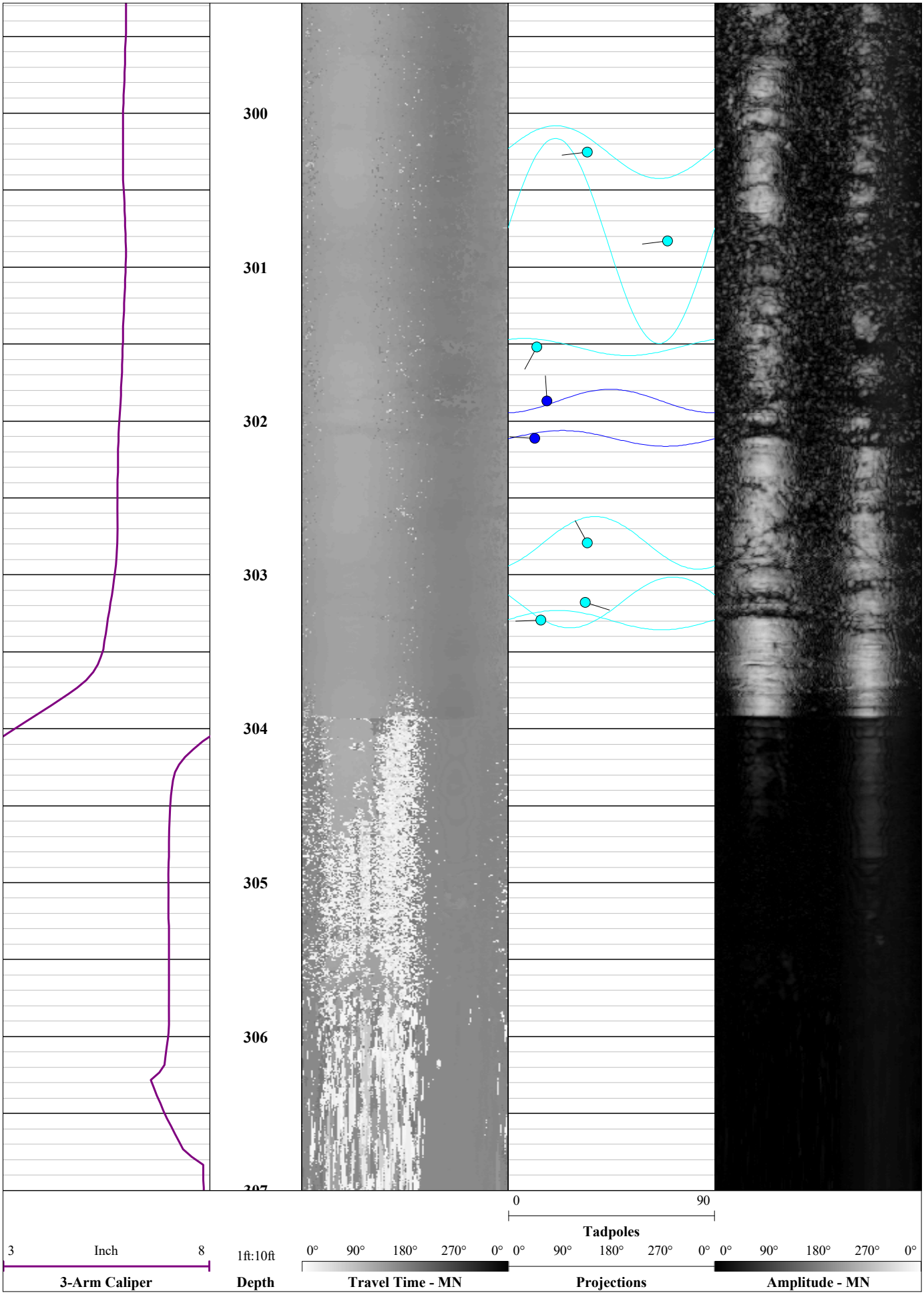

257
258
259
260
261
262
263
264
265


266
267
268
269
270
271
272
273

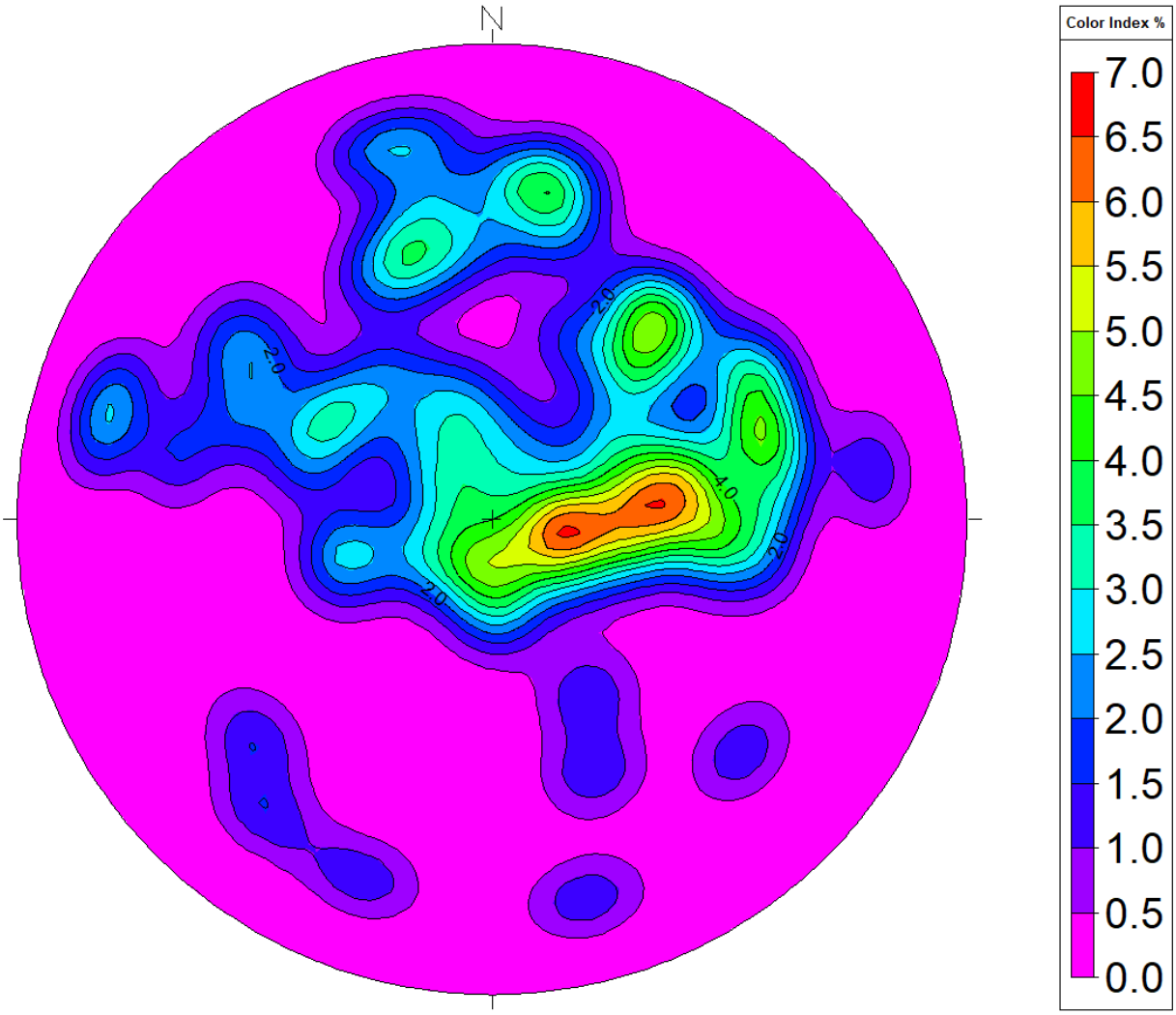

274
275
276
277
278
279
280
281
282


283
284
285
286
287
288
289
290


291
292
293
294
295
296
297
298
299

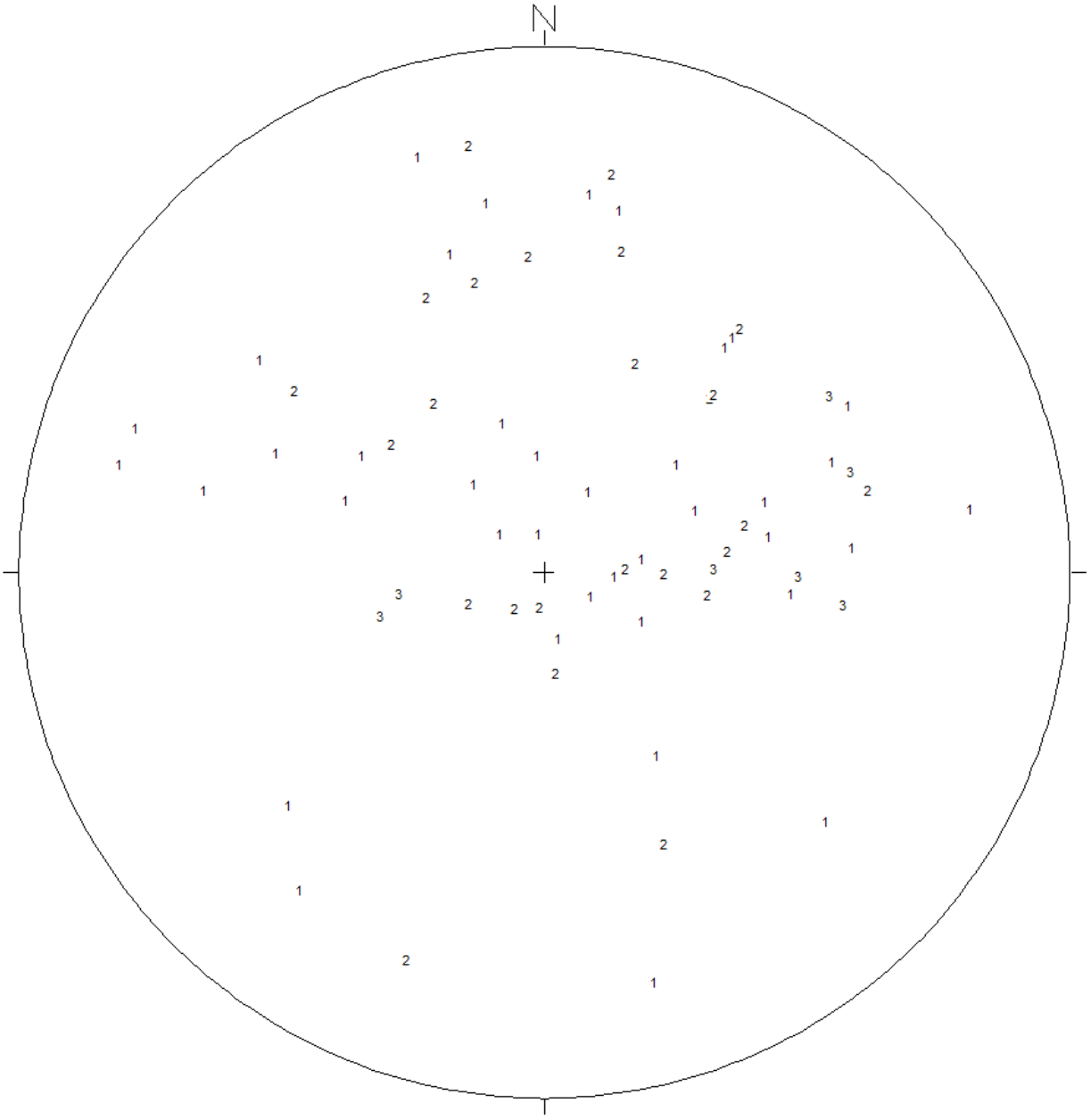

300
301
302
303
304
305
306
307
0
90
Tadpoles
3
Inch
8
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
Travel Time - MN
Projections
Amplitude - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-24A
10-11 September 2019



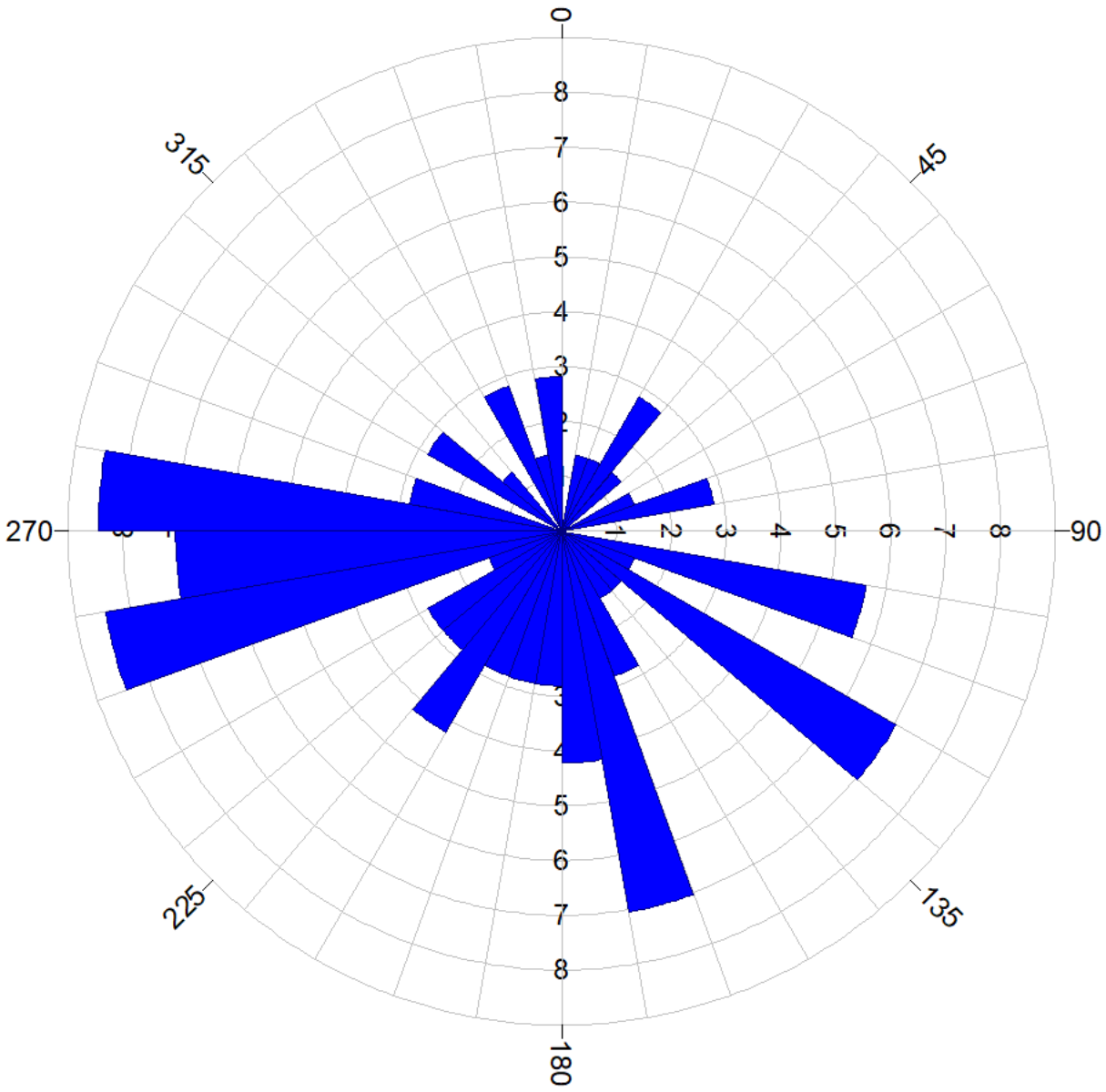
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-24A
10-11 September 2019



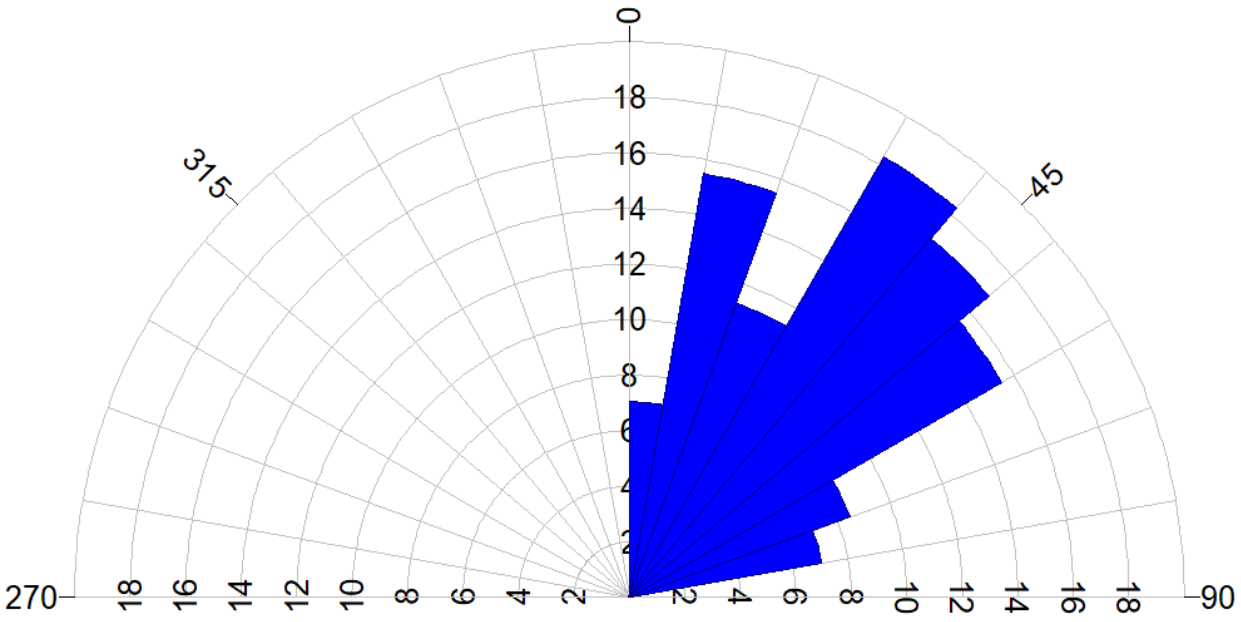
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-24A
10-11 September 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-24A
10-11 September 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-24A

10-11 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	69.25	227.2	162	52	1
2	69.27	227.3	313	61	1
3	71.16	233.5	64	14	2
4	71.83	235.7	219	44	1
5	71.85	235.7	144	31	2
6	71.91	235.9	161	23	1
7	72.27	237.1	170	59	1
8	72.43	237.6	136	17	1
9	73.29	240.5	13	7	2
10	73.52	241.2	224	36	2
11	73.59	241.4	203	34	2
12	73.67	241.7	189	64	2
13	73.69	241.8	165	46	2
14	74.13	243.2	338	48	2
15	74.34	243.9	242	54	1
16	75.11	246.4	127	31	2
17	75.38	247.3	277	38	1
18	75.49	247.7	120	34	1
19	75.64	248.2	346	71	1
20	76.19	250.0	259	31	2
21	76.30	250.3	124	49	2
22	76.45	250.8	193	51	2
23	76.50	251.0	176	49	2
24	76.97	252.5	224	37	2
25	77.01	252.7	232	25	1
26	77.18	253.2	125	57	1
27	77.18	253.2	219	46	1
28	77.31	253.6	281	25	2
29	77.44	254.1	273	39	3
30	77.50	254.3	278	47	3
31	77.70	254.9	253	50	3
32	77.89	255.5	239	52	3
33	77.96	255.8	219	48	2
34	78.06	256.1	257	52	2
35	78.09	256.2	186	60	1
36	78.43	257.3	108	72	1
37	78.87	258.8	121	9	1
38	79.10	259.5	191	58	1
39	79.86	262.0	20	69	2
40	80.01	262.5	169	70	2
41	82.16	269.6	112	47	1
42	82.70	271.3	250	24	1
43	82.76	271.5	267	48	1
44	82.79	271.6	102	57	1
45	83.04	272.4	254	35	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-24A

10-11 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	85.64	281.0	103	73	1
47	85.69	281.1	158	5	1
48	86.15	282.7	308	8	1
49	86.18	282.8	47.3	57.4	1
50	86.36	283.3	302.2	16.7	1
51	86.62	284.2	250.2	47.5	1
52	87.00	285.4	354.3	11.7	1
53	87.92	288.5	161.9	70.4	1
54	88.25	289.5	72.9	27.7	3
55	88.30	289.7	271.7	25.4	3
56	88.31	289.7	78.8	24.0	3
57	89.91	295.0	155.1	46.4	2
58	89.94	295.1	38.8	8.9	2
59	89.98	295.2	37.6	67.3	1
60	90.58	297.2	172.8	16.9	1
61	90.71	297.6	266.0	27.6	2
62	90.87	298.1	275.3	17.7	2
63	91.00	298.6	280.7	10.0	1
64	91.52	300.3	262.8	34.4	1
65	91.69	300.8	262.6	69.5	1
66	91.90	301.5	208.1	12.6	1
67	92.01	301.9	356.9	16.9	2
68	92.08	302.1	273.6	11.6	2
69	92.29	302.8	331.0	34.4	1
70	92.41	303.2	107.3	33.5	1
71	92.44	303.3	267.3	14.2	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper Natural Gamma

Company WSP
Well BH19-24A
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-24A
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81814 N
Longitude: 84.76479 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 356.7'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	10-11 Sept. 2019	10-11 Sept. 2019	10-11 Sept. 2019	
RUN NUMBER	5,6	2,6	6,1	
LOG TYPE	FTC	Natural Gamma	Caliper	
DEPTH-DRILLER	316'	316'	316'	
DEPTH-LOGGER	315'	315'	315'	
BTM LOG INTERVAL	306.3'	313.2'	310.0'	
TOP LOG INTERVAL	220.0'	0.0'	0.0'	
RECORDED BY	JBG/DRE	JBG/DRE	JBG/DRE	
WITNESSED BY	A. Hesse	A. Hesse	A. Hesse	
PROBE TYPE, S/N	2PFA #3656	ELXG #4314	3ACS#5596	
LOGGING SPEED	20 fpm	15 fpm	15 fpm	
A.S.D.E. / Sample Interval	.0.06' / 0.10'	0.11' / 0.10'	0.11' / 0.10'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

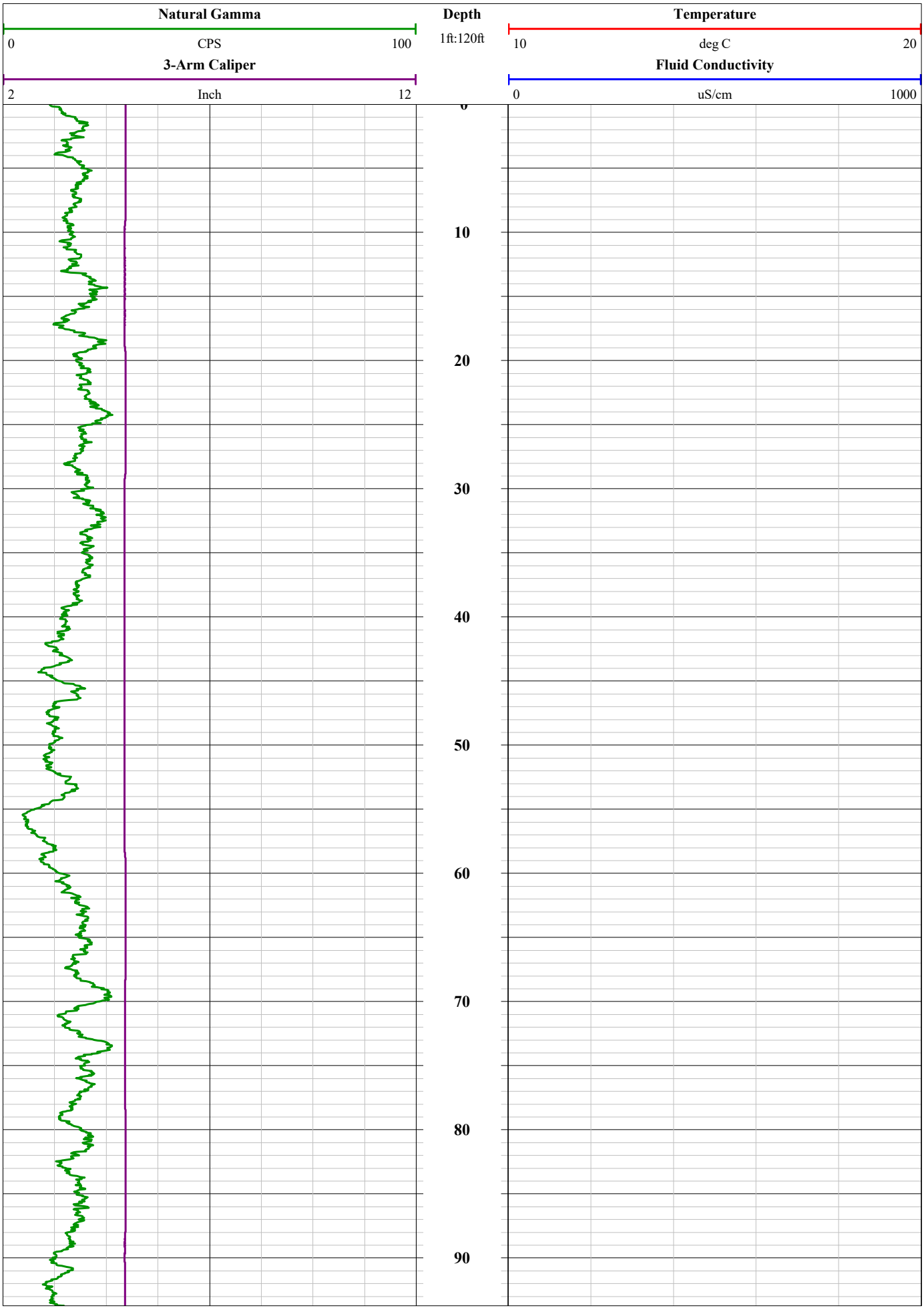
RUN No.	BIT	FROM	TO
1	6"	225'	316'

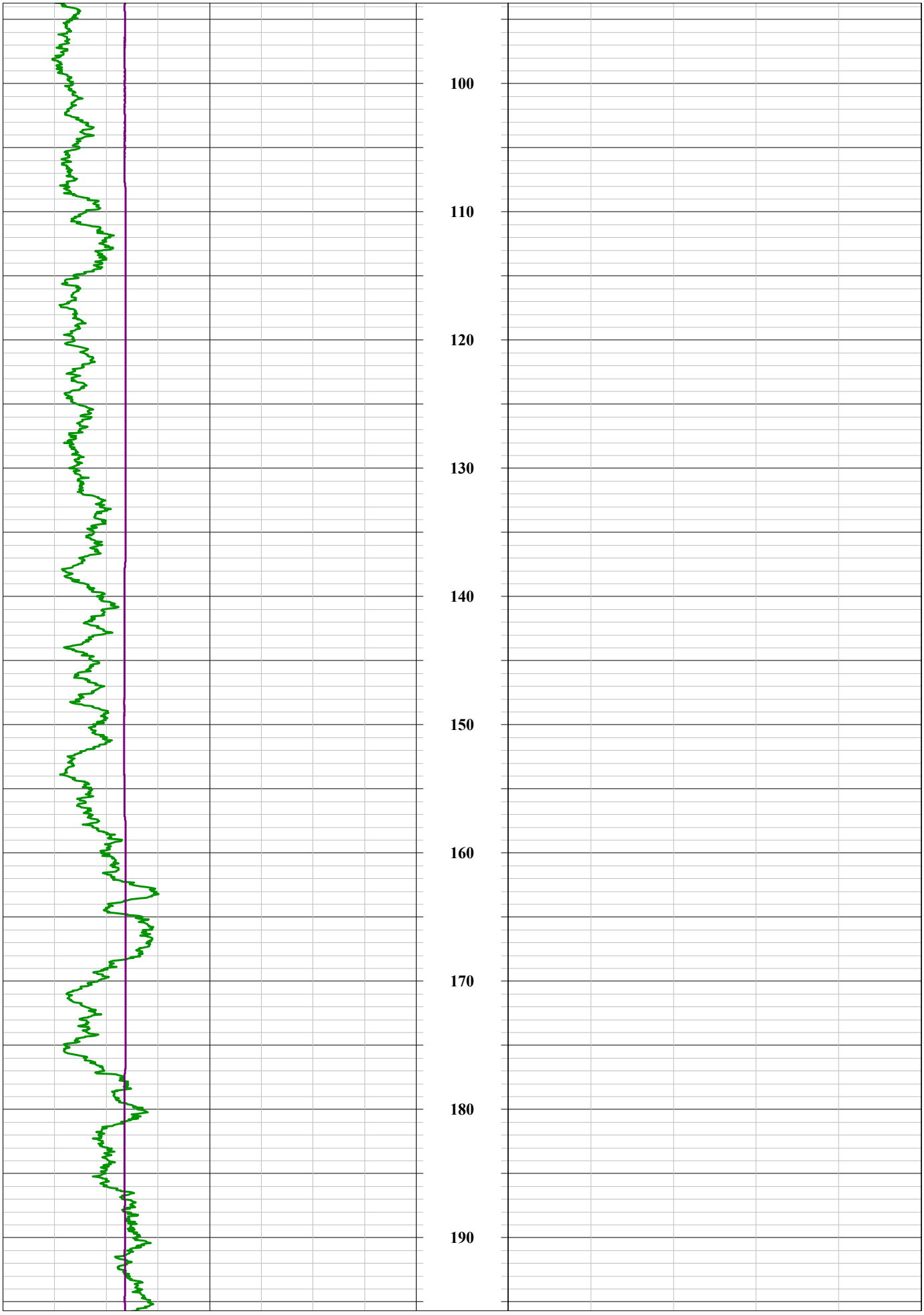
CASING RECORD

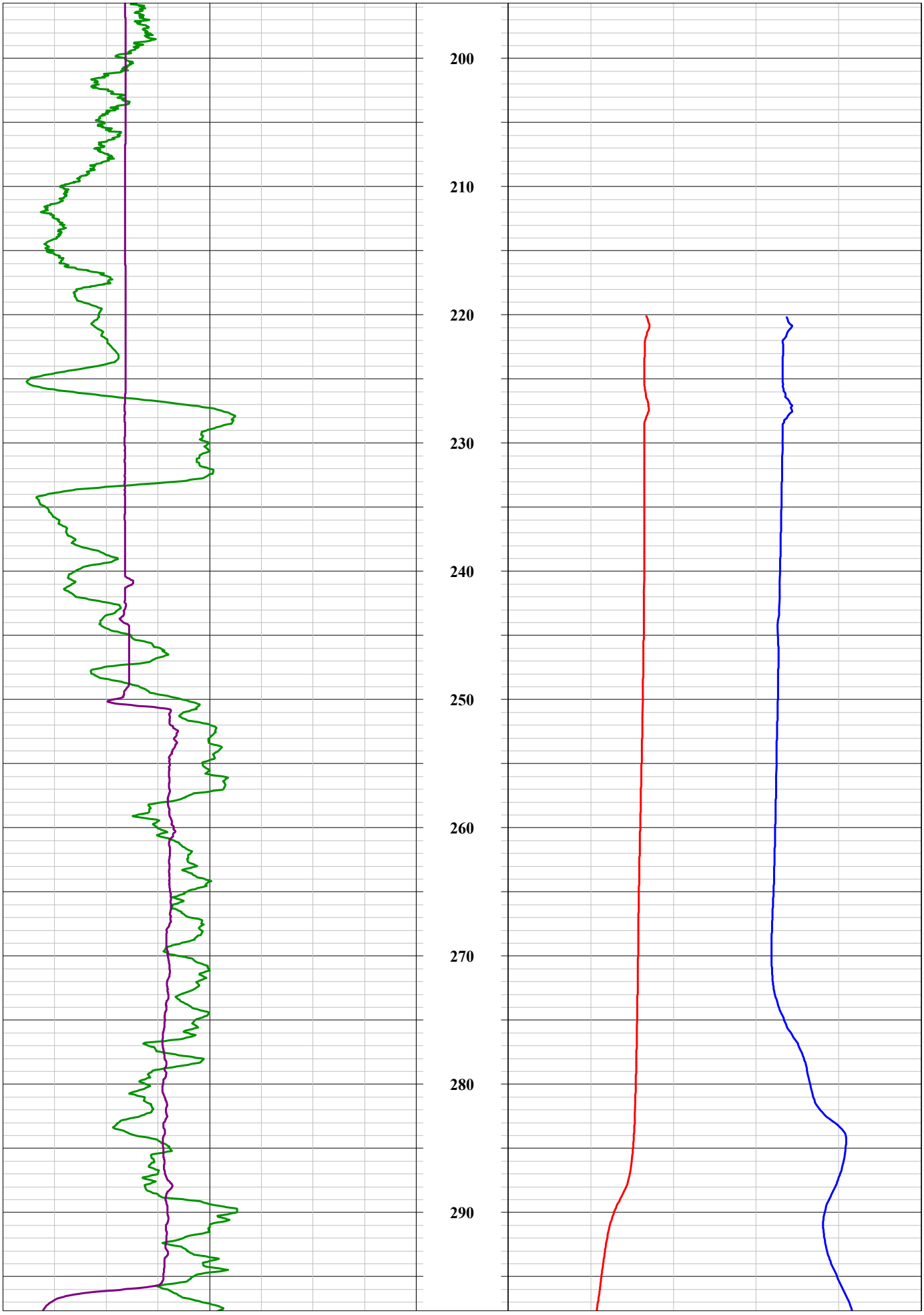
SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	225'

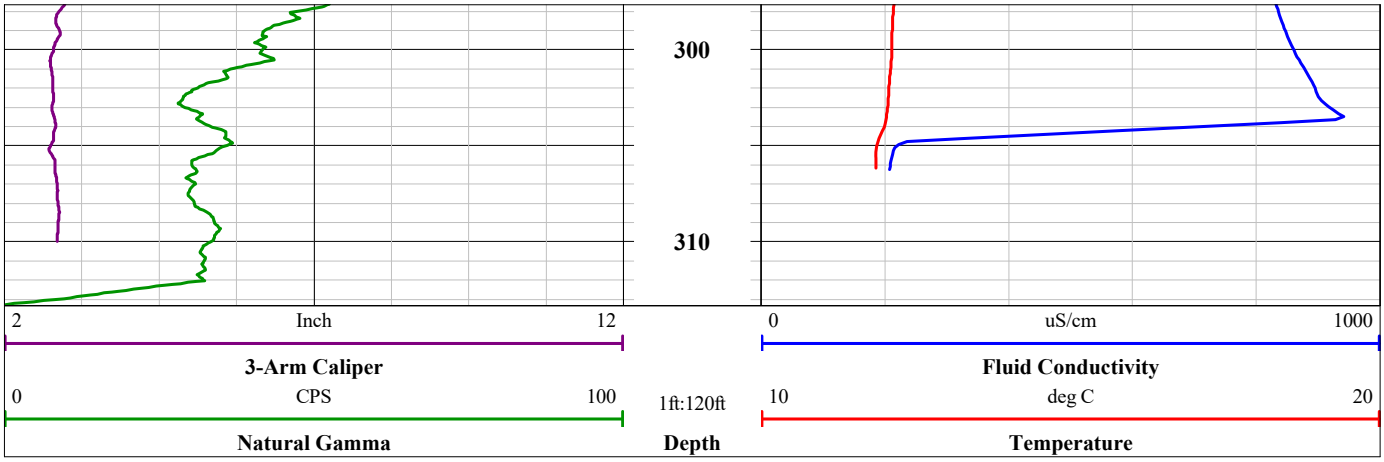
NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
2
Inch
12
Depth
1ft:120ft
Temperature
10
deg C
20
Fluid Conductivity
0
uS/cm
1000
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
2
Inch
12
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
10
deg C
20
Temperature

Borehole Deviation

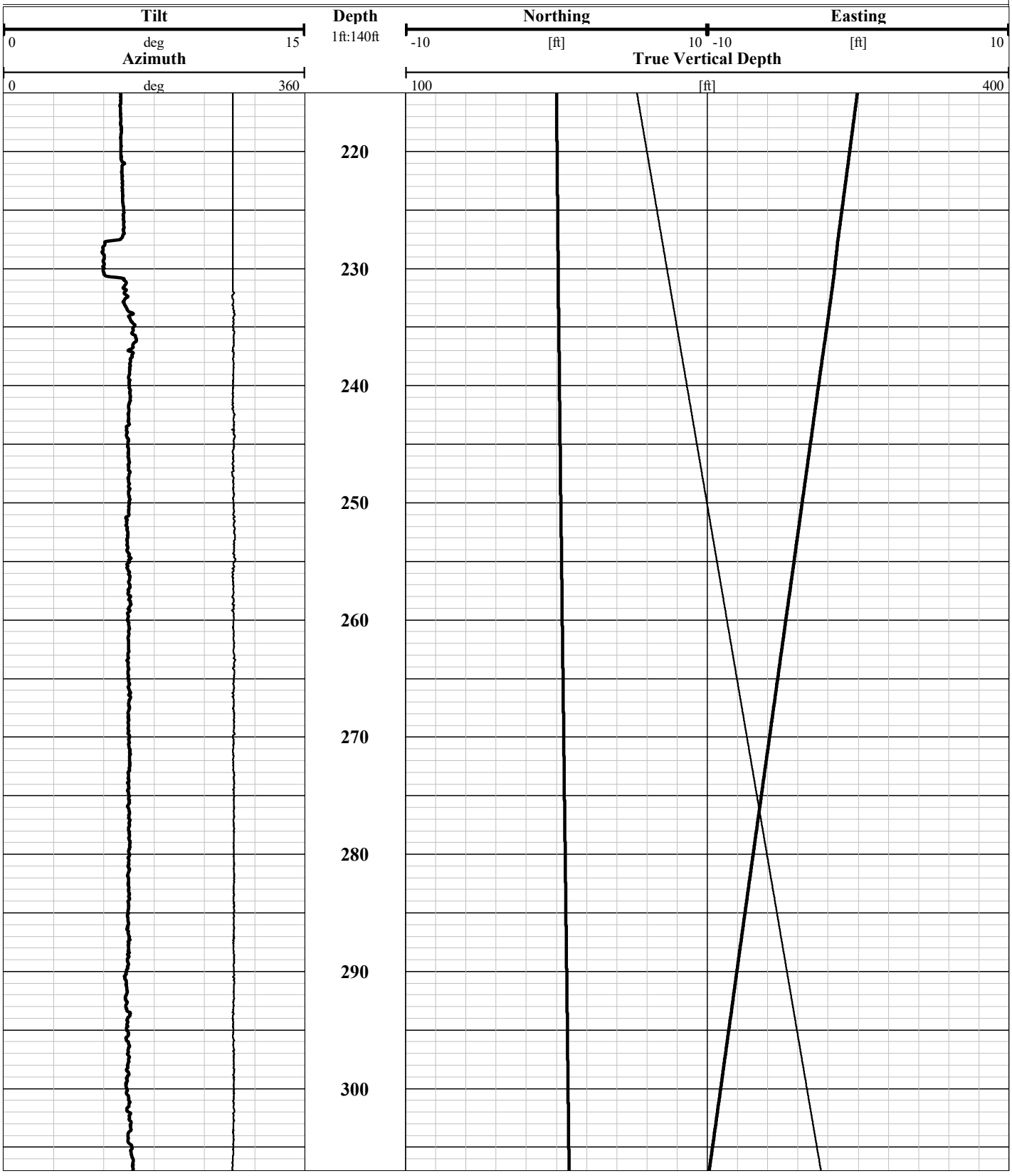
COLOG
borehole geophysics / hydrophysics

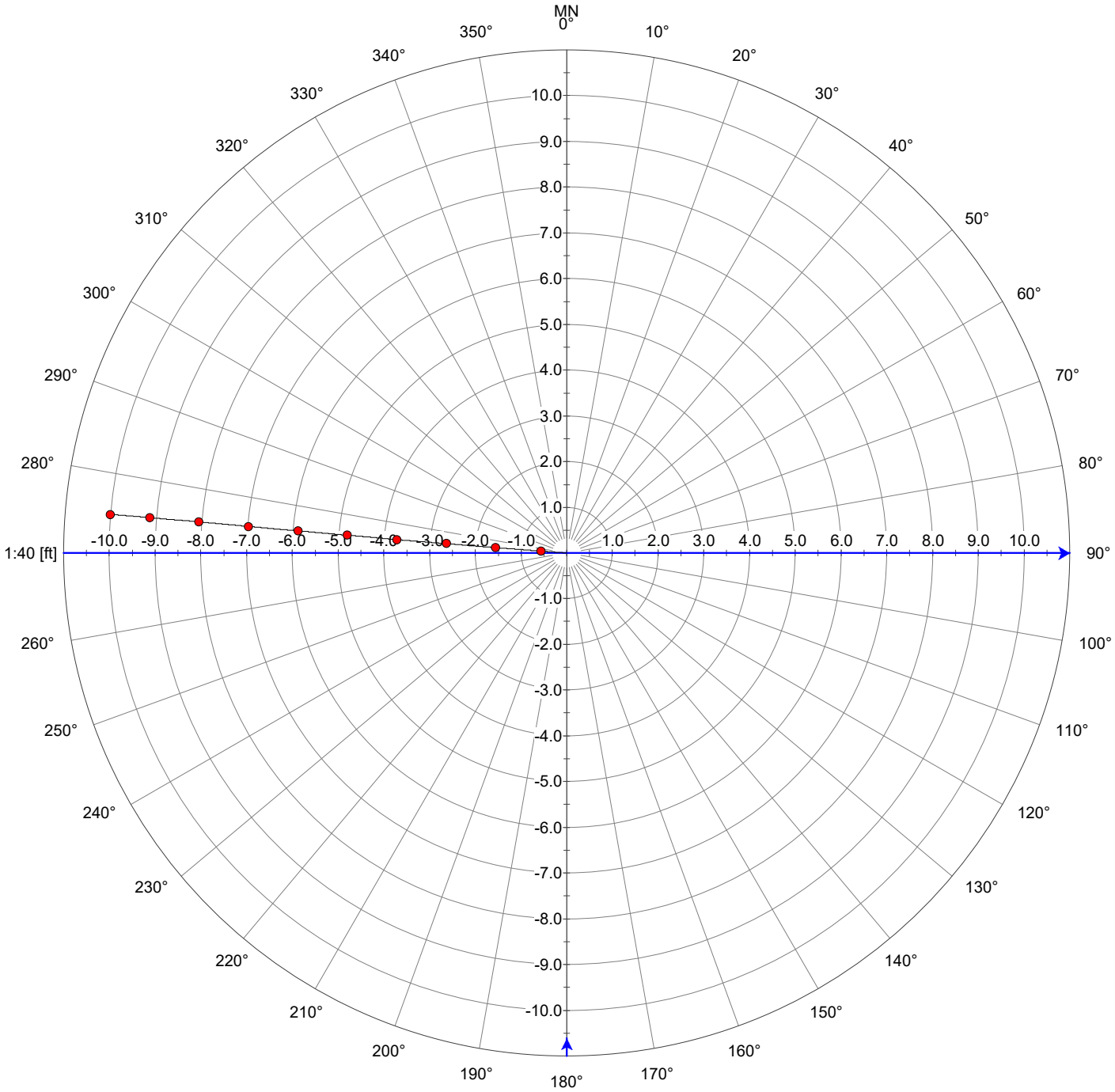
COMPANY: WSP
PROJECT: LR5T Project
DATE LOGGED: 10-11 Sept. 2019
WELL: BH19-24A - Mid Strait

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 356.7'** **Latitude: 45.81814 N** **Longitude: 84.76479 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1:40 [ft]
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-24A
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-24A
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81814 N
Longitude: 84.76479 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 356.7'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	10-11 Sept. 2019	10-11 Sept. 2019		
RUN NUMBER	2,6	2,6		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	316'	316'		
DEPTH-LOGGER	315'	315'		
BTM LOG INTERVAL	313.2'	314.4'		
TOP LOG INTERVAL	0.0'	215.9'		
RECORDED BY	JBG,DRE	JBG,DRE		
WITNESSED BY	A. Hesse	A. Hesse		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 fpm	20 fpm		
A.S.D.E. / Sample Interval	0.12' / 0.25'	0.12' / 0.25'		
Fluid Level / Fluid Type	NA/Water	NA/Water		

BOREHOLE RECORD

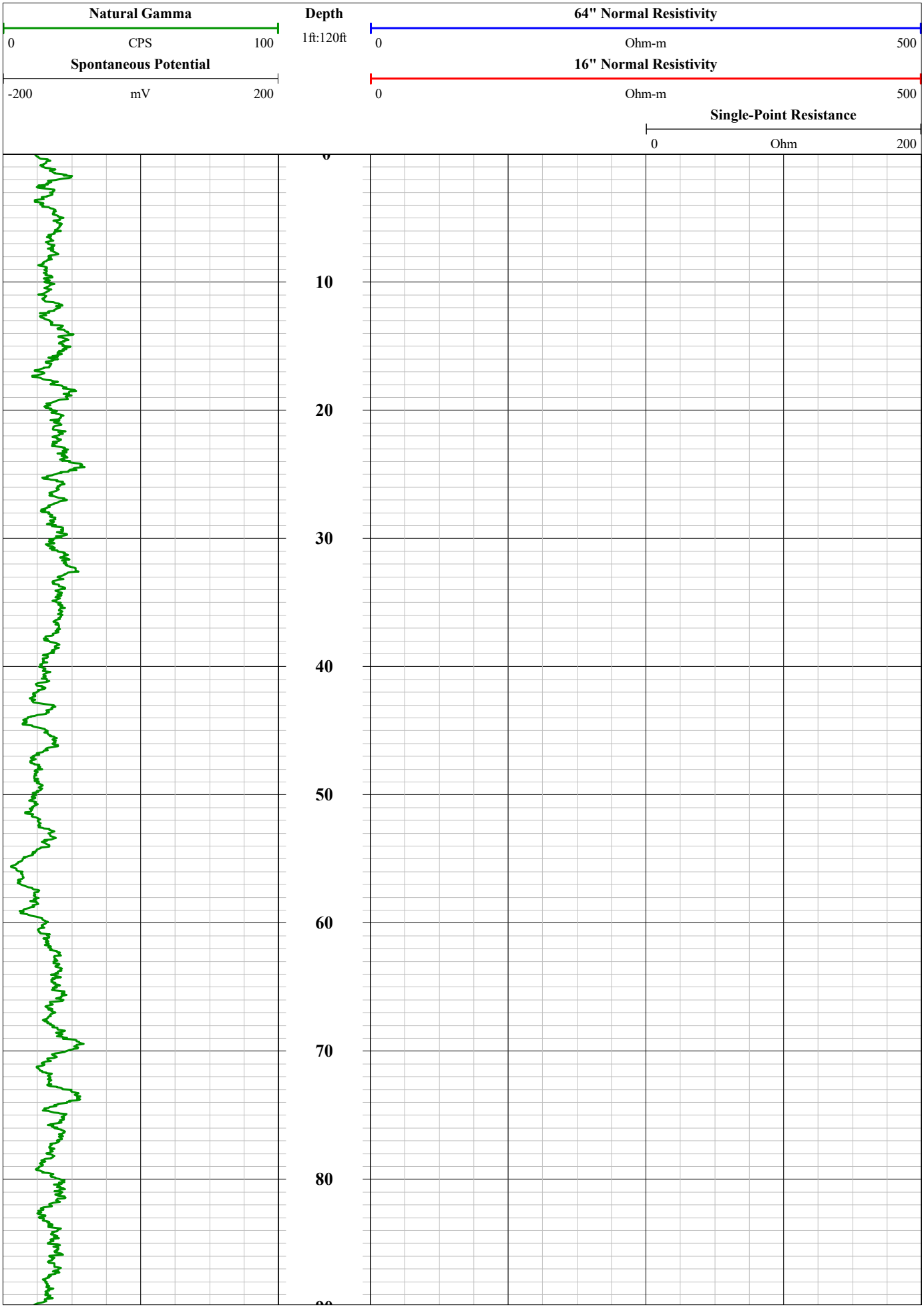
RUN No.	BIT	FROM	TO
1	6"	225'	316'

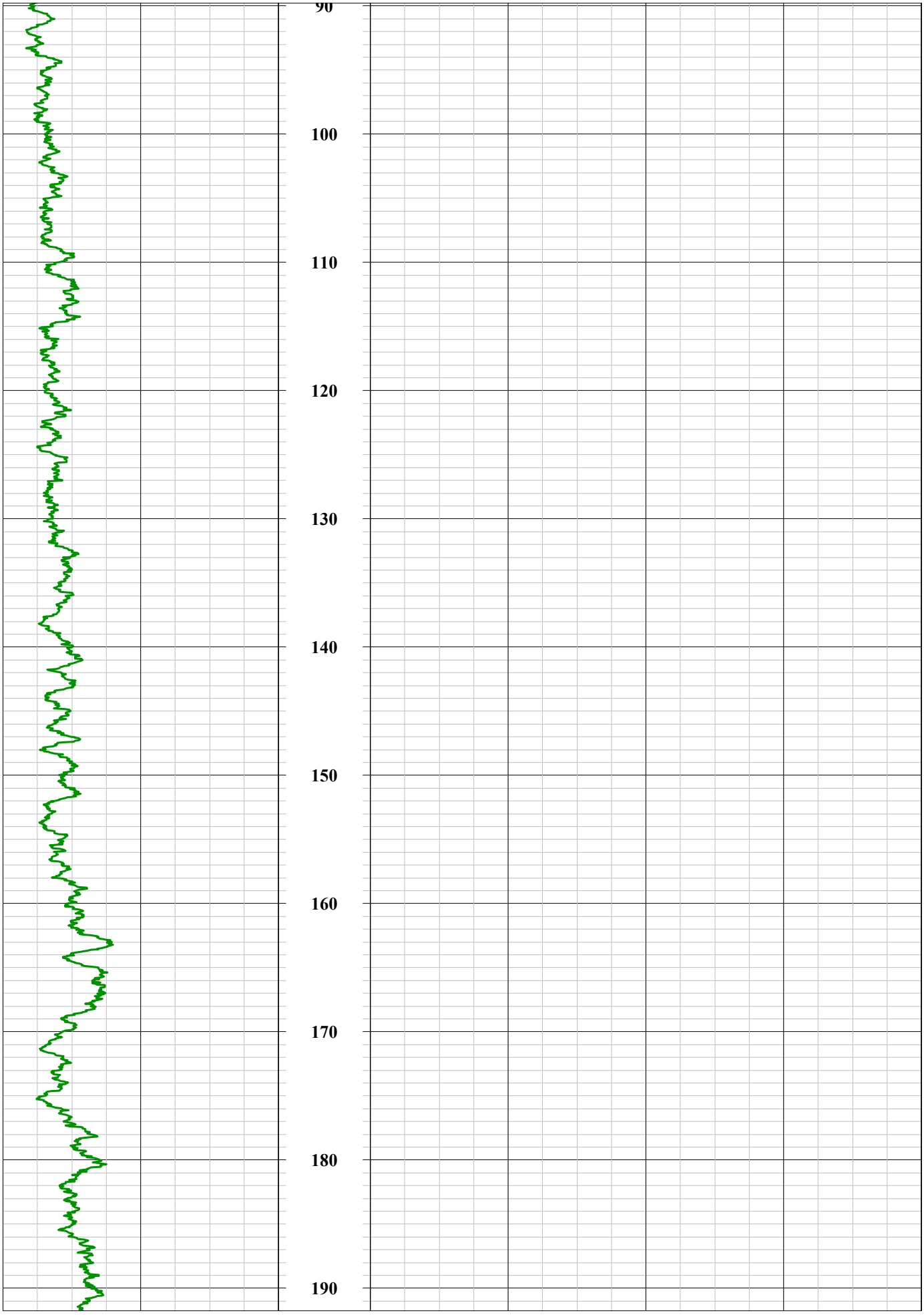
CASING RECORD

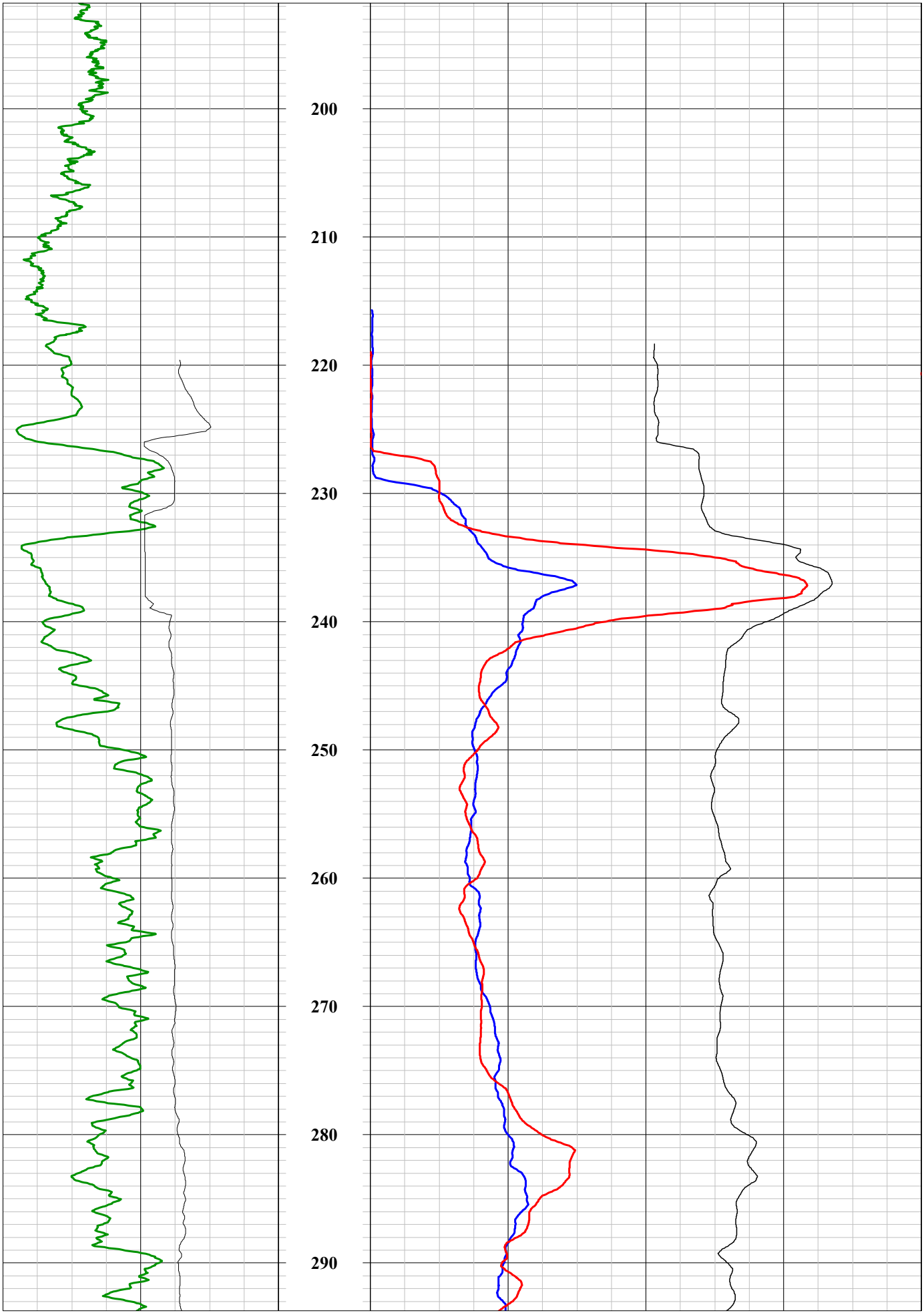
SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	225'

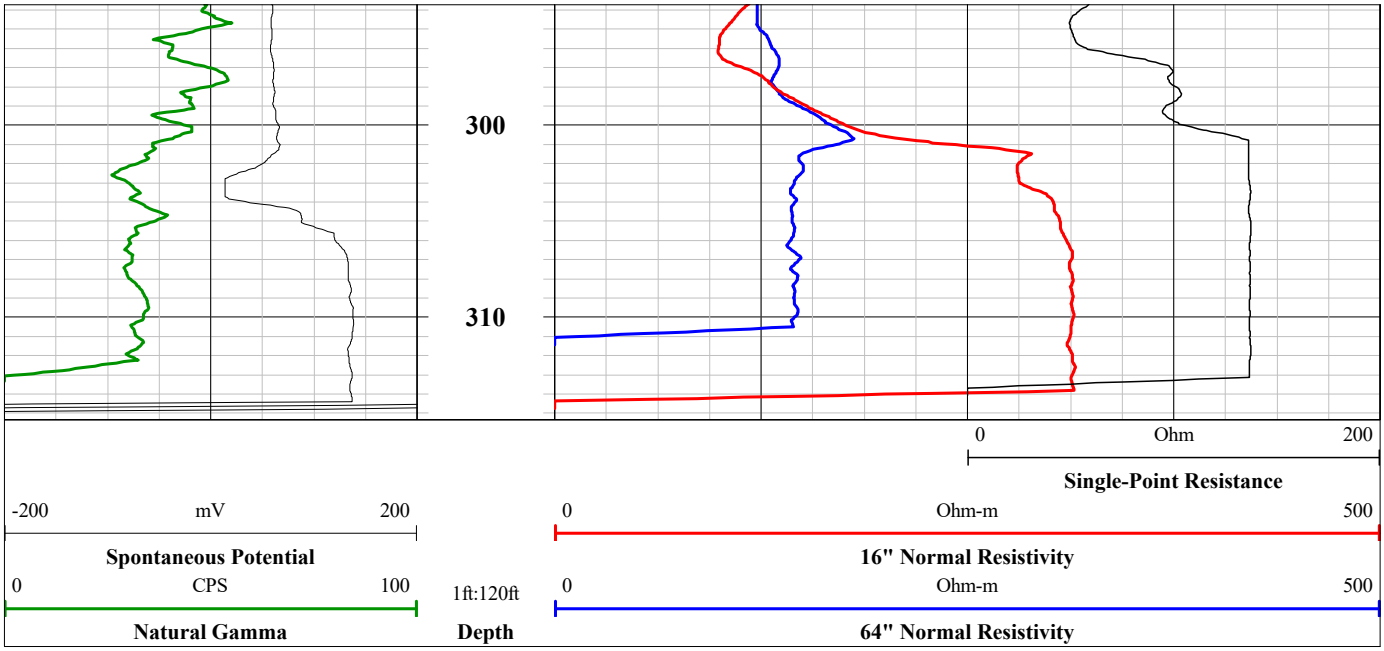
NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-200
mV
200
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
500
16" Normal Resistivity
0
Ohm-m
500
Single-Point Resistance
0
Ohm
200
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
0
Ohm
200
Single-Point Resistance
-200
mV
200
Spontaneous Potential
0
Ohm-m
500
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
500
64" Normal Resistivity

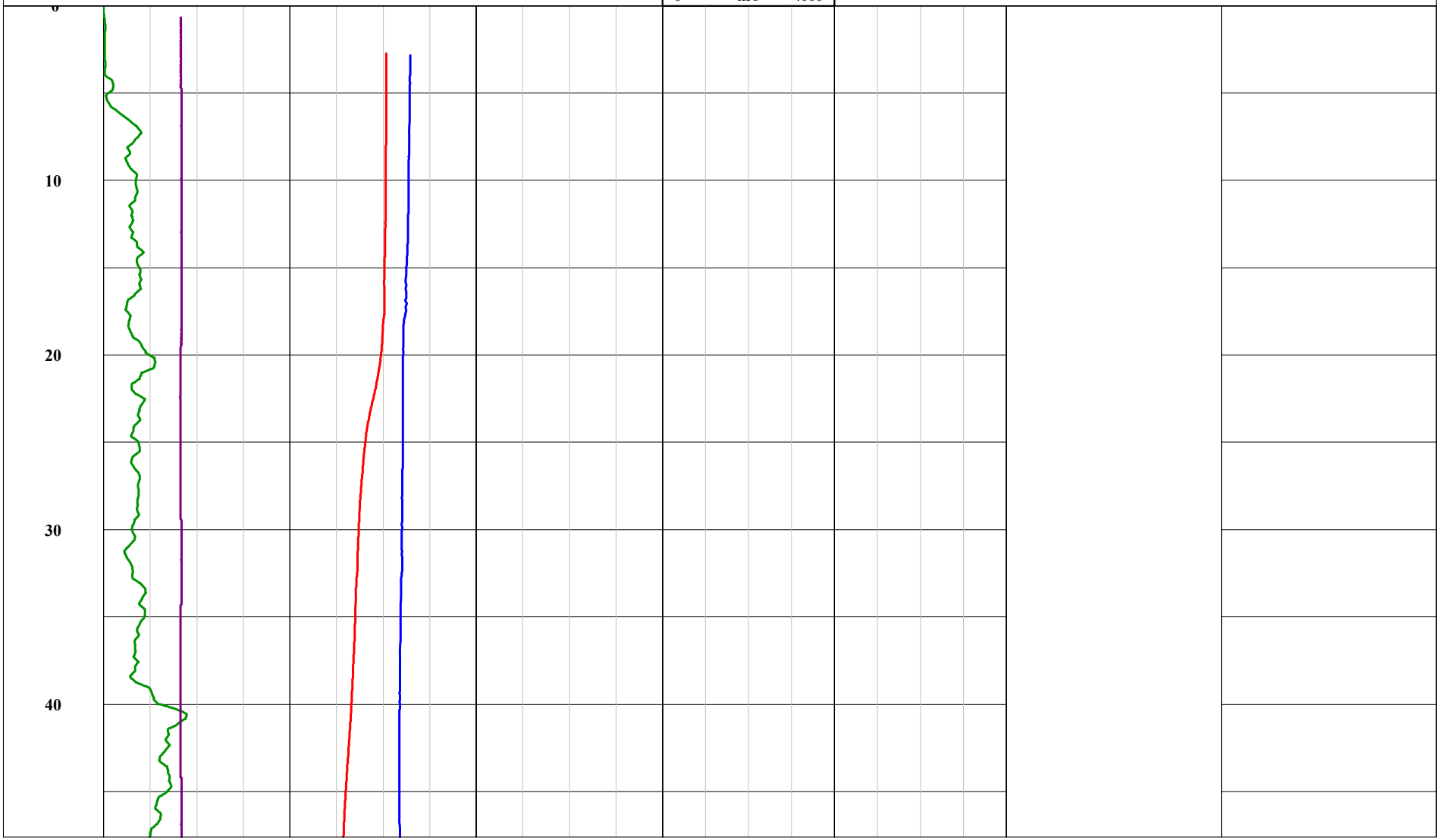
Geophysical Summary Plot

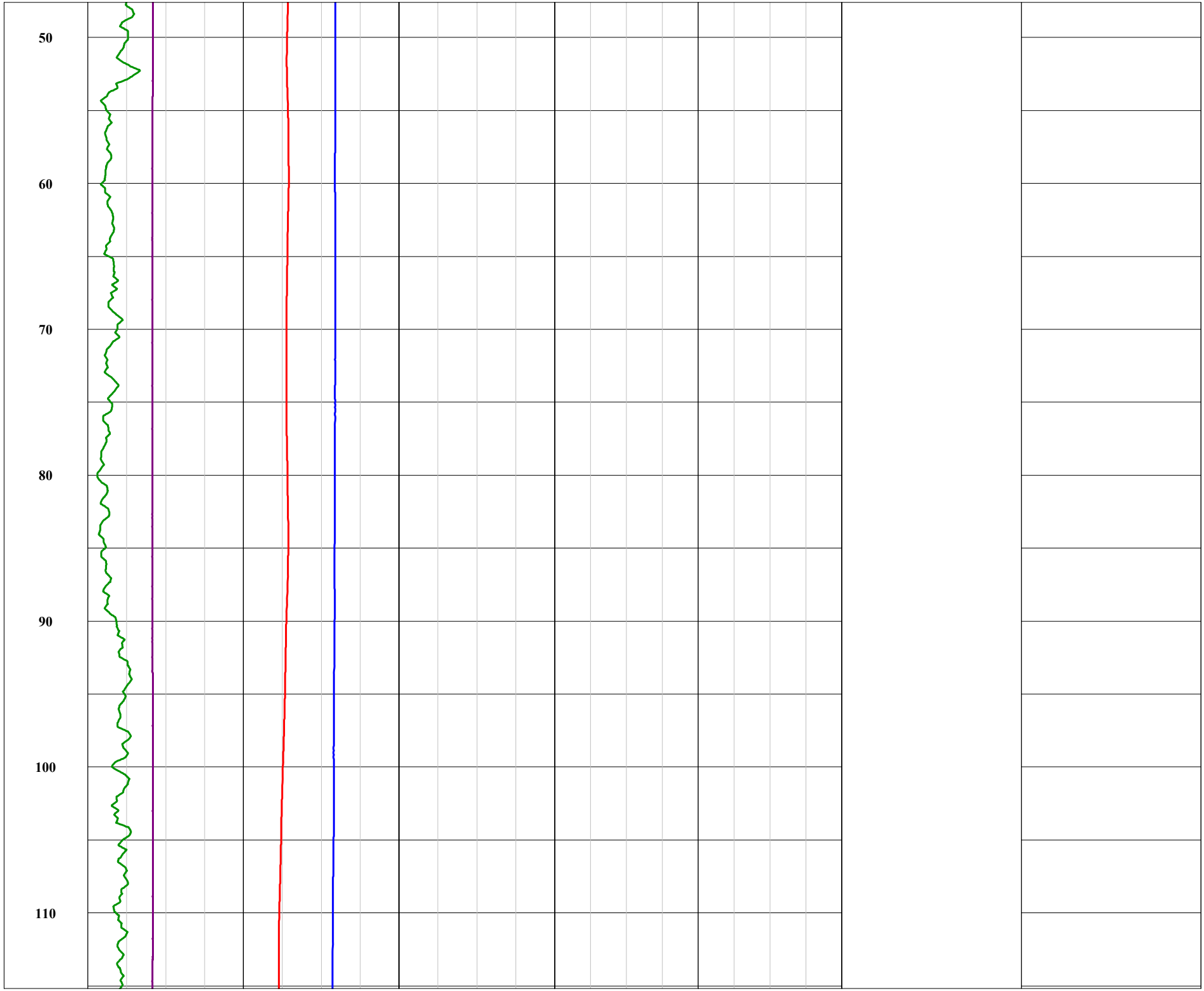
COLOG
borehole geophysics / hydrophysics

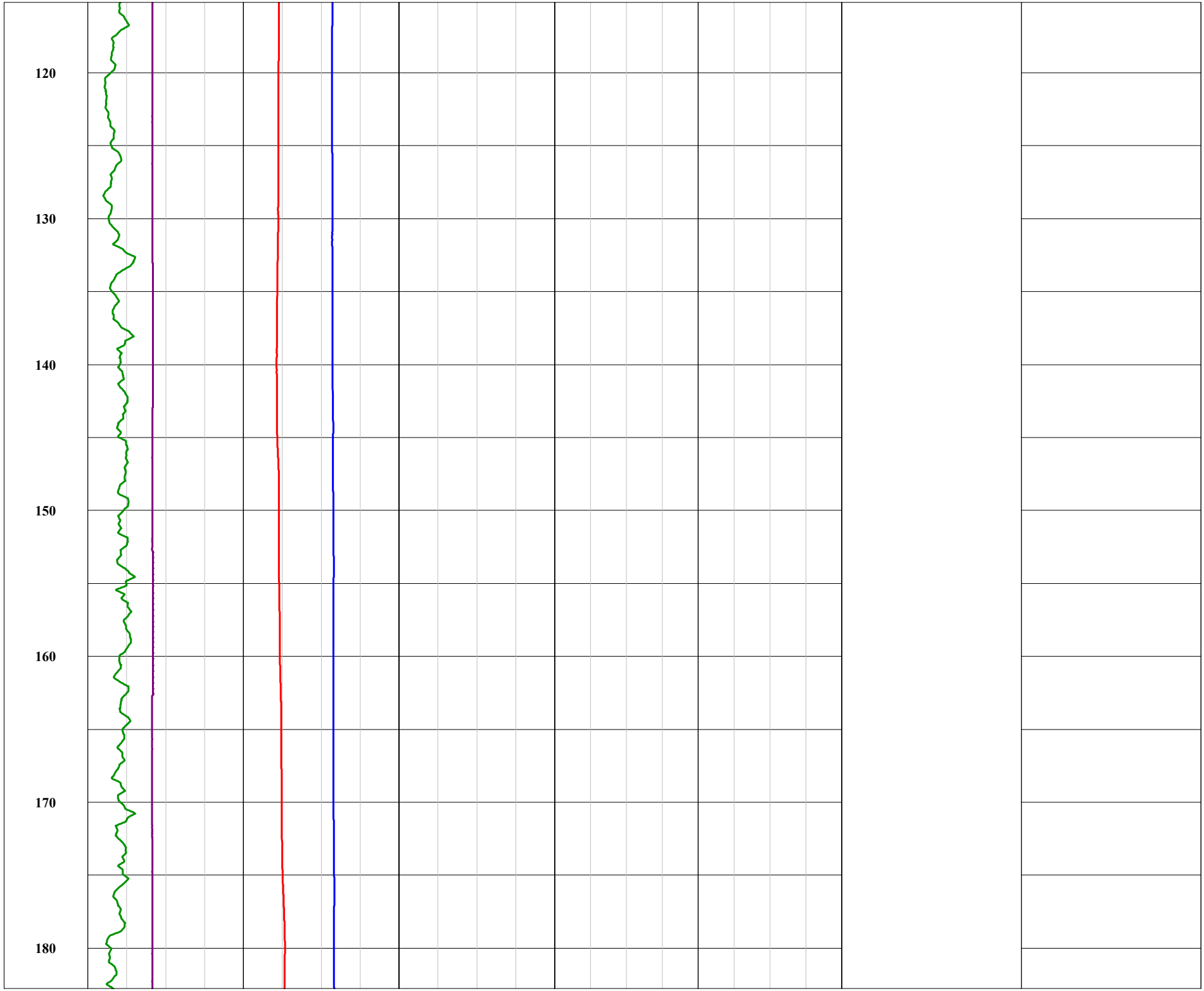
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 16 October 2019
WELL: BH19-25 - Mid Strait

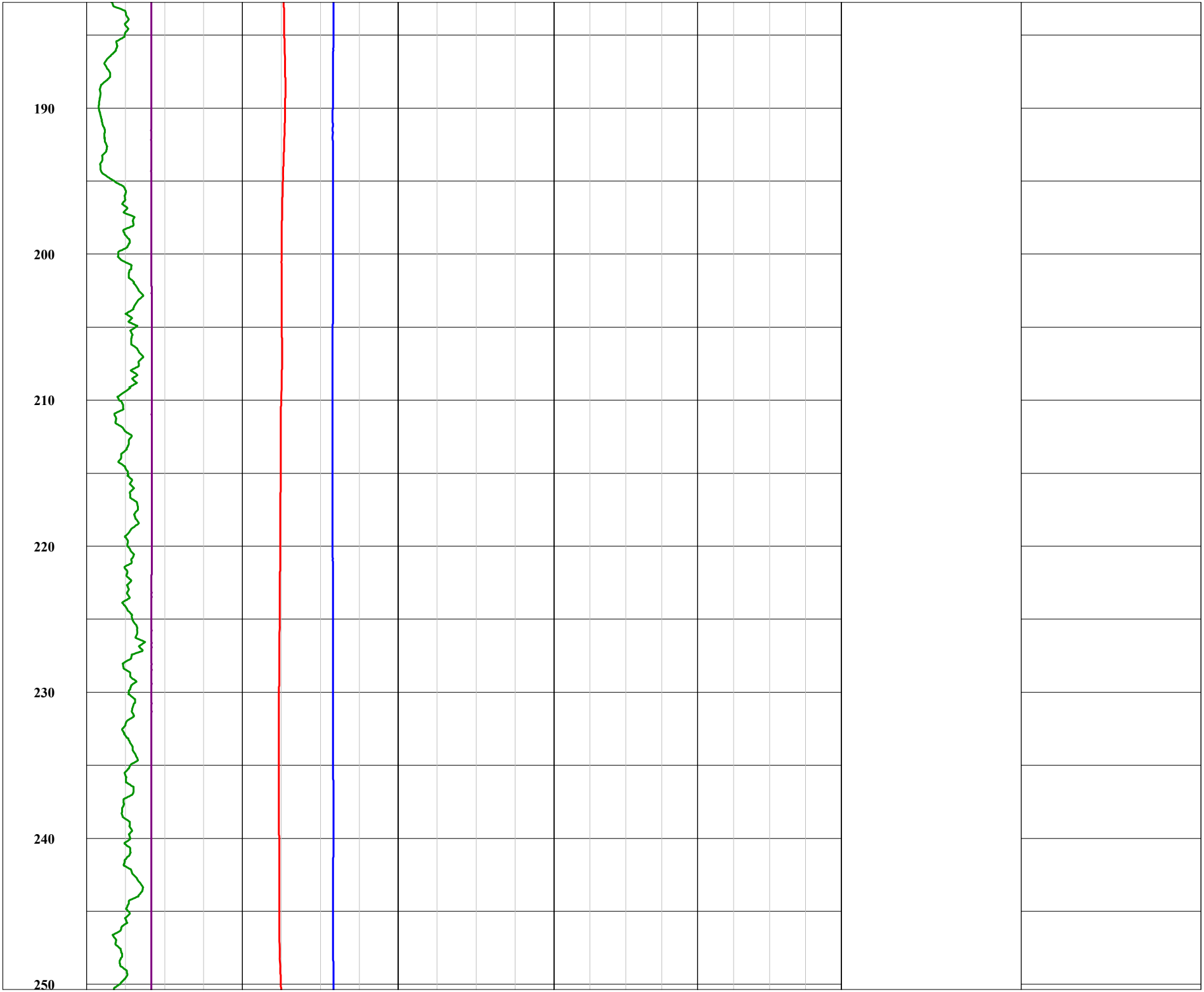
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

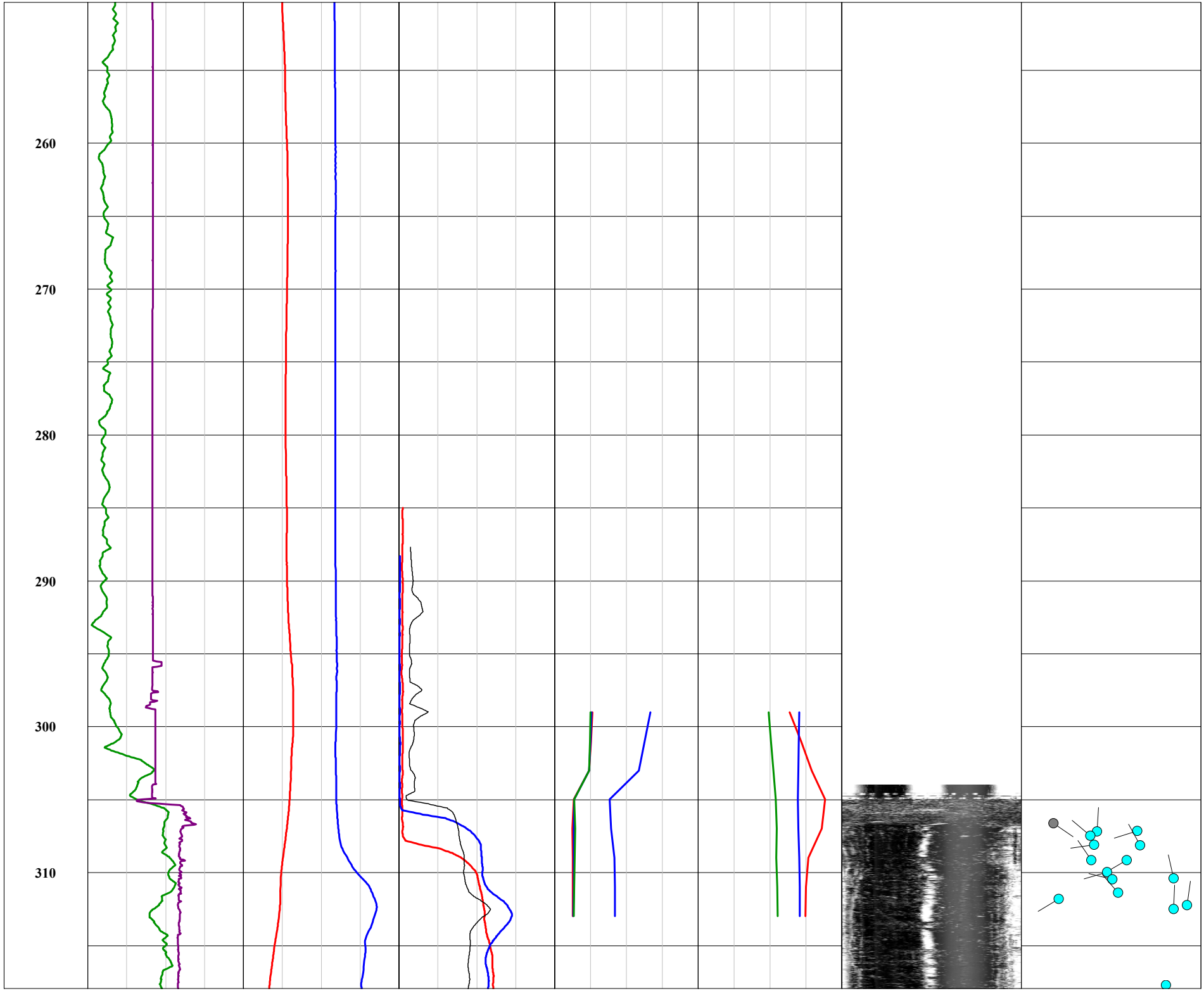
Depth	Natural Gamma	Temperature	64" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Amplitude-MN	Tadpoles
1ft:100ft	0 CPS 100	10 deg C 20	0 Ohm-m 100	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0 90
	3 - Arm Caliper	Fluid Conductivity	16" Normal Resistivity	Shear Velocity - Avg	S-Wave Slowness		
	3 Inch 9	0 uS/cm 1000	0 Ohm-m 100	0 m/s 4000	0 us/m 2000		
			Single-Point Resistance	Shear Velocity - Right	Poisson's Ratio		
			0 Ohm 100	0 m/s 4000	-1 1		
				Compressive Velocity			
				0 m/s 4000			

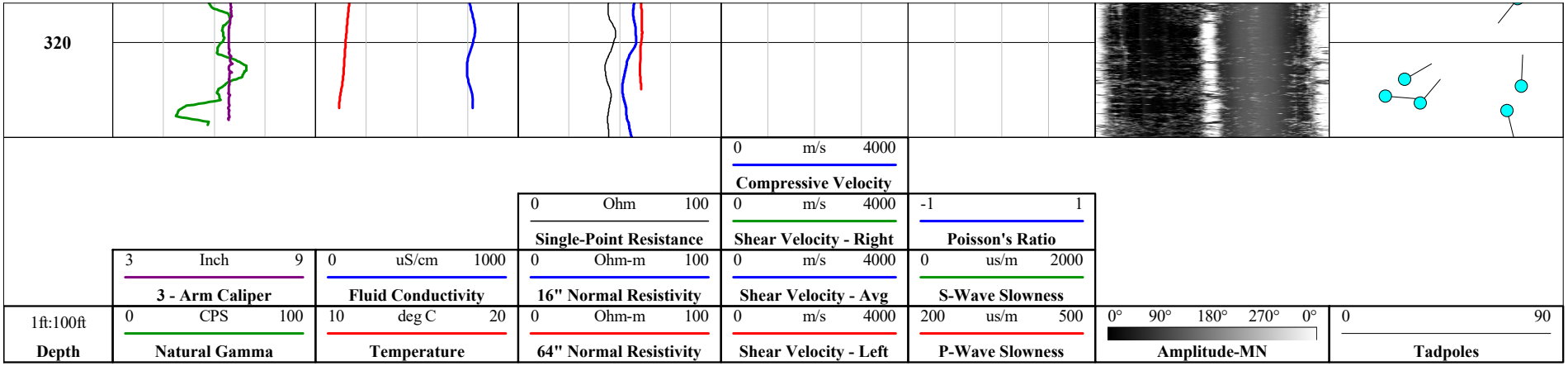



50
60
70
80
90
100
110


120
130
140
150
160
170
180


190
200
210
220
230
240
250


260
270
280
290
300
310


320
0 m/s 4000
Compressive Velocity
0 Ohm 100
Single-Point Resistance
0 m/s 4000
Shear Velocity - Right
-1 1
Poisson's Ratio
3 Inch 9
3 - Arm Caliper
0 uS/cm 1000
Fluid Conductivity
0 Ohm-m 100
16" Normal Resistivity
0 m/s 4000
Shear Velocity - Avg
0 us/m 2000
S-Wave Slowness
1ft:100ft
Depth
0 CPS 100
Natural Gamma
10 deg C 20
Temperature
0 Ohm-m 100
64" Normal Resistivity
0 m/s 4000
Shear Velocity - Left
200 us/m 500
P-Wave Slowness
0° 90° 180° 270° 0°
Amplitude-MN
0 90
Tadpoles

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-25
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-25
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81727 N
Longitude: 84.76514 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 398.0'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 October 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	326.36'			
DEPTH-LOGGER	326.9'			
BTM LOG INTERVAL	326.36'			
TOP LOG INTERVAL	304.0'			
RECORDED BY	CKL			
WITNESSED BY	Conrad Fischer - WSP			
PROBE TYPE, S/N	ALT ABI/#111018			
LOGGING SPEED	6 fpm			
A.S.D.E. / Sample Interval	0.17' / .008'			
Fluid Level / Fluid Type	NA/water			

BOREHOLE RECORD

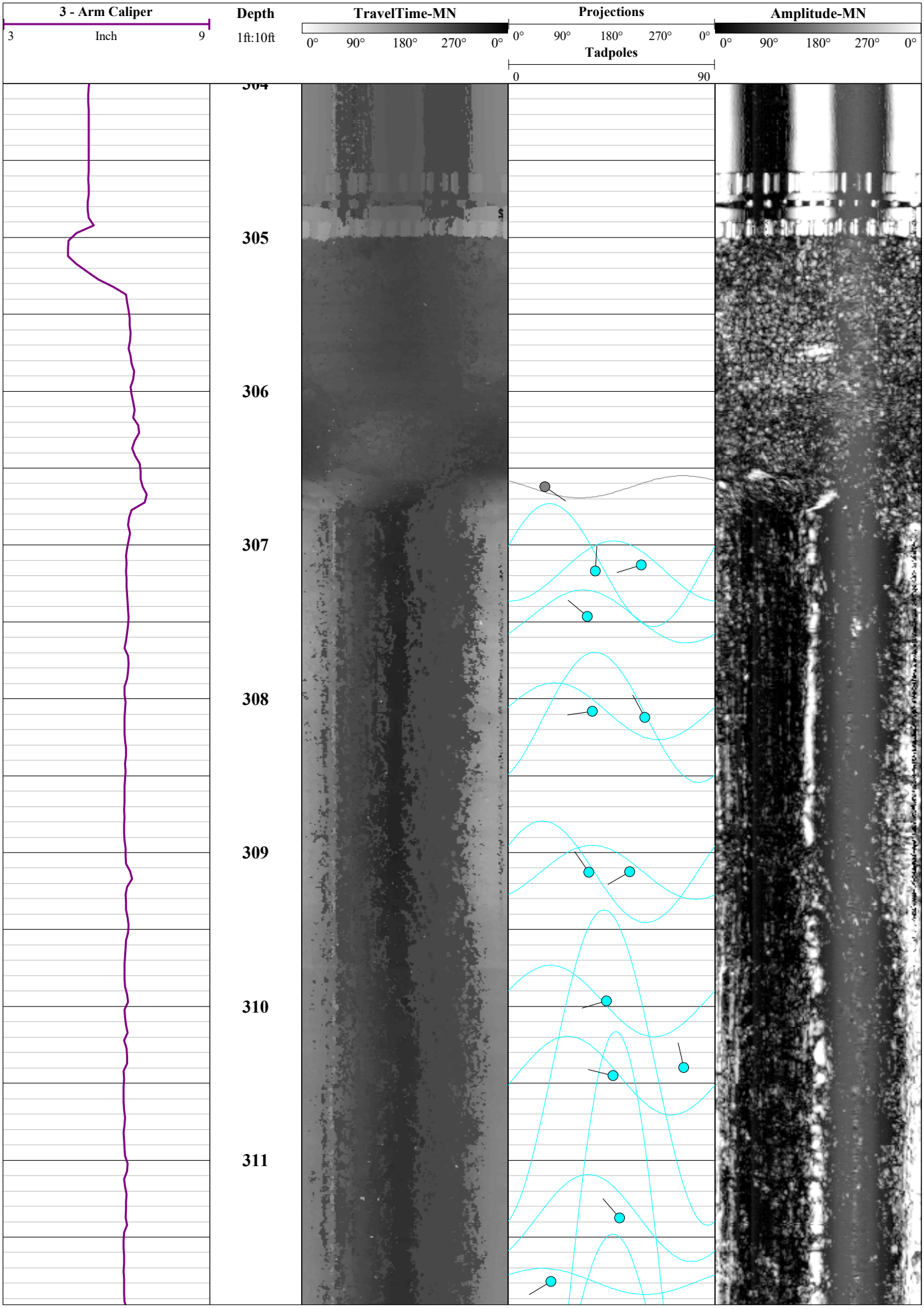
RUN No.	BIT	FROM	TO
1	5.5"	SU	305'
2	7"	305'	326.4'

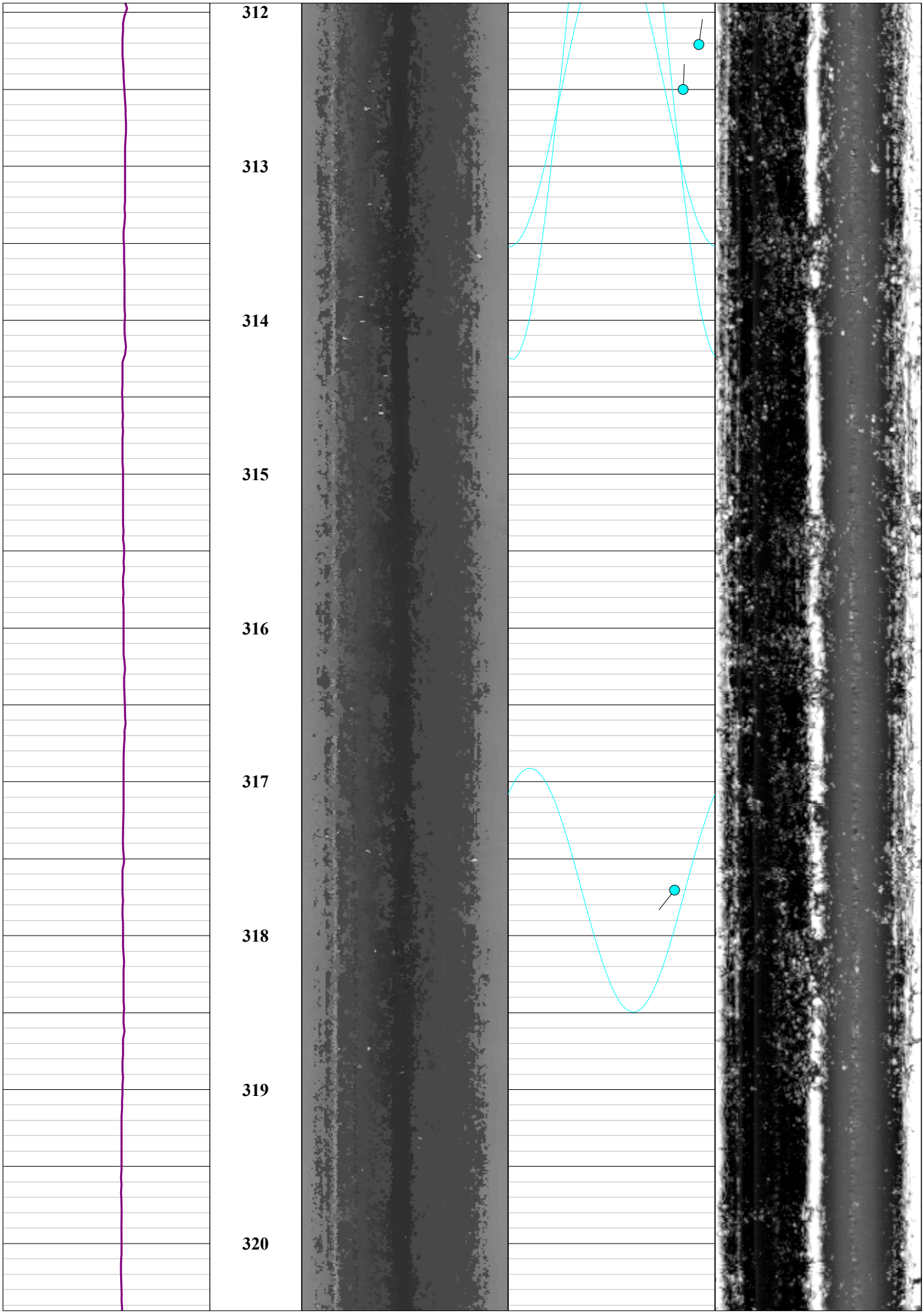
CASING RECORD

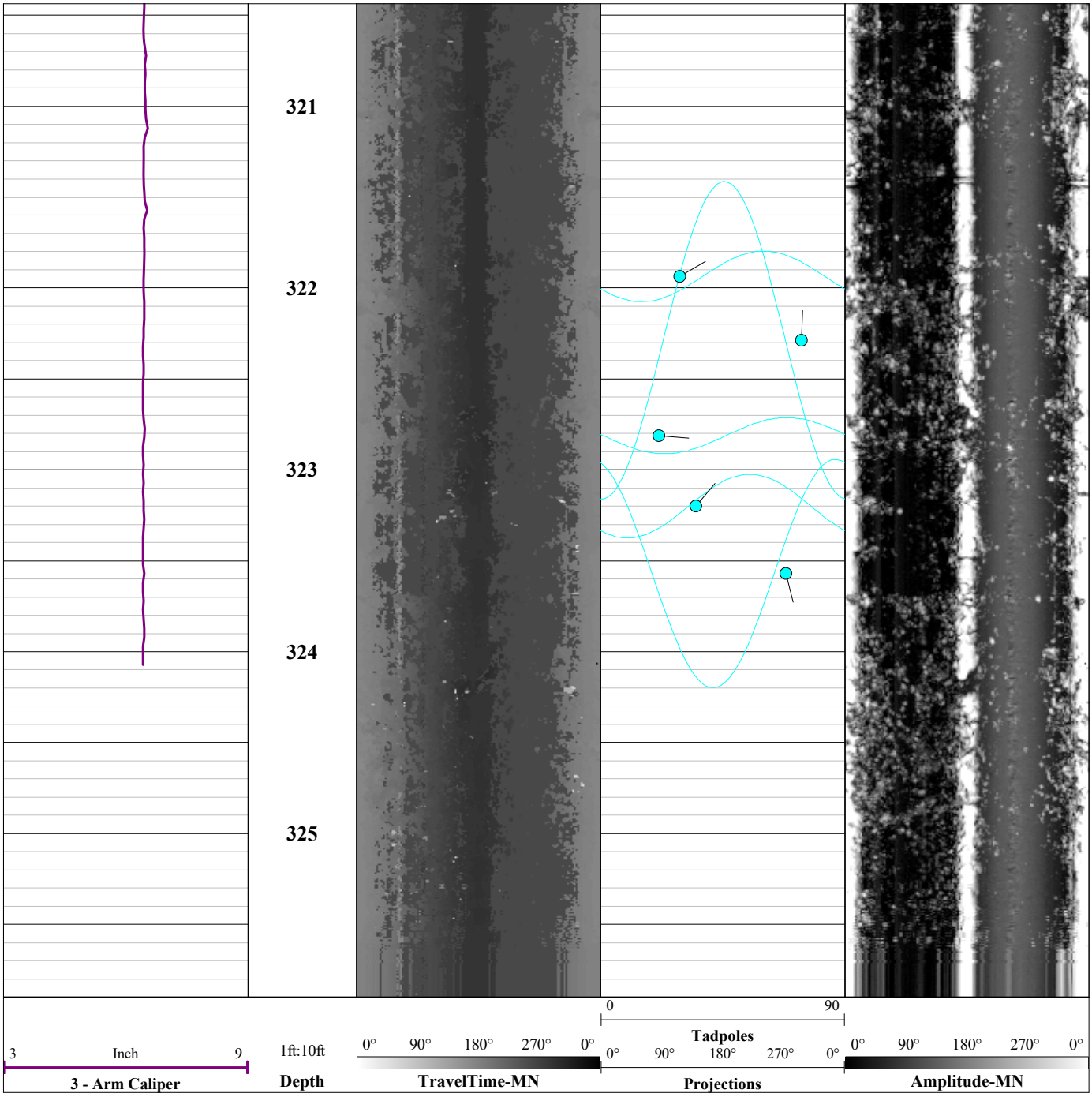
SIZE	WGT.	FROM	TO
5.5"	Steel	SU	305'

NA - Not Available, N/A - Not Applicable

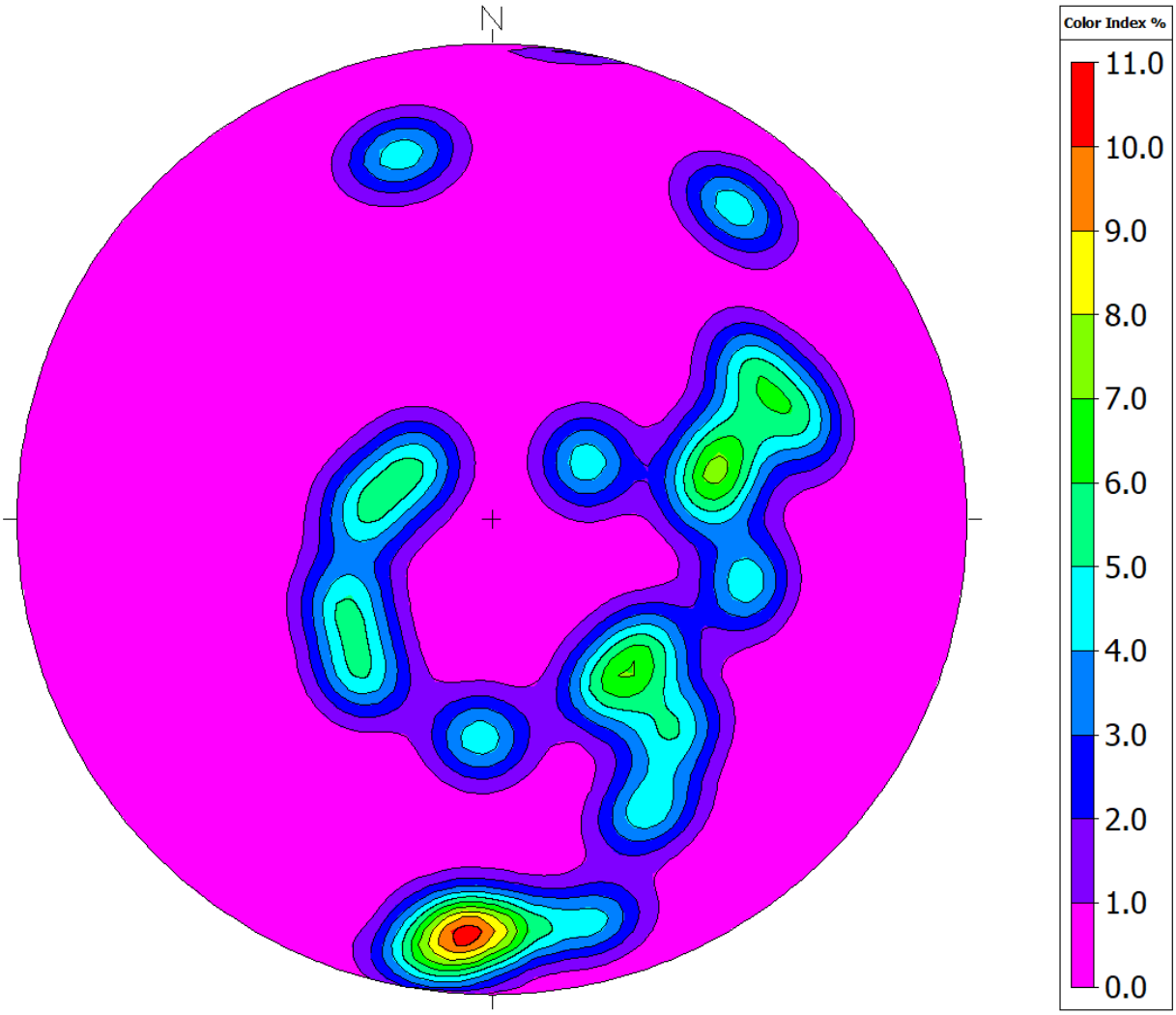
COMMENTS


3 - Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-MN
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude-MN
0°
90°
180°
270°
0°
305
306
307
308
309
310
311


312
313
314
315
316
317
318
319
320

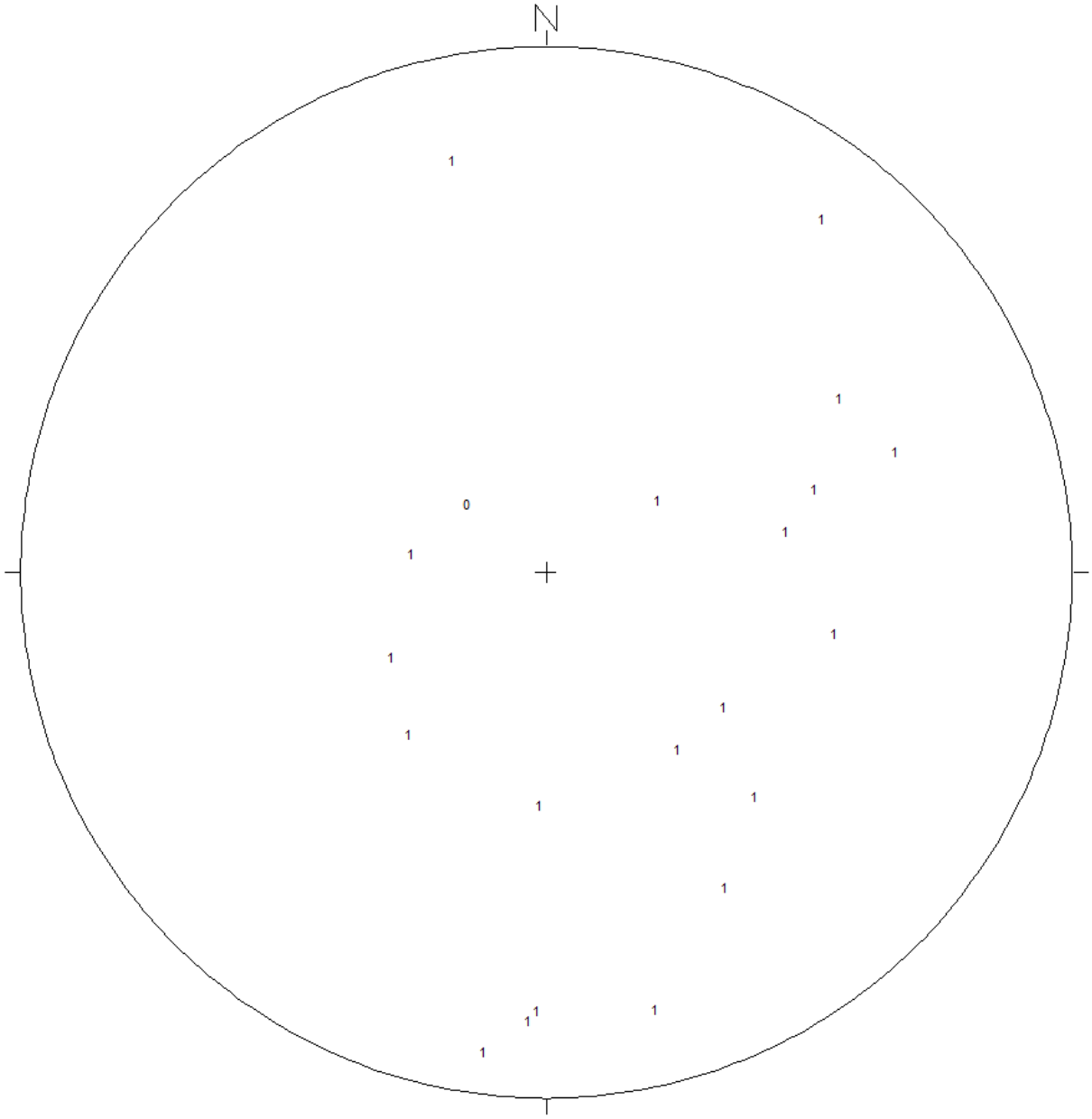

321
322
323
324
325
0
90
Tadpoles
3
Inch
9
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3 - Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-25
16 October 2019



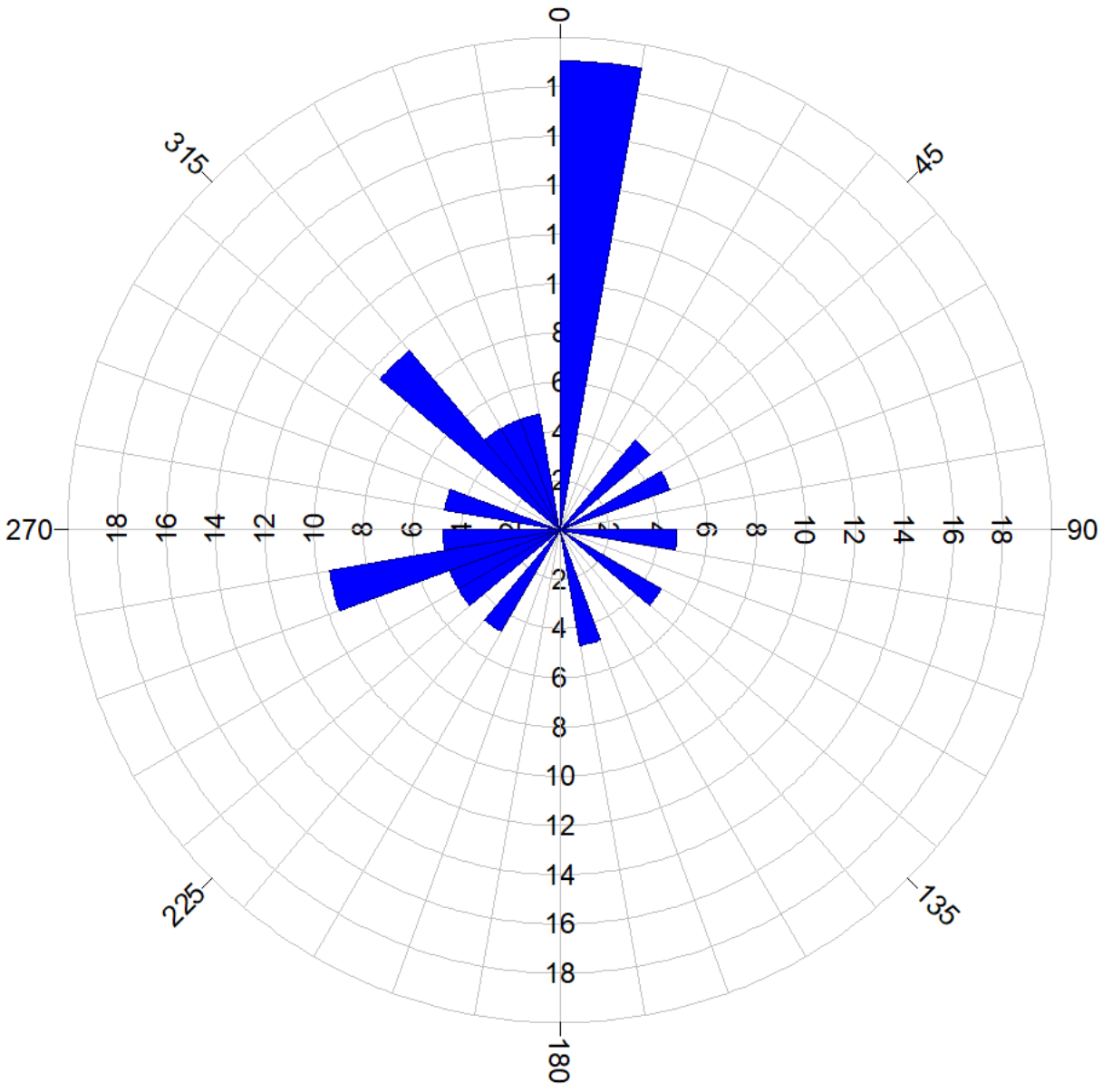
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-25
16 October 2019



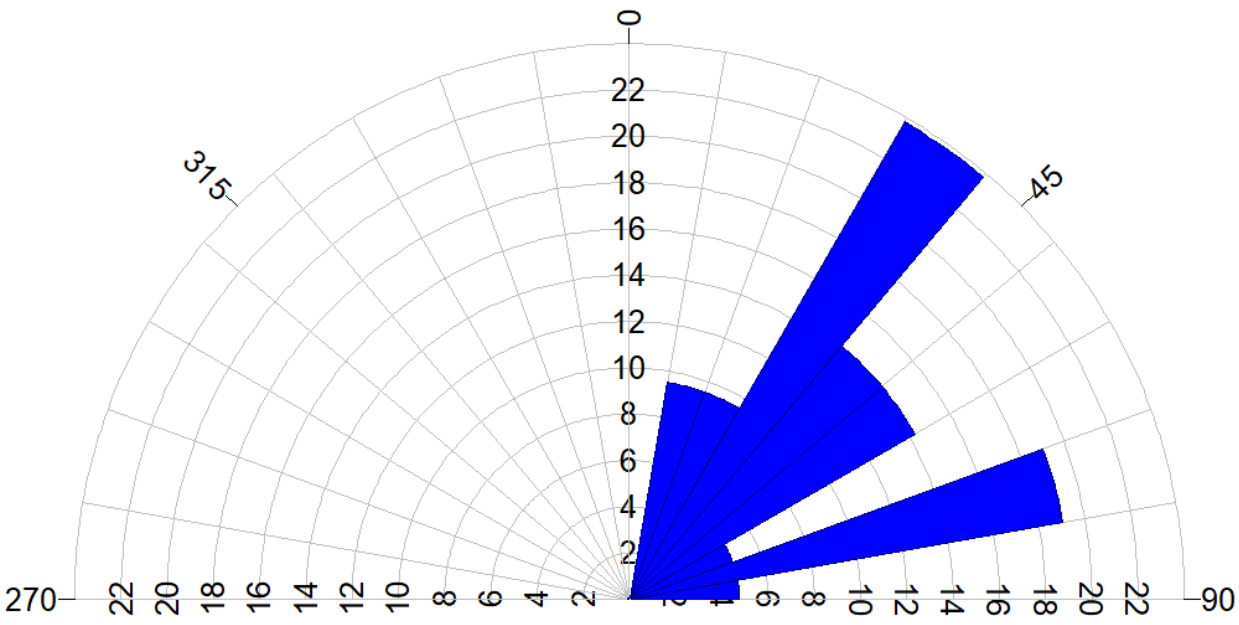
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-25
16 October 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-25
16 October 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-25

16 October 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	93.46	306.6	125	16	0
2	93.61	307.1	252	58	1
3	93.63	307.2	3	38	1
4	93.71	307.5	310	35	1
5	93.90	308.1	262	37	1
6	93.91	308.1	332	59	1
7	94.22	309.1	240	53	1
8	94.22	309.1	326	35	1
9	94.48	310.0	254	43	1
10	94.61	310.4	347	76	1
11	94.63	310.5	284	46	1
12	94.91	311.4	319	49	1
13	95.03	311.8	239	19	1
14	95.16	312.2	8	83	1
15	95.25	312.5	3	76	1
16	96.83	317.7	218	72	1
17	98.13	321.9	60	29	1
18	98.23	322.3	2	74	1
19	98.39	322.8	94	22	1
20	98.51	323.2	40	35	1
21	98.62	323.6	166	68	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-25
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-25
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81727 N
Longitude: 84.76514 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 398.0'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 October 2019	16 October 2019	16 October 2019	
RUN NUMBER	1	1	1	
LOG TYPE	FTC	Natural Gamma	Caliper	
DEPTH-DRILLER	326.36'	326.36'	326.36'	
DEPTH-LOGGER	326.9'	326.9'	326.9'	
BTM LOG INTERVAL	326.56'	326.9'	326.55'	
TOP LOG INTERVAL	0.0'	0.0'	0.0'	
RECORDED BY	CKL	CKL	CKL	
WITNESSED BY	Conrad Fischer - WSP	Conrad Fischer - WSP	Conrad Fischer - WSP	
PROBE TYPE, S/N	2PFA #3656	ELXG #4314	3ACS#3596	
LOGGING SPEED	20 fpm	20 fpm	15 fpm	
A.S.D.E. / Sample Interval	0.21' / 0.10'	0.4' / 0.25'	0.15' / 0.10'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

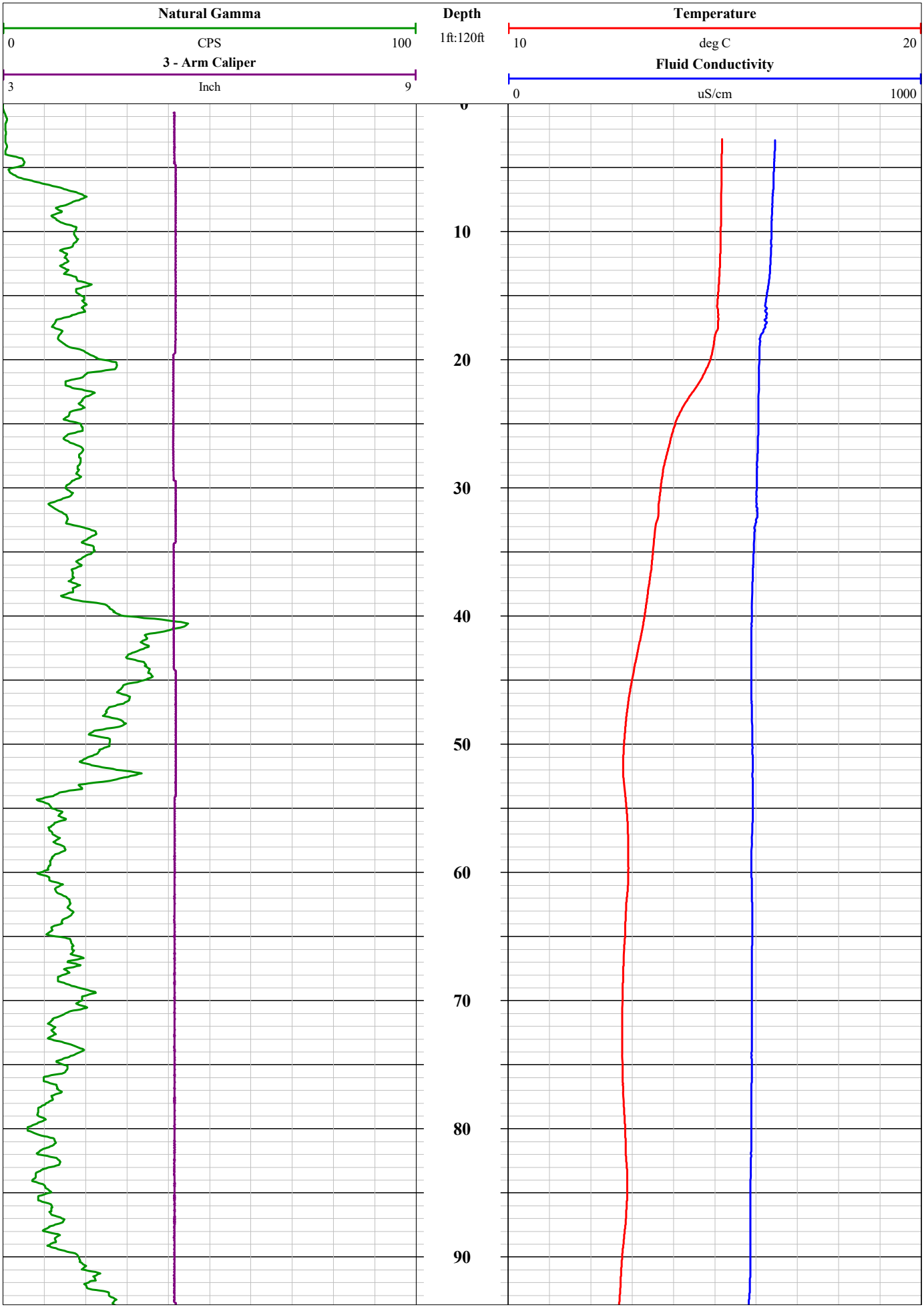
RUN No.	BIT	FROM	TO
1	5.5"	SU	305'
2	7"	305'	326.4'

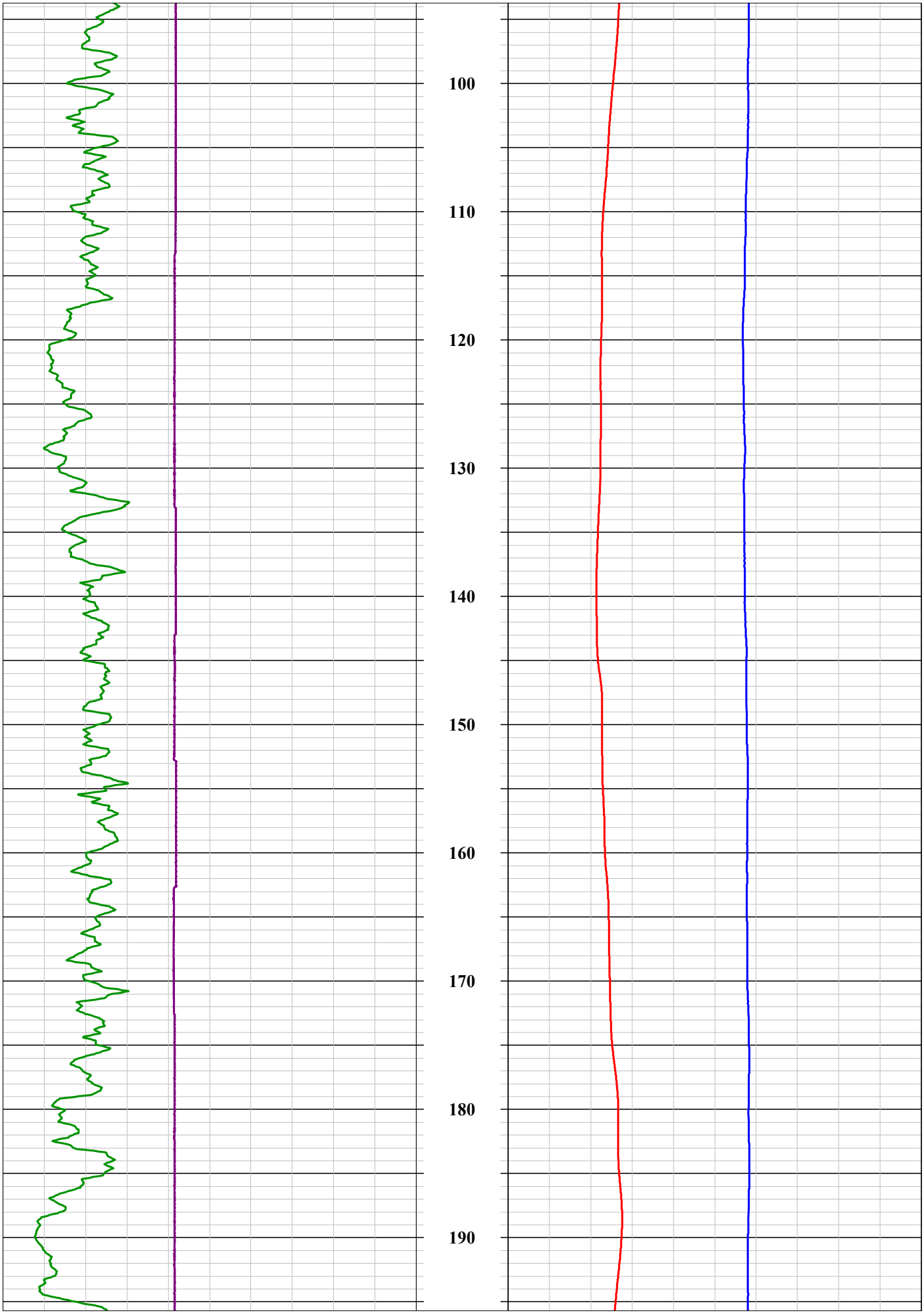
CASING RECORD

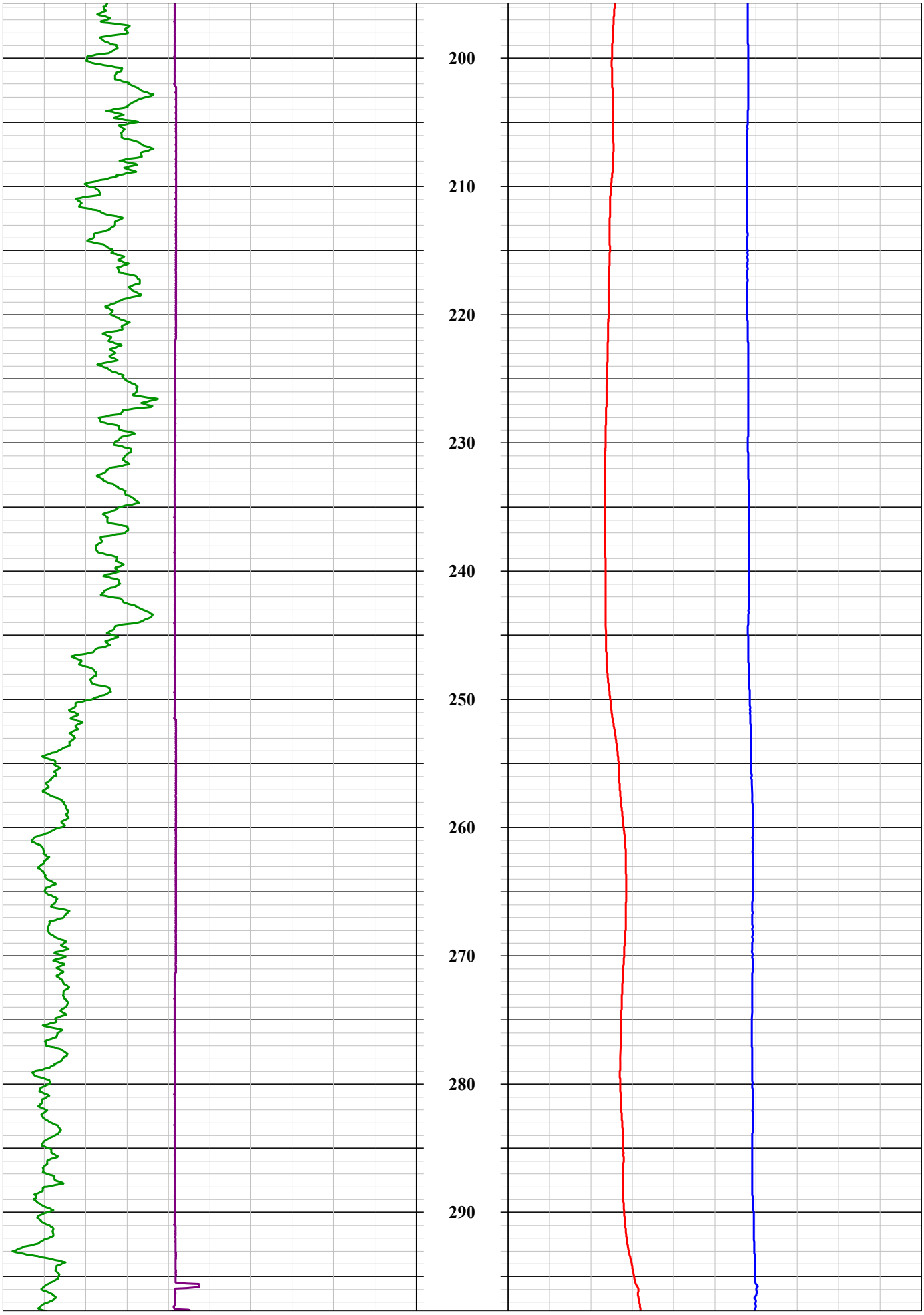
SIZE	WGT.	FROM	TO
5.5"	Steel	SU	305'

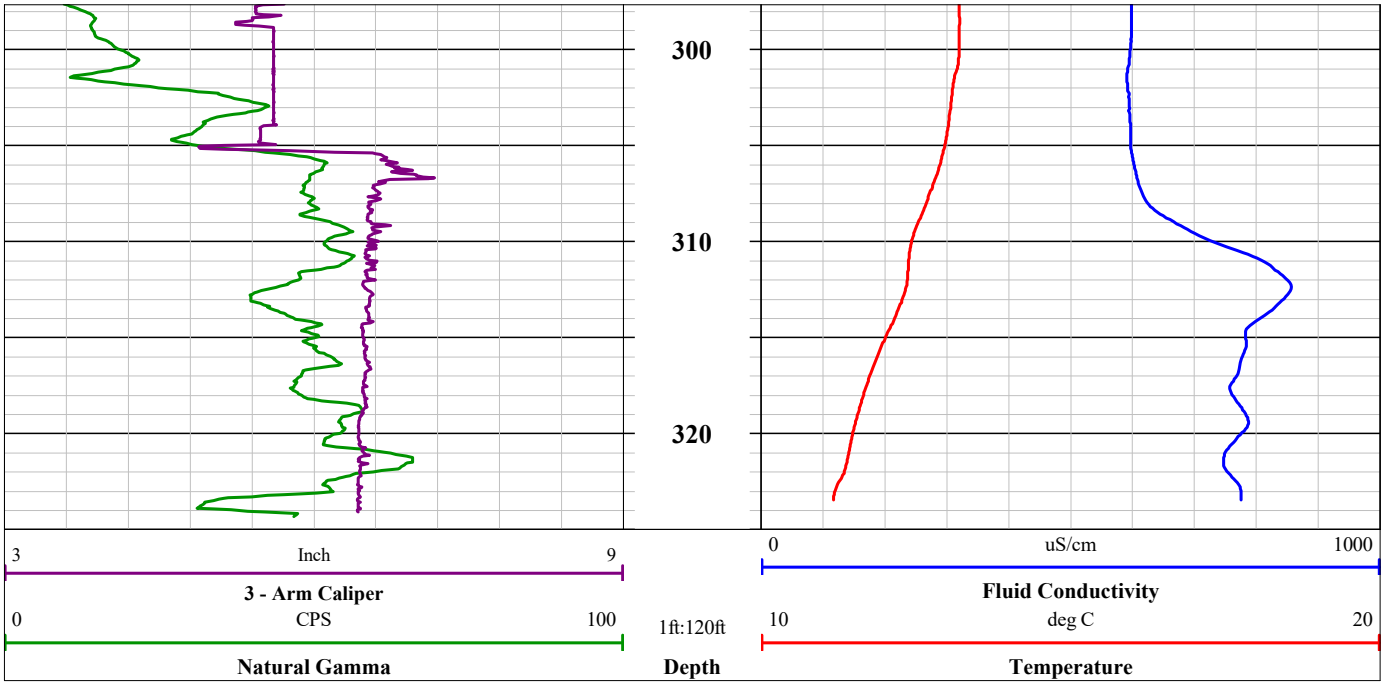
NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3 - Arm Caliper
3
Inch
9
Depth
1ft:120ft
Temperature
10
deg C
20
Fluid Conductivity
0
uS/cm
1000
0
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
320
3
Inch
9
3 - Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
10
deg C
20
Temperature

Borehole Deviation

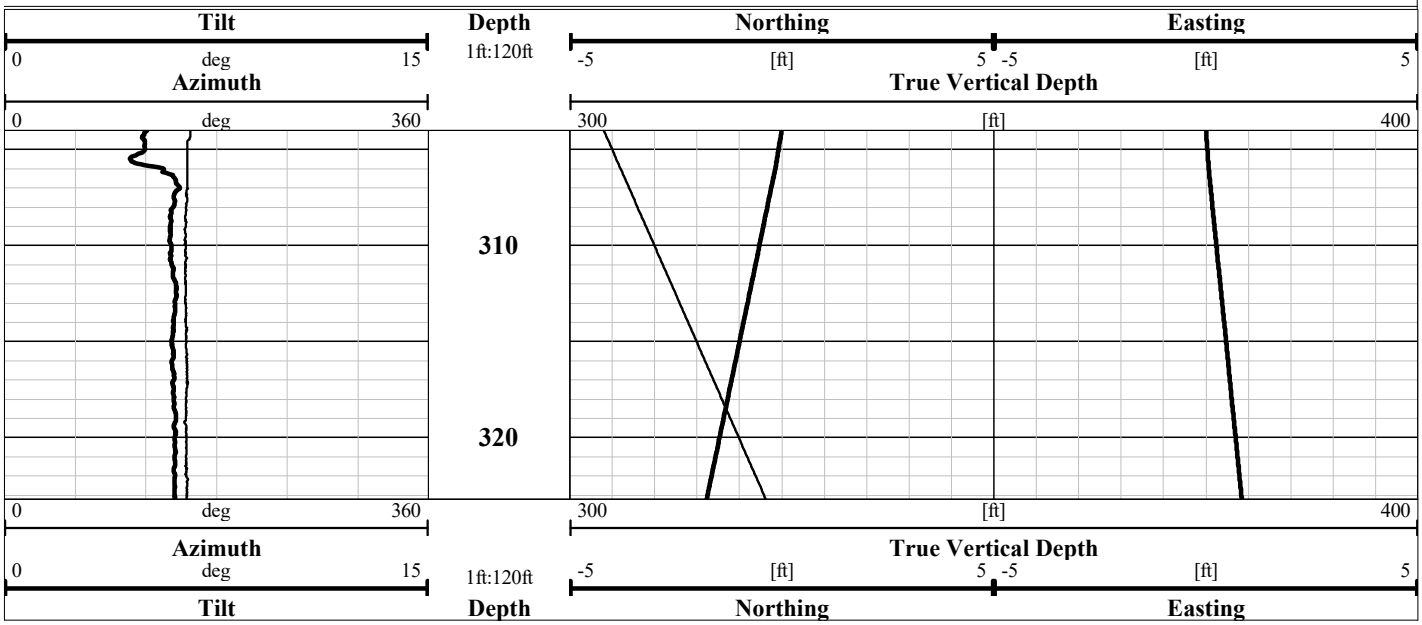
COLOG
borehole geophysics / hydrophysics

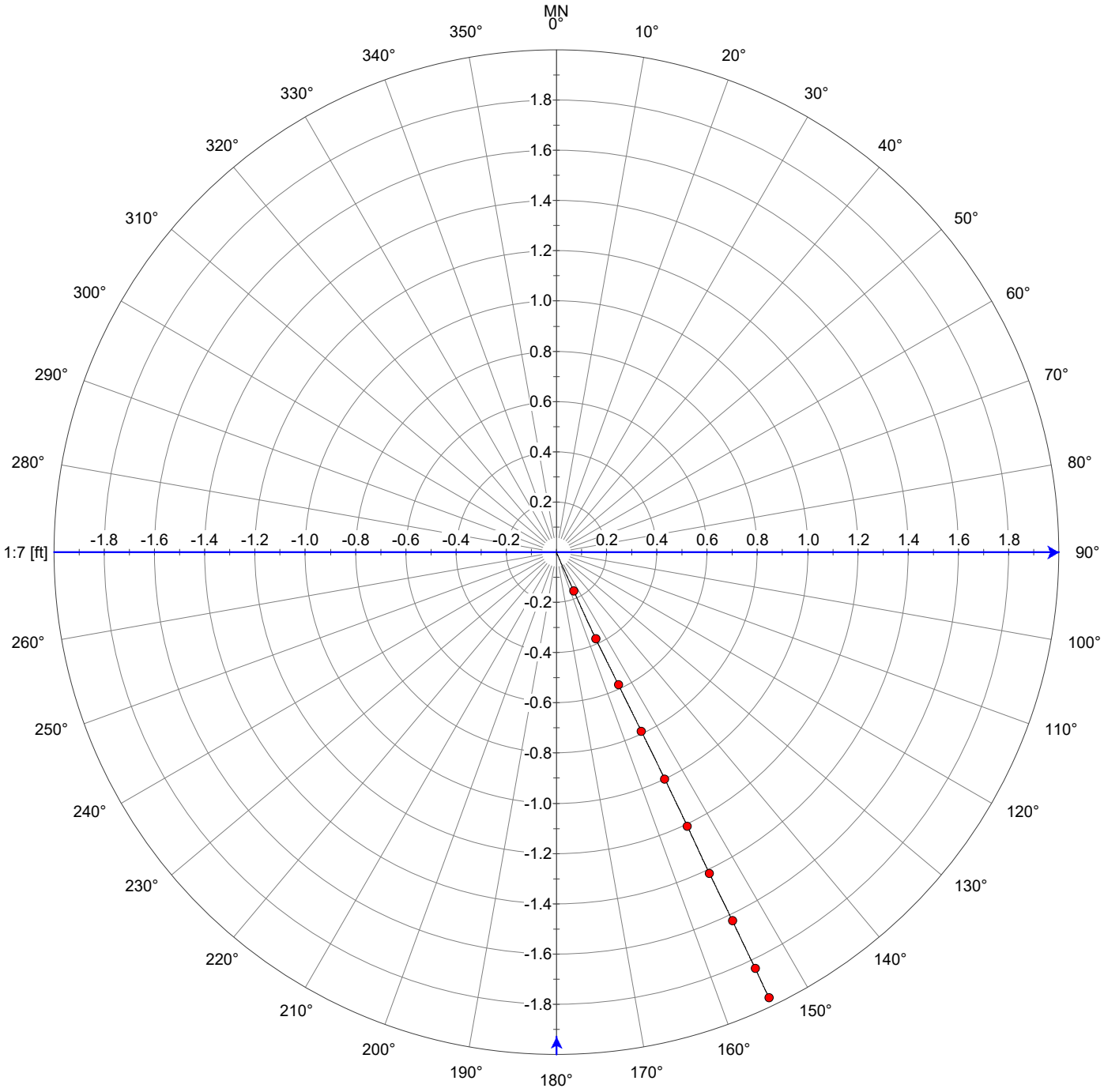
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 16 October 2019	WELL: BH19-25 - Mid Strait

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 398.0'** **Latitude: 45.81727 N** **Longitude: 84.76514 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
1:7 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-25
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-25
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81727 N
Longitude: 84.76514 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
3-Arm Caliper
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 398.0 '

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 October 2019	16 October 2019		
RUN NUMBER	1	1		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	326.36'	326.36'		
DEPTH-LOGGER	326.9'	326.9'		
BTM LOG INTERVAL	326.9'	326.9'		
TOP LOG INTERVAL	0.0'	285.0'		
RECORDED BY	CKL	CKL		
WITNESSED BY	Conrad Fischer - WSP	Conrad Fischer - WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 fpm	20 fpm		
A.S.D.E. / Sample Interval	0.4' / 0.25'	0.4' / 0.25'		
Fluid Level / Fluid Type	NA/water	NA/water		

BOREHOLE RECORD

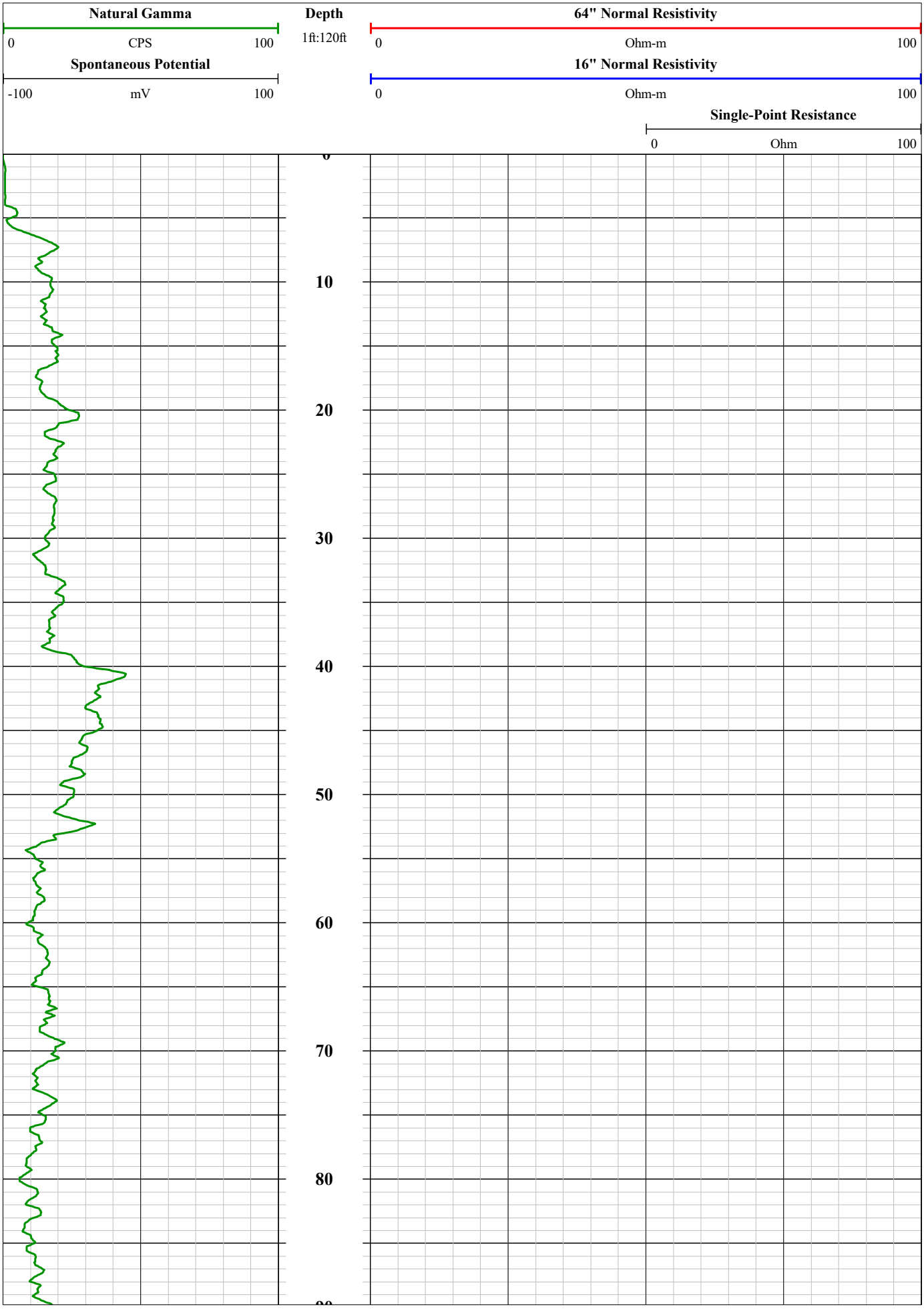
RUN No.	BIT	FROM	TO
1	5.5"	SU	305'
2	7"	305'	326.4'

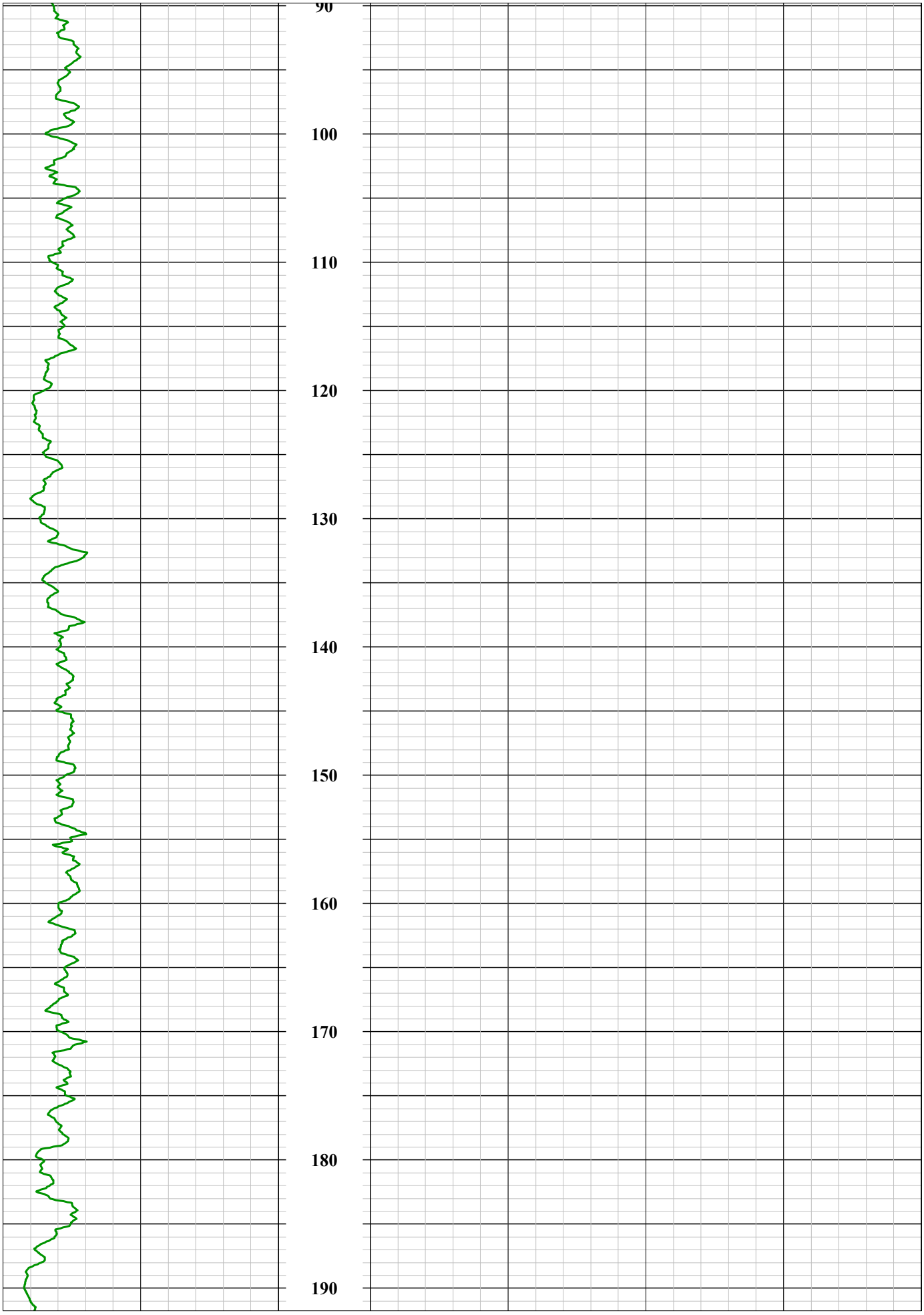
CASING RECORD

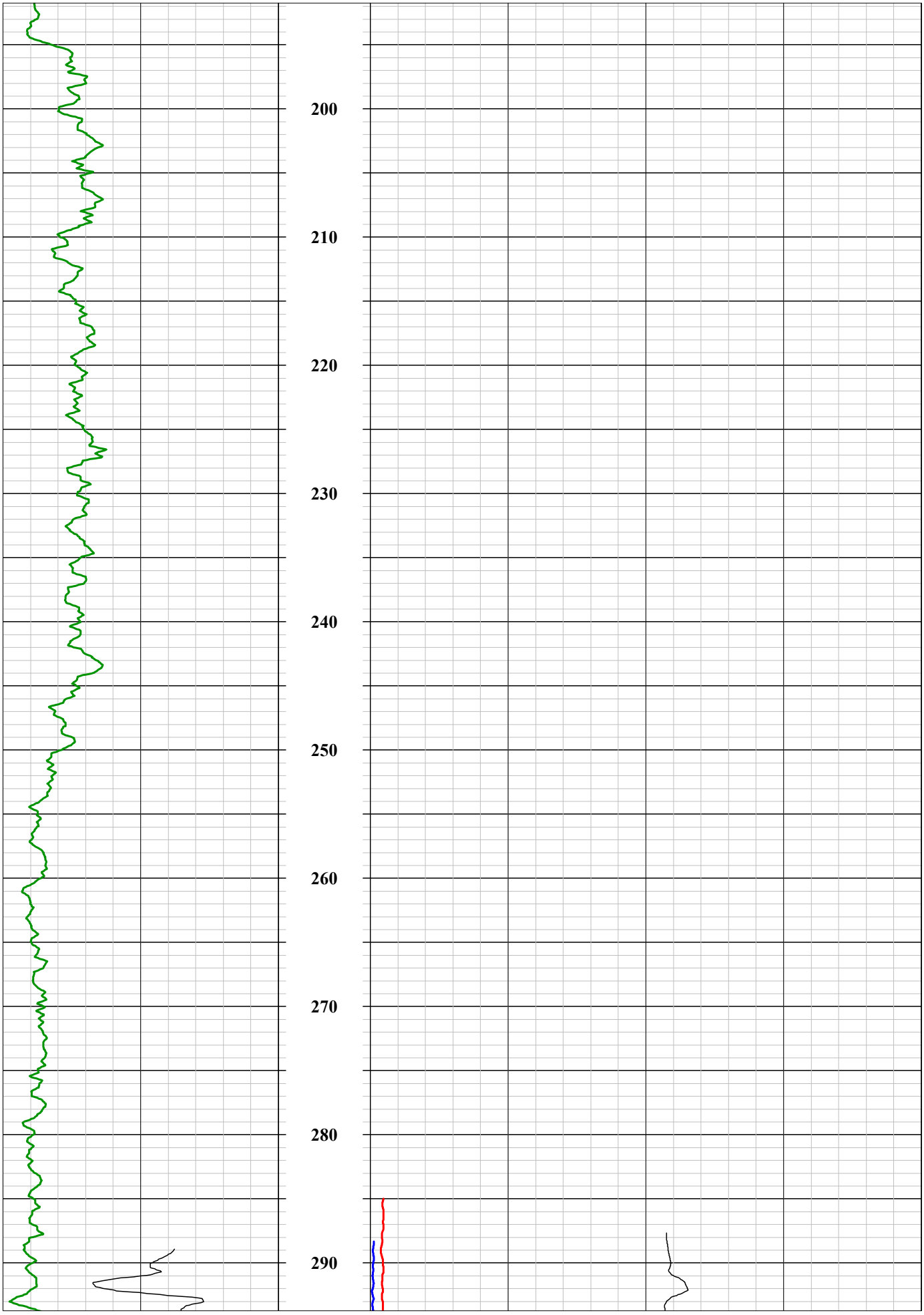
SIZE	WGT.	FROM	TO
5.5"	Steel	SU	305'

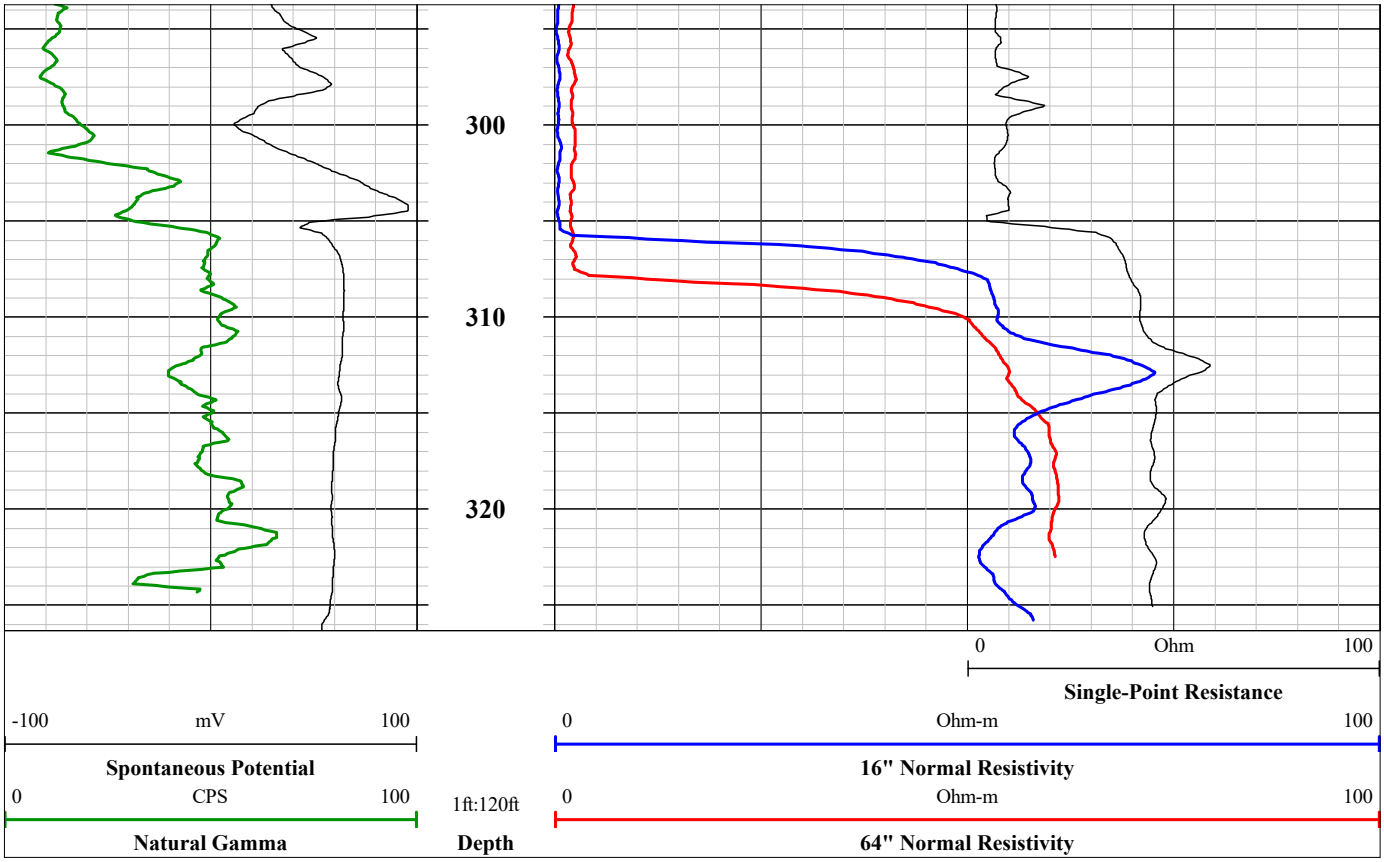
NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-100
mV
100
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
100
16" Normal Resistivity
0
Ohm-m
100
Single-Point Resistance
0
Ohm
100
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
320
0
Ohm
100
Single-Point Resistance
-100
mV
100
Spontaneous Potential
0
Ohm-m
100
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
100
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-25
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-25
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81727 N
Longitude: 84.76514 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric Log
Natural Gamma
3-Arm Caliper
Fluid Temp & Cond.

PERMANENT DATUM Mudline **ELEVATION** 398.0'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 October 2019			
RUN NUMBER	1			
LOG TYPE	PSLog			
DEPTH-DRILLER	326.36'			
DEPTH-LOGGER	326.9'			
BTM LOG INTERVAL	313.23'			
TOP LOG INTERVAL	289.0'			
RECORDED BY	CKL			
WITNESSED BY	Conrad Fischer - WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

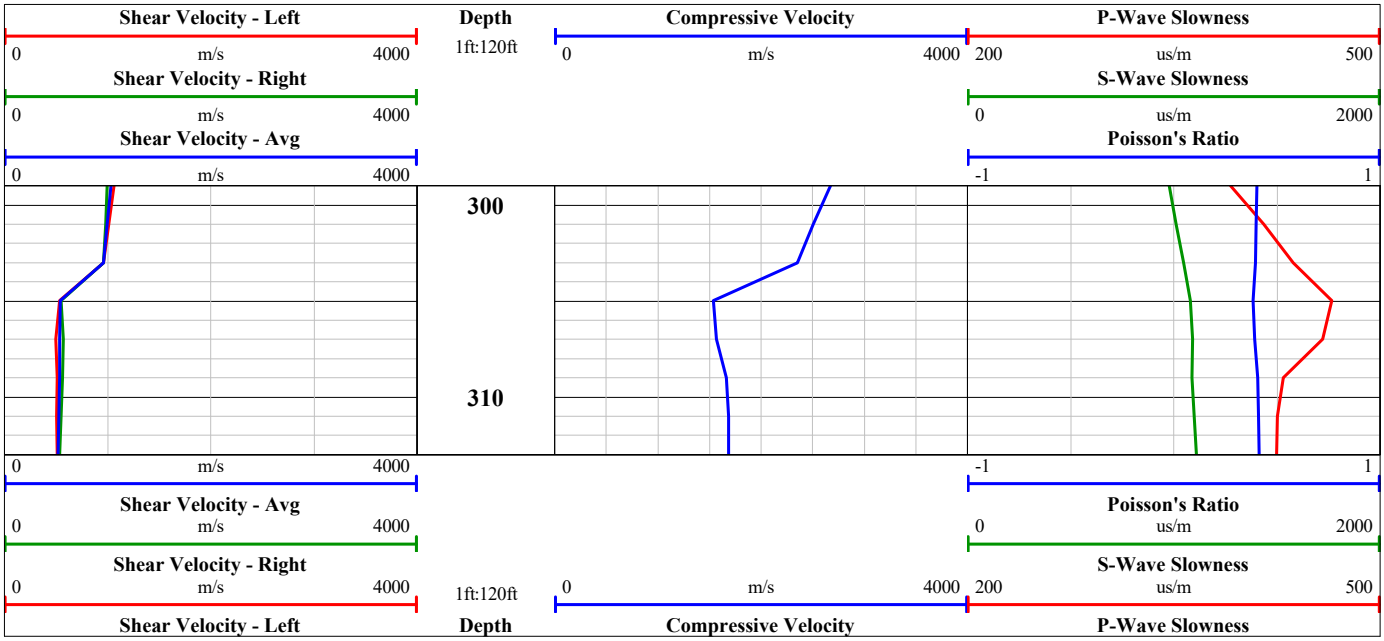
RUN No.	BIT	FROM	TO
1	5.5"	SU	305'
2	7"	305'	326.4'

CASING RECORD

SIZE	WGT.	FROM	TO
5.5"	Steel	SU	305'

NA - Not Available, N/A - Not Applicable

COMMENTS

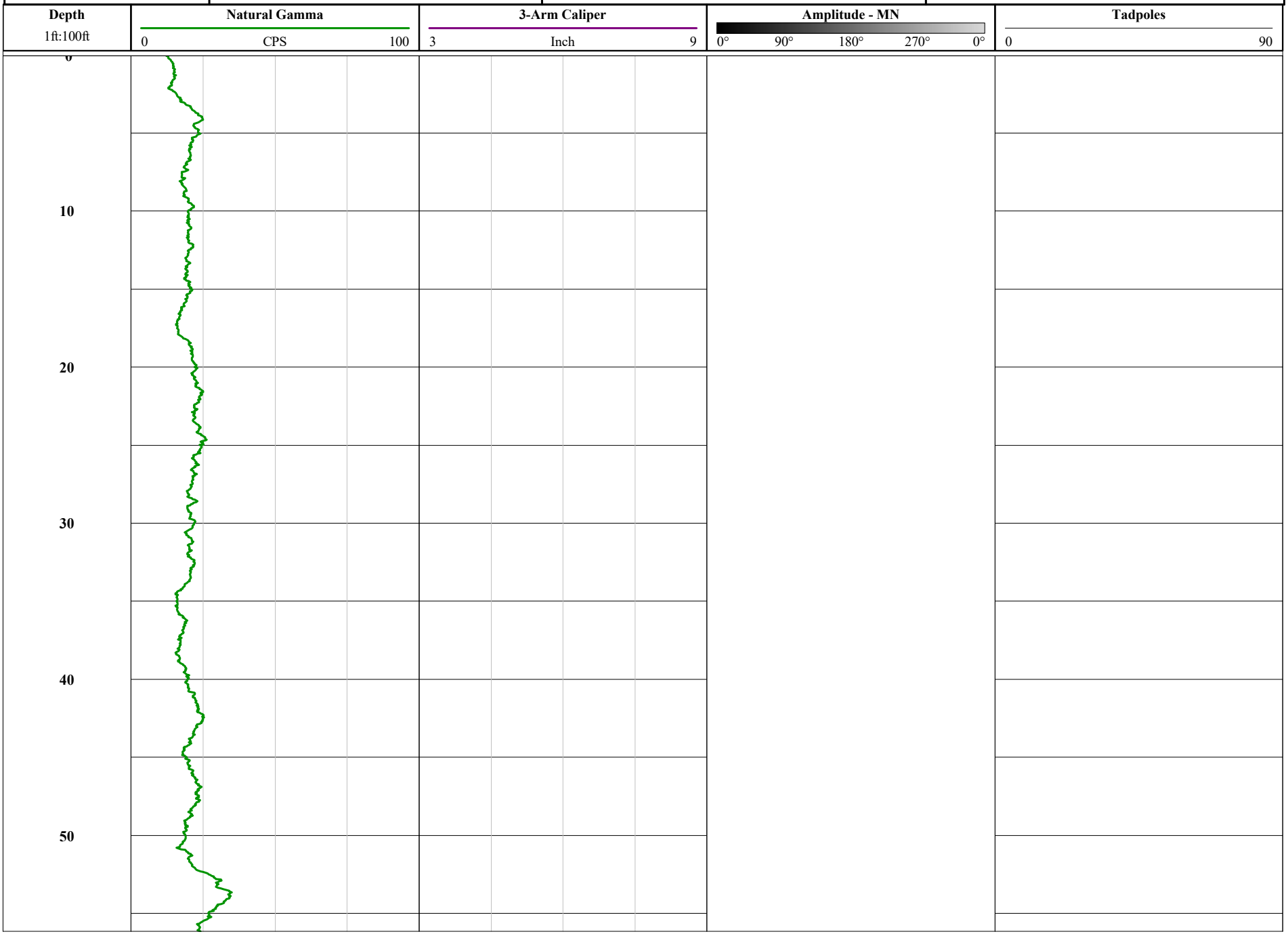

Shear Velocity - Left
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
0
m/s
4000
P-Wave Slowness
200
us/m
500
Shear Velocity - Right
0
m/s
4000
S-Wave Slowness
0
us/m
2000
Shear Velocity - Avg
0
m/s
4000
Poisson's Ratio
-1
1
300
310
0
m/s
4000
-1
1
Shear Velocity - Avg
0
m/s
4000
Poisson's Ratio
0
us/m
2000
Shear Velocity - Right
0
m/s
4000
1ft:120ft
0
m/s
4000
S-Wave Slowness
200
us/m
500
Shear Velocity - Left
Depth
Compressive Velocity
P-Wave Slowness

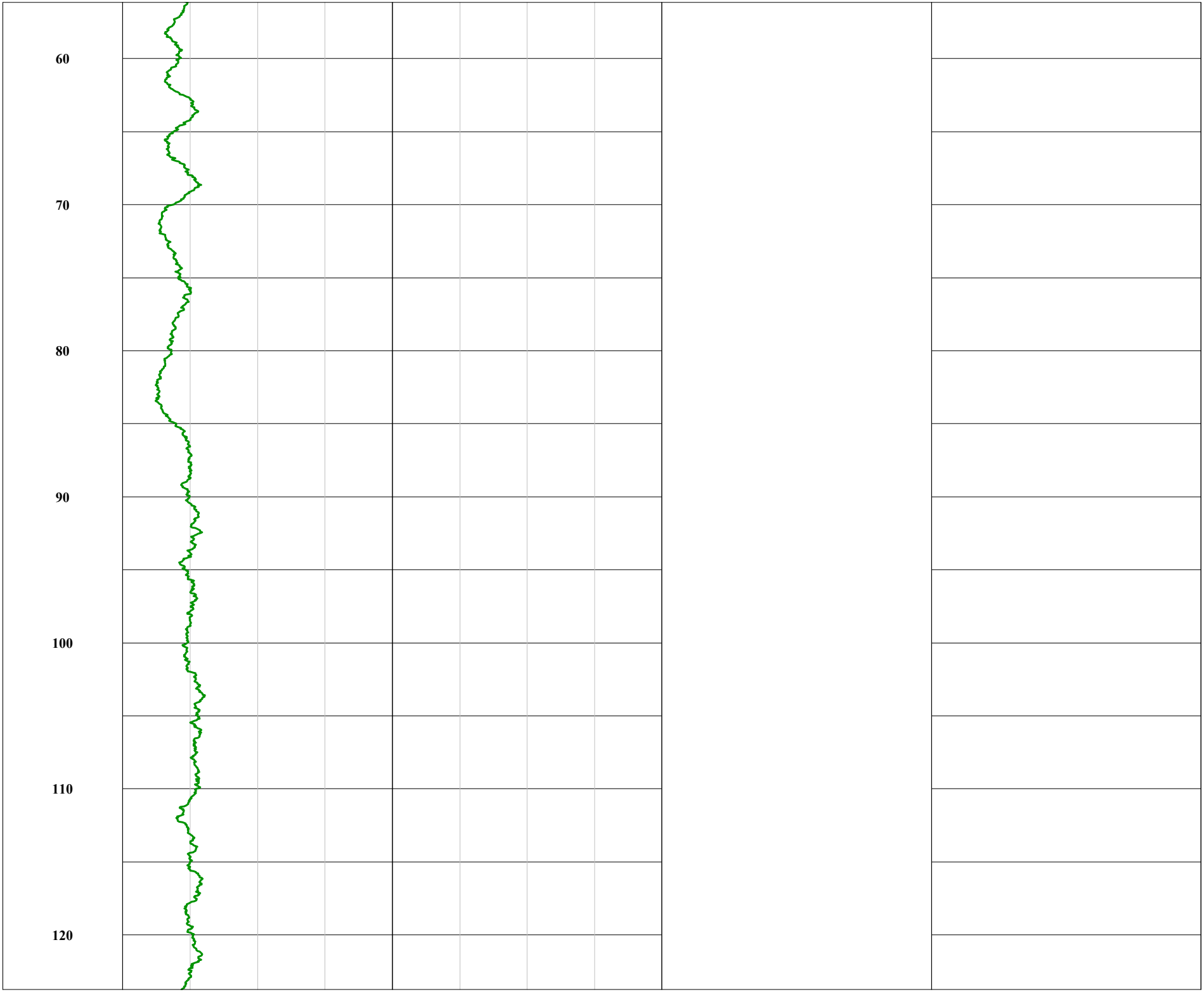
Geophysical Summary Plot

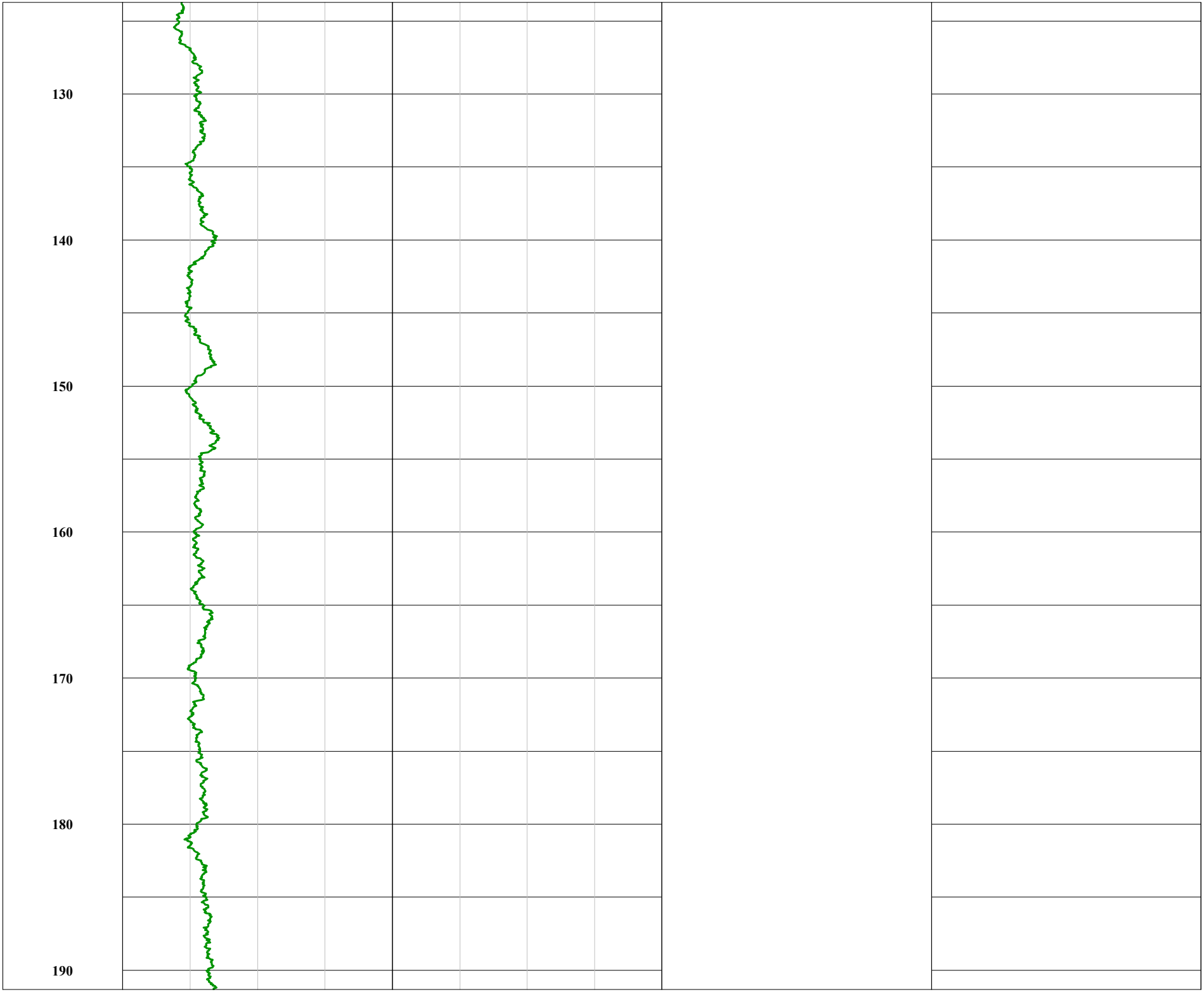
borehole geophysics / hydrophysics

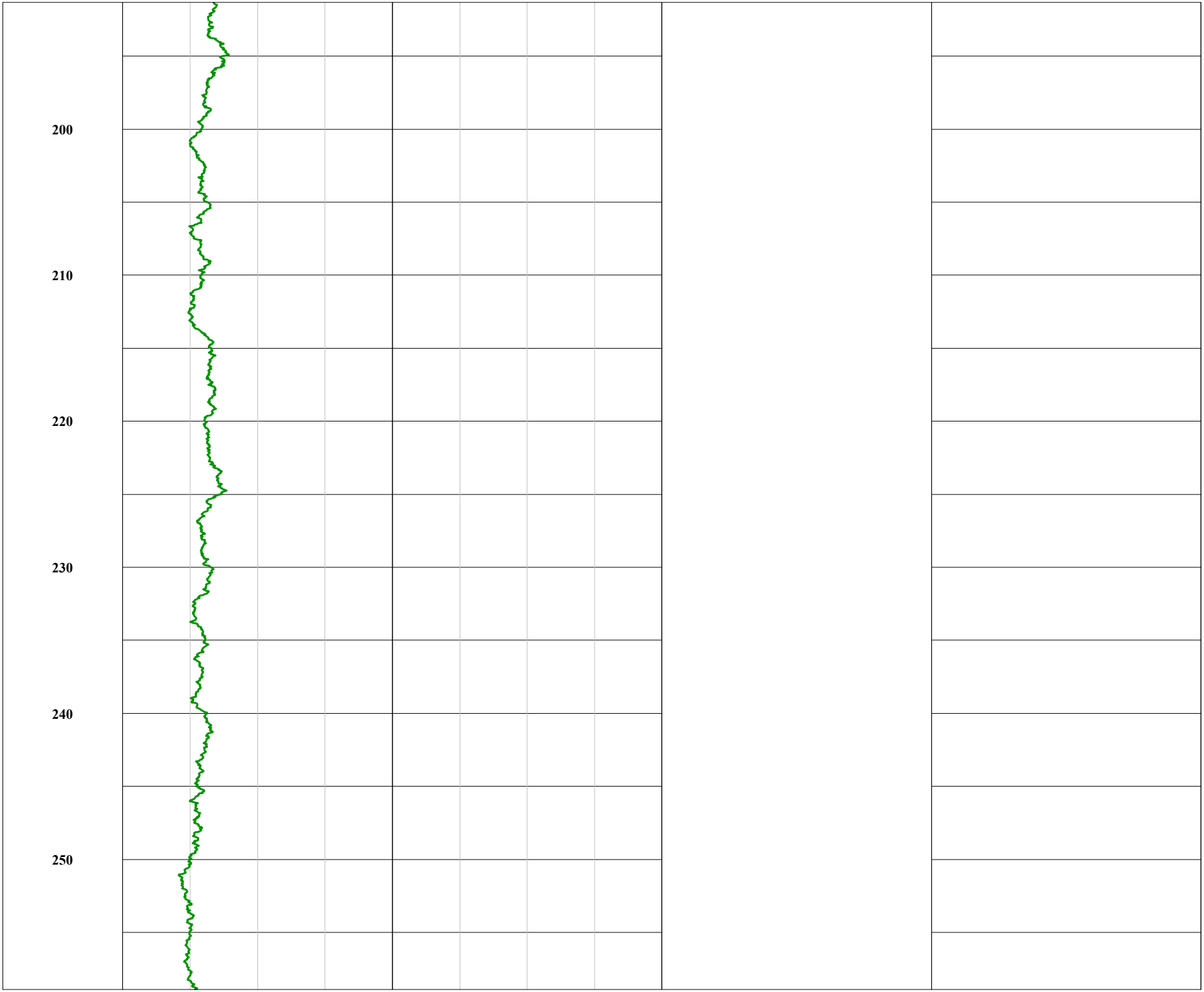
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 16 November 2019	WELL: BH19-26 - Mid Strait

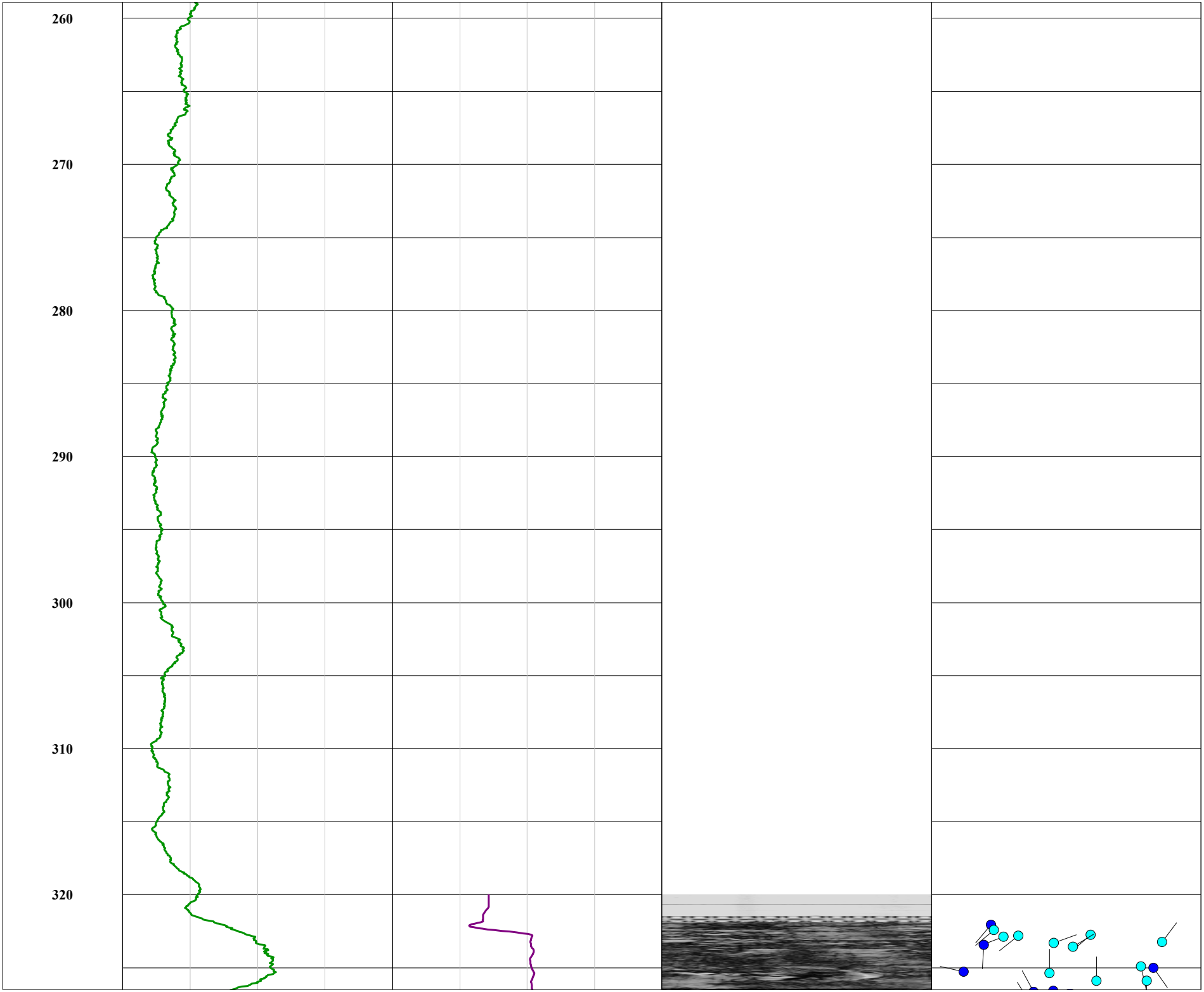
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

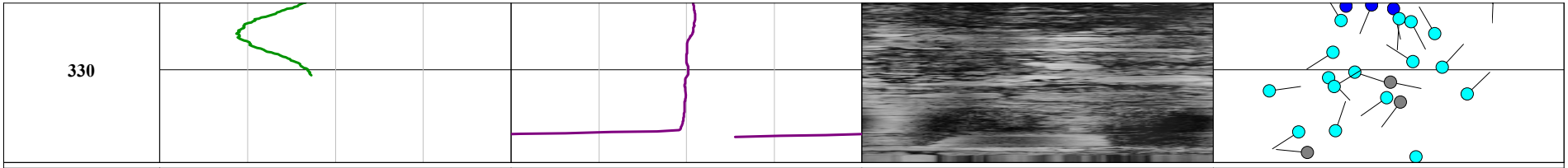



60
70
80
90
100
110
120


130
140
150
160
170
180
190


200
210
220
230
240
250


260
270
280
290
300
310
320



1ft:100ft	0 CPS 100	3 Inch 9	0° 90° 180° 270° 0°	0 90
Depth	**Natural Gamma**	**3-Arm Caliper**	**Amplitude - MN**	**Tadpoles**

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer
3-Arm Caliper
Natural Gamma-Ray

Company WSP
Well BH19-26
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-26
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81661 N
Longitude: 84.76659 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
None

PERMANENT DATUM Mudline **ELEVATION** 396.7'
LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**
DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 November 2019	16 November 2019	16 November 2019	
RUN NUMBER	1	1	1	
LOG TYPE	Natural Gamma	Caliper	Acoustic Televiewer	
DEPTH-DRILLER	336.2'	336.2'	336.2'	
DEPTH-LOGGER	334.9'	334.9'	334.9'	
BTM LOG INTERVAL	330.3'	333.5'	334.9'	
TOP LOG INTERVAL	0.0'	320.0'	320.0'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	Conrad Fischer -WSP	Conrad Fischer - WSP	Conrad Fischer -WSP	
PROBE TYPE, S/N	3ACS, 5788	3ACS, 5788	ABI40, 111018	
LOGGING SPEED	15 fpm	15 fpm	5 fpm	
A.S.D.E. / Sample Interval	0.4' / 0.1'	0.4' / 0.1'	0.5' / 0.008'	
Fluid Level / Fluid Type	NA / water	NA / water	NA / water	

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	7"	Mudline	51.8'
2	6"	51.8'	336.2'

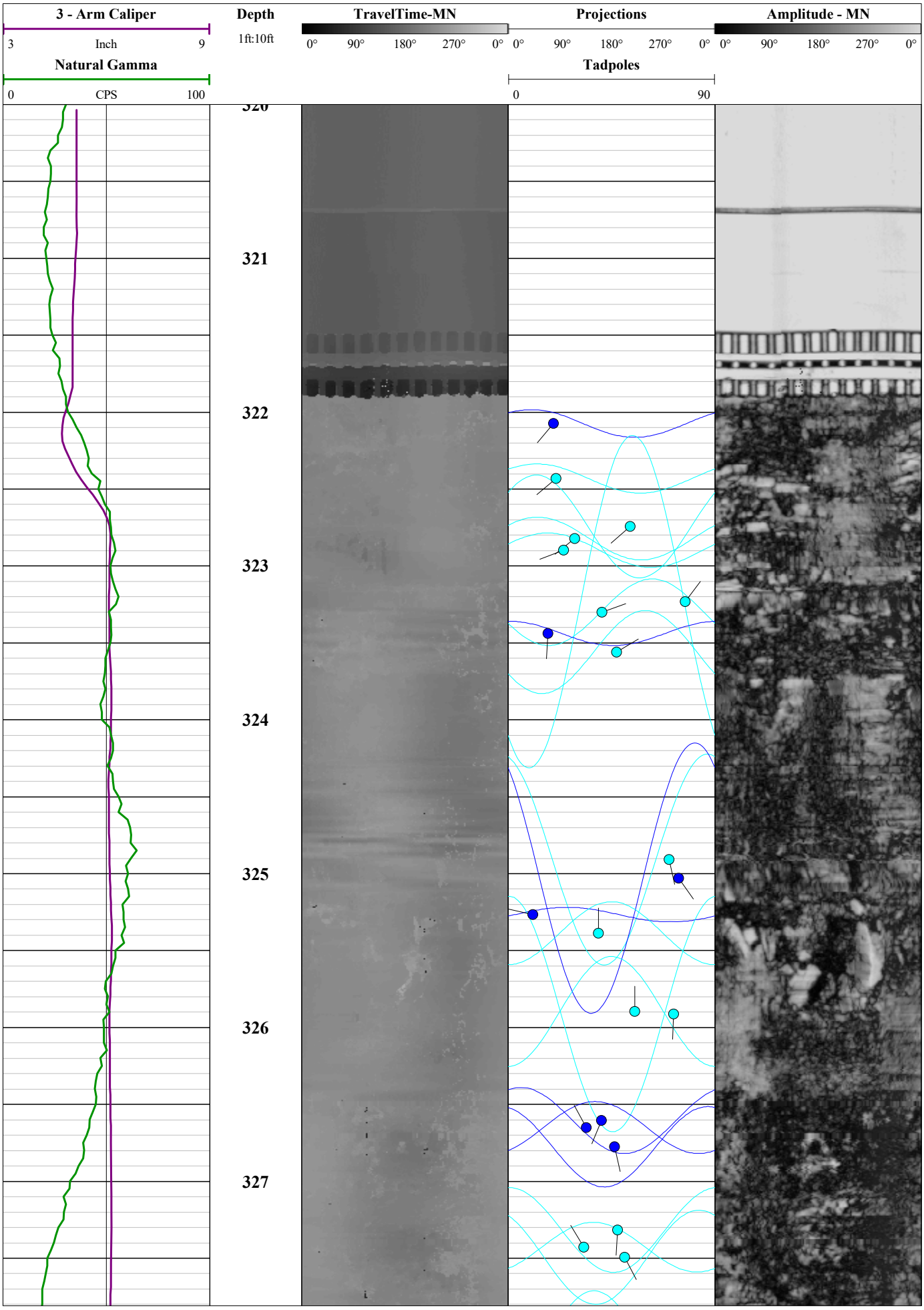
CASING RECORD

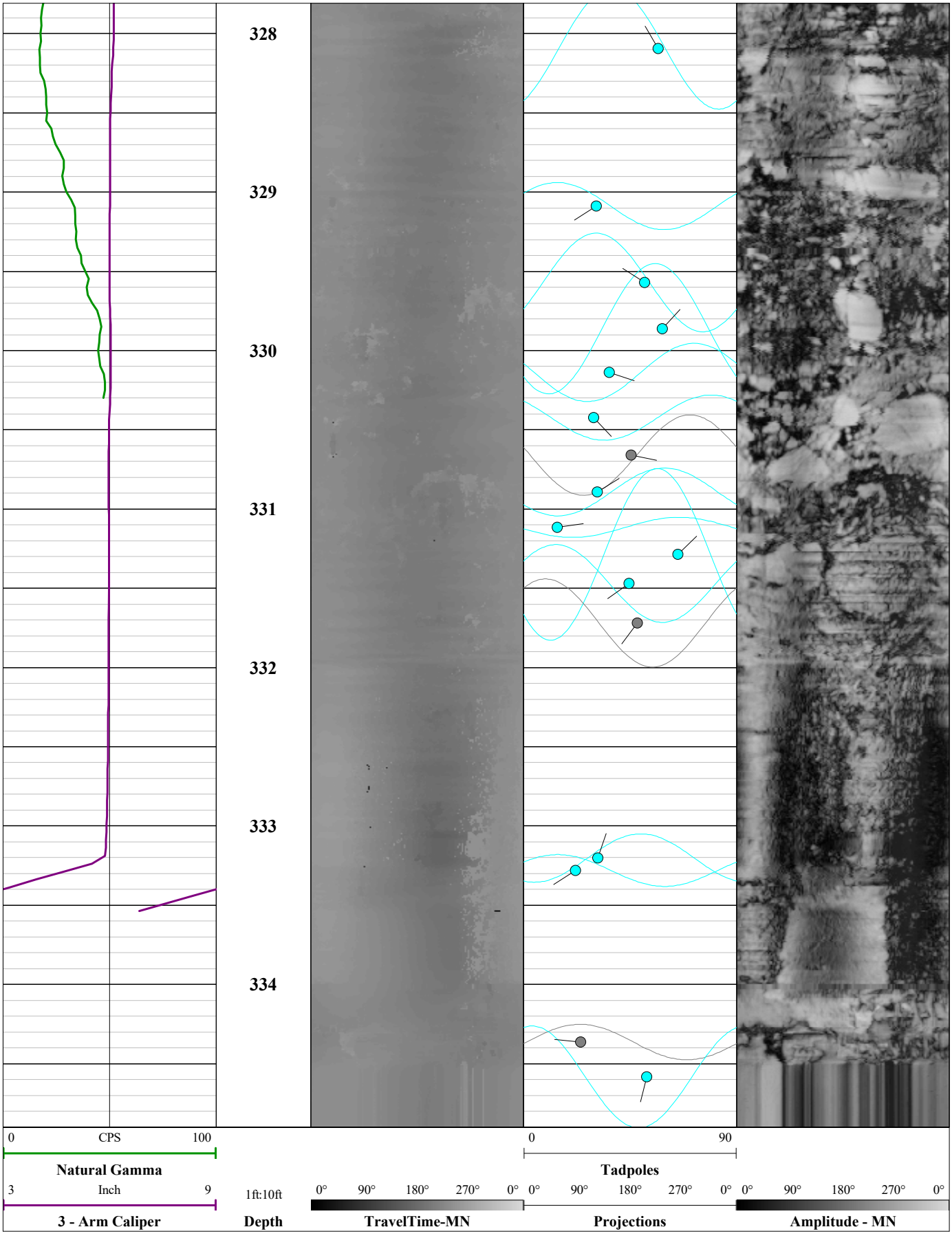
SIZE	WGT.	FROM	TO
7"	Steel	TOC	51.8'
6"	Steel	TOC	322'

NA - Not Available, N/A - Not Applicable

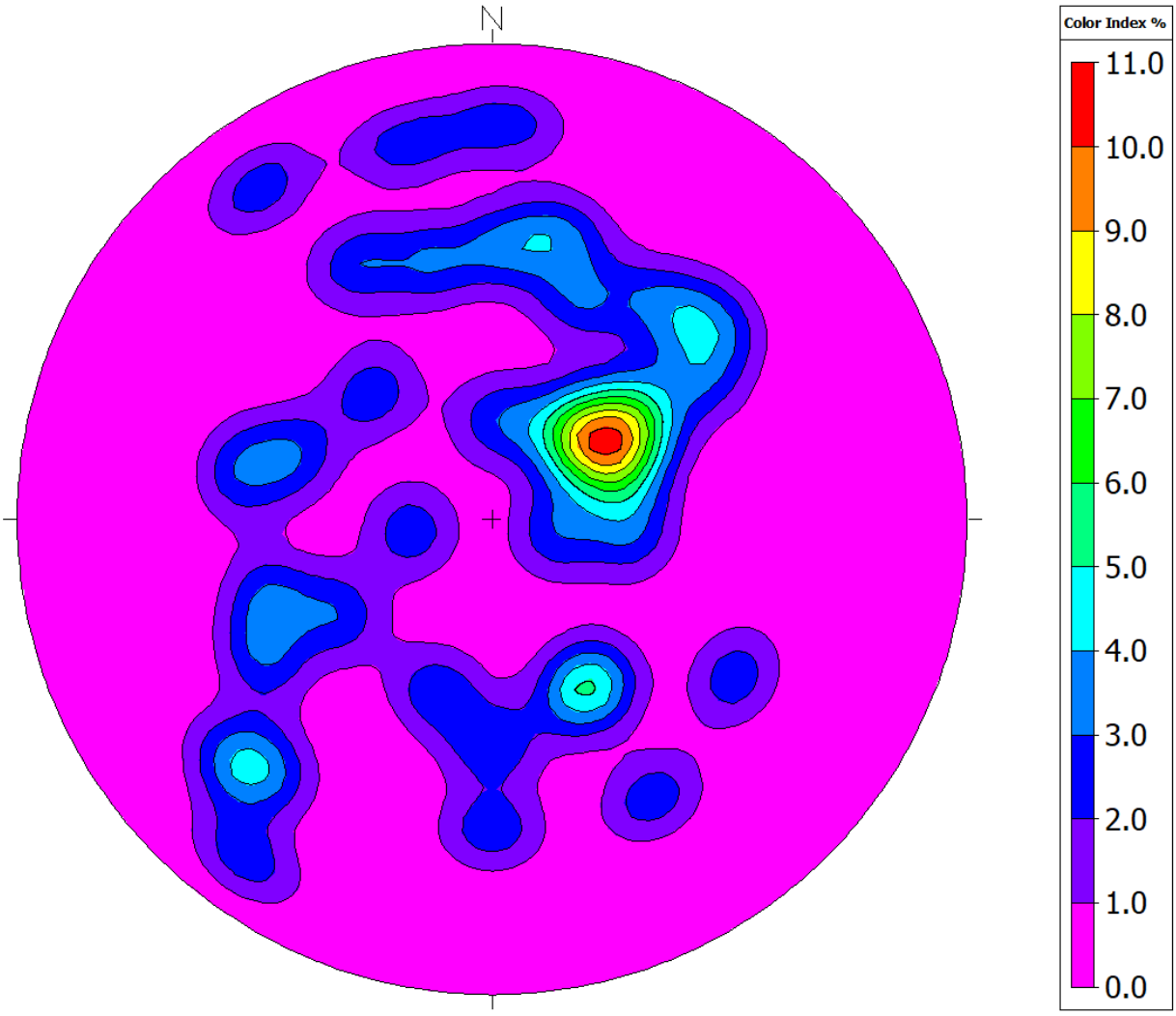
COMMENTS

Per WSP only Acoustic Televiewer and Natural Gamma data was to be collected on this boring.
3-Arm Caliper ran in conjunction with the Natural Gamma.


3 - Arm Caliper
3
Inch
9
Natural Gamma
0
CPS
100
Depth
1ft:10ft
TravelTime-MN
0° 90° 180° 270° 0°
Projections
0° 90° 180° 270° 0°
Tadpoles
0
90
Amplitude - MN
0° 90° 180° 270° 0°
320
321
322
323
324
325
326
327

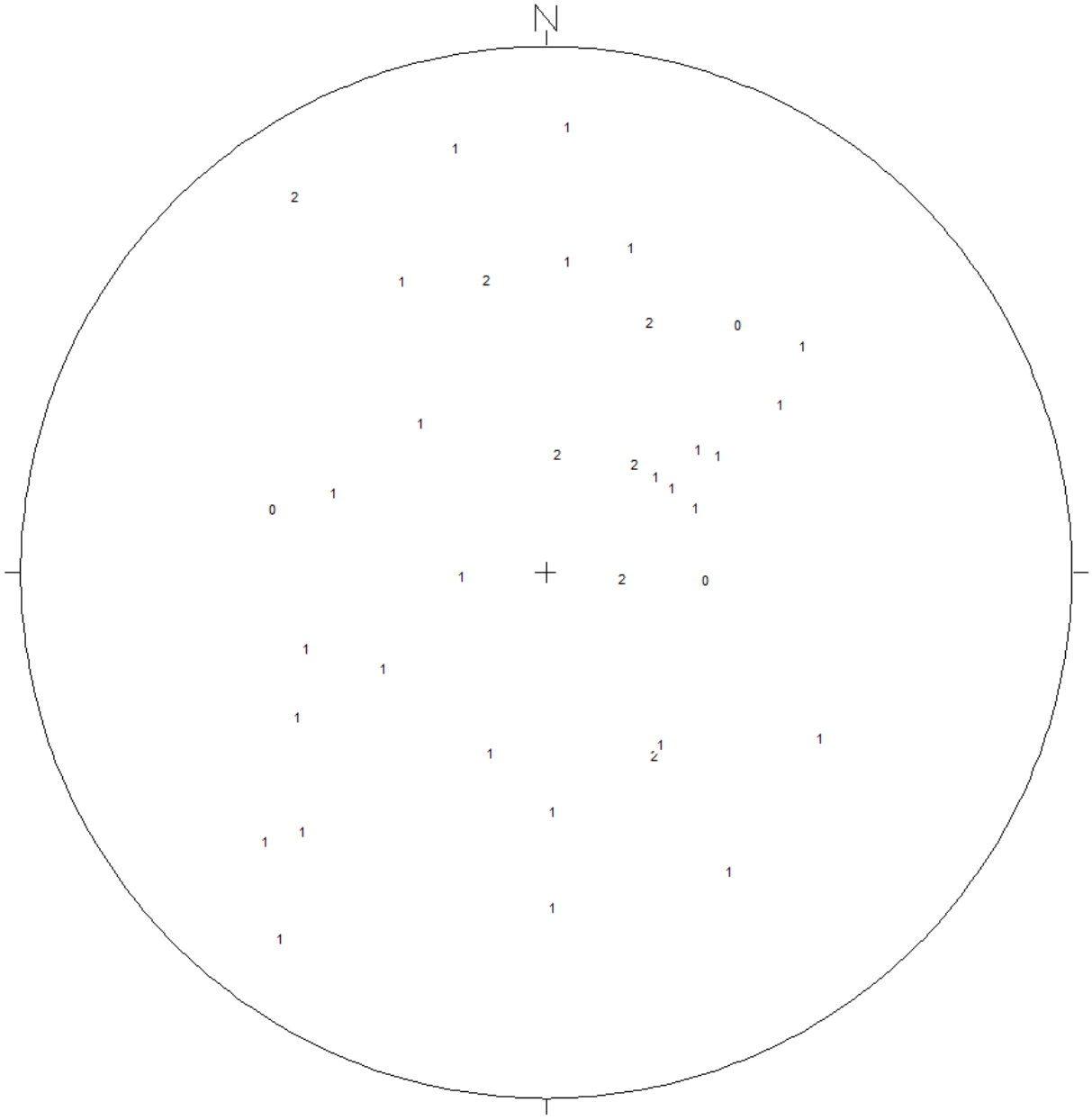

328
329
330
331
332
333
334
0
CPS
100
Natural Gamma
3
Inch
9
3 - Arm Caliper
1ft:10ft
Depth
0°
90°
180°
270°
0°
TravelTime-MN
0
90
Tadpoles
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Amplitude - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-26
16 November 2019



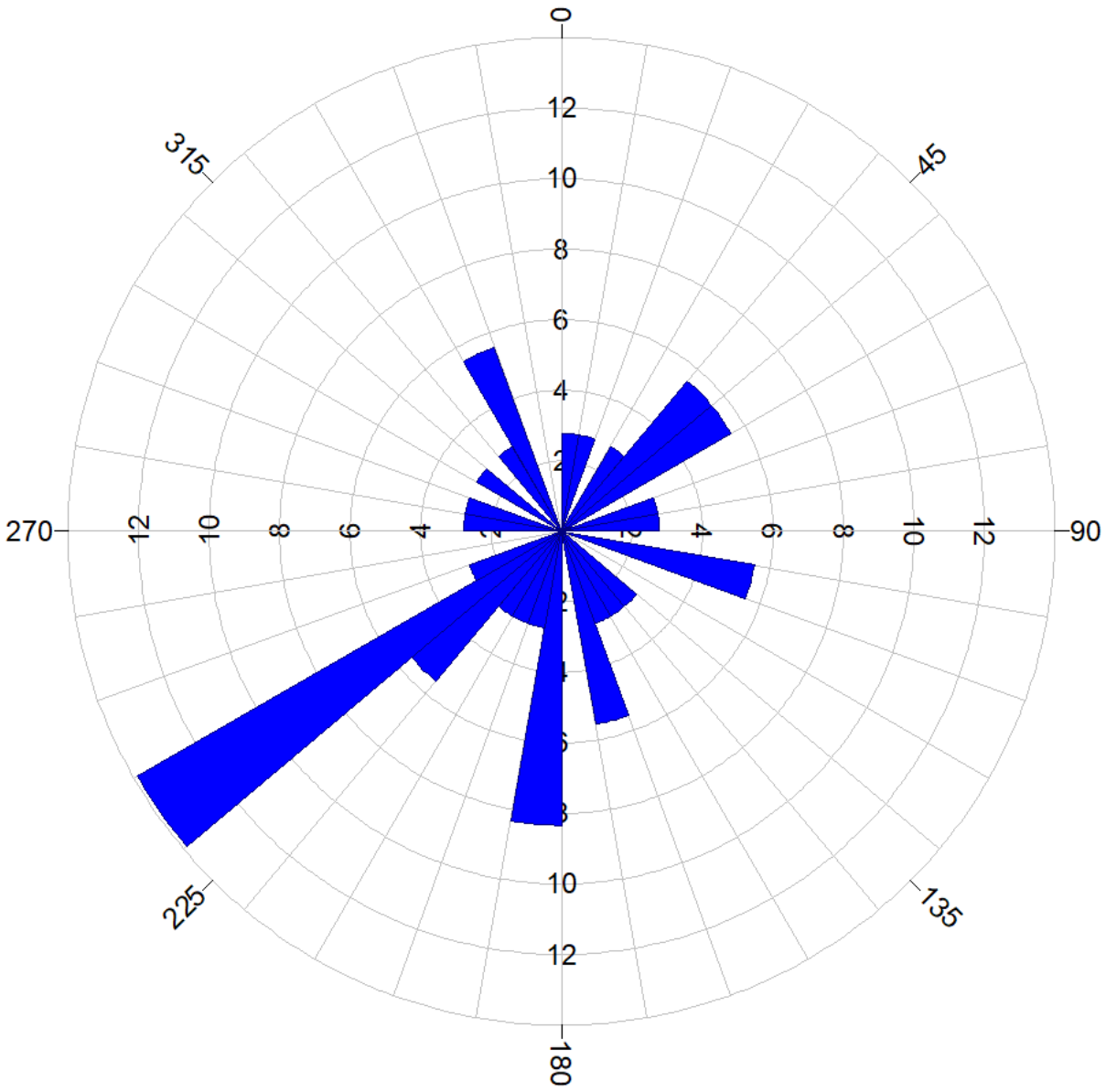
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-26
16 November 2019



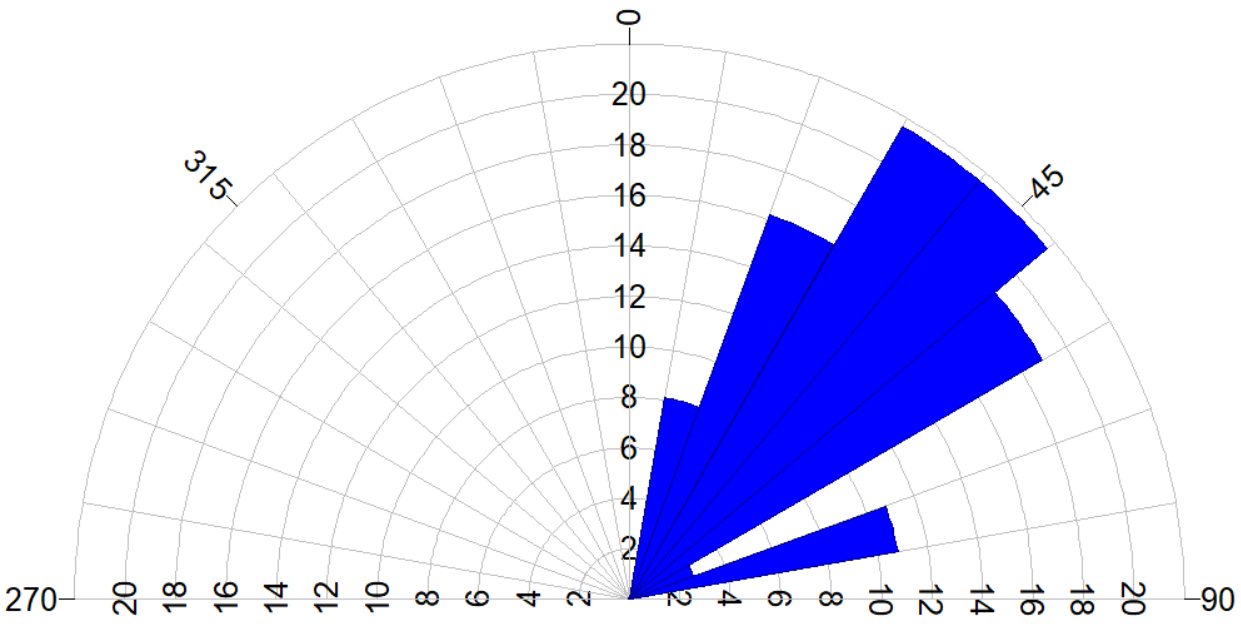
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-26
16 November 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-26
16 November 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-26

16 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	98.17	322.1	220	20	2
2	98.28	322.4	230	21	1
3	98.37	322.7	229	53	1
4	98.40	322.8	232	29	1
5	98.42	322.9	249	24	1
6	98.52	323.2	36	77	1
7	98.54	323.3	71	41	1
8	98.58	323.4	183	17	2
9	98.62	323.6	59	47	1
10	99.03	324.9	167	70	1
11	99.07	325.0	145	74	2
12	99.14	325.3	282	11	2
13	99.18	325.4	360	39	1
14	99.33	325.9	0	55	1
15	99.34	325.9	182	72	1
16	99.55	326.6	202	41	2
17	99.56	326.7	332	34	2
18	99.60	326.8	167	46	2
19	99.77	327.3	183	48	1
20	99.80	327.4	329	33	1
21	99.82	327.5	152	51	1
22	100.00	328.1	330	57	1
23	100.31	329.1	237	31	1
24	100.45	329.6	303	51	1
25	100.54	329.9	43	59	1
26	100.63	330.1	108	36	1
27	100.71	330.4	137	30	1
28	100.79	330.7	101	45	0
29	100.86	330.9	58	31	1
30	100.92	331.1	82	14	1
31	100.97	331.3	46	65	1
32	101.03	331.5	235	44	1
33	101.11	331.7	218	48	0
34	101.56	333.2	18	31	1
35	101.58	333.3	238	22	1
36	101.91	334.4	276	24	0
37	101.98	334.6	194	52	1

All directions are with respect to Magnetic North.

Borehole Deviation

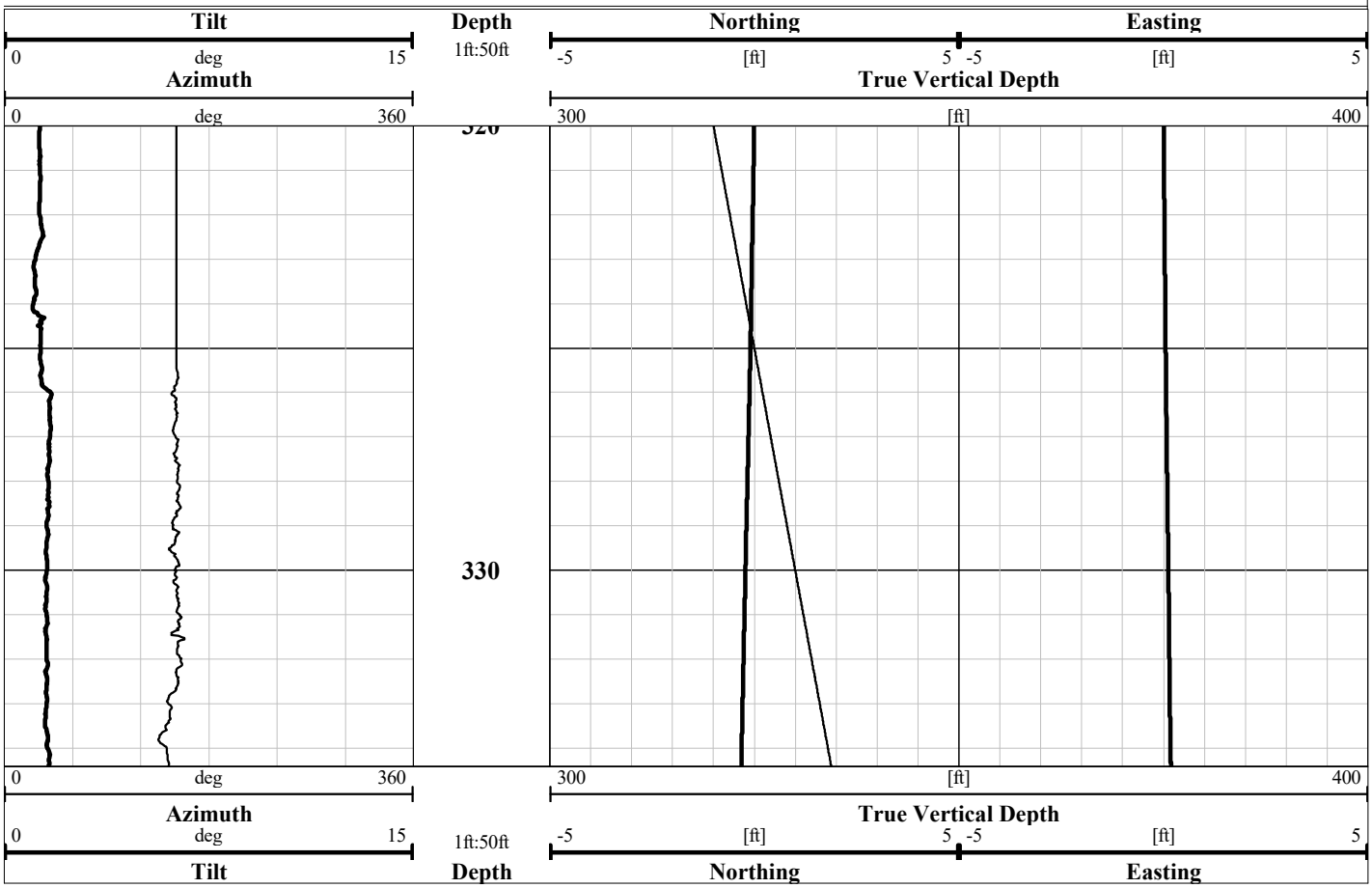
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 16 Nov. 2019	WELL: BH19-26 - Mid Strait

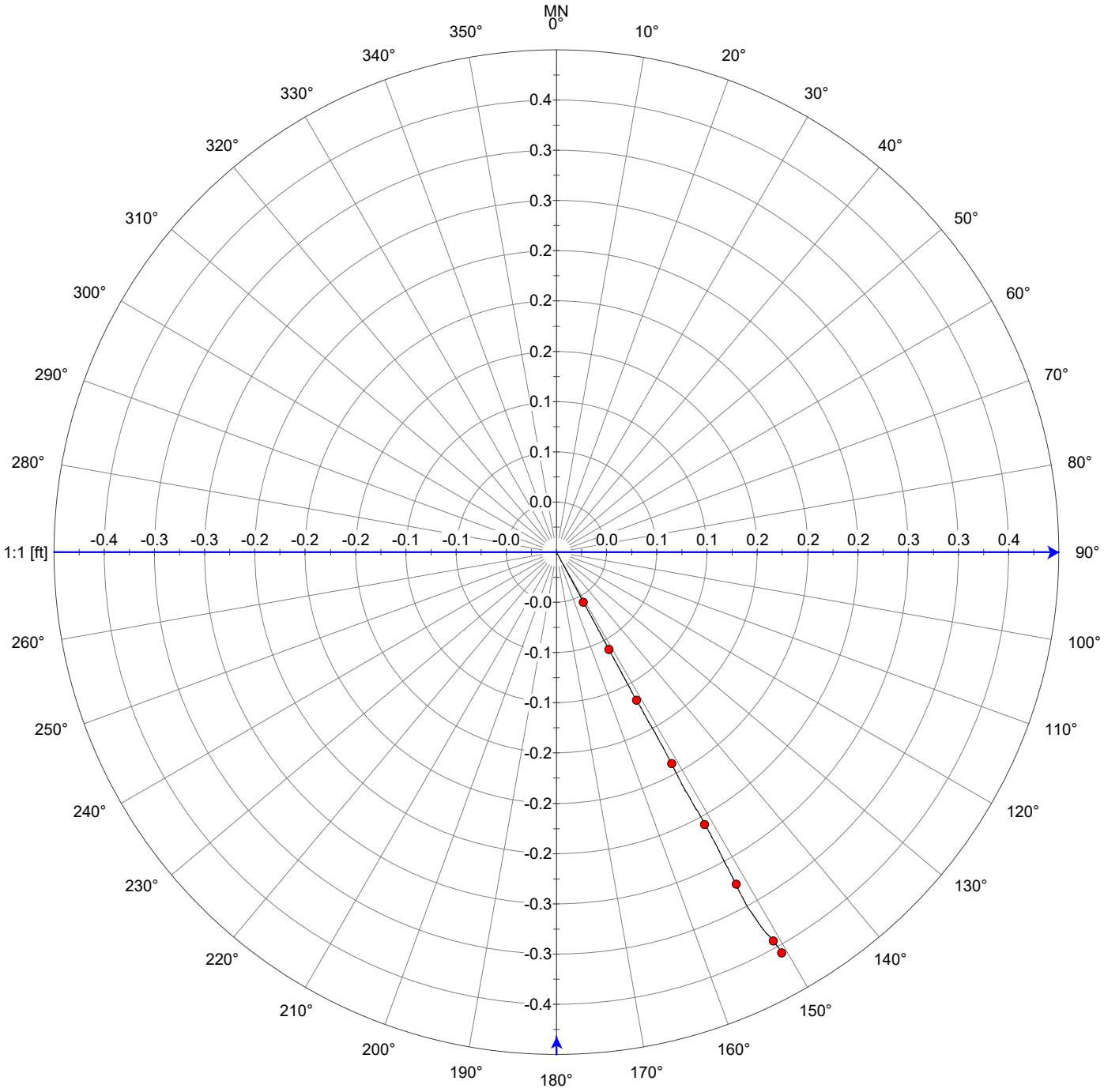
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

borehole geophysics / hydrophysics

COMMENTS:

Straits of Mackinac **Elevation: 396.7'** **Latitude: 45.81661 N** **Longitude: 84.76659 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
0.4
0.3
0.3
0.2
0.2
0.2
0.1
0.1
0.0
-0.0
-0.1
-0.1
-0.2
-0.2
-0.2
-0.3
-0.3
-0.4
-0.4 -0.3 -0.3 -0.2 -0.2 -0.2 -0.1 -0.1 -0.0
0.0 0.1 0.1 0.2 0.2 0.2 0.3 0.3 0.4
1:1 [ft]

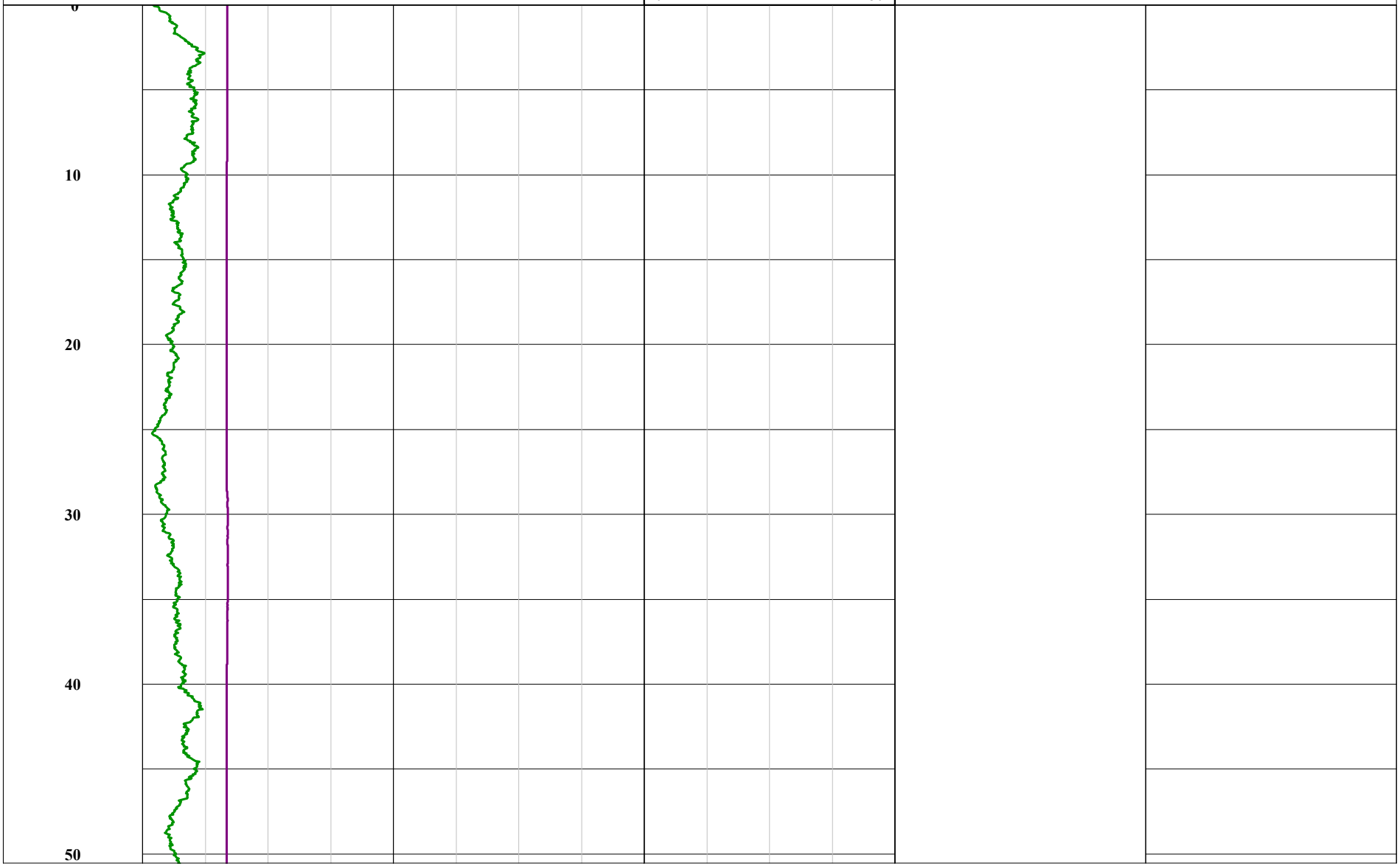
Geophysical Summary Plot

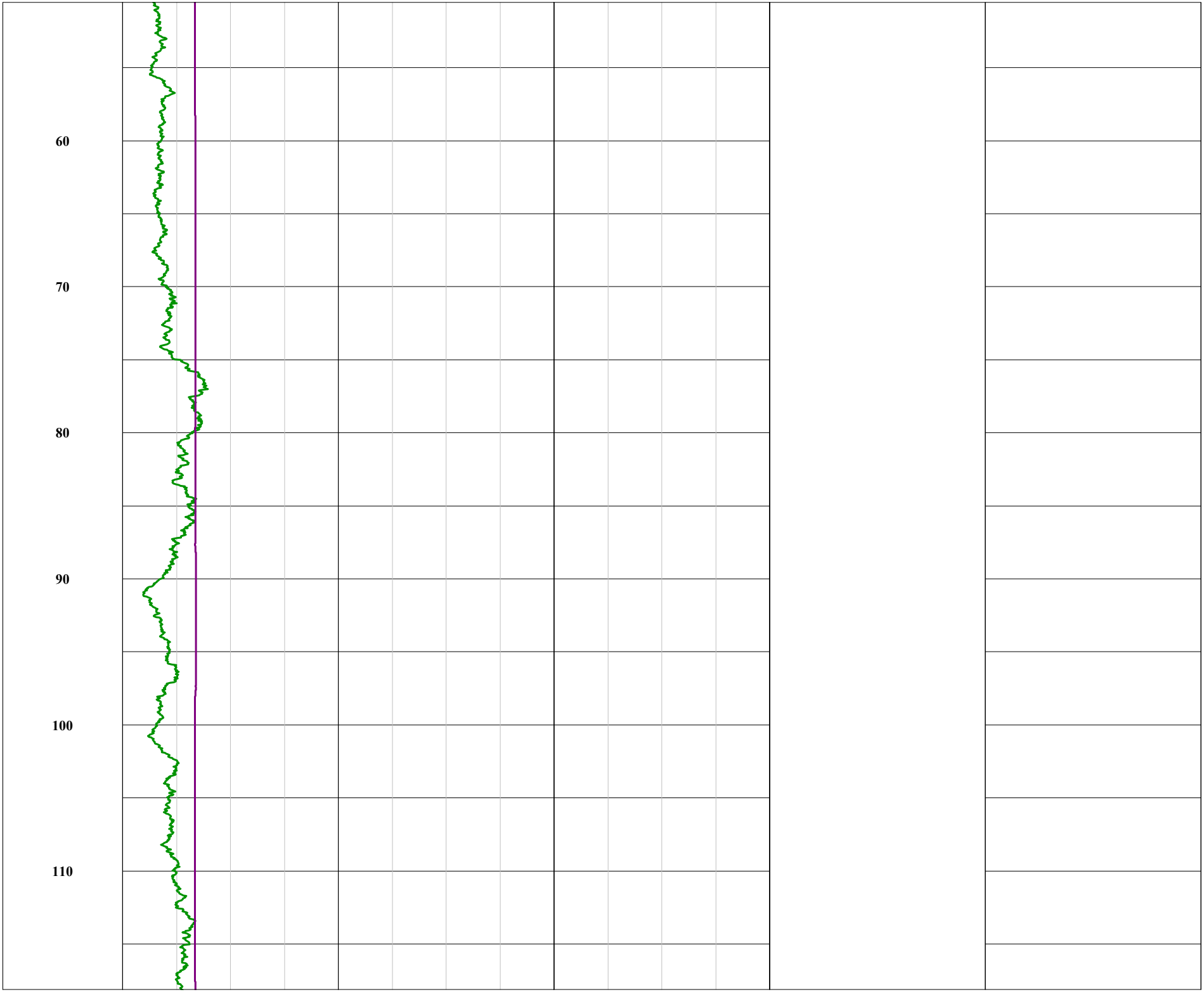
COLOG
borehole geophysics / hydrophysics

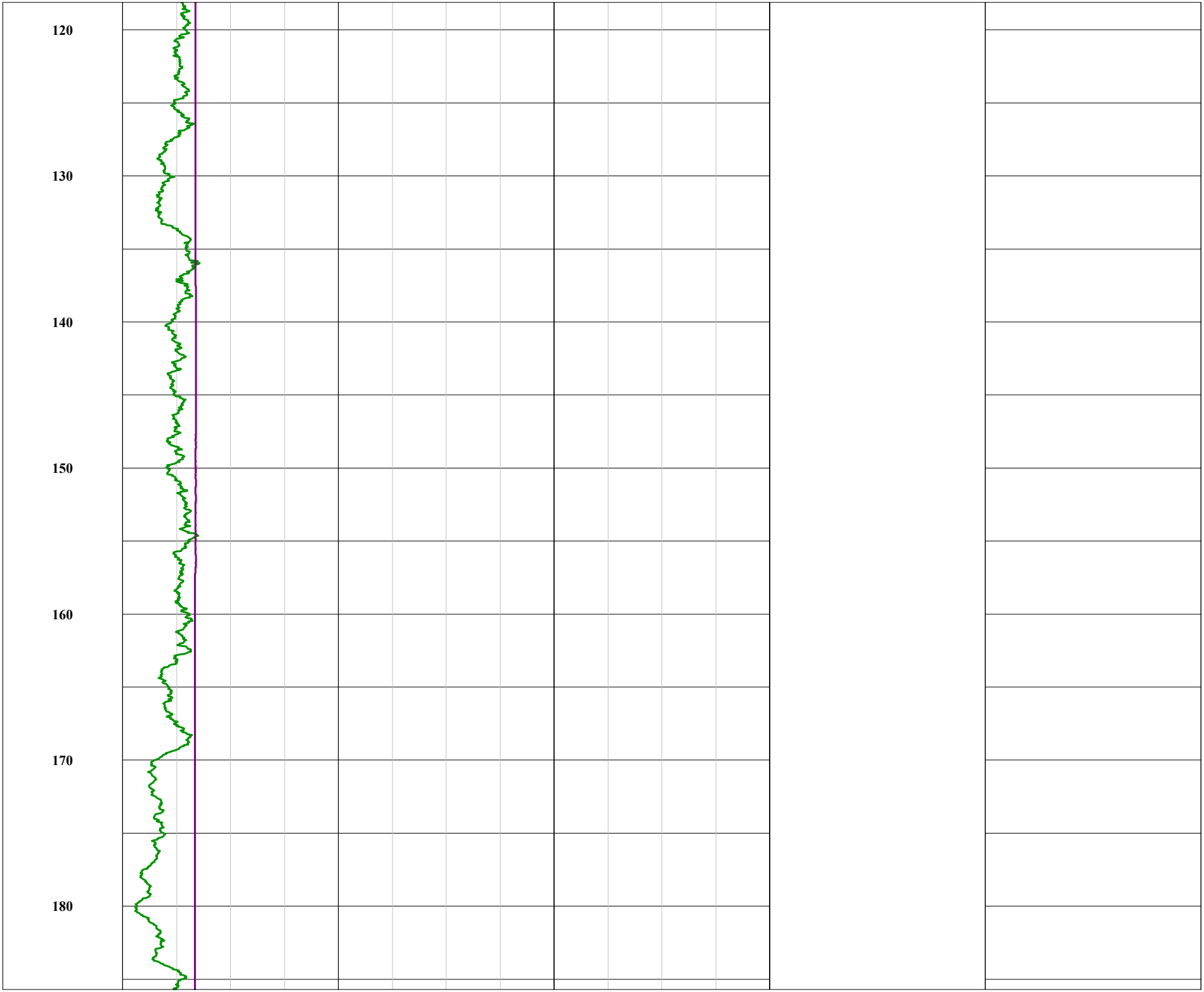
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 1 November 2019
WELL: BH19-27 - Mid Strait

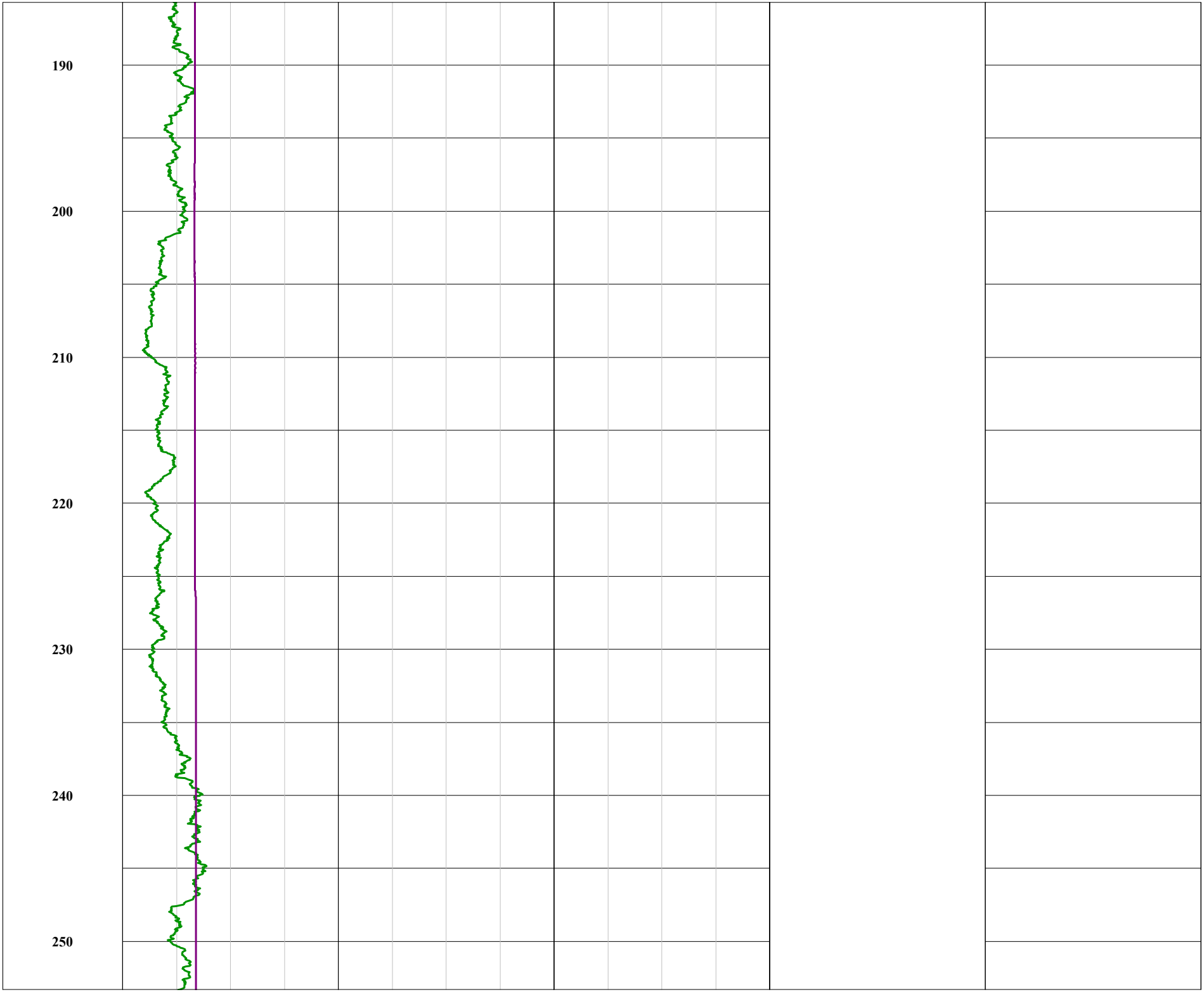
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

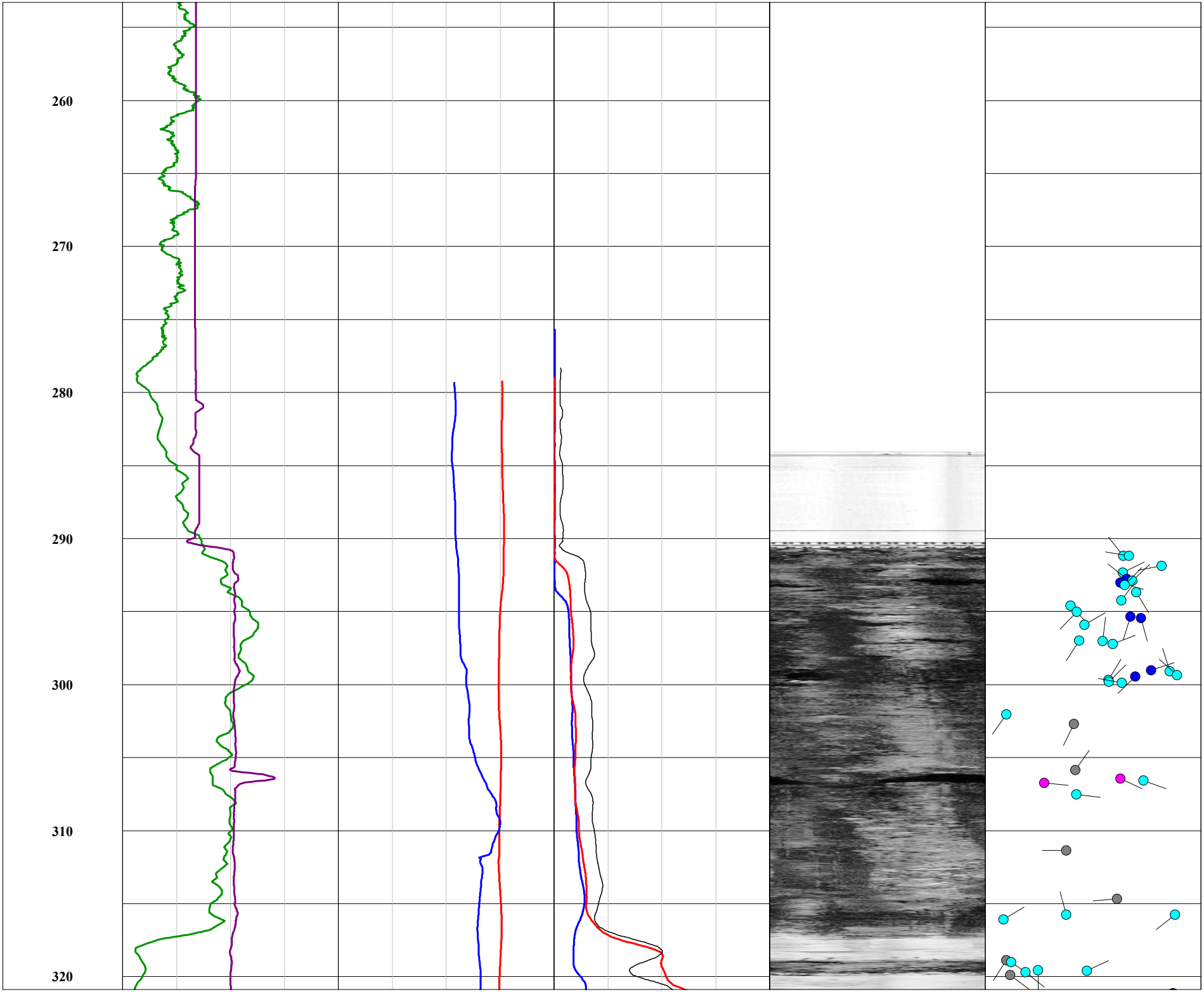
Depth	Natural Gamma	Temperature	64" Normal Resistivity	Amplitude-MN	Tadpoles
1ft:100ft	0 CPS 100	5 deg C 15	0 OHMM 500	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	Fluid Conductivity	16" Normal Resistivity		
	3 Inch 9	0 uS/cm 1000	0 OHMM 500		
			Single-Point Resistance		
			0 OHM 250		

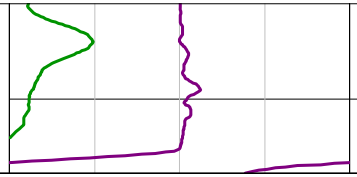


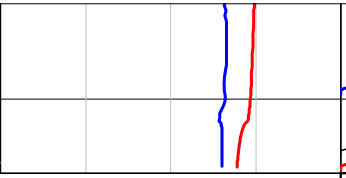

60
70
80
90
100
110

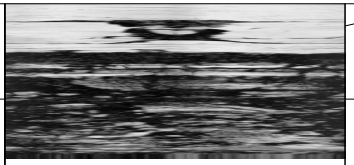

120
130
140
150
160
170
180

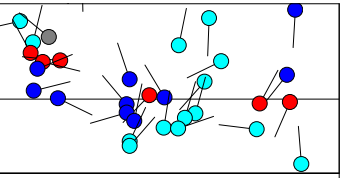

190
200
210
220
230
240
250


260
270
280
290
300
310
320









			0 OHM 250 **Single-Point Resistance**		
	3 Inch 9 **3-Arm Caliper**	0 uS/cm 1000 **Fluid Conductivity**	0 OHMM 500 **16" Normal Resistivity**		
1ft:100ft **Depth**	0 CPS 100 **Natural Gamma**	5 deg C 15 **Temperature**	0 OHMM 500 **64" Normal Resistivity**	0° 90° 180° 270° 0° **Amplitude-MN**	0 90 **Tadpoles**

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-27
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-27
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81551 N
Longitude: 84.76579 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 418.3'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	1 November 2019			
RUN NUMBER	2			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	328.3'			
DEPTH-LOGGER	328'			
BTM LOG INTERVAL	327.6'			
TOP LOG INTERVAL	284'			
RECORDED BY	JBG			
WITNESSED BY	WSP			
PROBE TYPE, S/N	ALT ABI #111018			
LOGGING SPEED	5 fpm			
A.S.D.E. / Sample Interval	0.6' / 0.0024'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

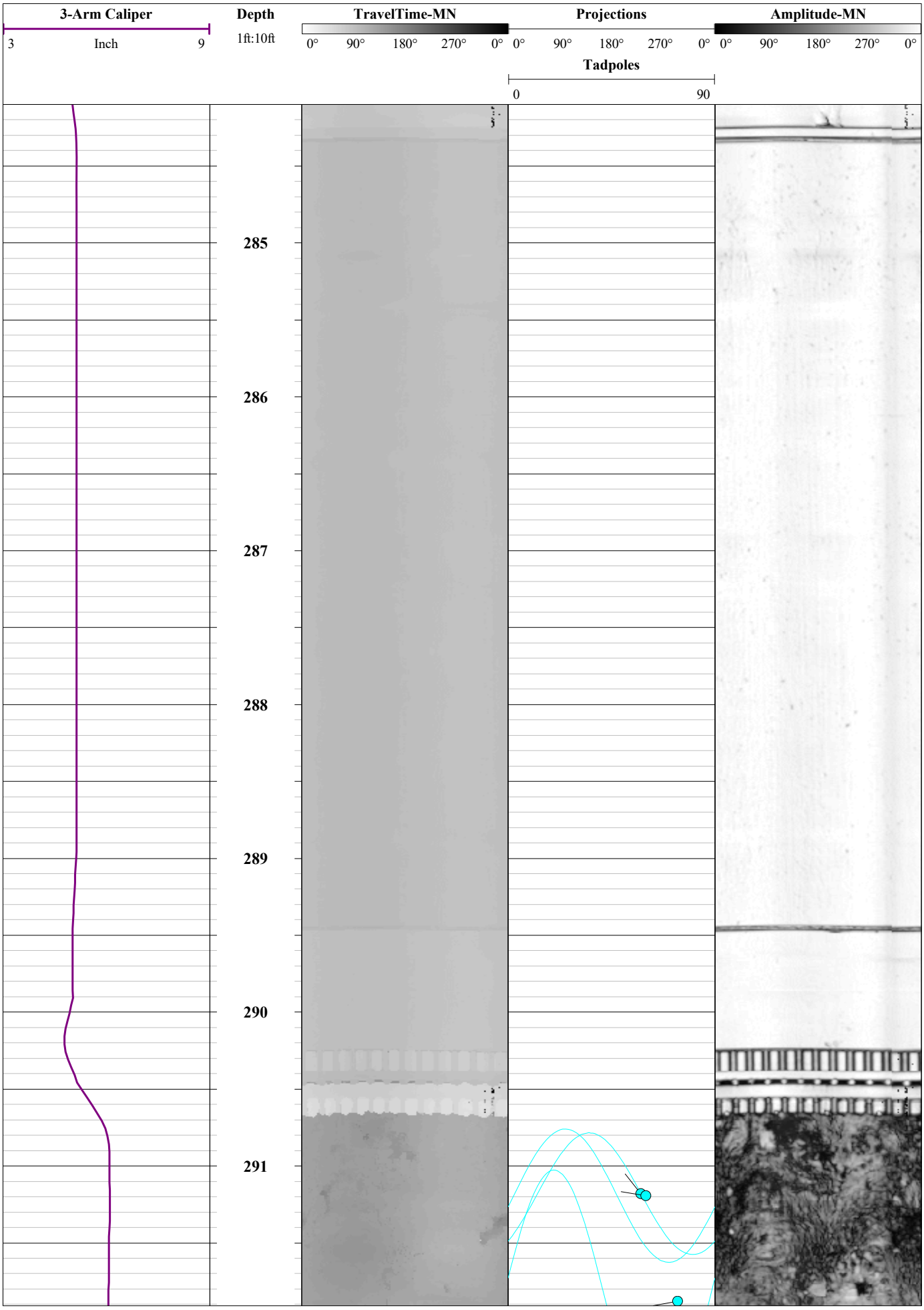
RUN No.	BIT	FROM	TO
1	7"	TOC	75.13'

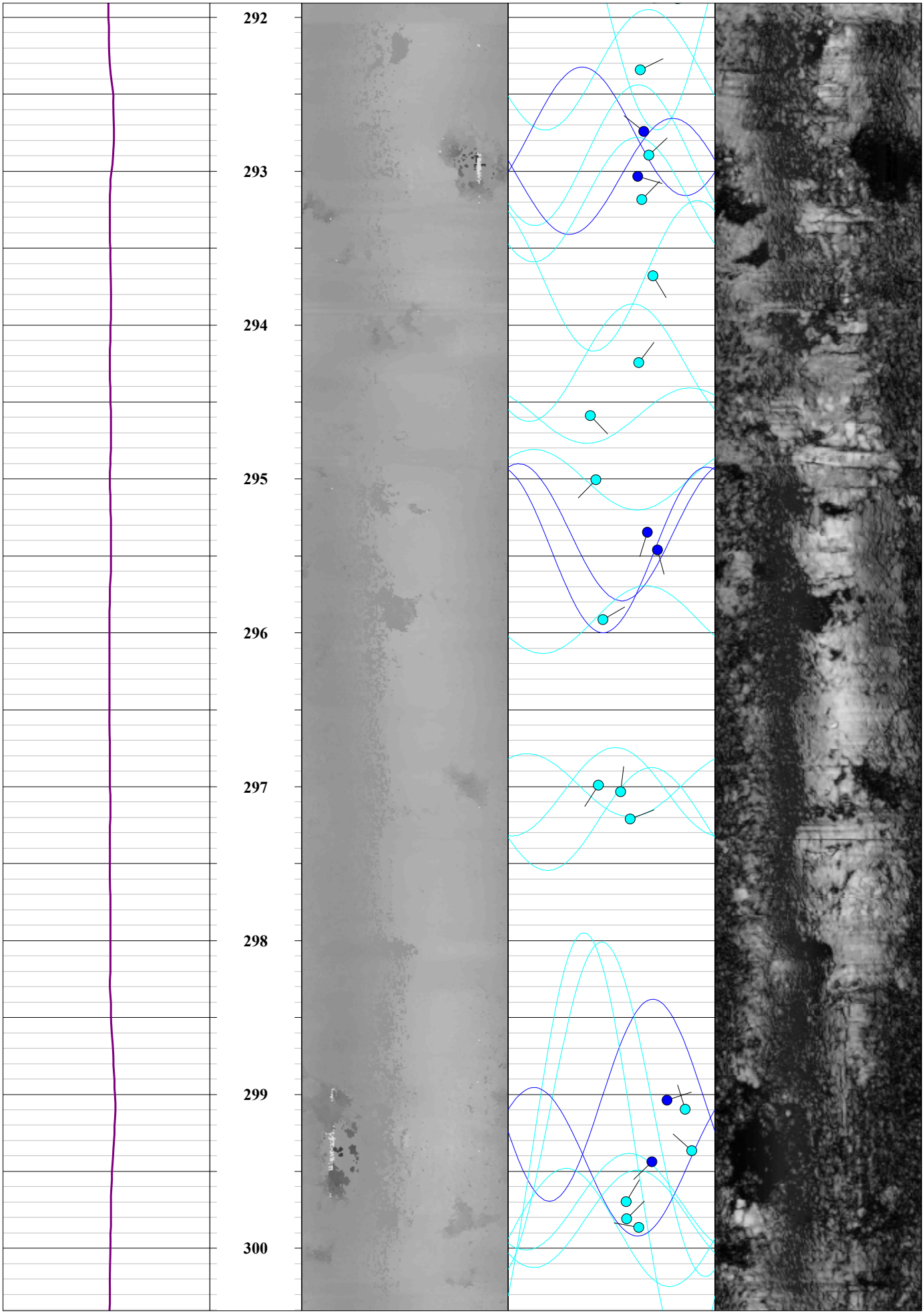
CASING RECORD

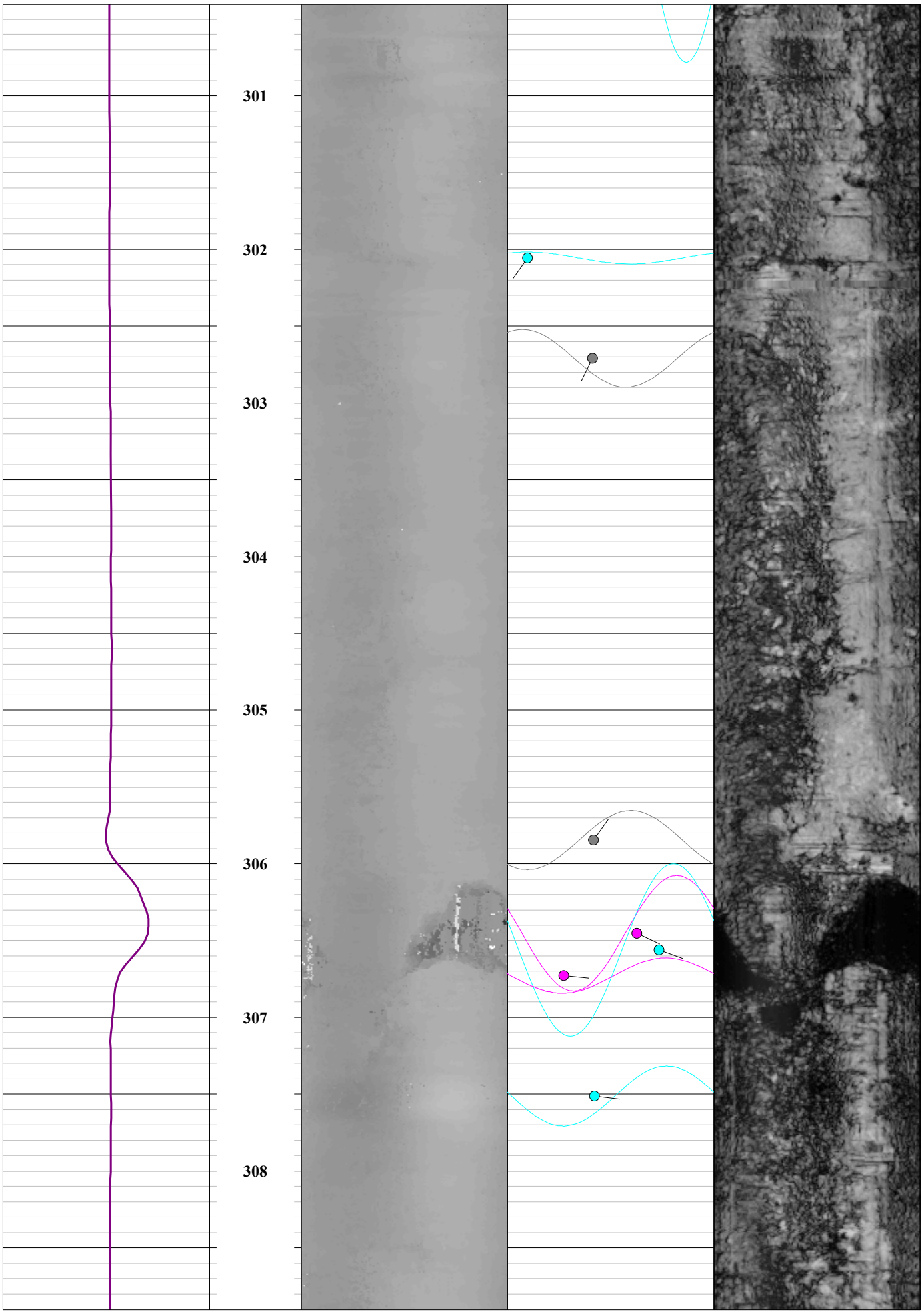
SIZE	WGT.	FROM	TO
6"	Steel	TOC	290.28'

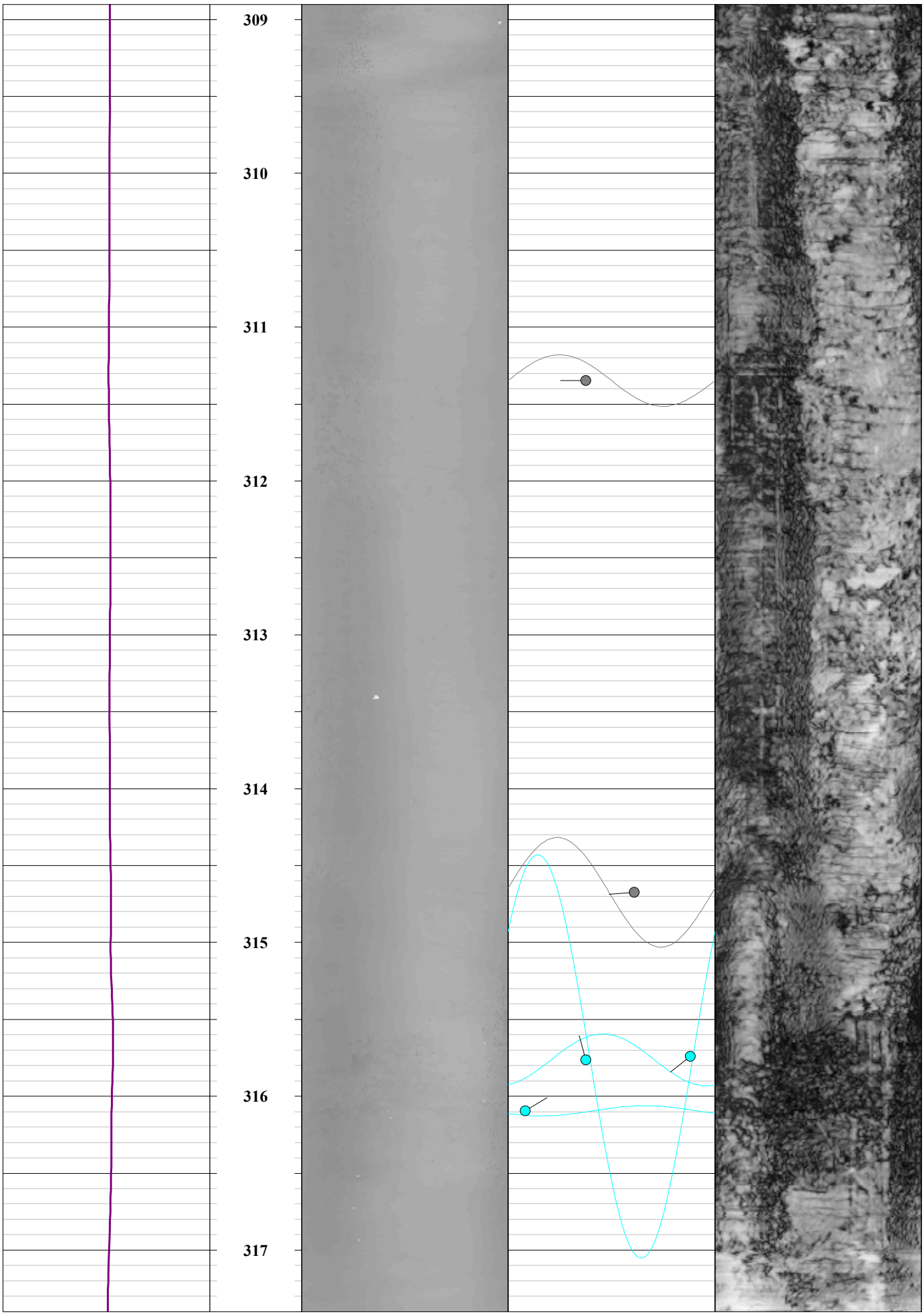
NA - Not Available, N/A - Not Applicable

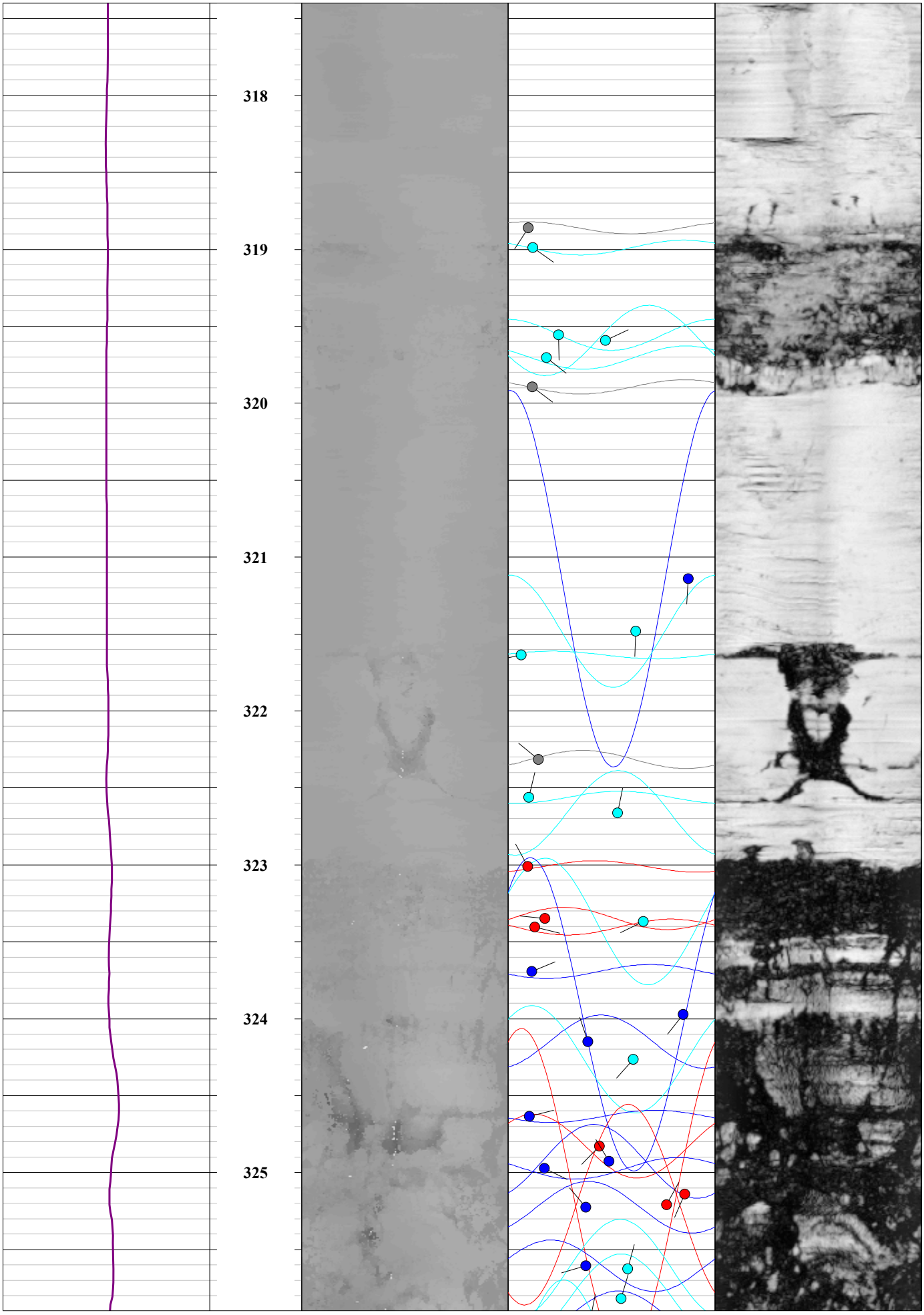
COMMENTS

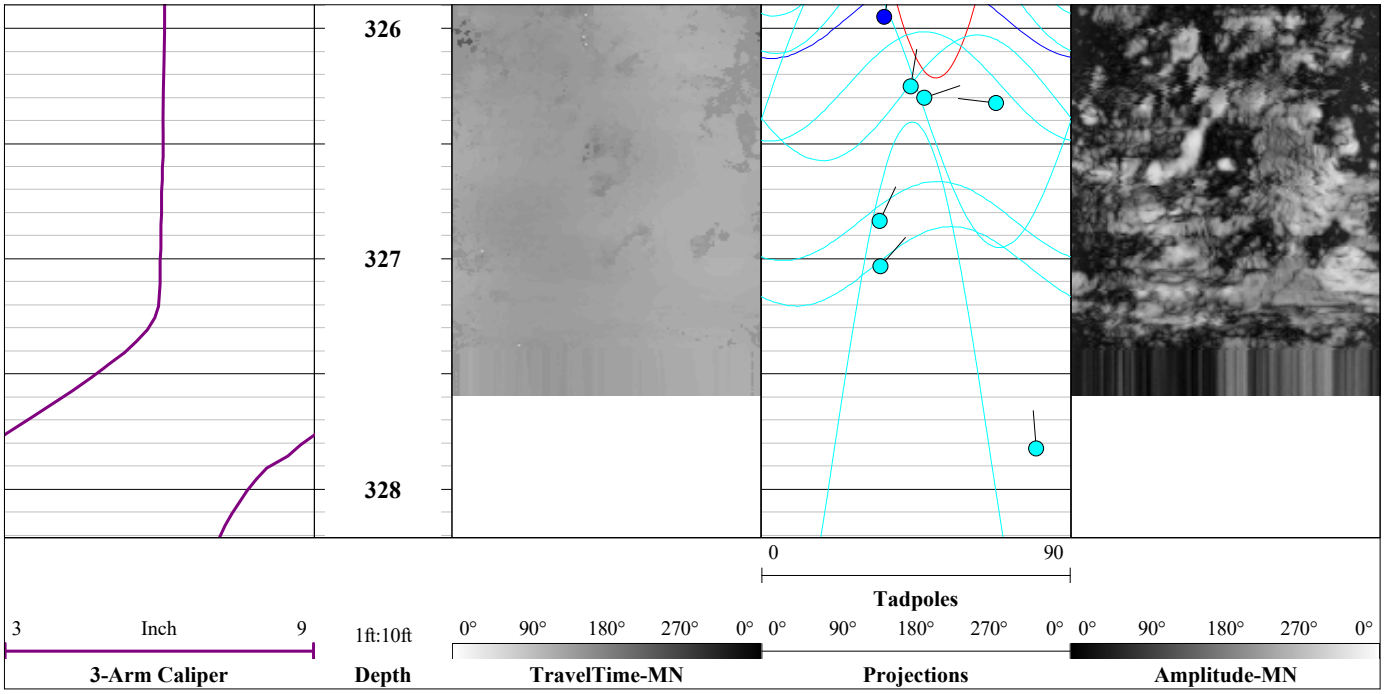

3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-MN
0° 90° 180° 270° 0°
Projections
0° 90° 180° 270° 0°
Tadpoles
0
90
Amplitude-MN
0° 90° 180° 270° 0°
285
286
287
288
289
290
291


292
293
294
295
296
297
298
299
300

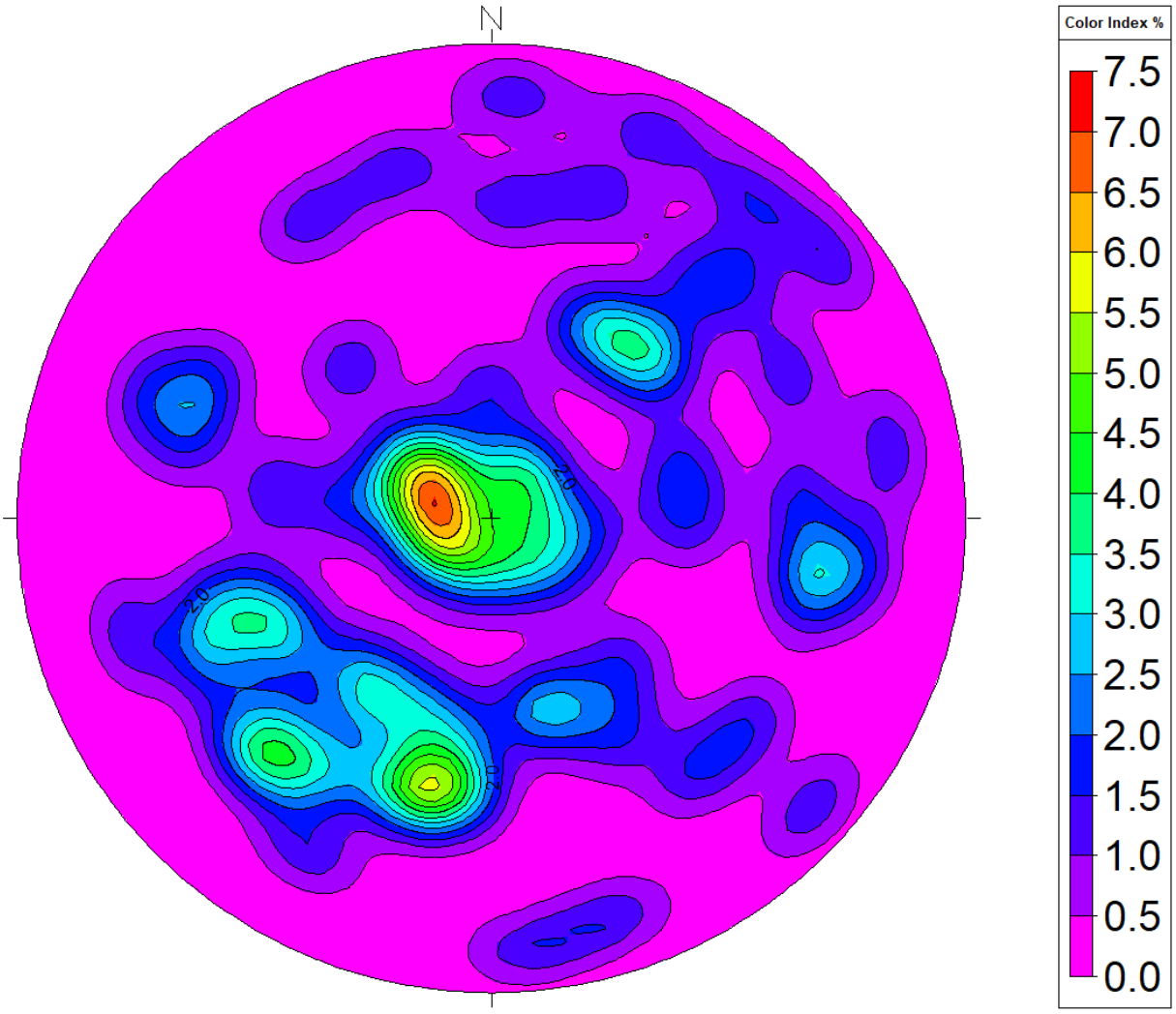

301
302
303
304
305
306
307
308


309
310
311
312
313
314
315
316
317


318
319
320
321
322
323
324
325

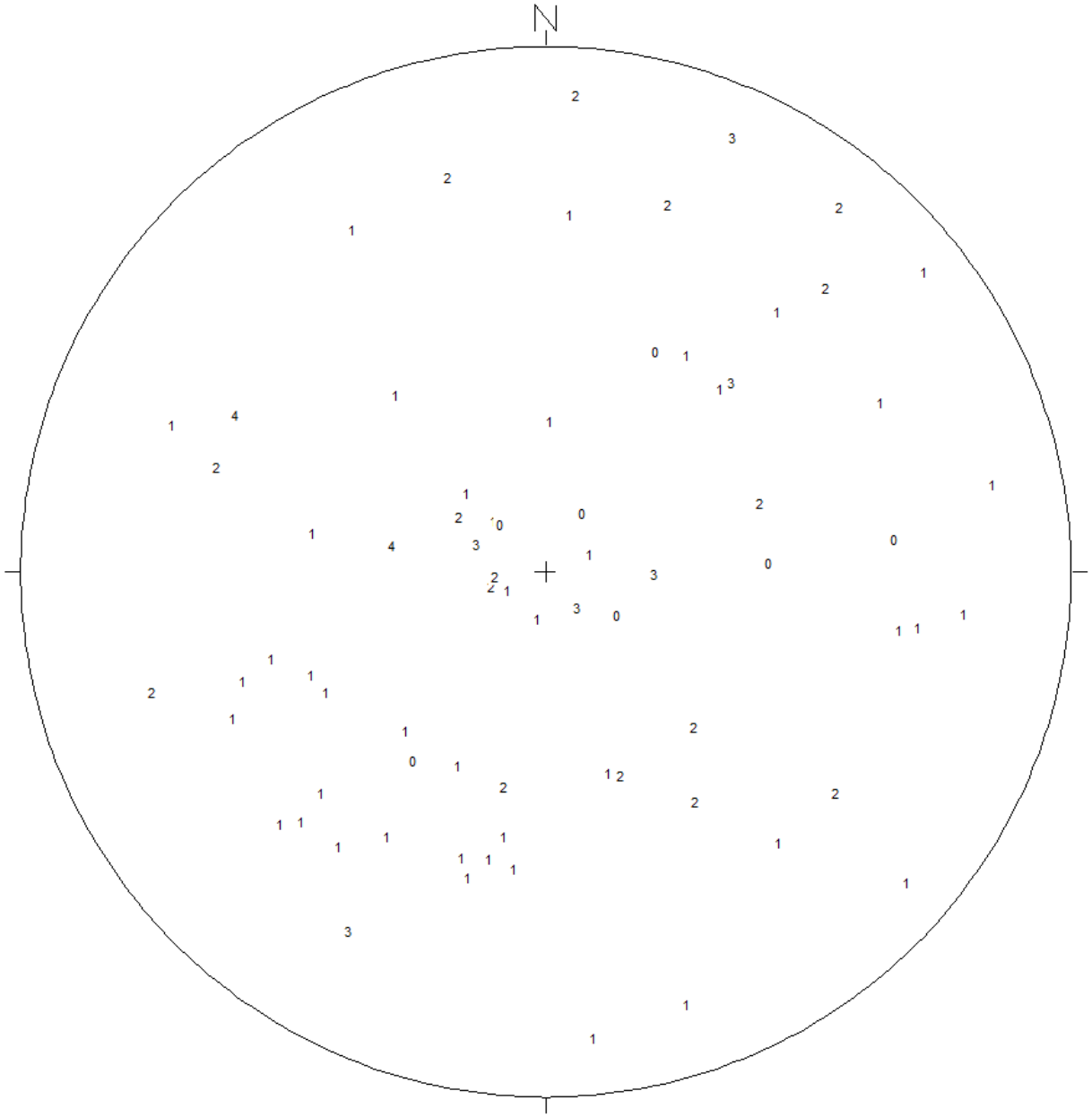

326
327
328
0
90
Tadpoles
3
Inch
9
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-27
1 November 2019



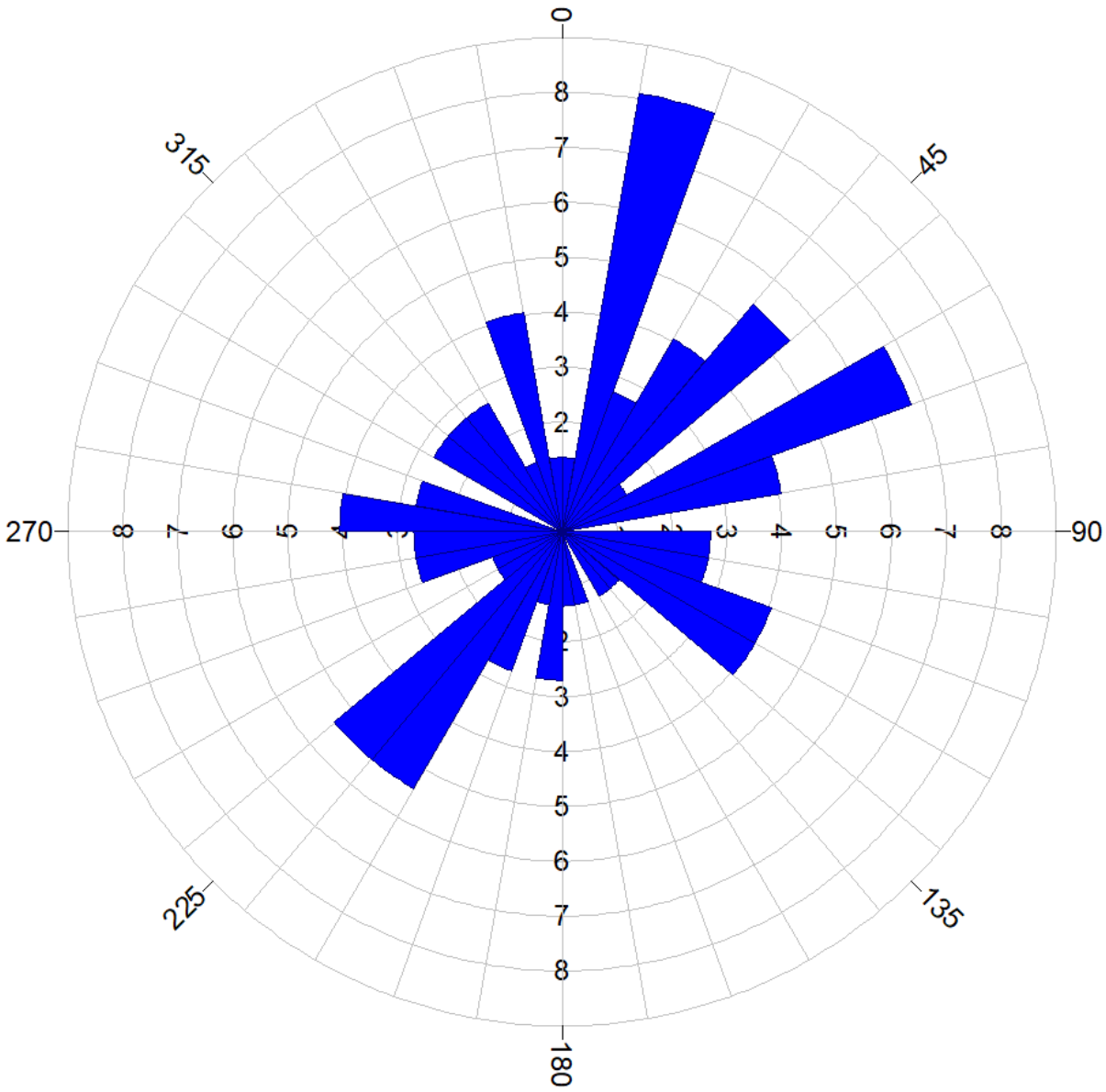
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-27
1 November 2019



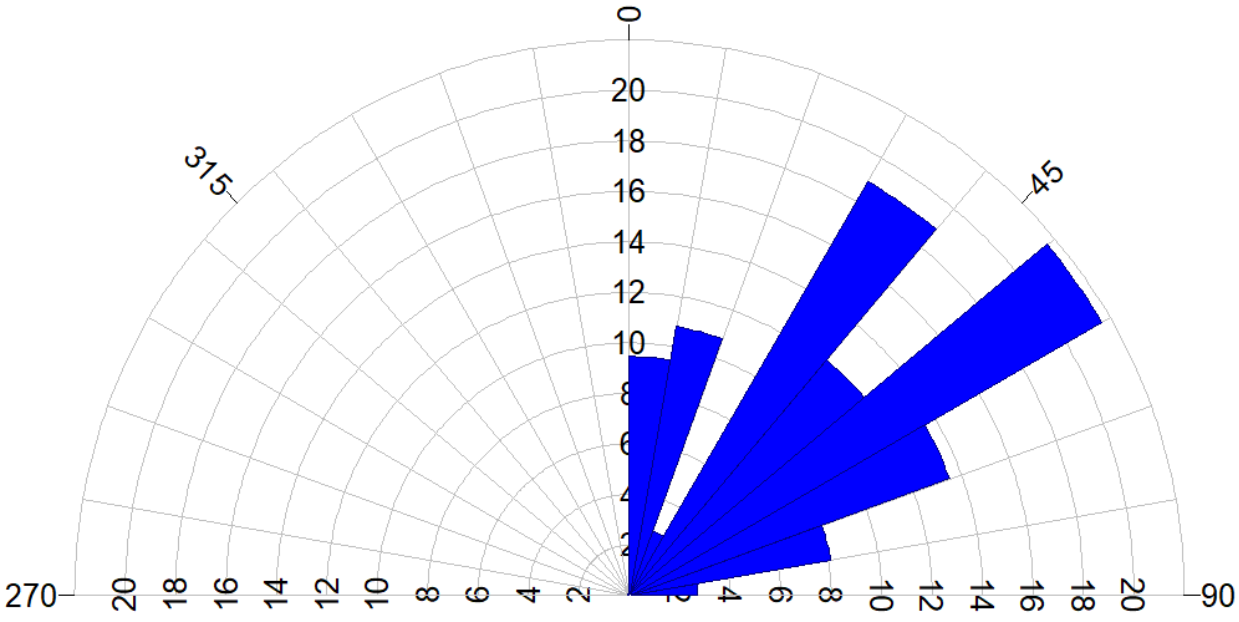
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-27
1 November 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-27
1 November 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-27

1 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	88.75	291.2	321	58	1
2	88.75	291.2	280	60	1
3	88.97	291.9	260	74	1
4	89.11	292.3	64	57	1
5	89.23	292.7	309	59	2
6	89.28	292.9	46	61	1
7	89.32	293.0	106	56	2
8	89.36	293.2	44	58	1
9	89.51	293.7	149	63	1
10	89.68	294.2	37	57	1
11	89.79	294.6	137	36	1
12	89.92	295.0	224	38	1
13	90.02	295.4	198	61	2
14	90.06	295.5	165	65	2
15	90.19	295.9	60	41	1
16	90.52	297.0	213	39	1
17	90.53	297.0	7	49	1
18	90.59	297.2	69	53	1
19	91.15	299.0	72	69	2
20	91.17	299.1	343	77	1
21	91.24	299.4	312	80	1
22	91.27	299.4	225	63	2
23	91.35	299.7	31	51	1
24	91.38	299.8	45	52	1
25	91.40	299.9	281	57	1
26	92.07	302.1	215	9	1
27	92.27	302.7	206	37	0
28	93.22	305.9	35	38	0
29	93.41	306.5	115	56	4
30	93.44	306.6	110	66	1
31	93.49	306.7	96	25	4
32	93.73	307.5	97	38	1
33	94.90	311.4	270	34	0
34	95.91	314.7	266	55	0
35	96.24	315.7	232	79	1
36	96.24	315.8	345	34	1
37	96.34	316.1	58	8	1
38	97.19	318.9	212	9	0
39	97.23	319.0	126	11	1
40	97.40	319.6	179	22	1
41	97.41	319.6	65	42	1
42	97.44	319.7	129	17	1
43	97.50	319.9	127	10	0
44	97.88	321.1	183	78	2
45	97.99	321.5	183	56	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-27

1 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	98.04	321.6	257	6	1
47	98.24	322.3	309	13	0
48	98.32	322.6	14	9	1
49	98.35	322.7	12	48	1
50	98.45	323.0	331	8	3
51	98.56	323.4	276	16	3
52	98.56	323.4	244	59	1
53	98.58	323.4	104	12	3
54	98.66	323.7	68	10	2
55	98.75	324.0	219	76	2
56	98.80	324.2	342	35	2
57	98.83	324.3	222	54	1
58	98.95	324.6	76	9	2
59	99.01	324.8	225	40	3
60	99.04	324.9	329	44	2
61	99.05	325.0	116	16	2
62	99.10	325.1	203	77	3
63	99.12	325.2	29	69	3
64	99.13	325.2	319	34	2
65	99.25	325.6	254	34	2
66	99.25	325.6	15	52	1
67	99.31	325.8	17	49	1
68	99.35	326.0	12	36	2
69	99.44	326.3	10	44	1
70	99.46	326.3	71	47	1
71	99.46	326.3	277	68	1
72	99.62	326.8	25	35	1
73	99.68	327.0	41	35	1
74	99.92	327.8	355	80	1

All directions are with respect to Magnetic North.

Borehole Deviation

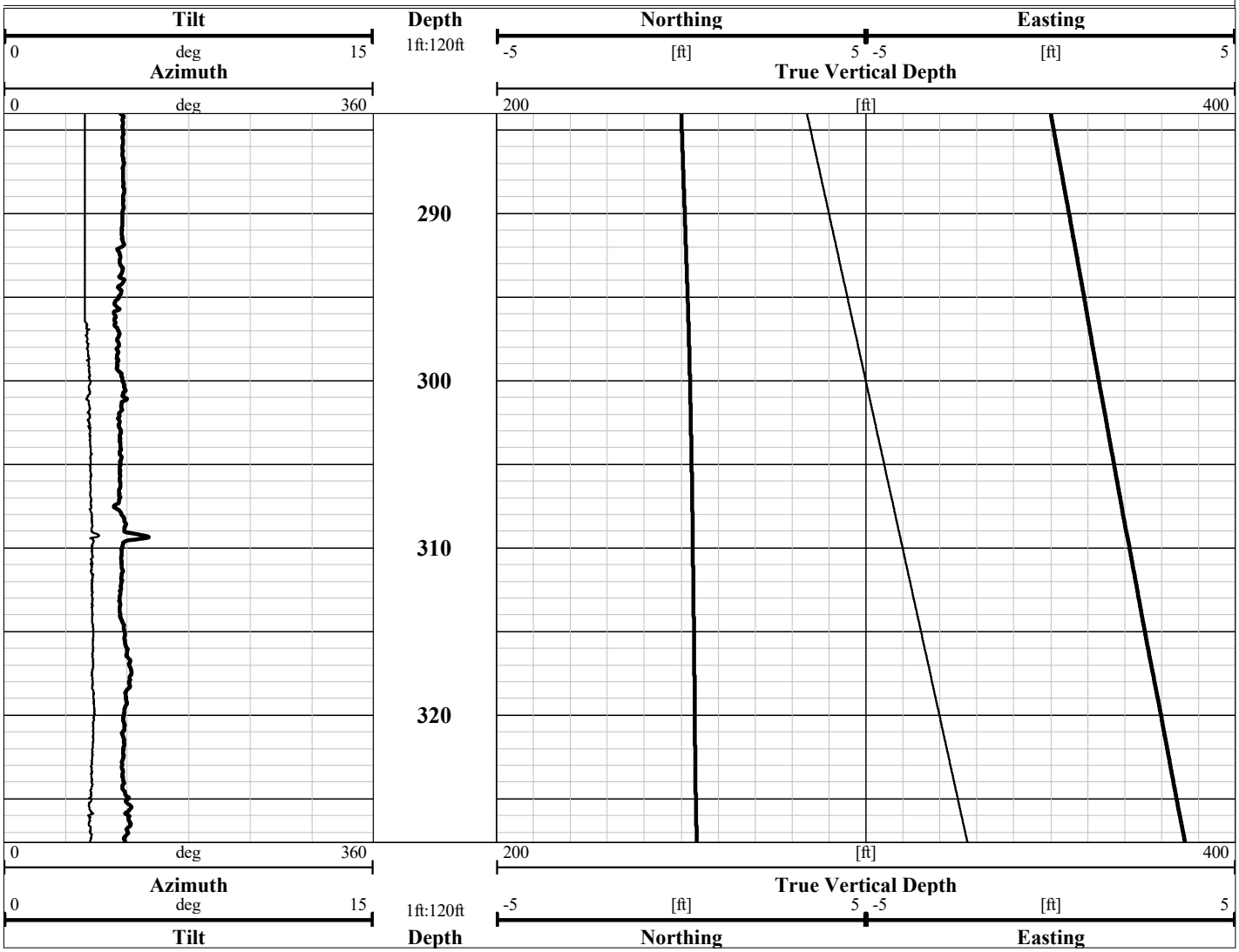
COLOG
borehole geophysics / hydrophysics

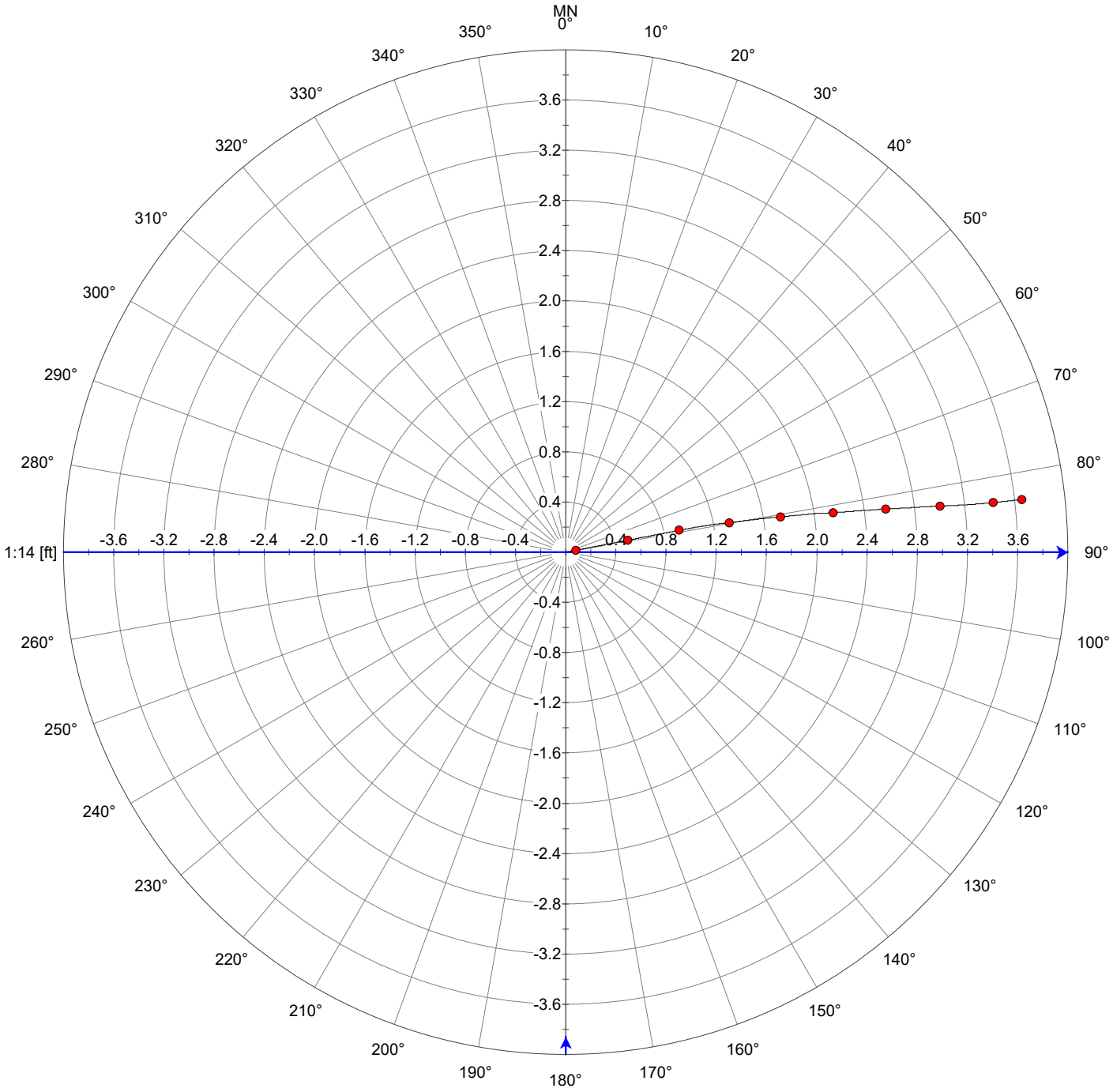
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 1 November 2019	WELL: BH19-27 - Mid Strait

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 418.3'** **Latitude: 45.81551 N** **Longitude: 84.76579 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
-0.4
-0.8
-1.2
-1.6
-2.0
-2.4
-2.8
-3.2
-3.6
1:14 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-27
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-27
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81551 N
Longitude: 84.76579 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Fluid Temp. & Cond.
3-Arm Caliper

PERMANENT DATUM Mudline **ELEVATION** 418.3'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	1 November 2019	1 November 2019		
RUN NUMBER	4	4		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	328.3'	328.3'		
DEPTH-LOGGER	328'	328'		
BTM LOG INTERVAL	326.6'	327.9'		
TOP LOG INTERVAL	0.0'	275.7'		
RECORDED BY	JBG	JBG		
WITNESSED BY	WSP	WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 ft/min	20 ft/min		
A.S.D.E. / Sample Interval	0.2' / 0.25'	0.2' / 0.25'		
Fluid Level / Fluid Type	NA/ water	NA/ water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	7"	TOC	75.13'

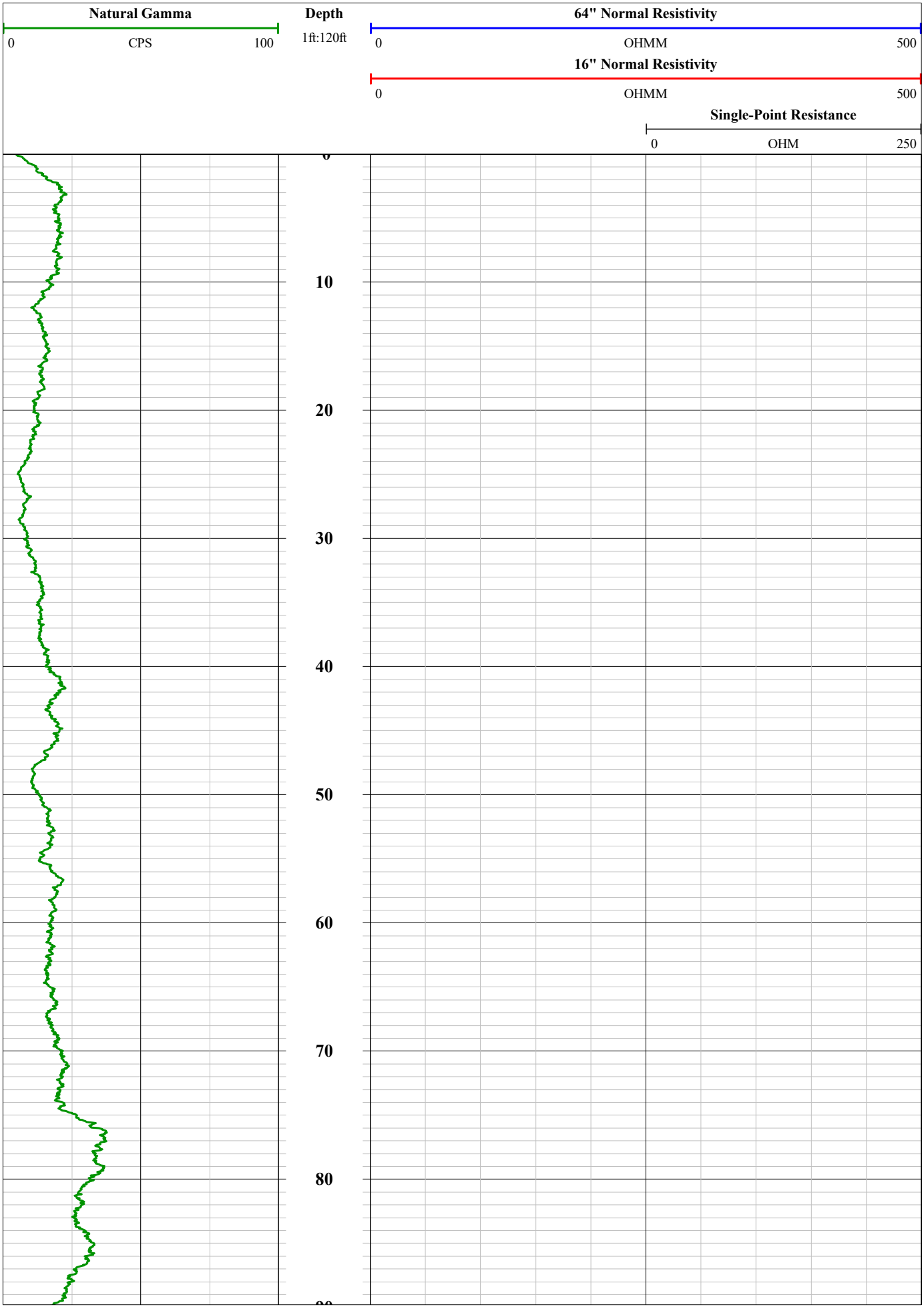
CASING RECORD

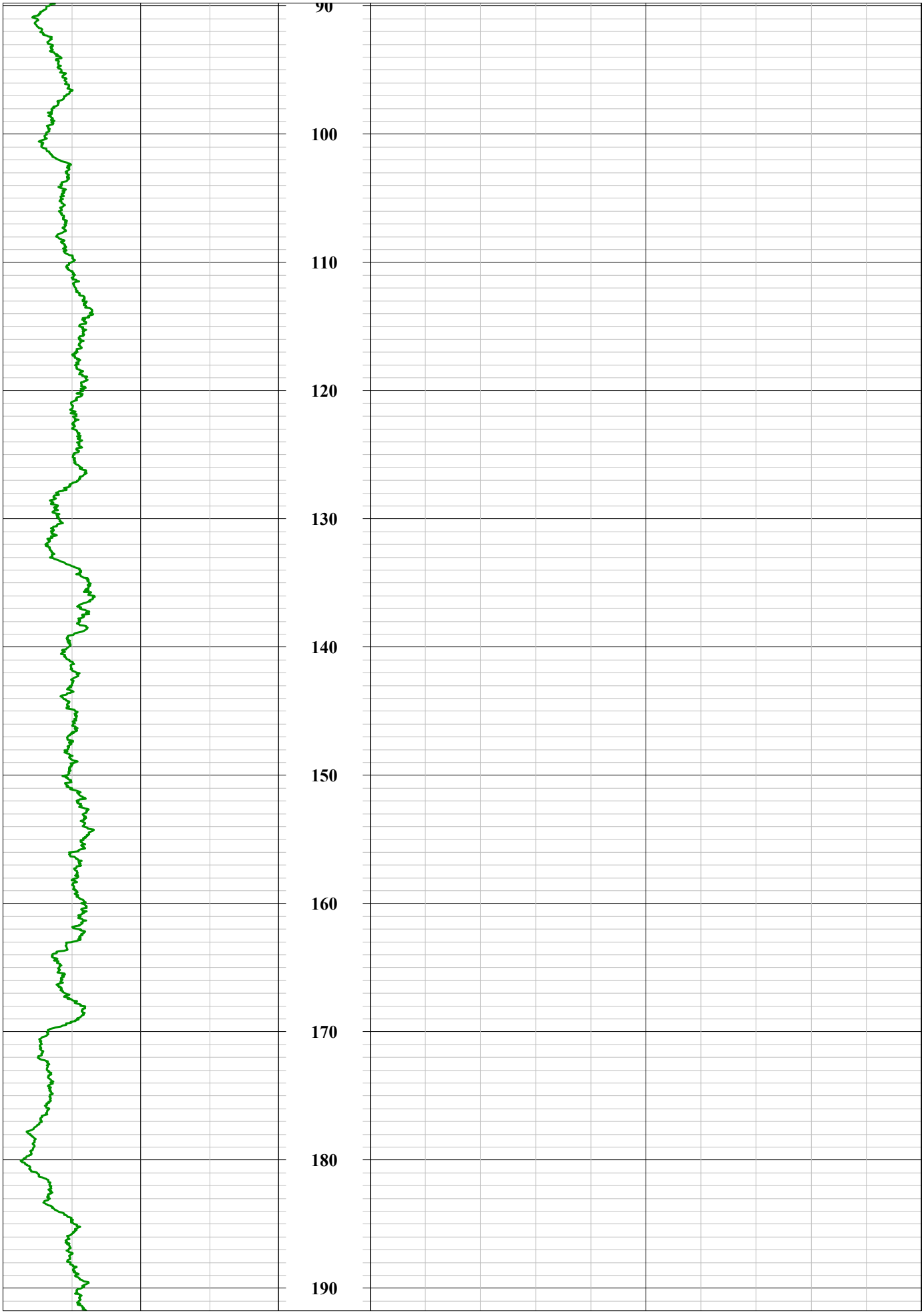
SIZE	WGT.	FROM	TO
6"	Steel	TOC	290.28'

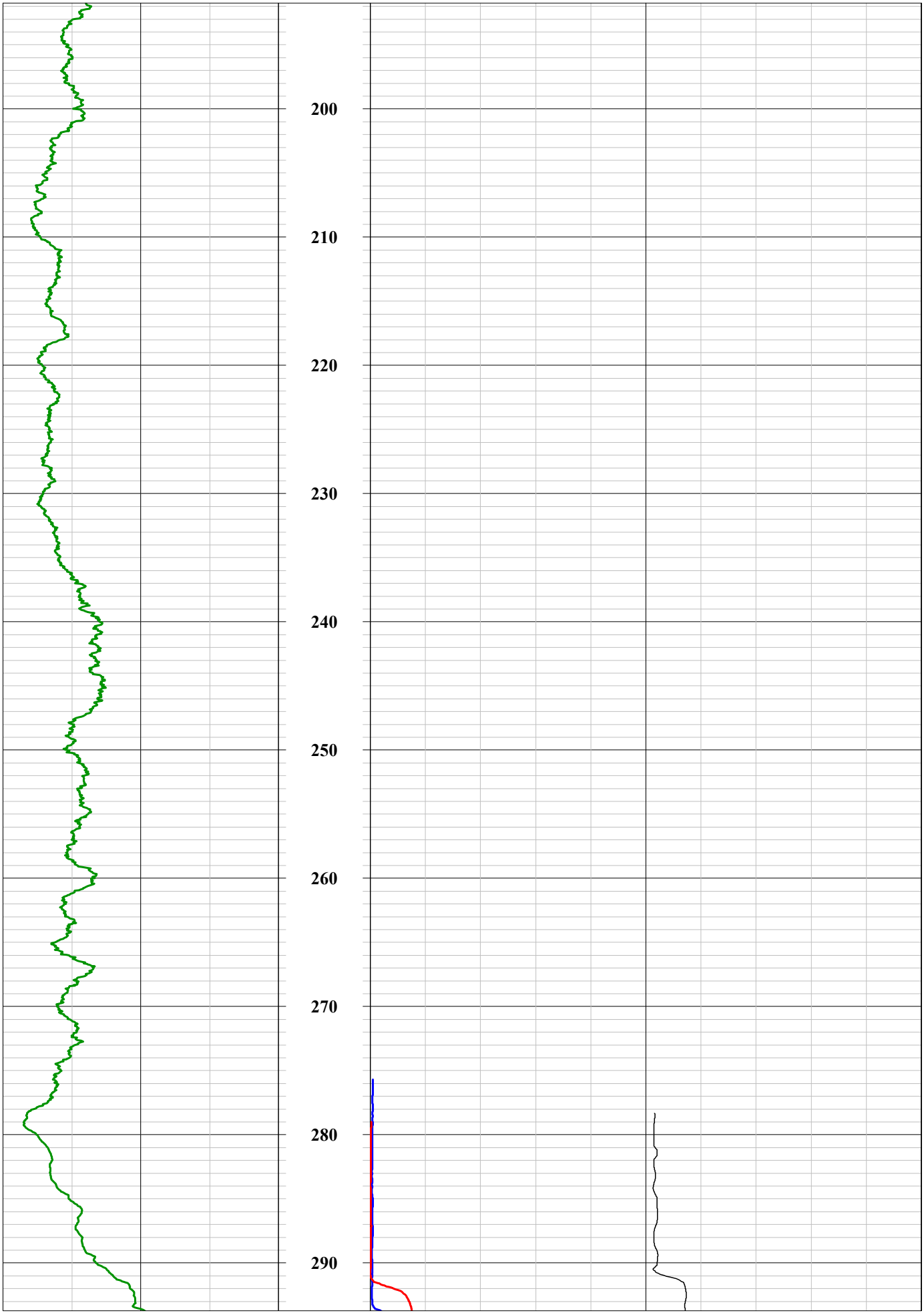
NA - Not Available, N/A - Not Applicable

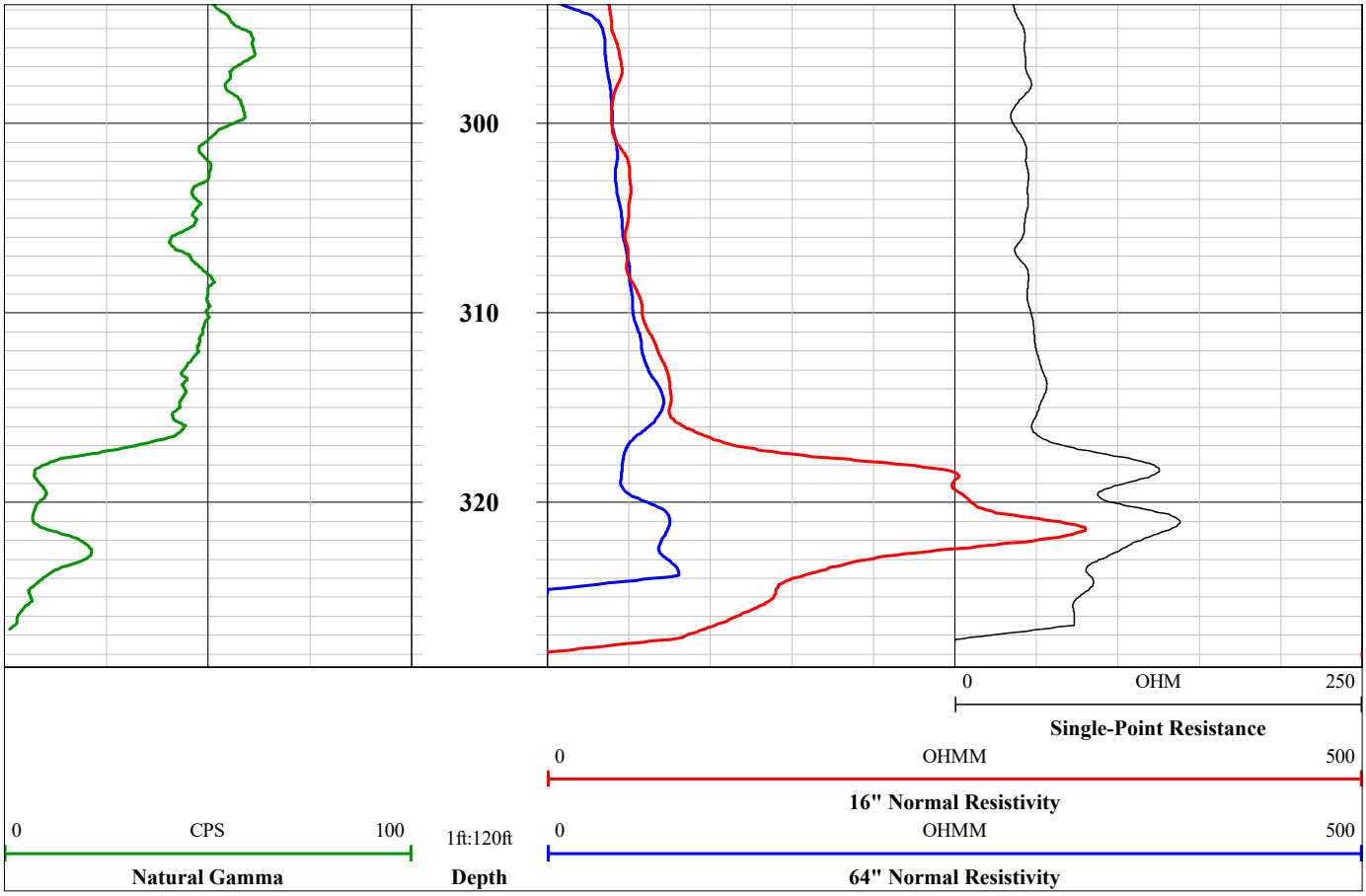
COMMENTS

Spontaneous Potential omitted due to configuration error.


Natural Gamma
0
CPS
100
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
500
16" Normal Resistivity
0
OHMM
500
Single-Point Resistance
0
OHM
250
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
320
0
OHM
250
Single-Point Resistance
0
OHMM
500
16" Normal Resistivity
0
CPS
100
1ft:120ft
0
OHMM
500
Natural Gamma
Depth
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-27
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-27
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81551 N
Longitude: 84.76579 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
Acoustic Televiewer

PERMANENT DATUM Mudline **ELEVATION** 418.3'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	1 November 2019	1 November 2019	1 November 2019	
RUN NUMBER	1	3	4	
LOG TYPE	Fluid Temp & Cond	3-Armed Caliper	Natural Gamma	
DEPTH-DRILLER	328.3'	328.3'	328.3'	
DEPTH-LOGGER	328'	328'	328'	
BTM LOG INTERVAL	328'	327.9'	326.6'	
TOP LOG INTERVAL	279.3'	0.0'	0.0'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	WSP	WSP	WSP	
PROBE TYPE, S/N	2PFA #3656	3ACS#3596	ELXG #4314	
LOGGING SPEED	15 ft/min	14 ft/min	20 ft/min	
A.S.D.E. / Sample Interval	0.7' / 0.10'	0.3' / 0.10'	0.2' / 0.25'	
Fluid Level / Fluid Type	NA / water	NA / water	NA / water	

BOREHOLE RECORD

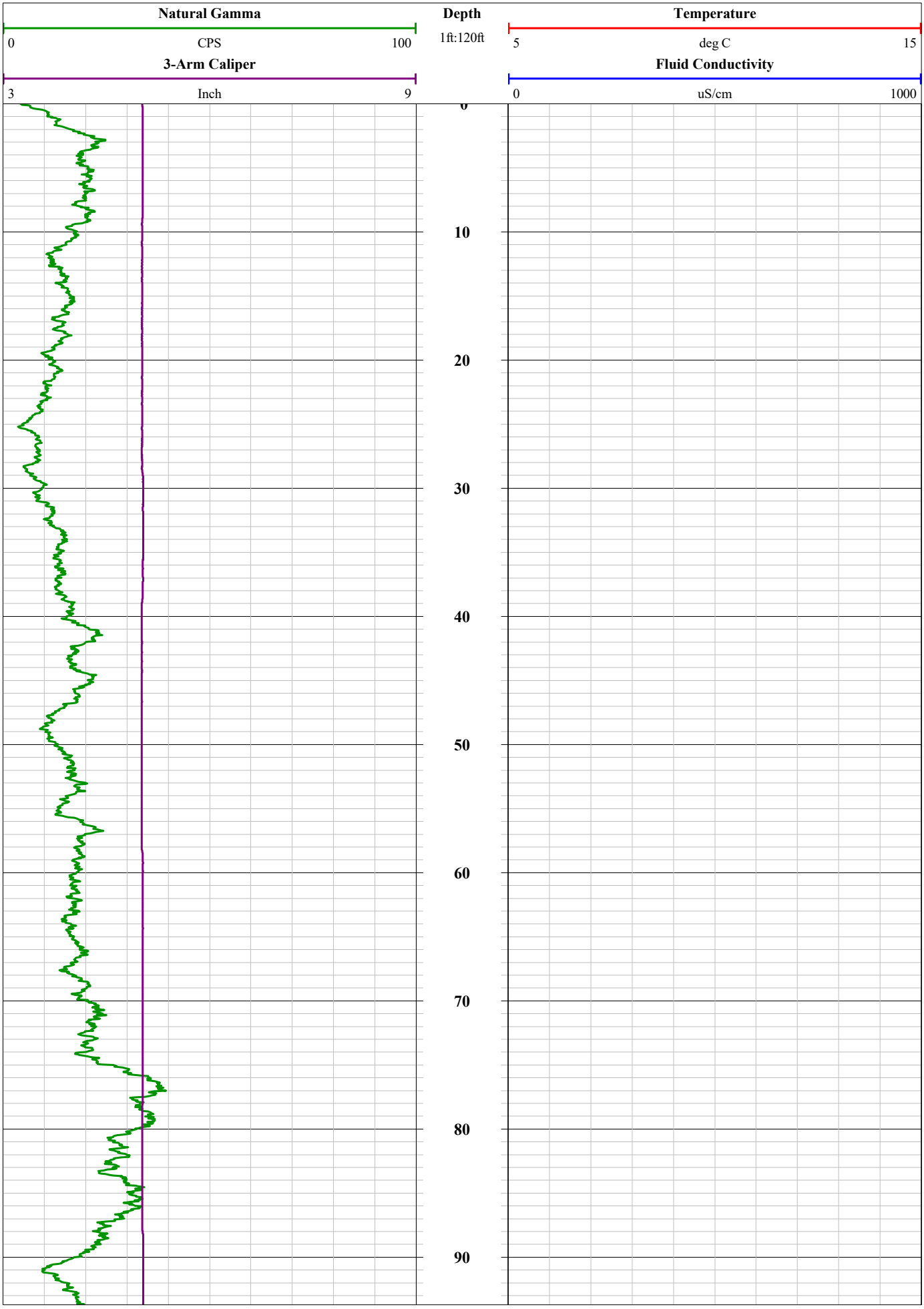
RUN No.	BIT	FROM	TO
1	7"	TOC	75.13'

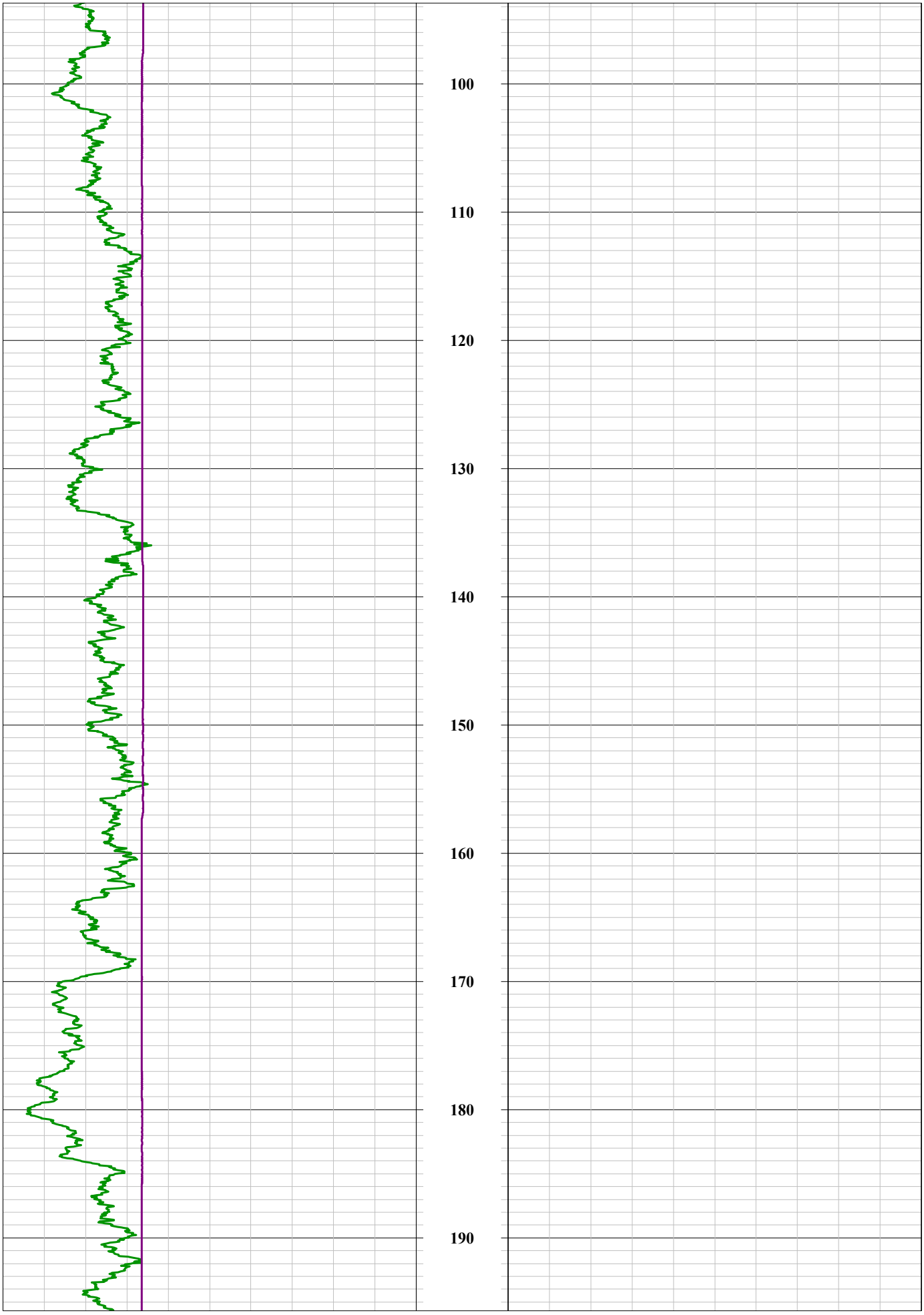
CASING RECORD

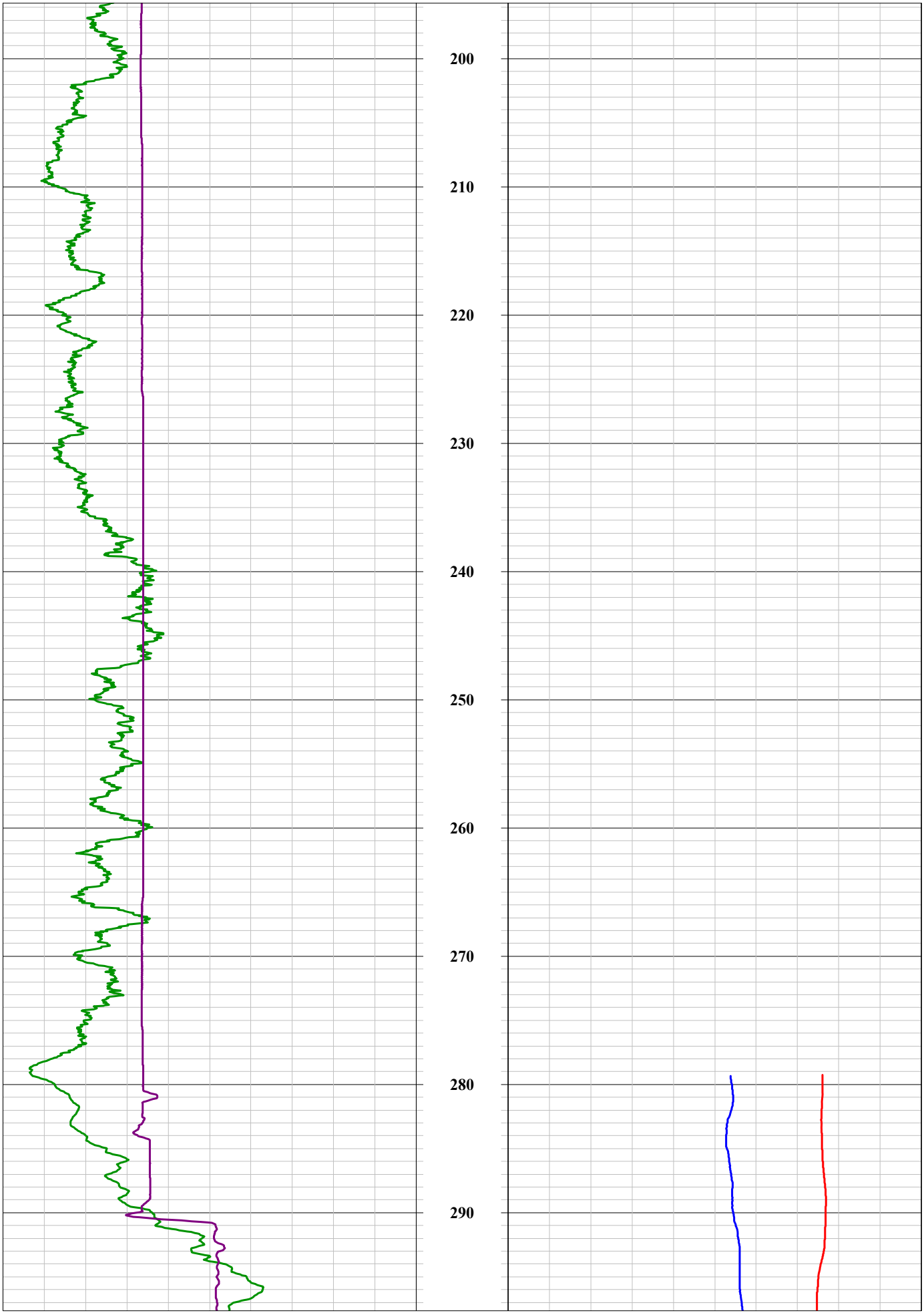
SIZE	WGT.	FROM	TO
6"	Steel	TOC	290.28'

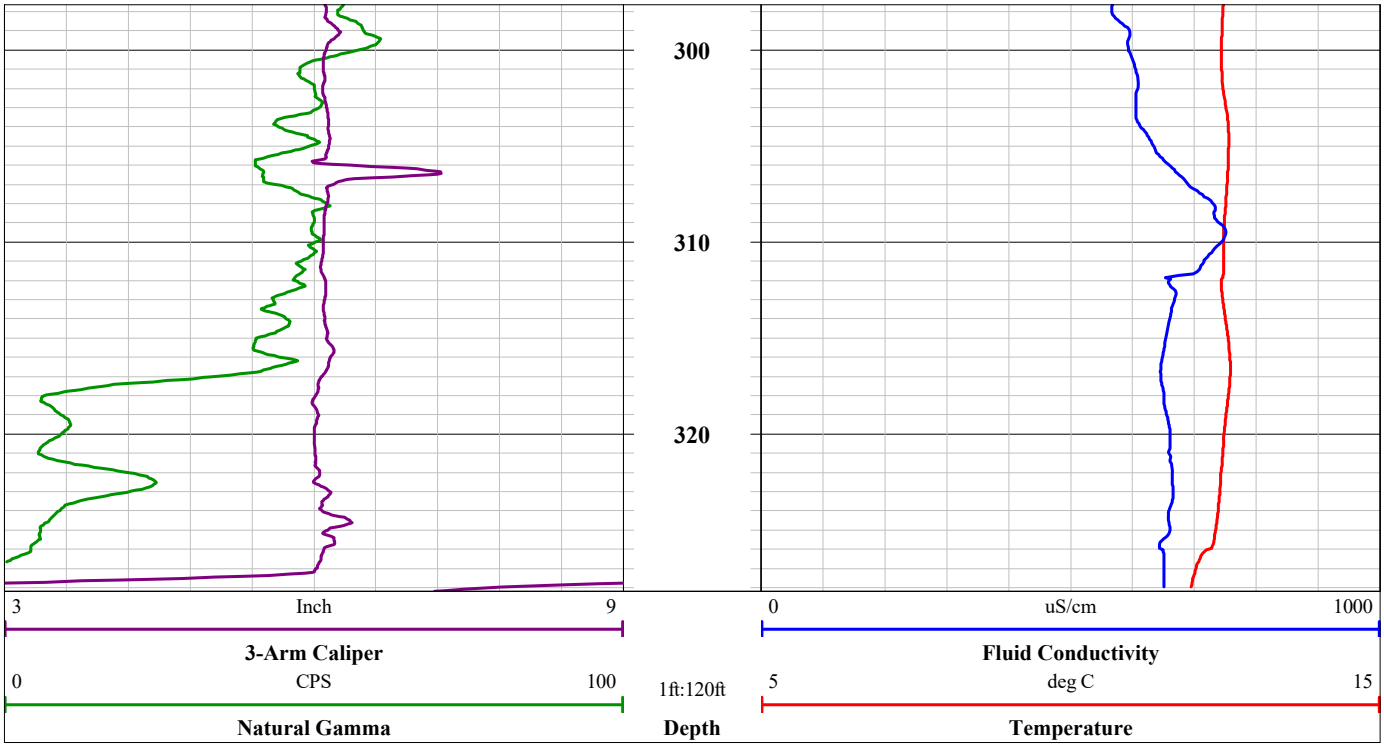
NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
3
Inch
9
Depth
1ft:120ft
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
1000
0
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
260
270
280
290


300
310
320
3
Inch
9
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
5
deg C
15
Temperature

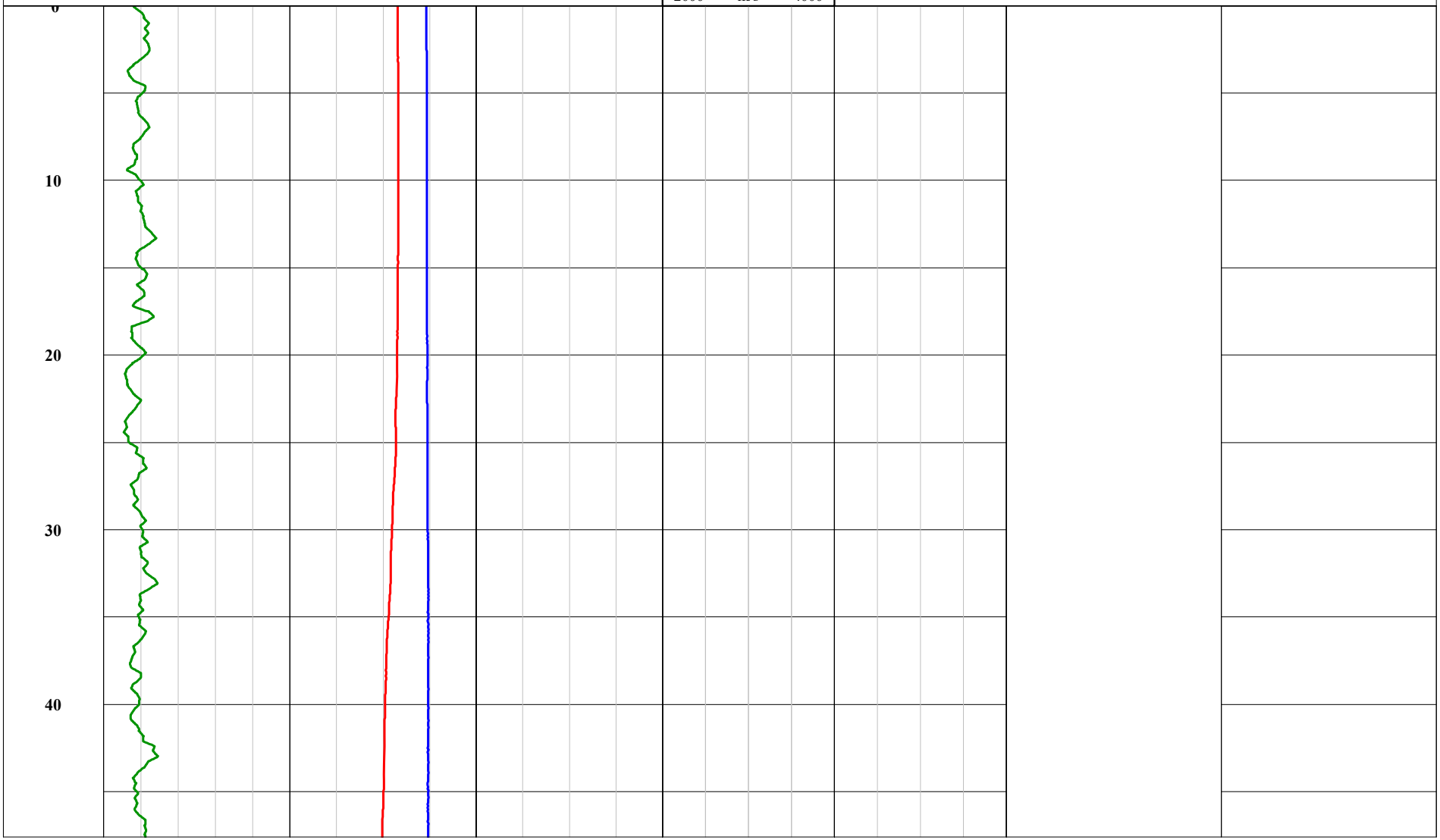
Geophysical Summary Plot

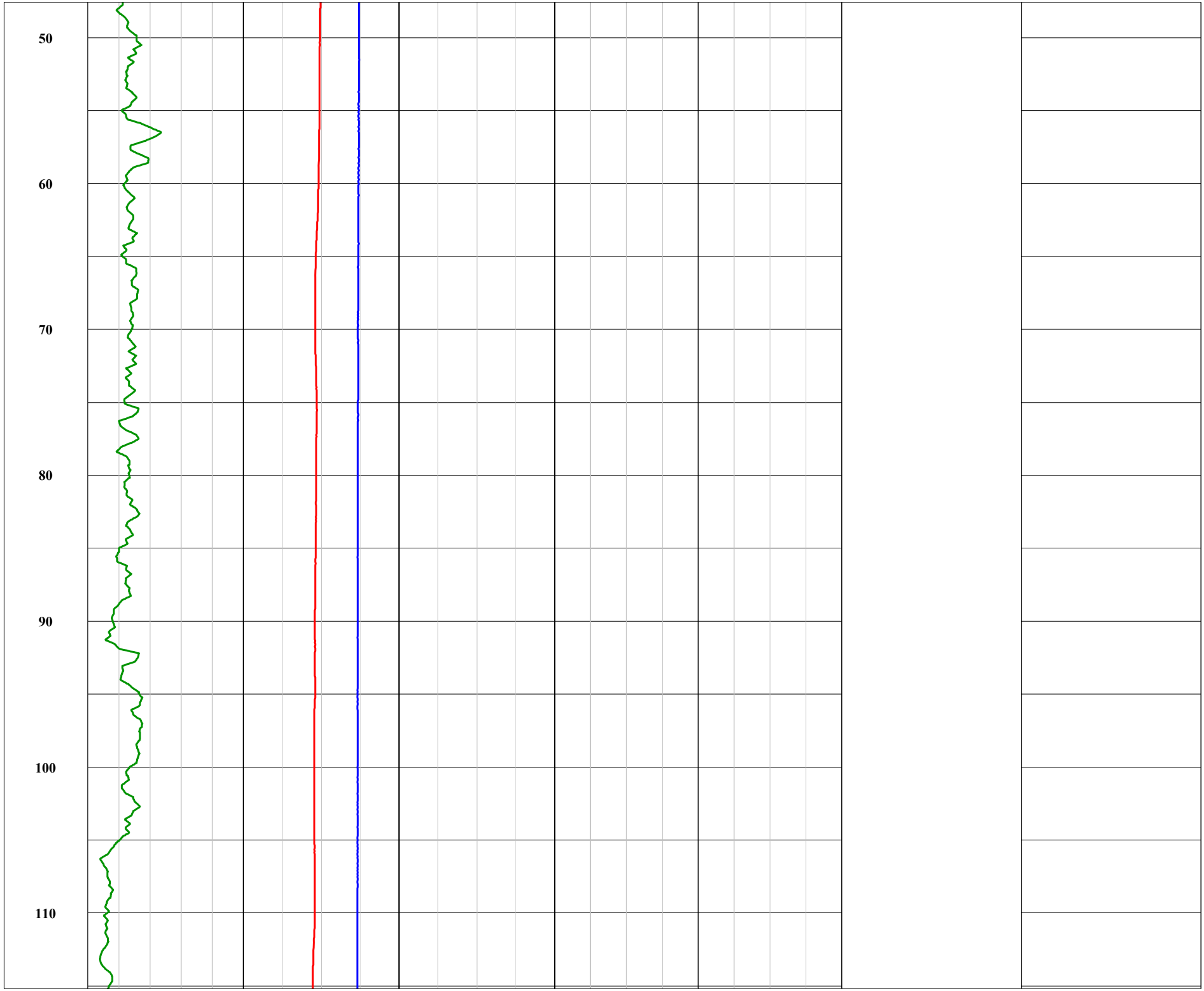
COLOG
borehole geophysics / hydrophysics

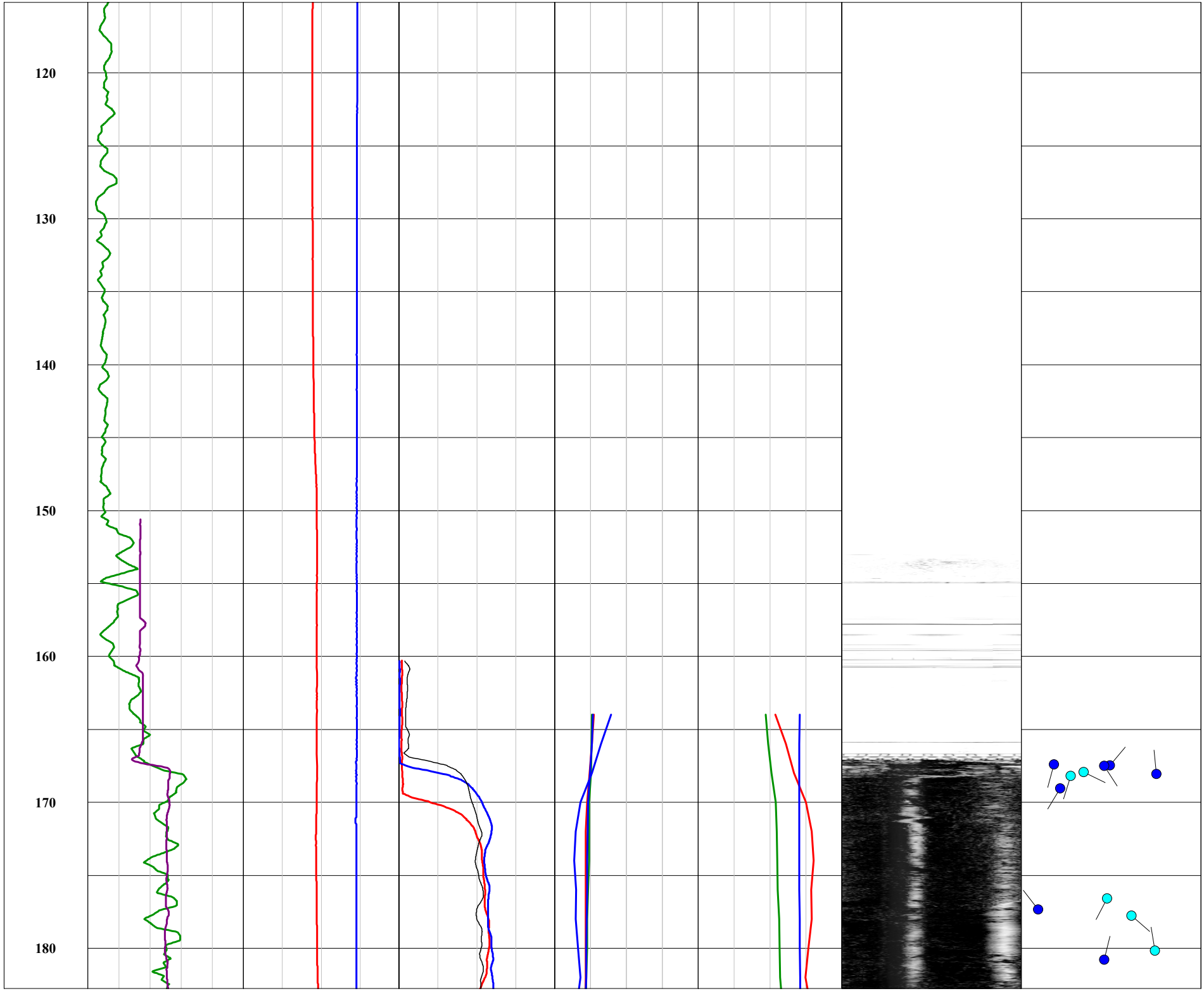
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 20 October 2019
WELL: BH19-28 - Mid Strait

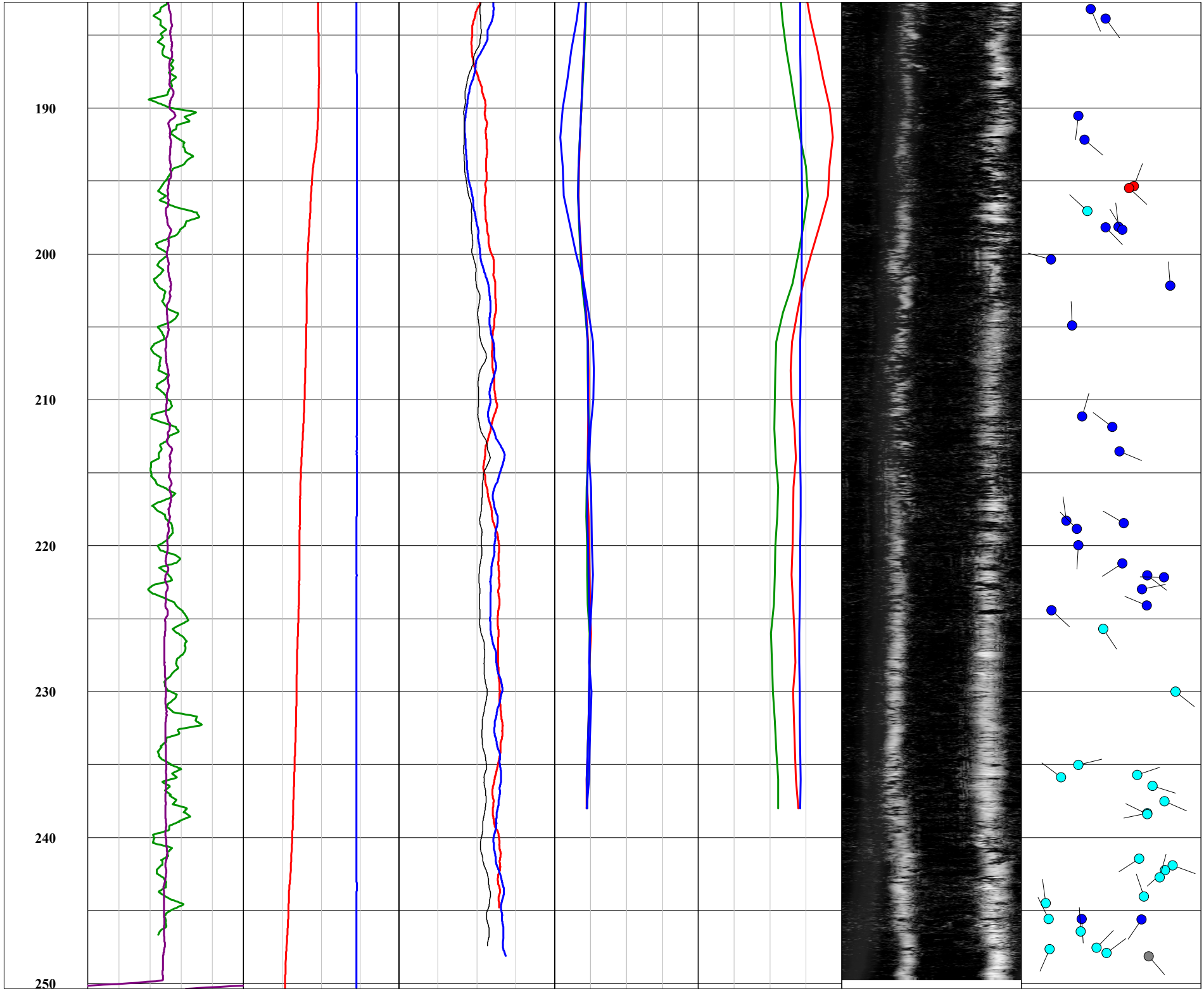
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	Temperature	64" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Amplitude-MN	Tadpoles
1ft:100ft	0 CPS 100	10 deg C 20	0 Ohm-m 100	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	**Fluid Conductivity**	**16" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**		
	3 inch 9	600 uS/cm 1000	0 Ohm-m 100	0 m/s 4000	0 us/m 2000		
			Single-Point Resistance	**Shear Velocity - Avg**	**Poisson's Ratio**		
			0 Ohm 50	0 m/s 4000	-1 1		
				Compressive Velocity			
				2000 m/s 4000			




50
60
70
80
90
100
110


120
130
140
150
160
170
180


190
200
210
220
230
240
250

					2000 m/s 4000 **Compressive Velocity**			
				0 Ohm 50 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-1 1 **Poisson's Ratio**		
	3 inch 9 **3-Arm Caliper**	600 uS/cm 1000 **Fluid Conductivity**		0 Ohm-m 100 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**		
1ft:100ft **Depth**	0 CPS 100 **Natural Gamma**	10 deg C 20 **Temperature**		0 Ohm-m 100 **64" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Left**	200 us/m 500 **P-Wave Slowness**	0° 90° 180° 270° 0° **Amplitude-MN**	0 90 **Tadpoles**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-28
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-28
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81439 N
Longitude: 84.76743 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 399.9'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 October 2019			
RUN NUMBER	2			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	249.77'			
DEPTH-LOGGER	249.7'			
BTM LOG INTERVAL	249.7'			
TOP LOG INTERVAL	150'			
RECORDED BY	CKL			
WITNESSED BY	WSP			
PROBE TYPE, S/N	ALT ABI/#111018			
LOGGING SPEED	5 fpm			
A.S.D.E. / Sample Interval	0.07'/.008			
Fluid Level / Fluid Type	NA/water			

BOREHOLE RECORD

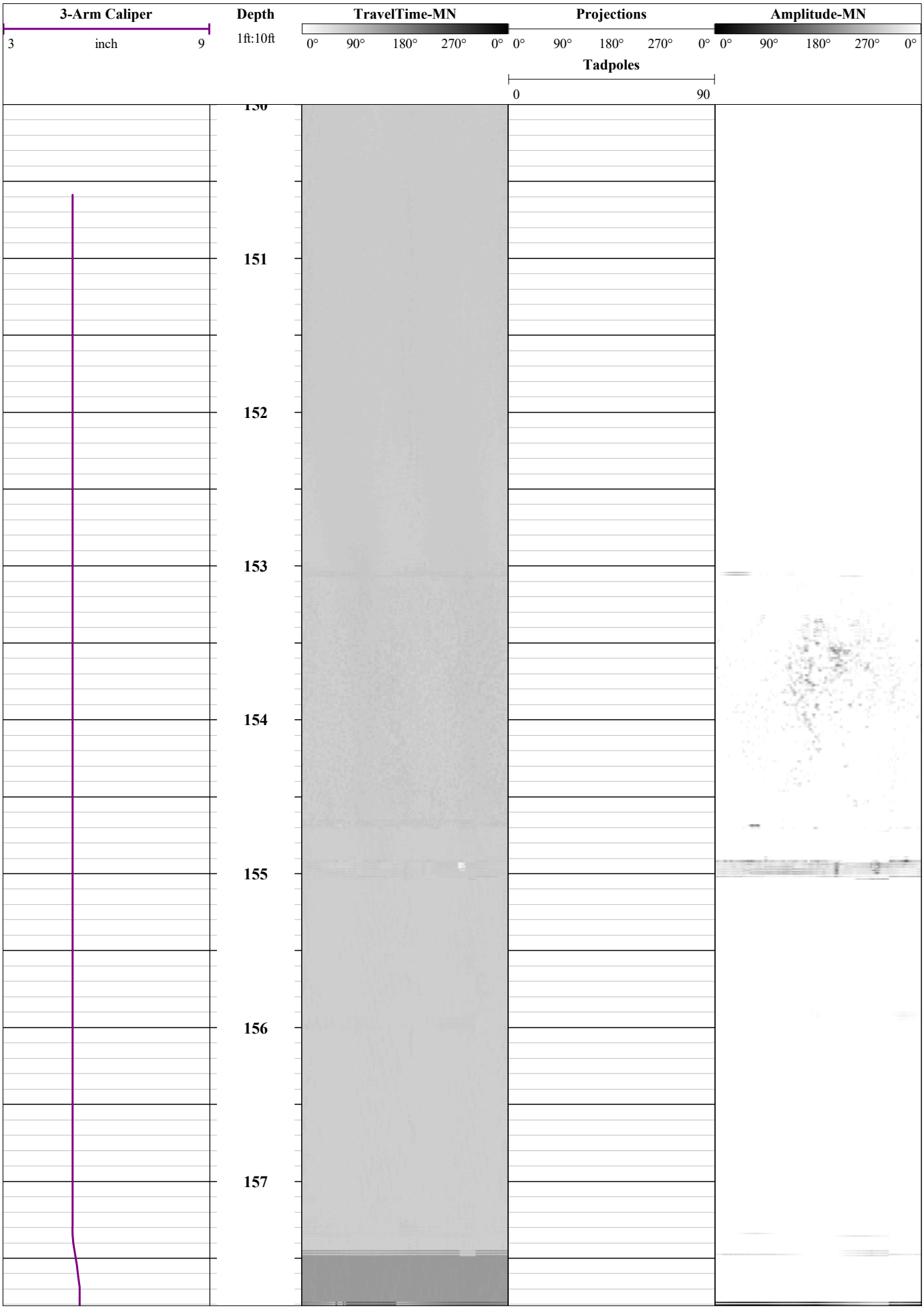
RUN No.	BIT	FROM	TO
1	5 7/8"	Mudline	167.28'
2	7"	Mudline	249.77'

CASING RECORD

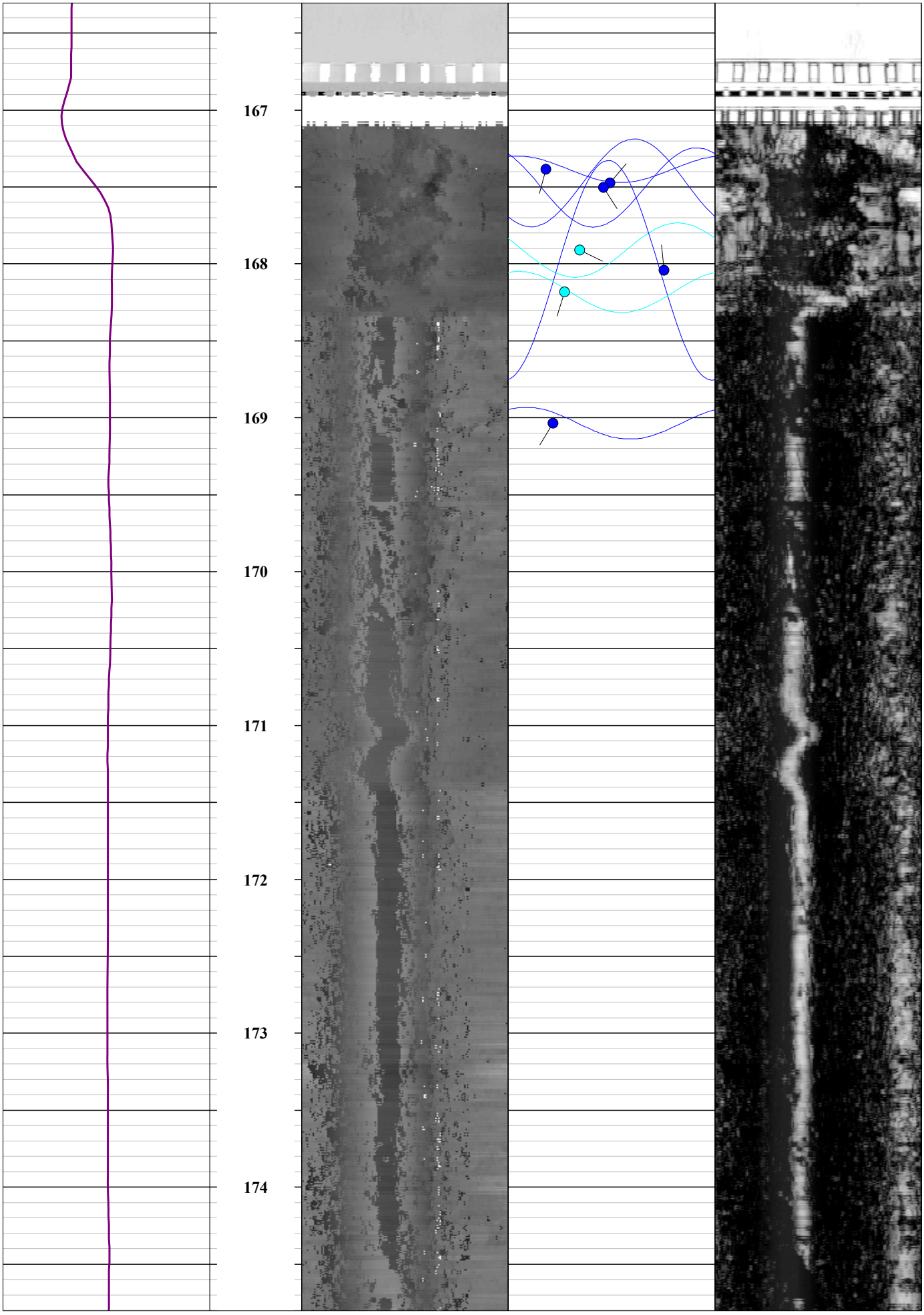
SIZE	WGT.	FROM	TO
5 7/8"	Steel	Mudline	167.28'
7"	Steel	Mudline	249.77'

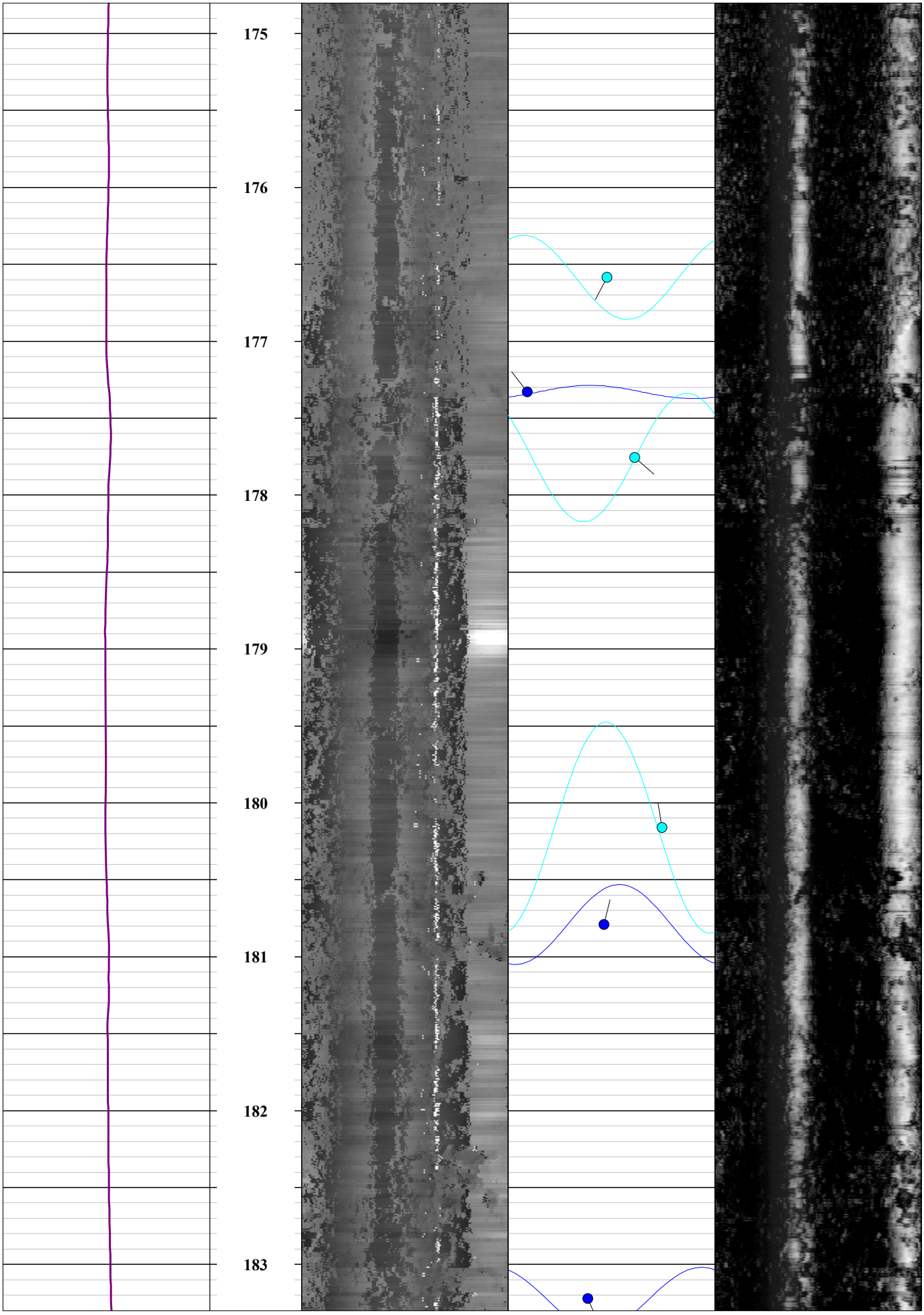
NA - Not Available, N/A - Not Applicable

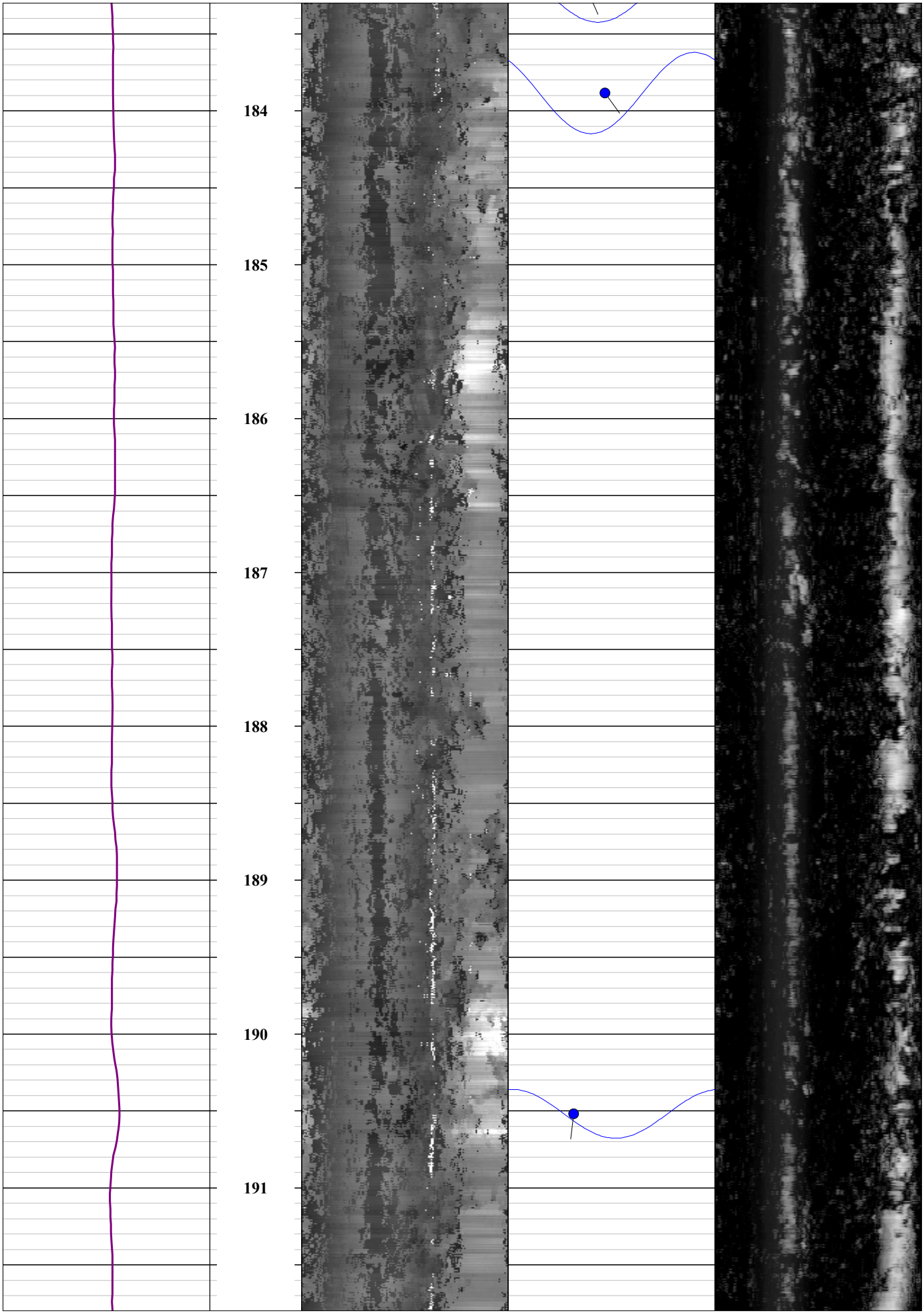
COMMENTS

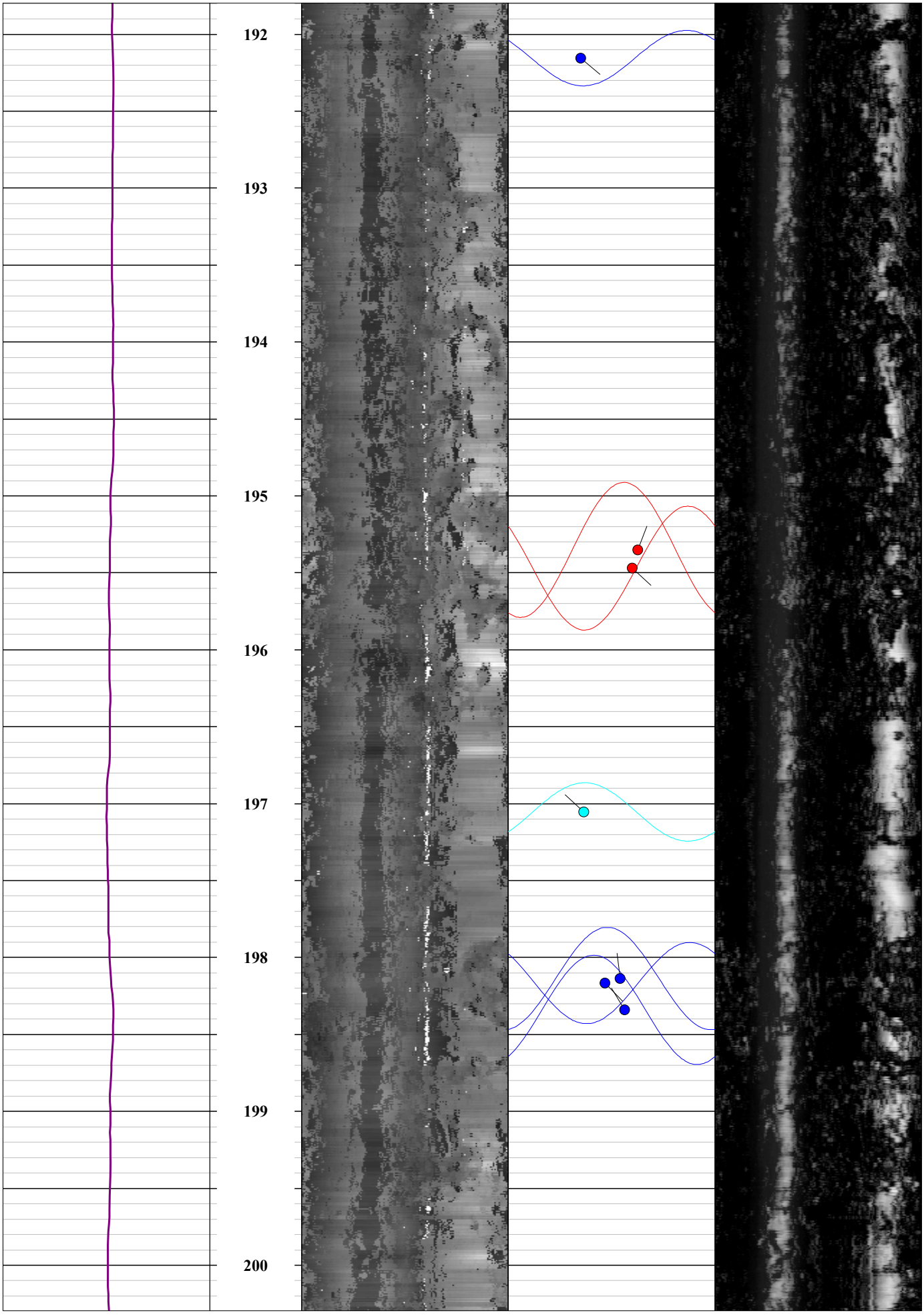

3-Arm Caliper
3
inch
9
Depth
1ft:10ft
TravelTime-MN
0° 90° 180° 270° 0°
Projections
0° 90° 180° 270° 0°
Tadpoles
0
90
Amplitude-MN
0° 90° 180° 270° 0°
150
151
152
153
154
155
156
157

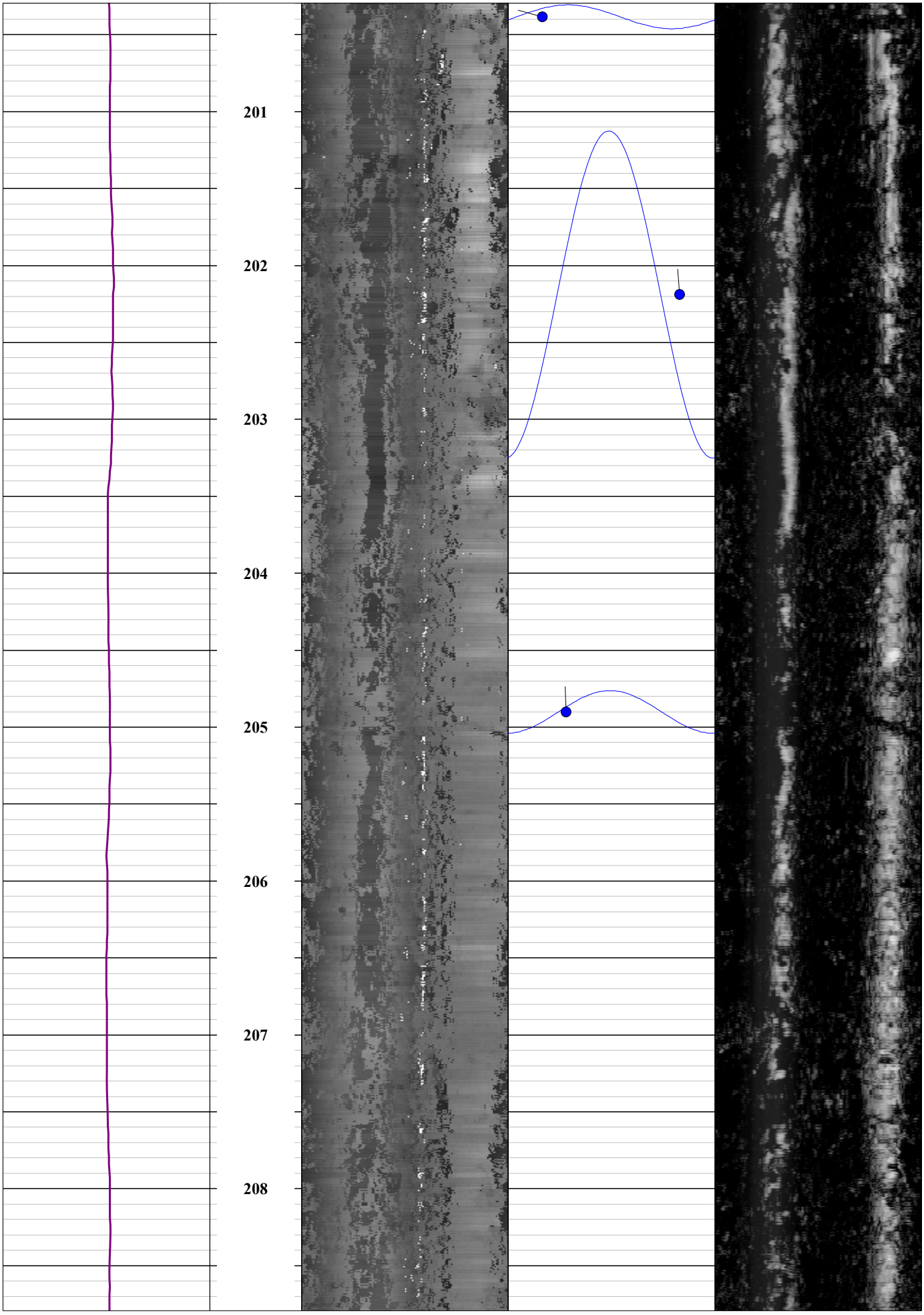
158
159
160
161
162
163
164
165
166

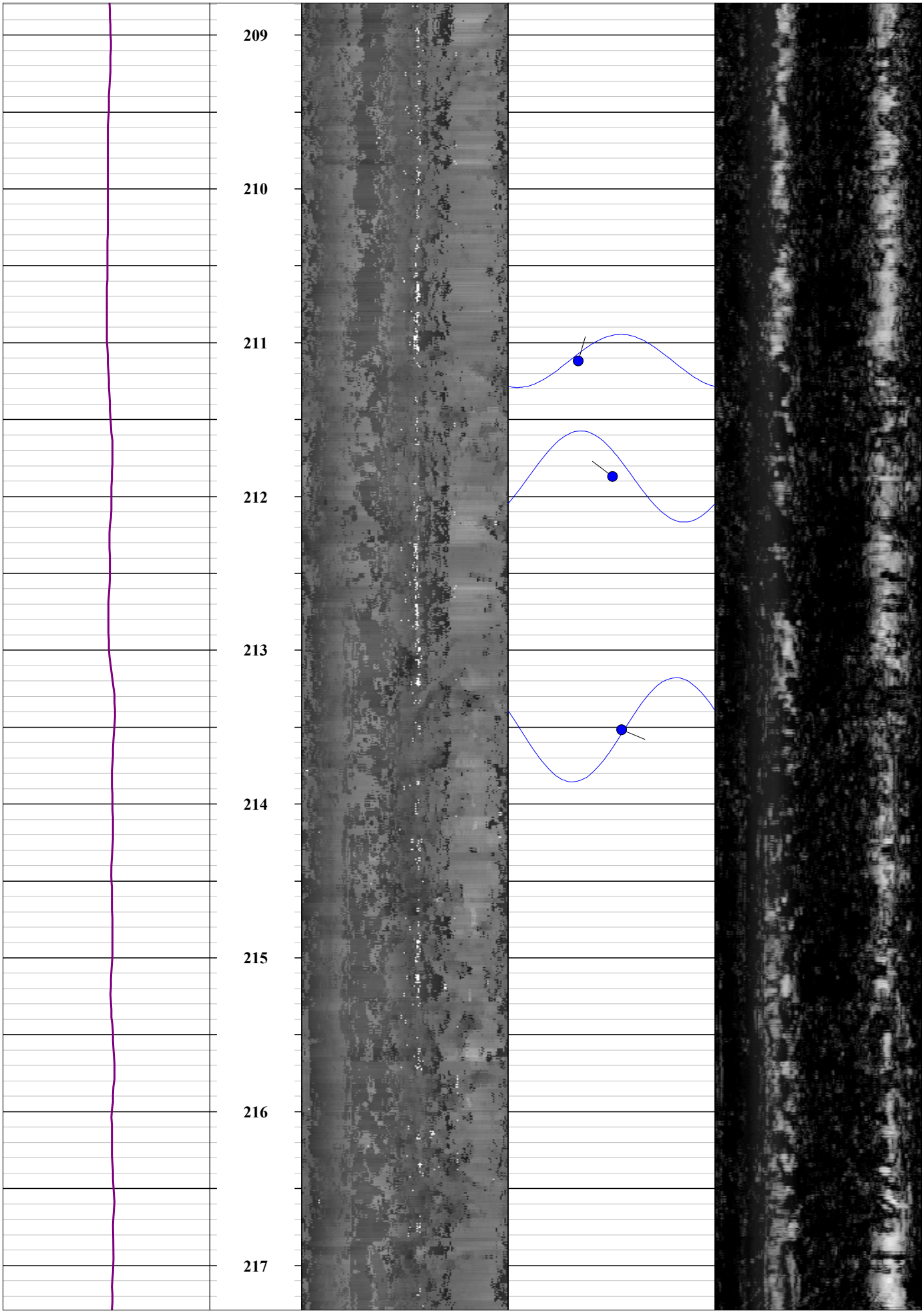

167
168
169
170
171
172
173
174

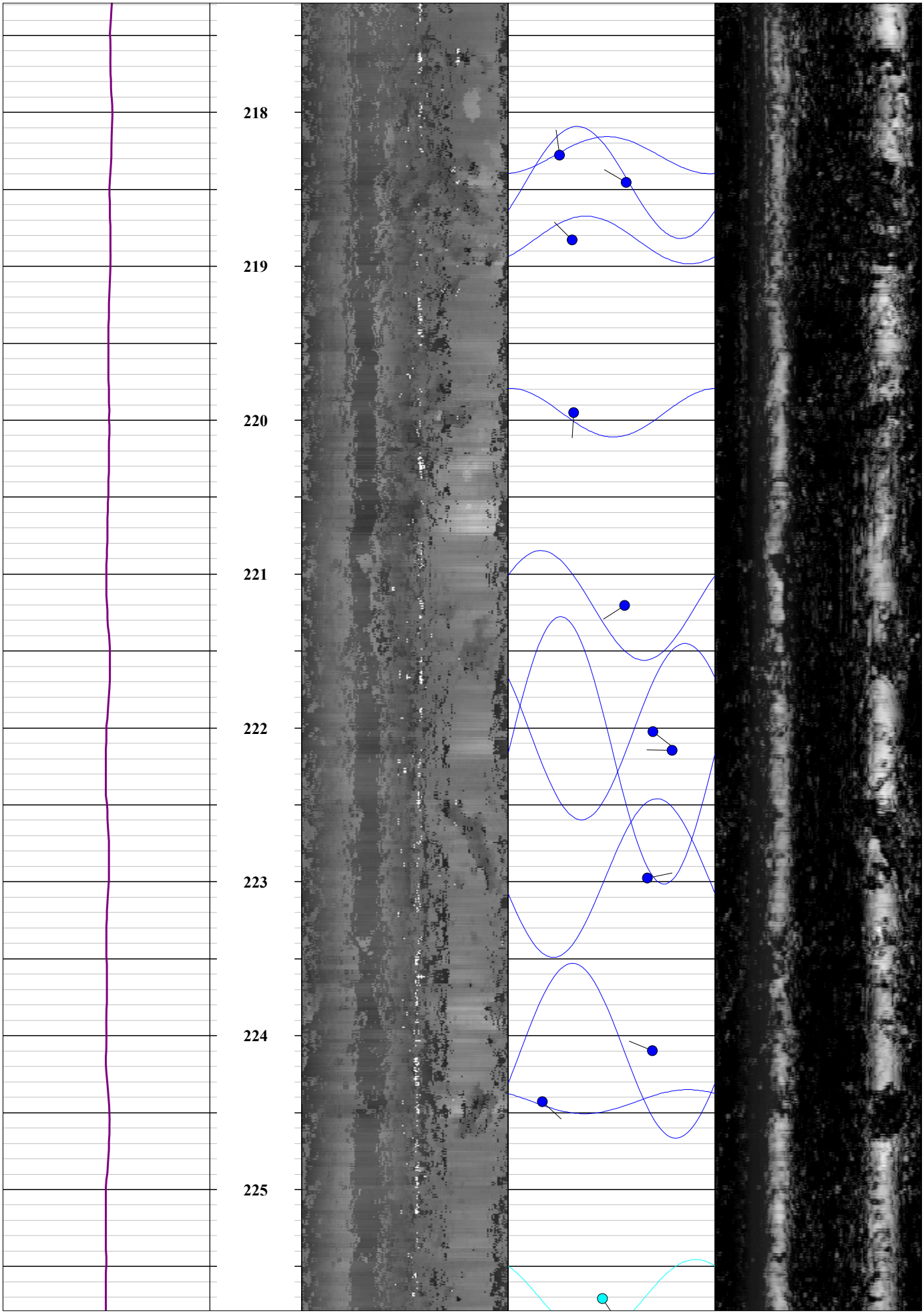

175
176
177
178
179
180
181
182
183

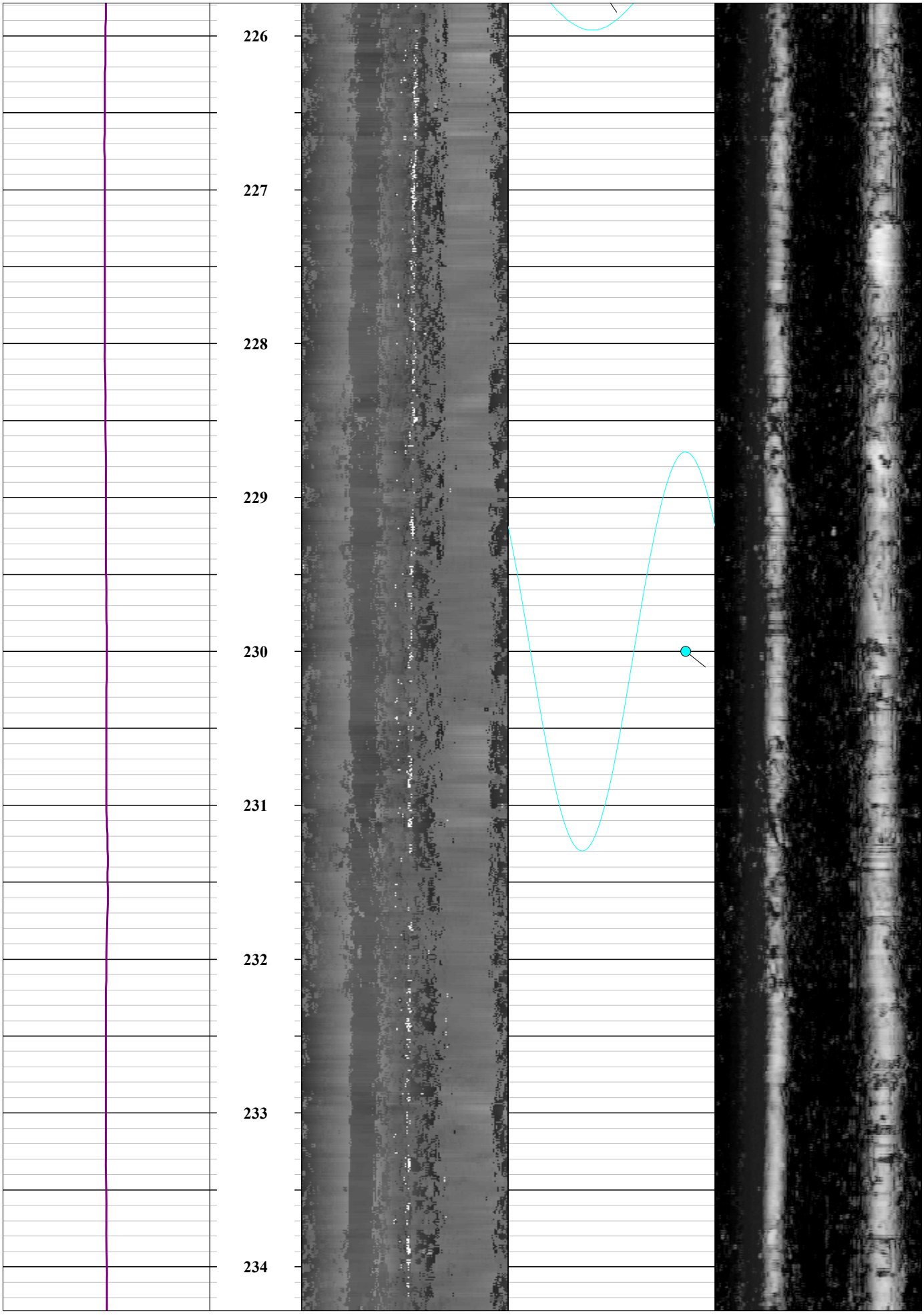

184
185
186
187
188
189
190
191

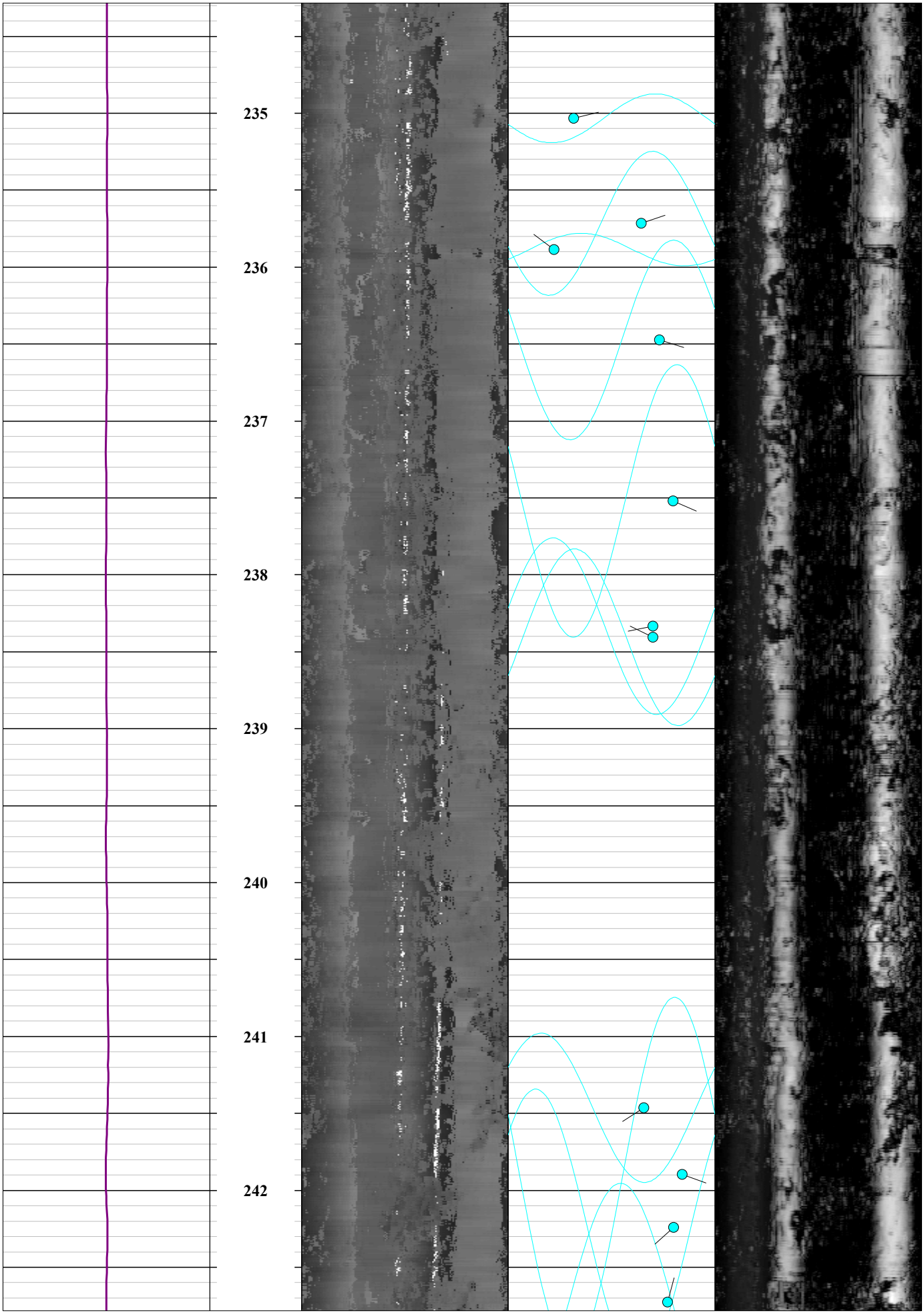

192
193
194
195
196
197
198
199
200

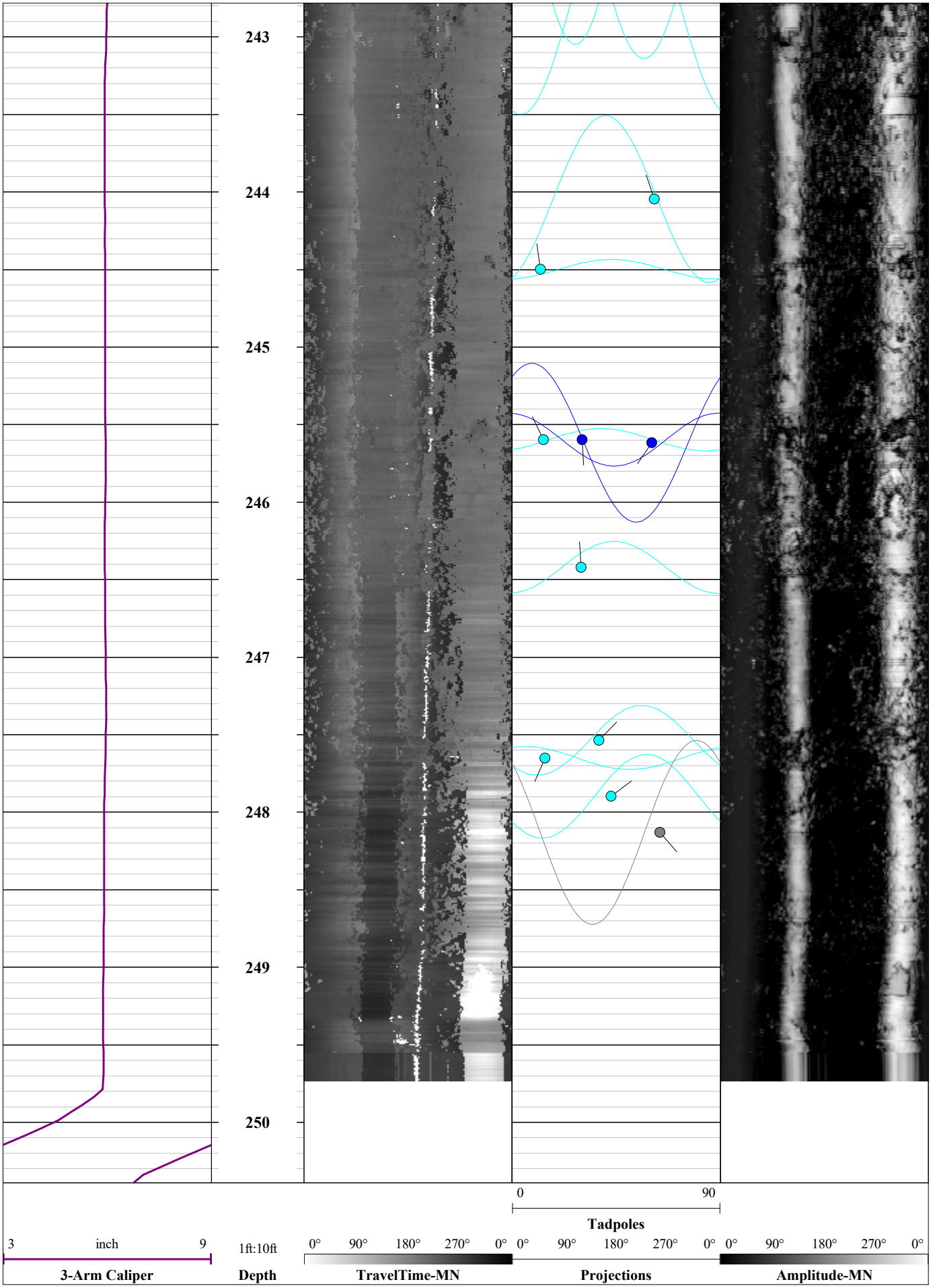

201
202
203
204
205
206
207
208


209
210
211
212
213
214
215
216
217

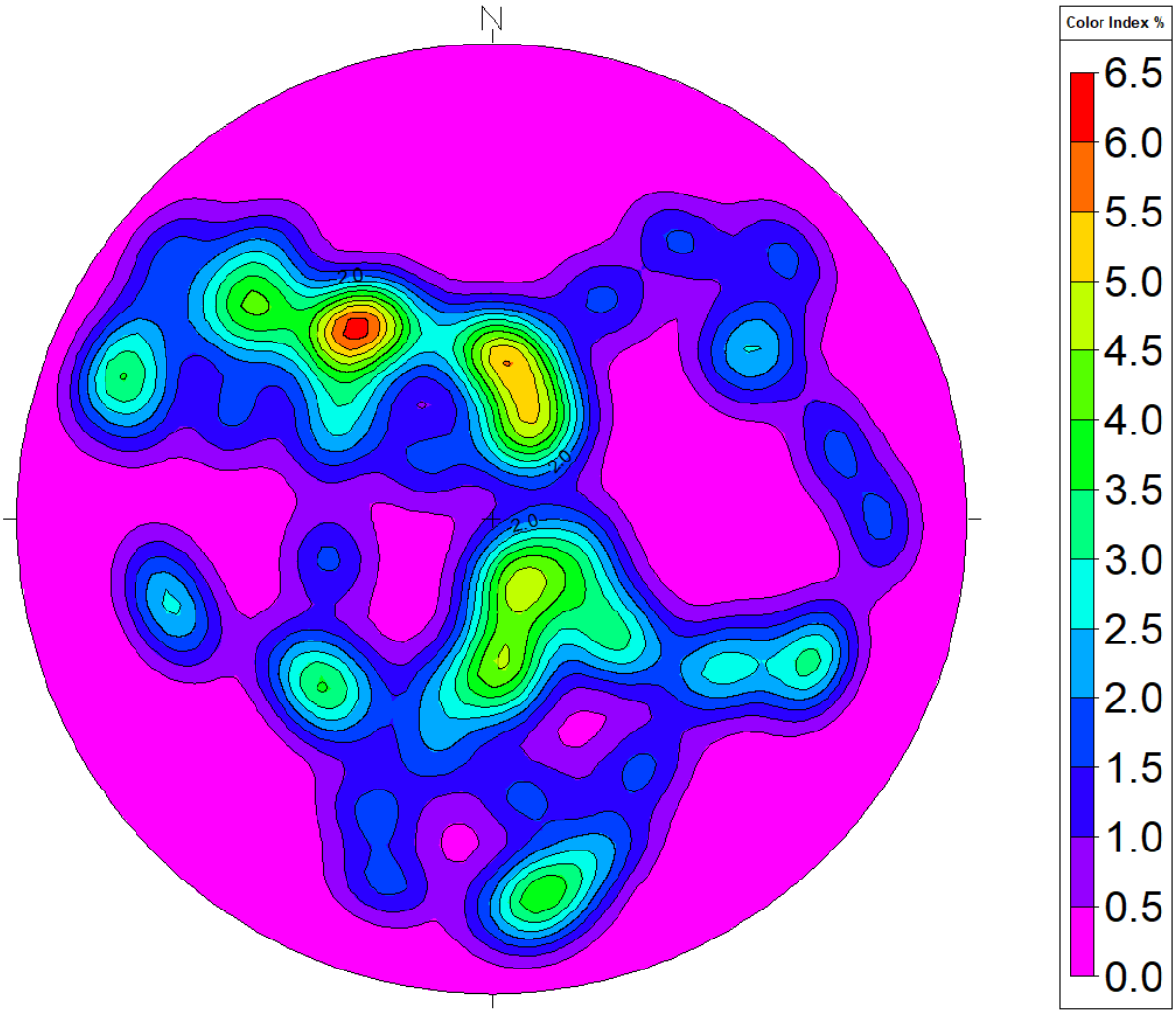

218
219
220
221
222
223
224
225


226
227
228
229
230
231
232
233
234


235
236
237
238
239
240
241
242

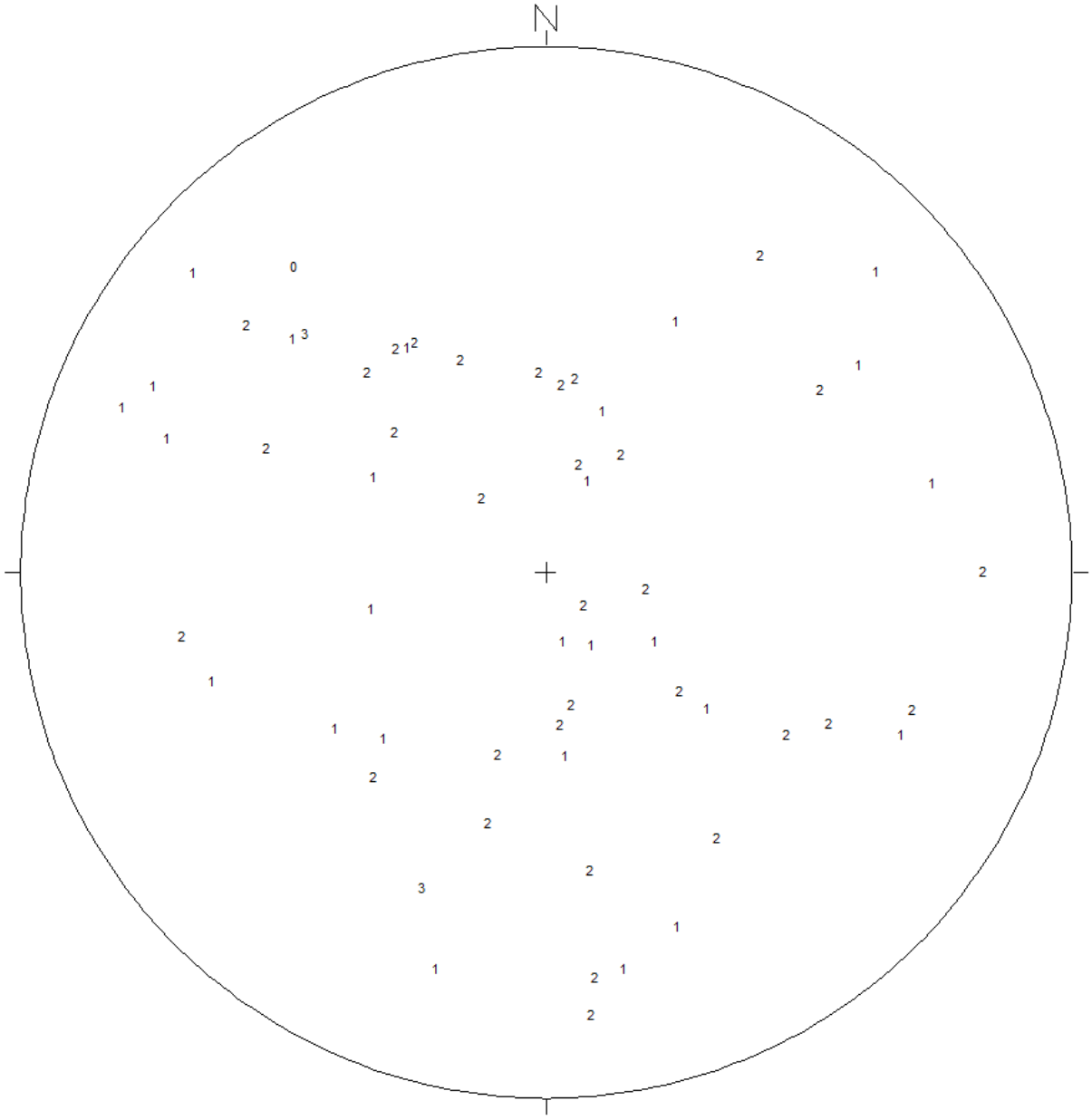

243
244
245
246
247
248
249
250
0
90
Tadpoles
3
inch
9
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-28
20 October 2019



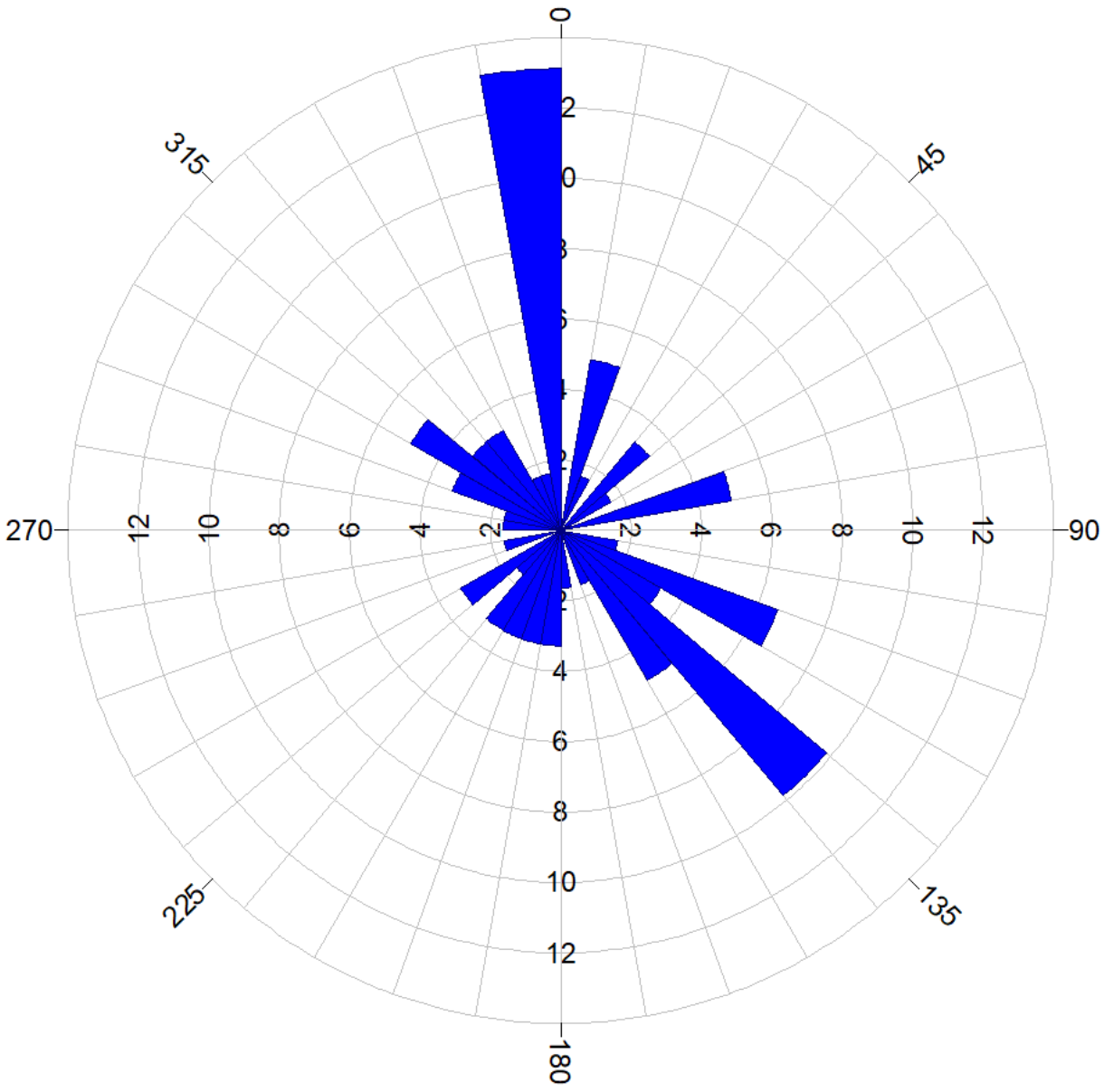
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-28
20 October 2019



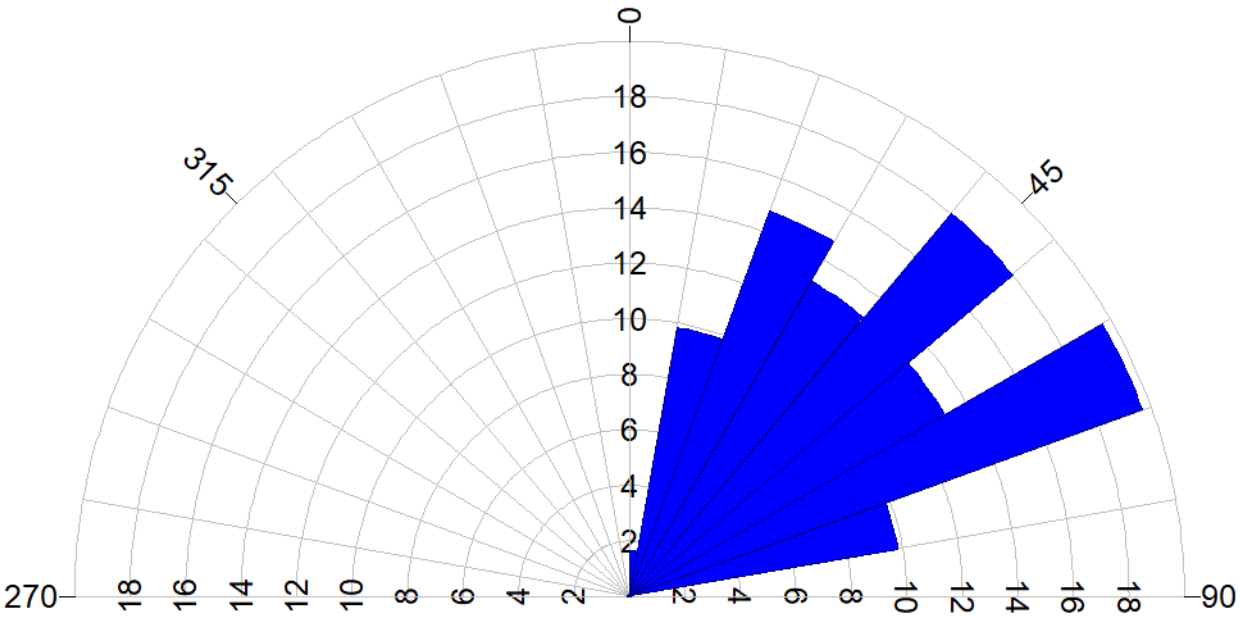
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-28
20 October 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-28
20 October 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-28

20 October 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	51.02	167.4	195	16	2
2	51.04	167.5	40	44	2
3	51.05	167.5	148	41	2
4	51.18	167.9	116	31	1
5	51.22	168.0	354	68	2
6	51.26	168.2	198	25	1
7	51.52	169.0	212	20	2
8	53.82	176.6	207	43	1
9	54.05	177.3	322	8	2
10	54.18	177.8	131	55	1
11	54.91	180.2	350	67	1
12	55.10	180.8	14	42	2
13	55.85	183.2	156	35	2
14	56.05	183.9	144	42	2
15	58.07	190.5	187	29	2
16	58.57	192.2	130	32	2
17	59.54	195.4	22	56	3
18	59.58	195.5	133	54	3
19	60.06	197.1	313	33	1
20	60.39	198.1	353	49	2
21	60.40	198.2	136	42	2
22	60.45	198.3	329	51	2
23	61.08	200.4	285	15	2
24	61.63	202.2	355	75	2
25	62.45	204.9	357	25	2
26	64.35	211.1	16	31	2
27	64.58	211.9	306	46	2
28	65.08	213.5	112	49	2
29	66.53	218.3	352	22	2
30	66.59	218.5	300	51	2
31	66.70	218.8	315	28	2
32	67.04	220.0	183	28	2
33	67.42	221.2	237	51	2
34	67.67	222.0	128	63	2
35	67.71	222.2	271	71	2
36	67.96	223.0	79	61	2
37	68.31	224.1	292	63	2
38	68.41	224.4	133	15	2
39	68.80	225.7	146	41	1
40	70.10	230.0	129	77	1
41	71.64	235.0	76	29	1
42	71.84	235.7	71	58	1
43	71.90	235.9	307	20	1
44	72.08	236.5	108	66	1
45	72.40	237.5	114	72	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-28

20 October 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	72.64	238.3	258	63	1
47	72.66	238.4	296	63	1
48	73.60	241.5	237	59	1
49	73.73	241.9	110	76	1
50	73.83	242.2	228	72	1
51	73.98	242.7	16	69	1
52	74.39	244.1	341	62	1
53	74.52	244.5	352	12	1
54	74.86	245.6	334	14	1
55	74.86	245.6	176	30	2
56	74.86	245.6	214	60	2
57	75.11	246.4	356	30	1
58	75.45	247.5	44	38	1
59	75.48	247.7	203	14	1
60	75.56	247.9	53	43	1
61	75.63	248.1	139	64	0

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-28
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-28
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81439 N
Longitude: 84.76743 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 399.9'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 October 2019	20 October 2019	20 October 2019	
RUN NUMBER	1	3	4	
LOG TYPE	FTC	Natural Gamma	Caliper	
DEPTH-DRILLER	249.77'	249.77'	249.77'	
DEPTH-LOGGER	250'	249'	249.8'	
BTM LOG INTERVAL	250.2'	246.7'	249.8'	
TOP LOG INTERVAL	0.0'	0.0'	150.6'	
RECORDED BY	CKL	CKL	CKL	
WITNESSED BY	WSP	WSP	WSP	
PROBE TYPE, S/N	2PFA #2656	ELXG #4314	3ACS#3596	
LOGGING SPEED	20 fpm	20 fpm	15 fpm	
A.S.D.E. / Sample Interval	0.19' / 0.10'	0.05' / 0.25'	0.42' / 0.10'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

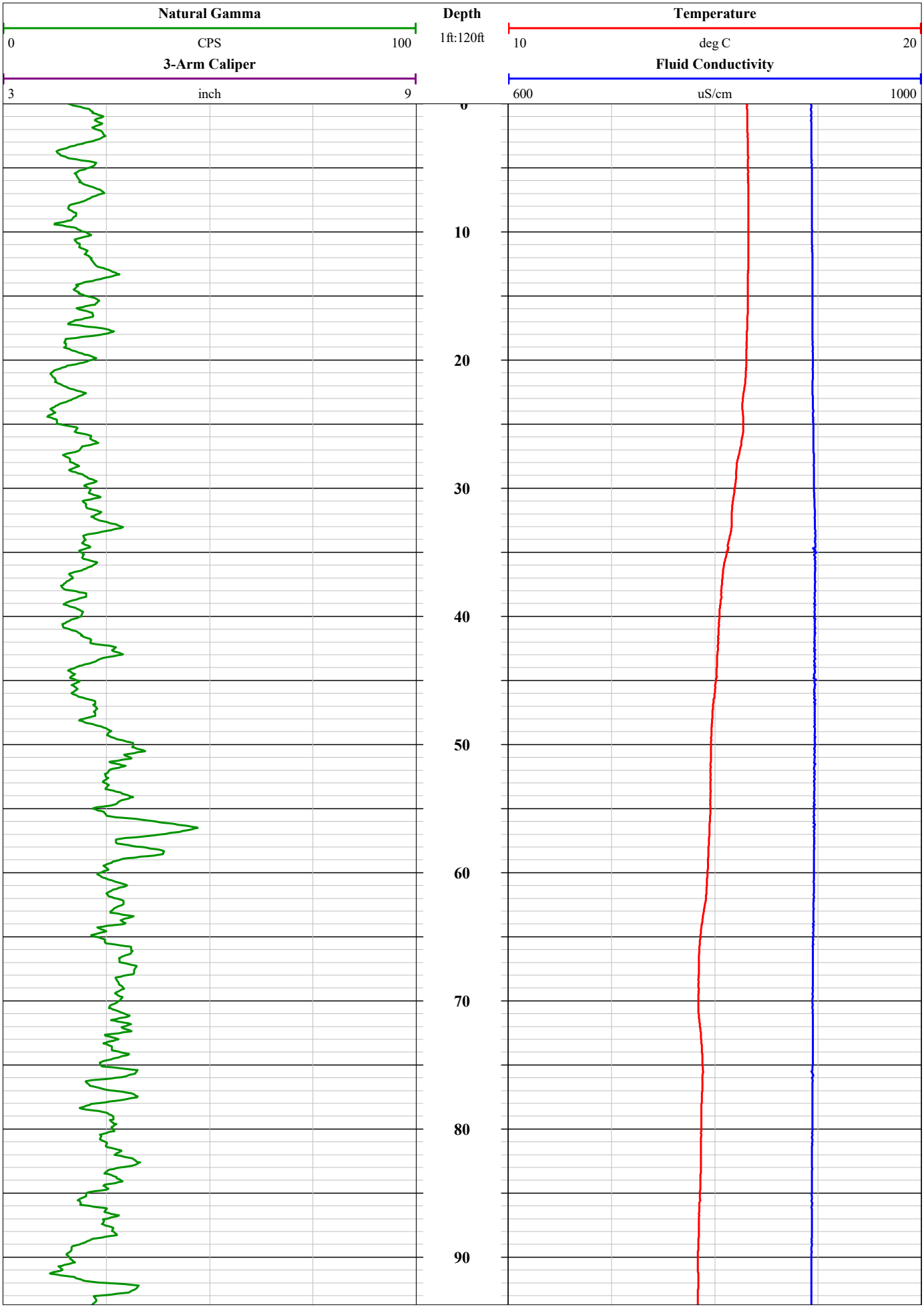
RUN No.	BIT	FROM	TO
1	5 7/8"	Mudline	167.28'
2	7"	Mudline	249.77'

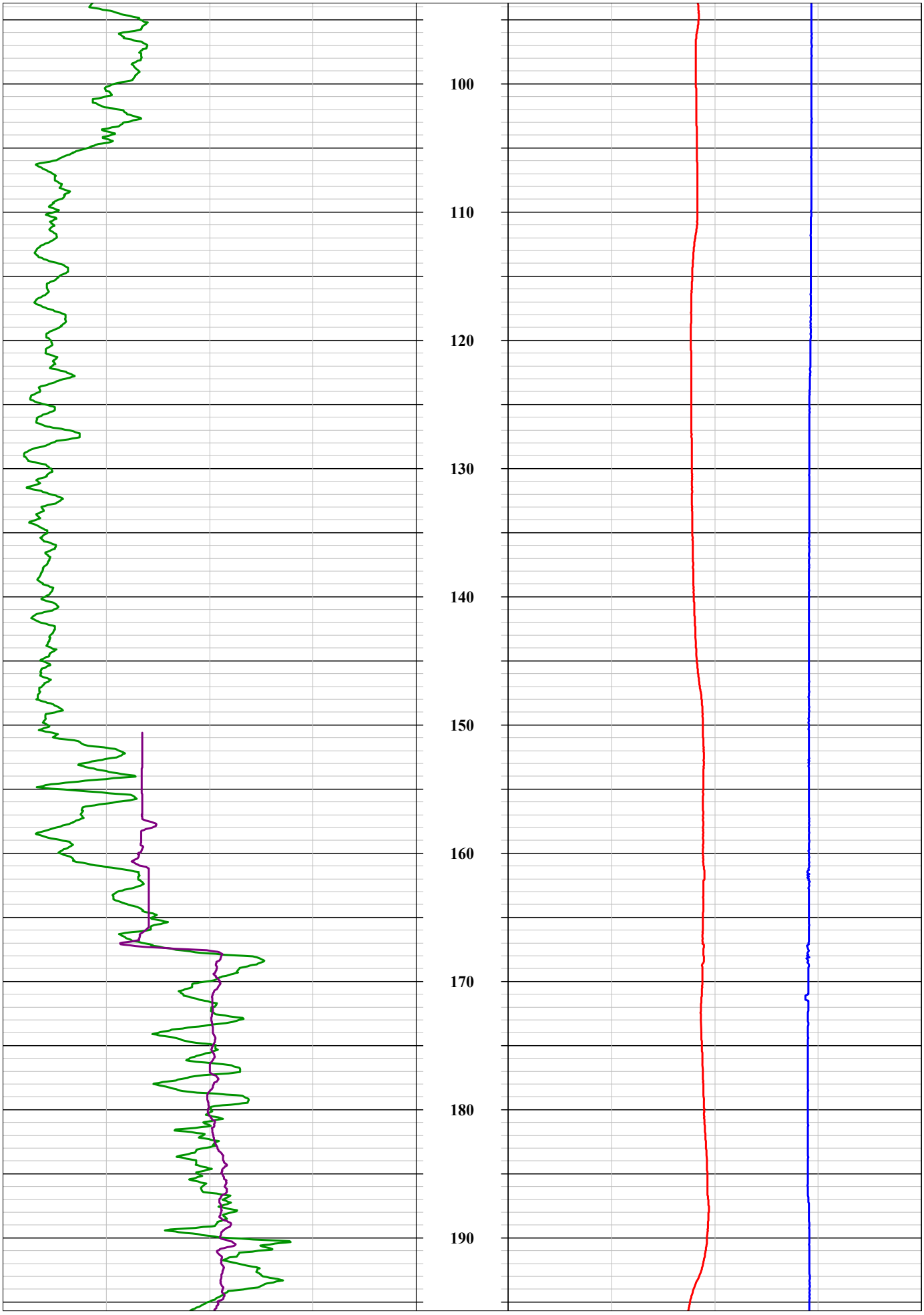
CASING RECORD

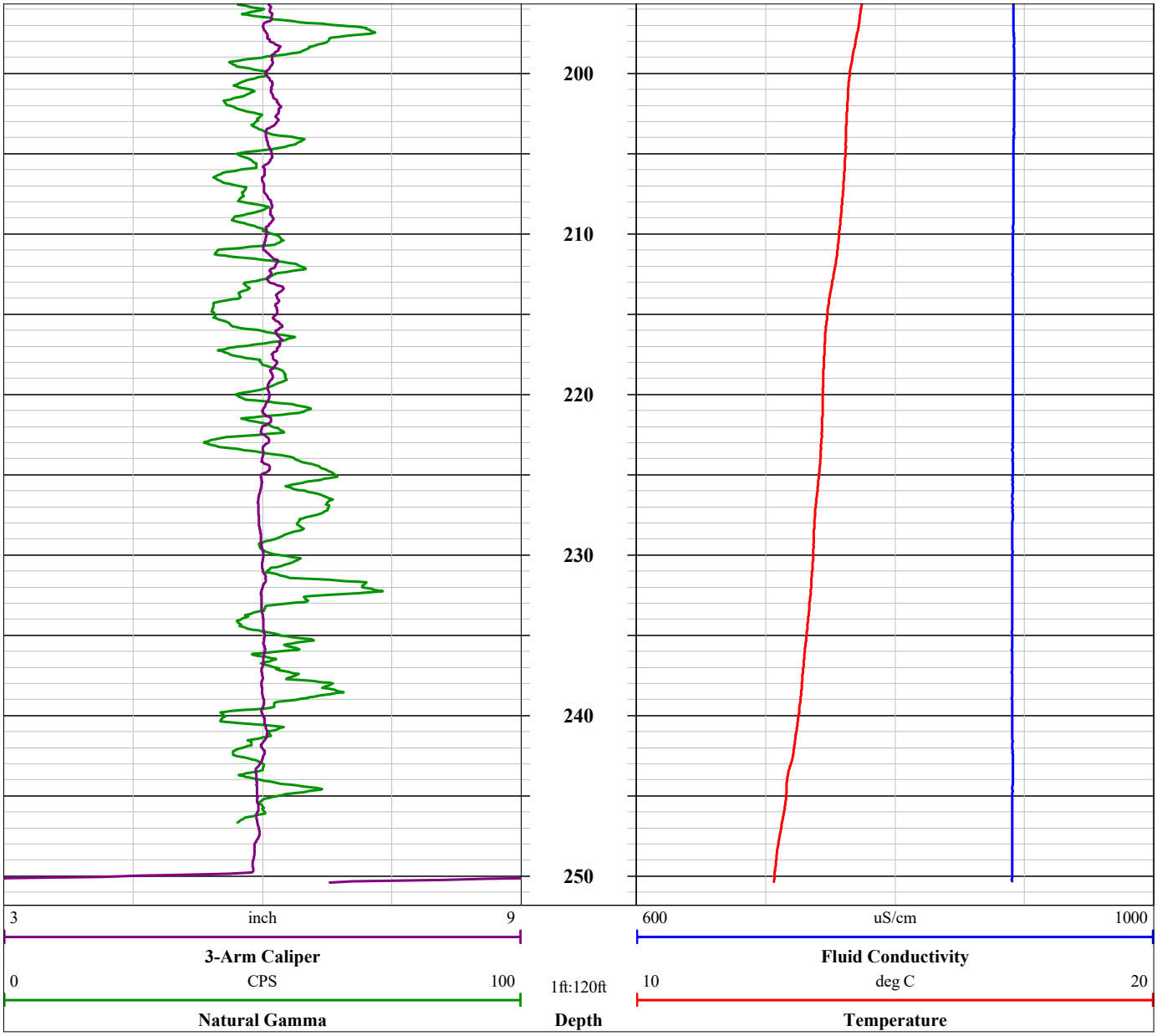
SIZE	WGT.	FROM	TO
5 7/8"	Steel	Mudline	167.28'
7 "	Steel	Mudline	249.77'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
3
inch
9
Depth
1ft:120ft
Temperature
10
deg C
20
Fluid Conductivity
600
uS/cm
1000
0
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
250
3
inch
9
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
600
uS/cm
1000
Fluid Conductivity
10
deg C
20
Temperature

Borehole Deviation

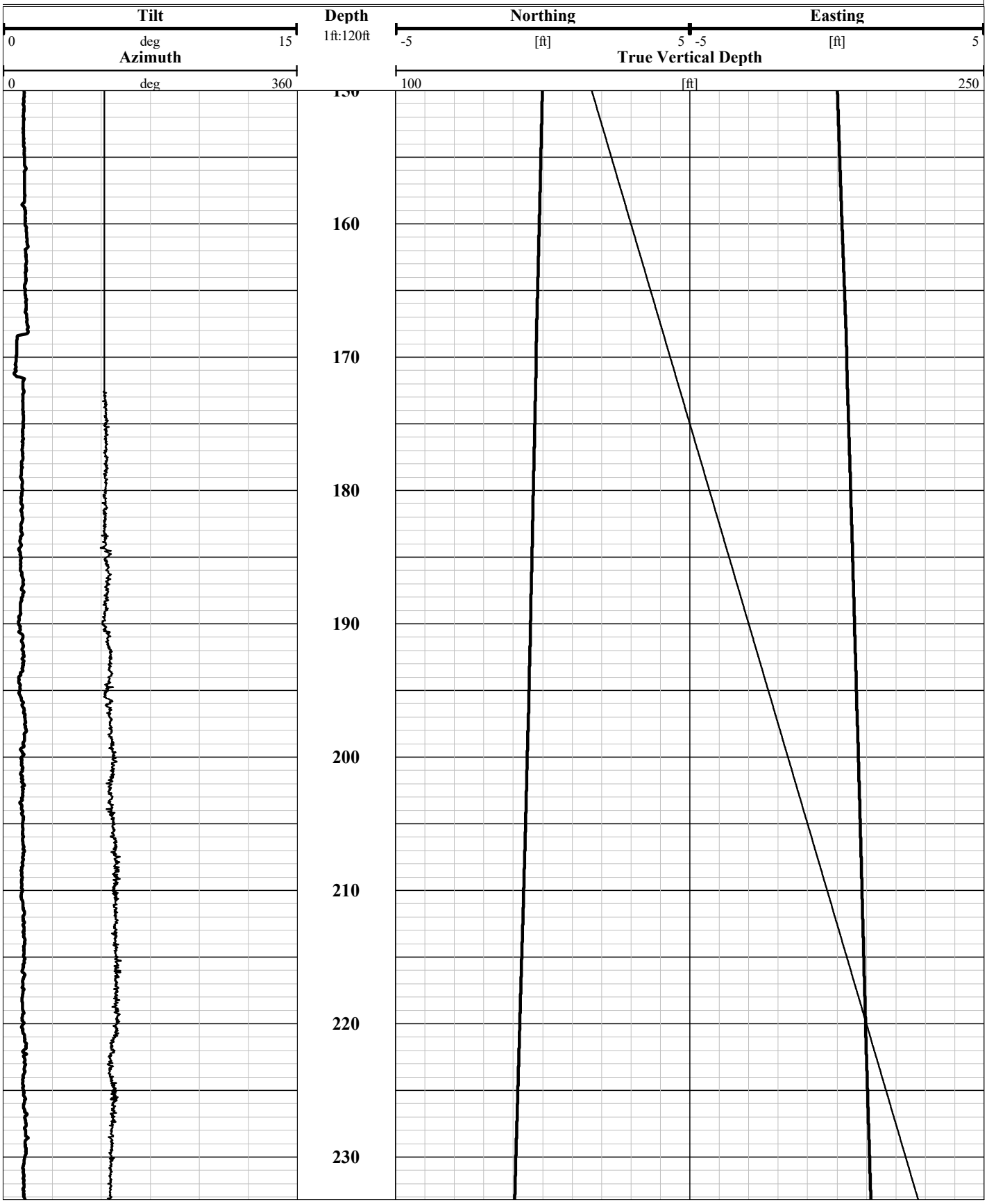
COLOG
borehole geophysics / hydrophysics

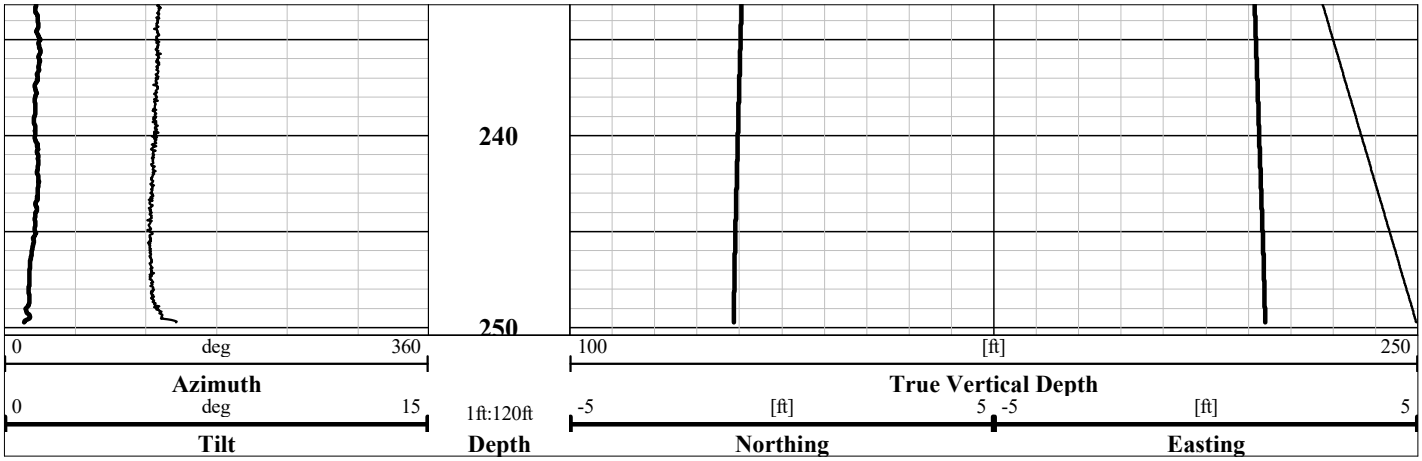
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 20 October 2019	WELL: BH19-28 - Mid Strait

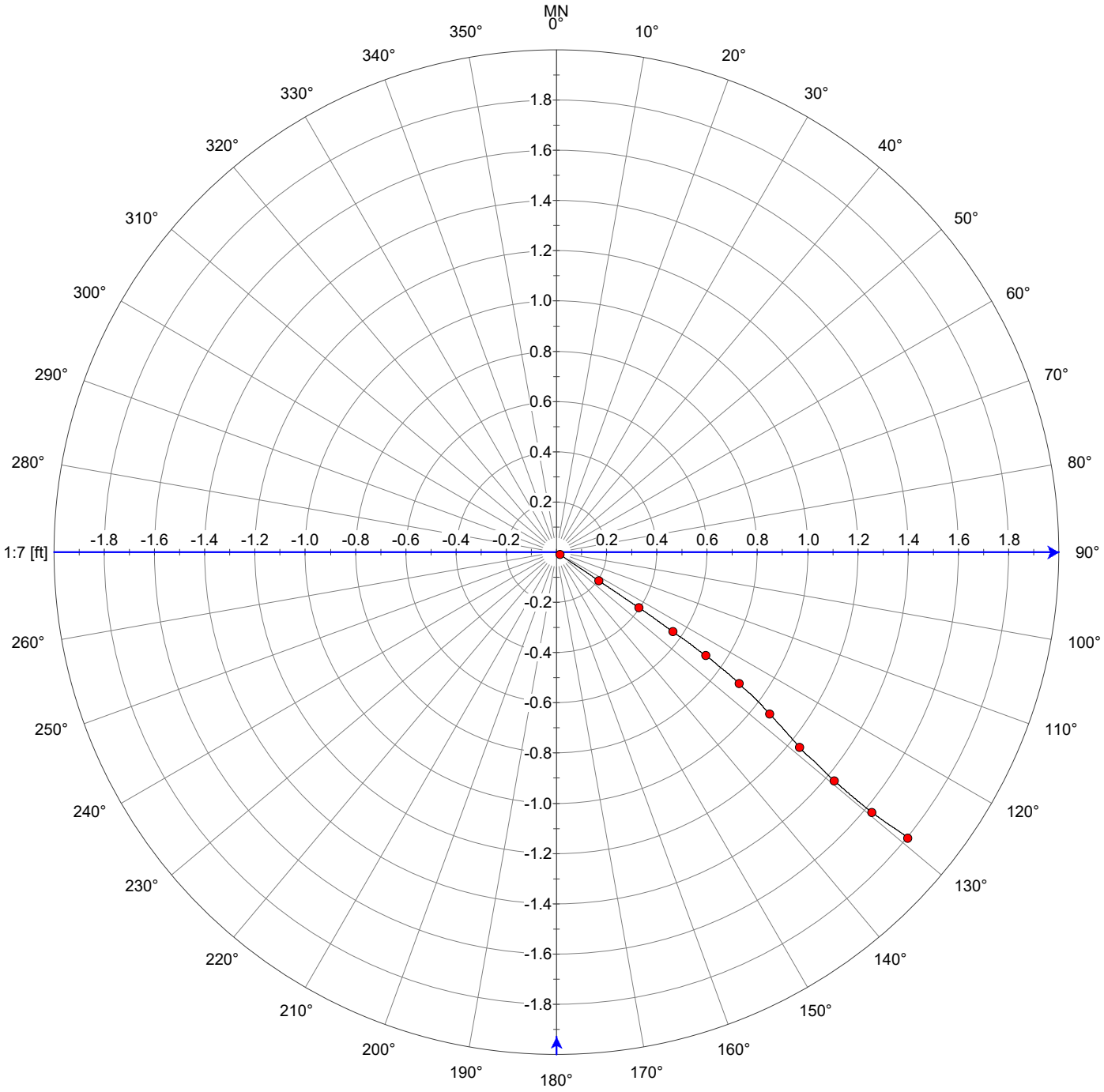
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 399.9'** **Latitude: 45.81439 N** **Longitude: 84.76743 W**




240
250
0
deg
360
Azimuth
0
deg
15
Tilt
1ft:120ft
Depth
100
[ft]
250
True Vertical Depth
-5
[ft]
5
Northing
-5
[ft]
5
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1:7 [ft]
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-28
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-28
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81439 N
Longitude: 84.76743 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 399.9'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 October 2019	20 October 2019		
RUN NUMBER	3	3		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	249.77'	249.77'		
DEPTH-LOGGER	249'	249'		
BTM LOG INTERVAL	246.7'	248.2'		
TOP LOG INTERVAL	0.0'	160.2'		
RECORDED BY	CKL	CKL		
WITNESSED BY	WSP	WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 fpm	20 fpm		
A.S.D.E. / Sample Interval	0.05' / 0.25'	0.05' / 0.25'		
Fluid Level / Fluid Type	NA/water	NA/water		

BOREHOLE RECORD

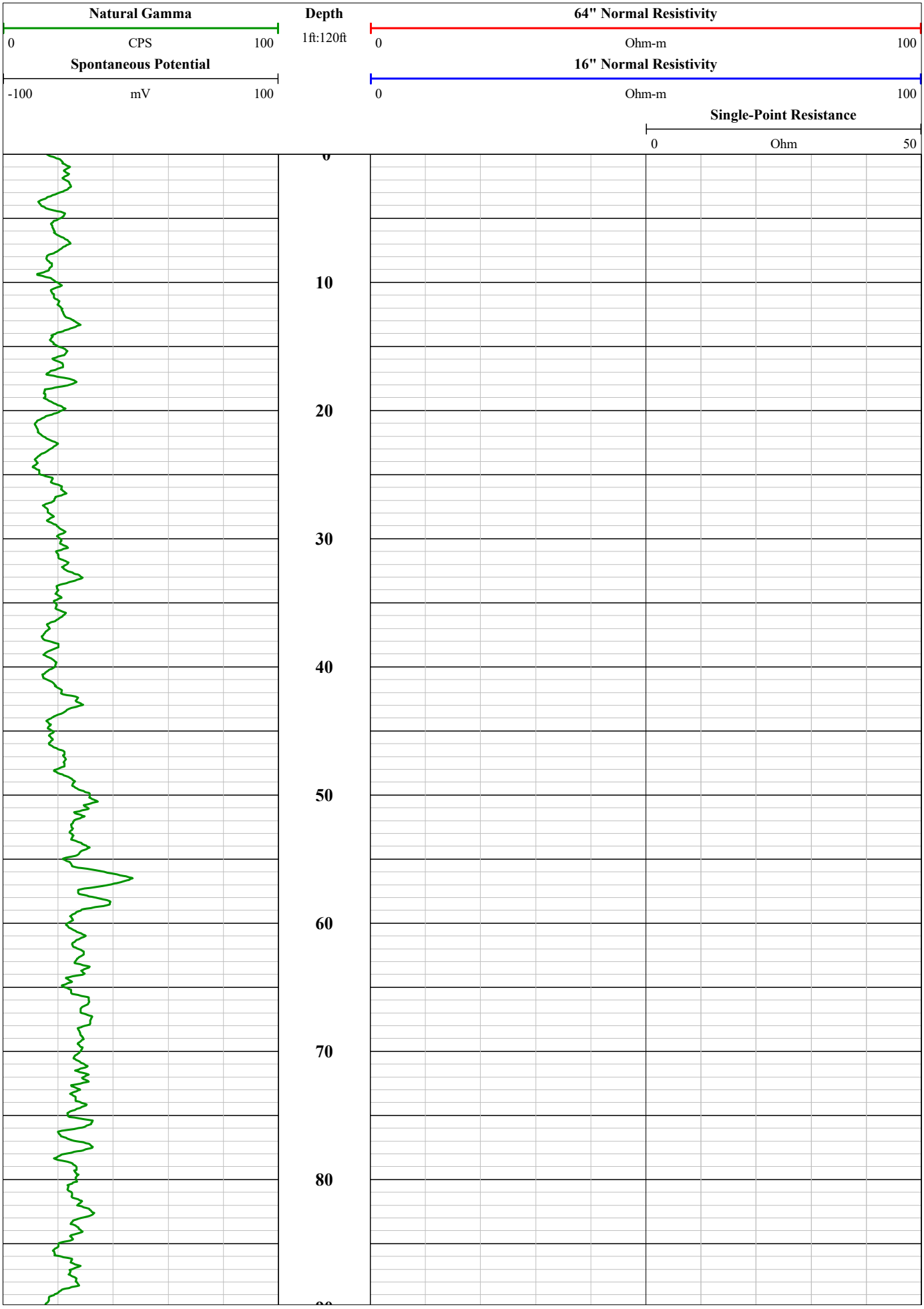
RUN No.	BIT	FROM	TO
1	5 7/8"	Mudline	167.28'
2	7"	Mudline	249.77'

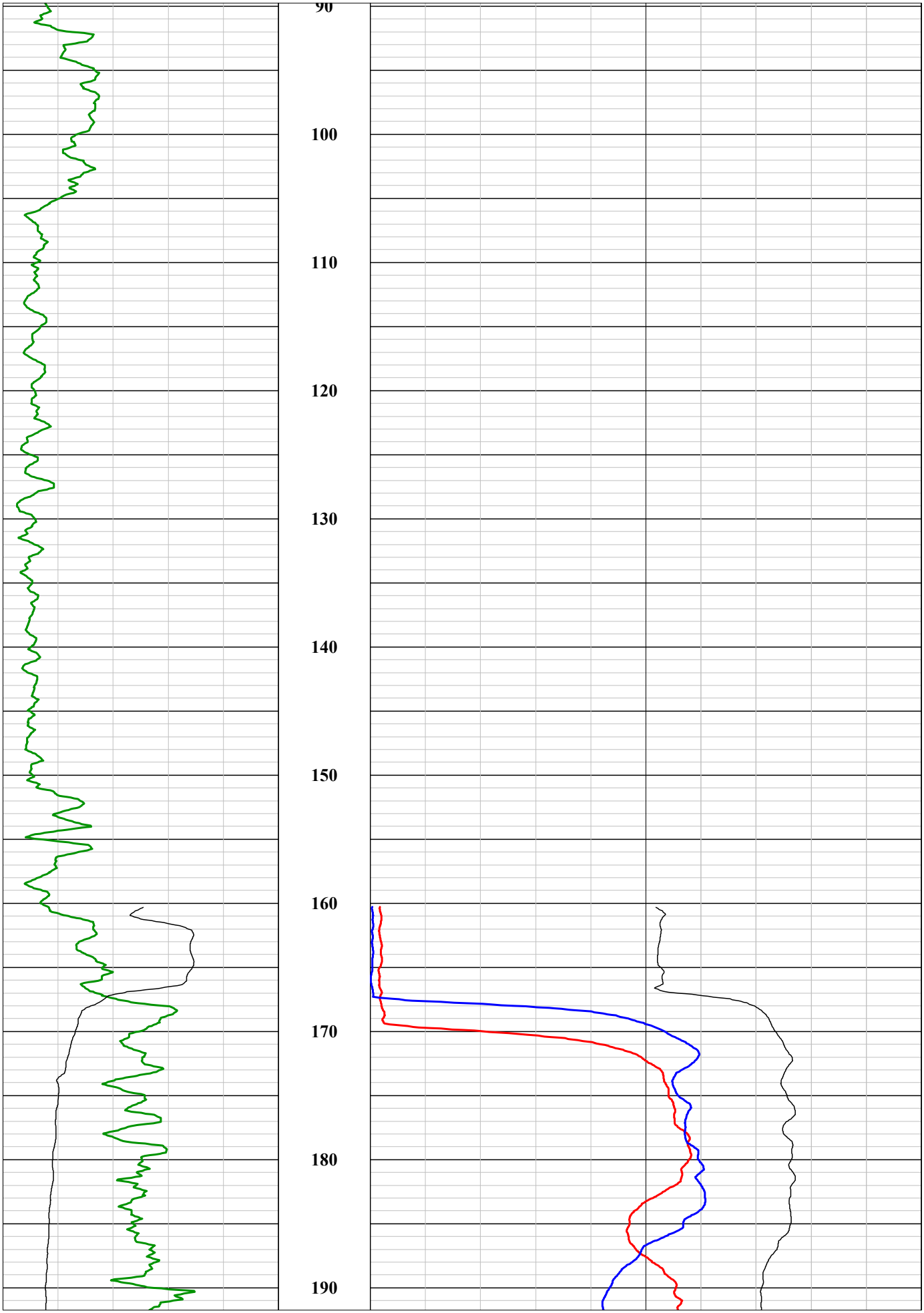
CASING RECORD

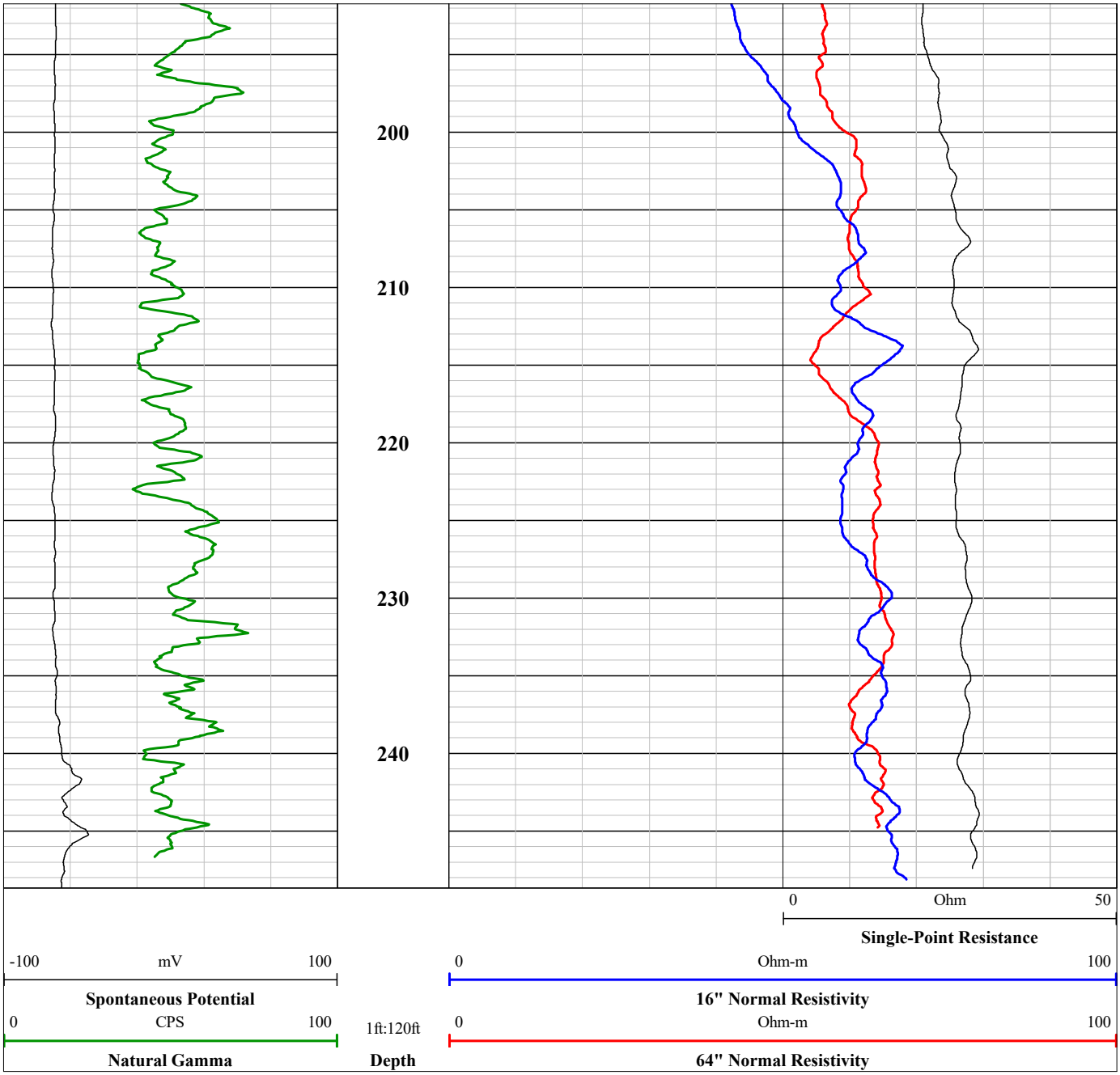
SIZE	WGT.	FROM	TO
5 7/8"	Steel	Mudline	167.28'
7"	Steel	Mudline	249.77'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-100
mV
100
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
100
16" Normal Resistivity
0
Ohm-m
100
Single-Point Resistance
0
Ohm
50
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
0
Ohm
50
Single-Point Resistance
-100
mV
100
Spontaneous Potential
0
Ohm-m
100
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
100
64" Normal Resistivity

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-28
Project L5RT Project
County Mackinac
State MI

COMPANY WSP
WELL BH19-28
PROJECT L5RT Project
COUNTY Mackinac **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81439 N
Longitude: 84.76743 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
Acoustic Televiewer

PERMANENT DATUM Mudline **ELEVATION** 399.9'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 October 2019			
RUN NUMBER	5			
LOG TYPE	PSLog			
DEPTH-DRILLER	249.77'			
DEPTH-LOGGER	238'			
BTM LOG INTERVAL	238'			
TOP LOG INTERVAL	164'			
RECORDED BY	CKL			
WITNESSED BY	WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	1.67'/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

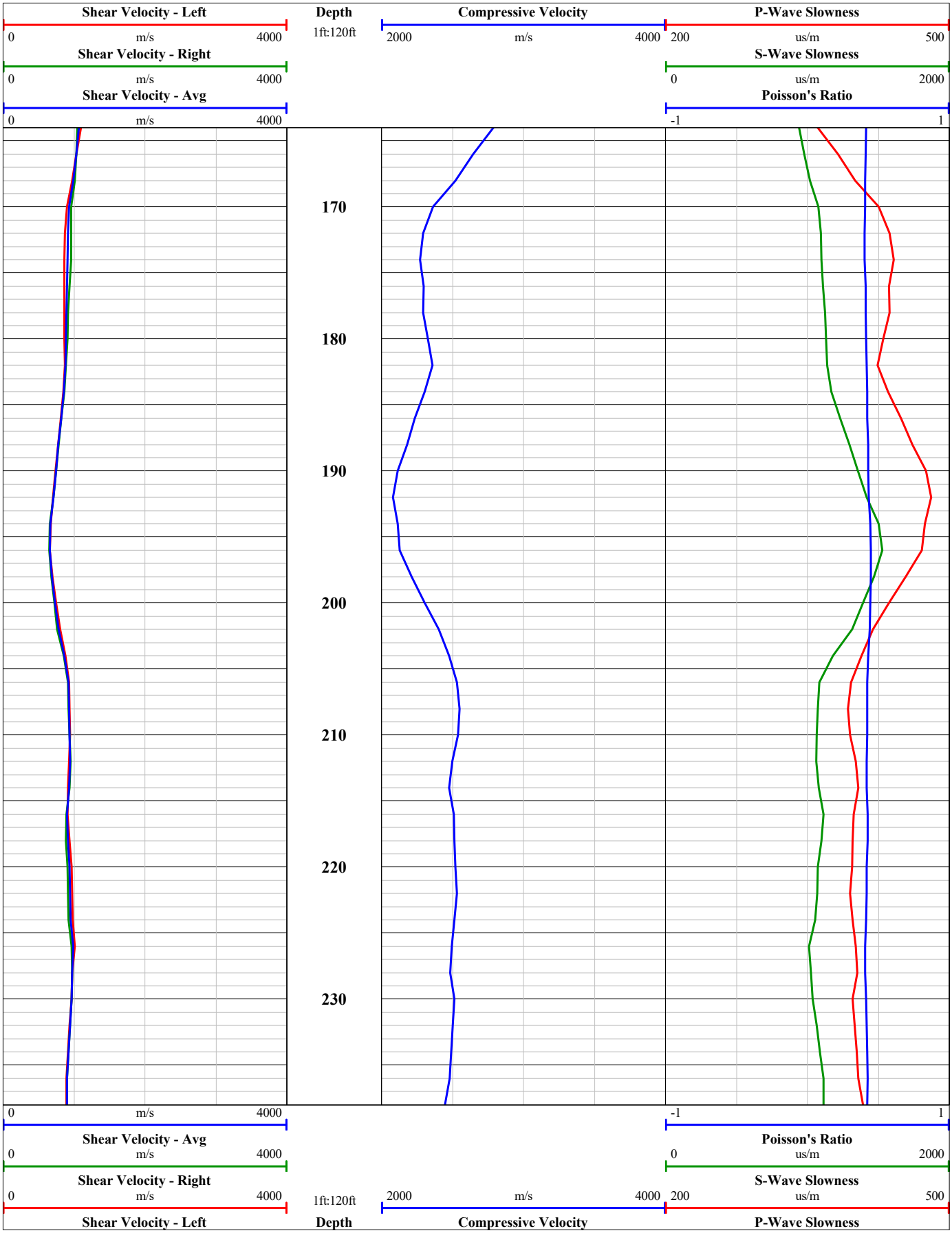
RUN No.	BIT	FROM	TO
1	5 7/8"	Mudline	167.28'
2	7"	Mudline	249.77'

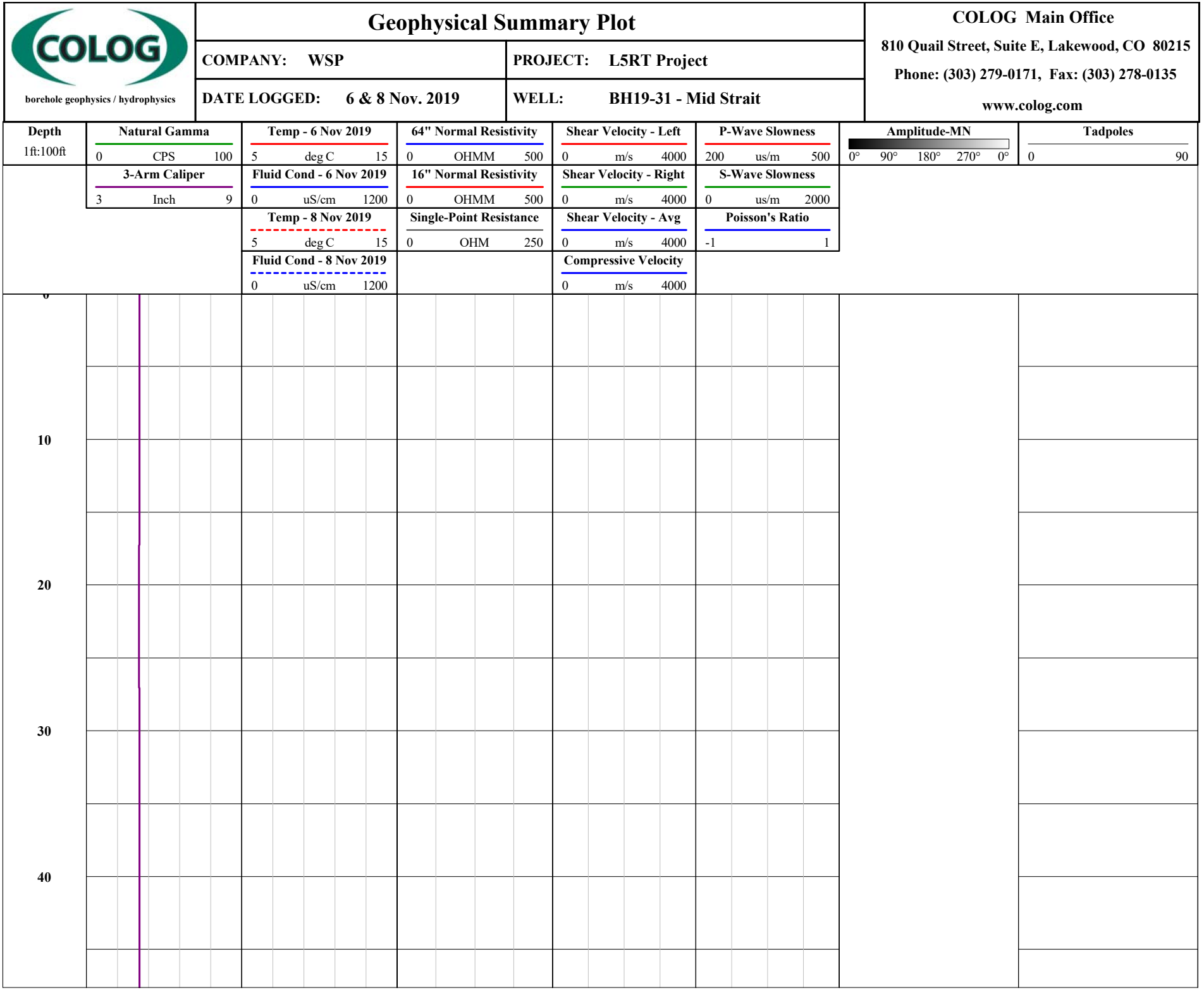
CASING RECORD

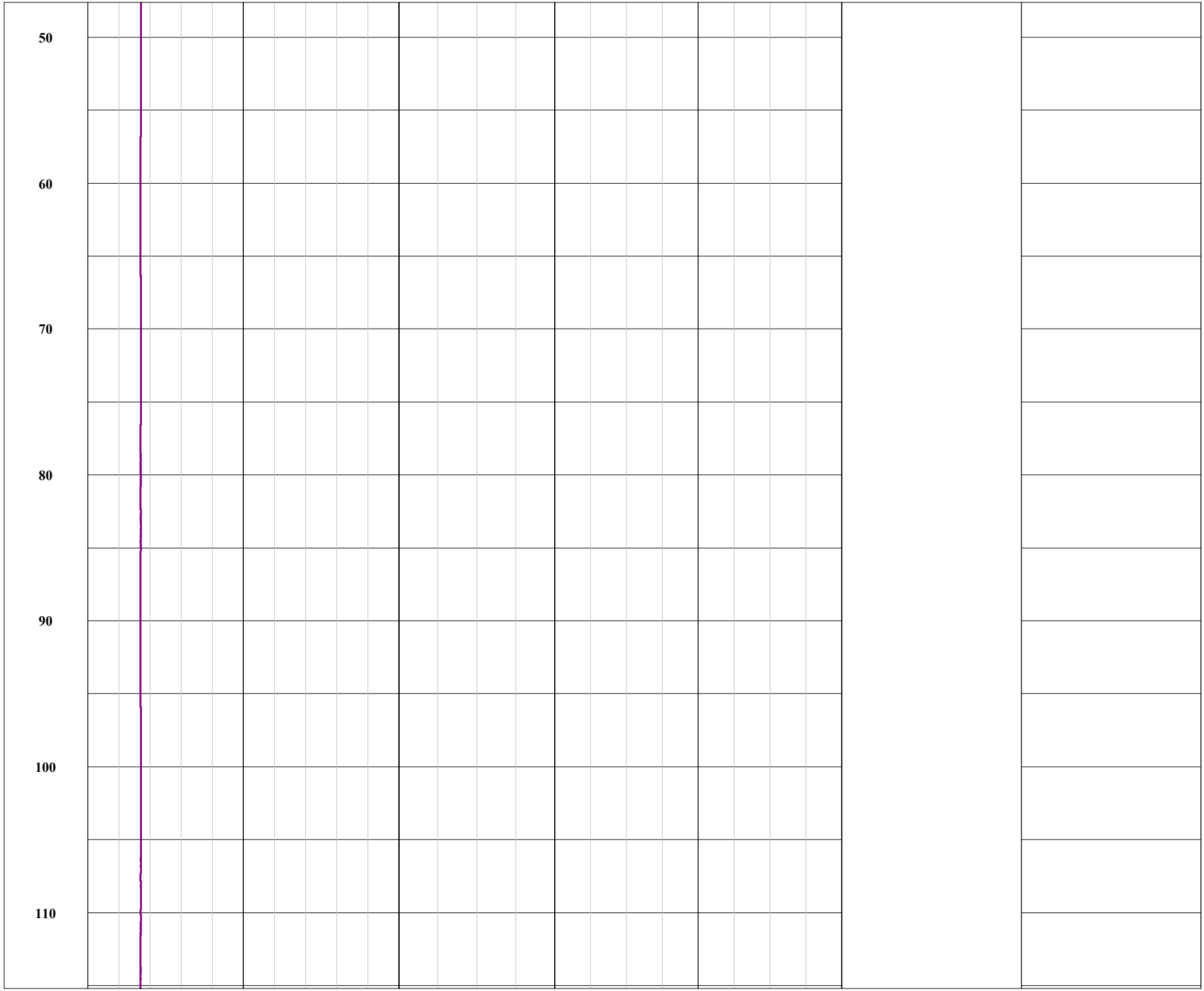
SIZE	WGT.	FROM	TO
5 7/8"	Steel	Mudline	167.28'
7"	Steel	Mudline	249.77'

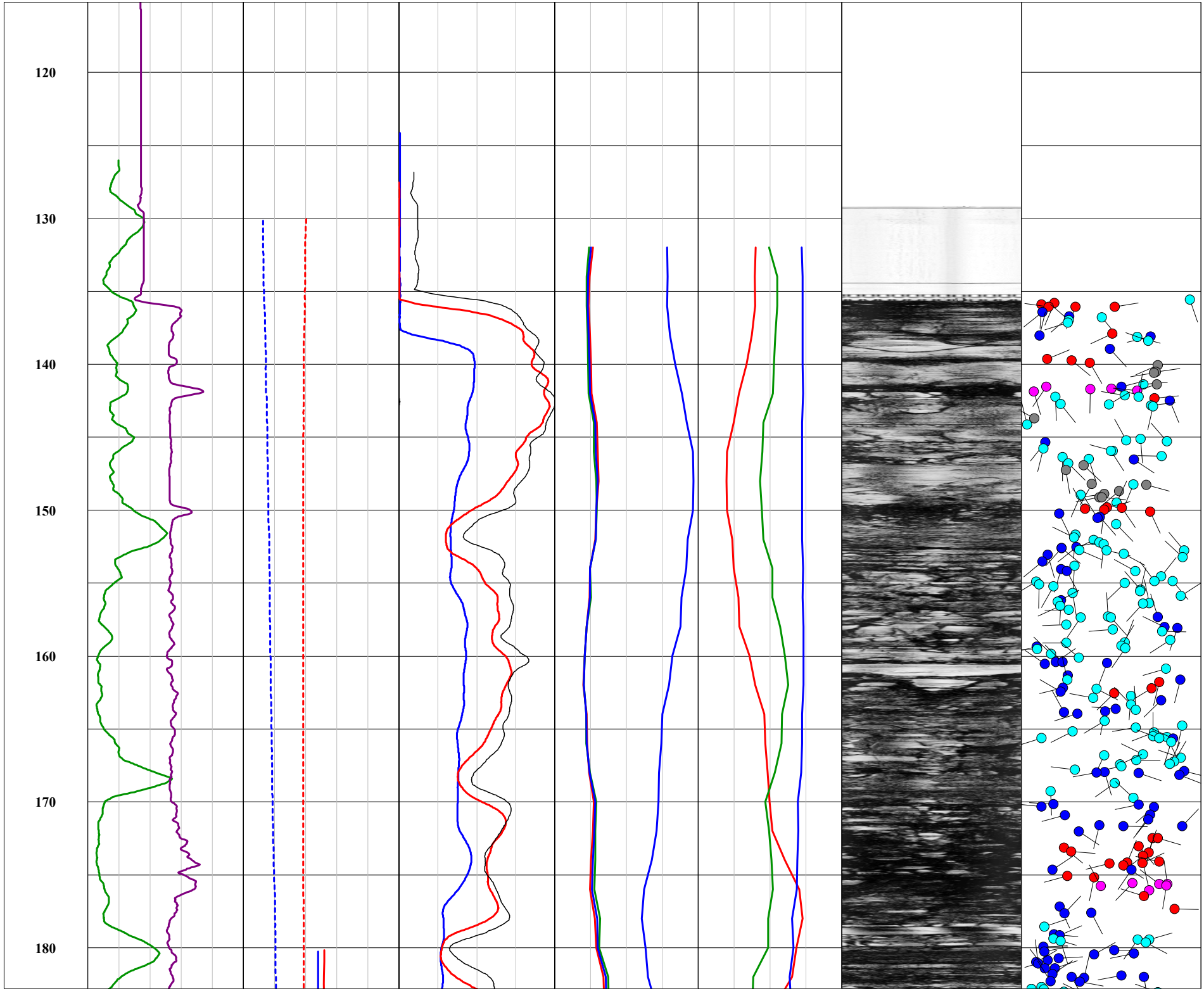
NA - Not Available, N/A - Not Applicable

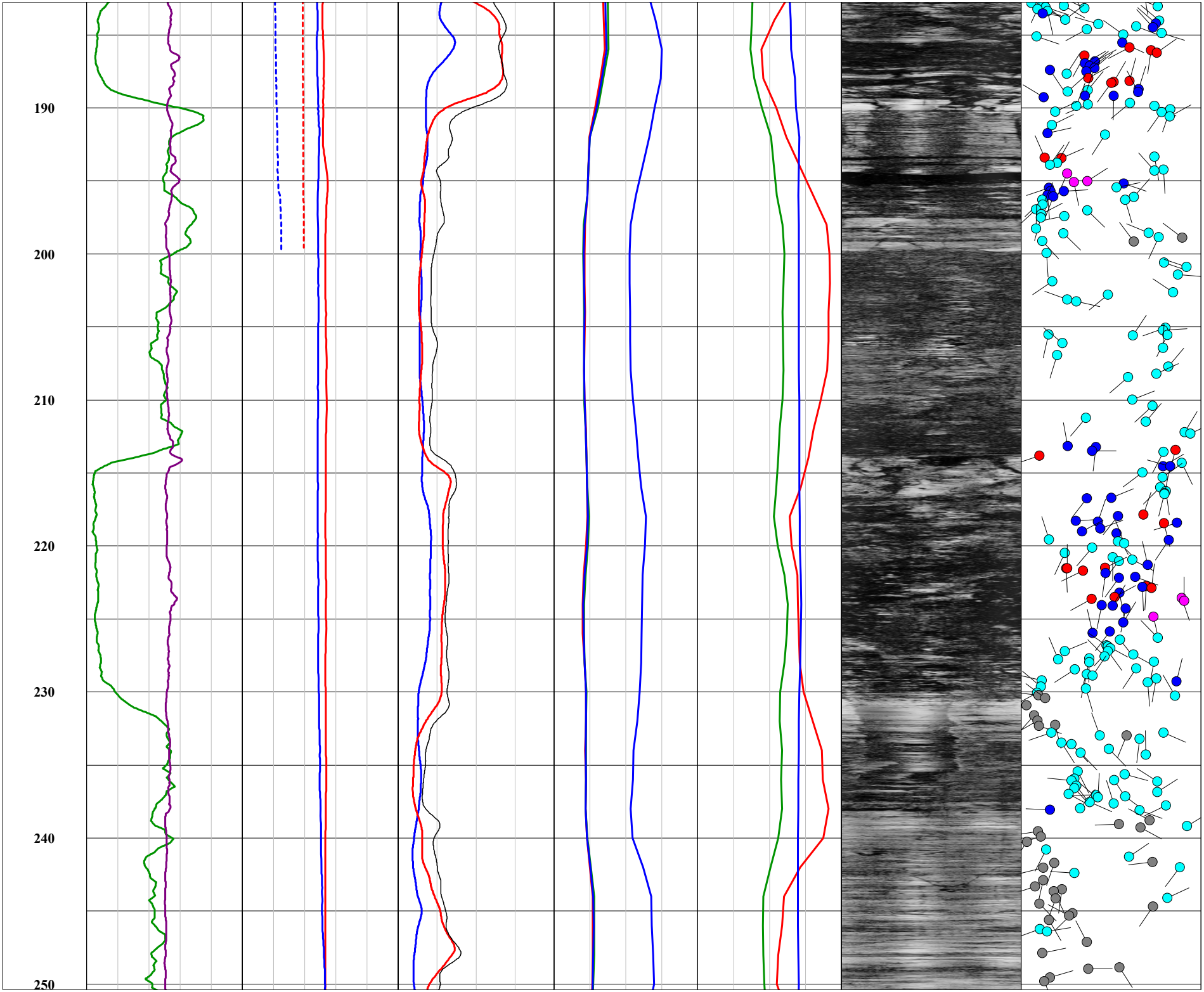
COMMENTS

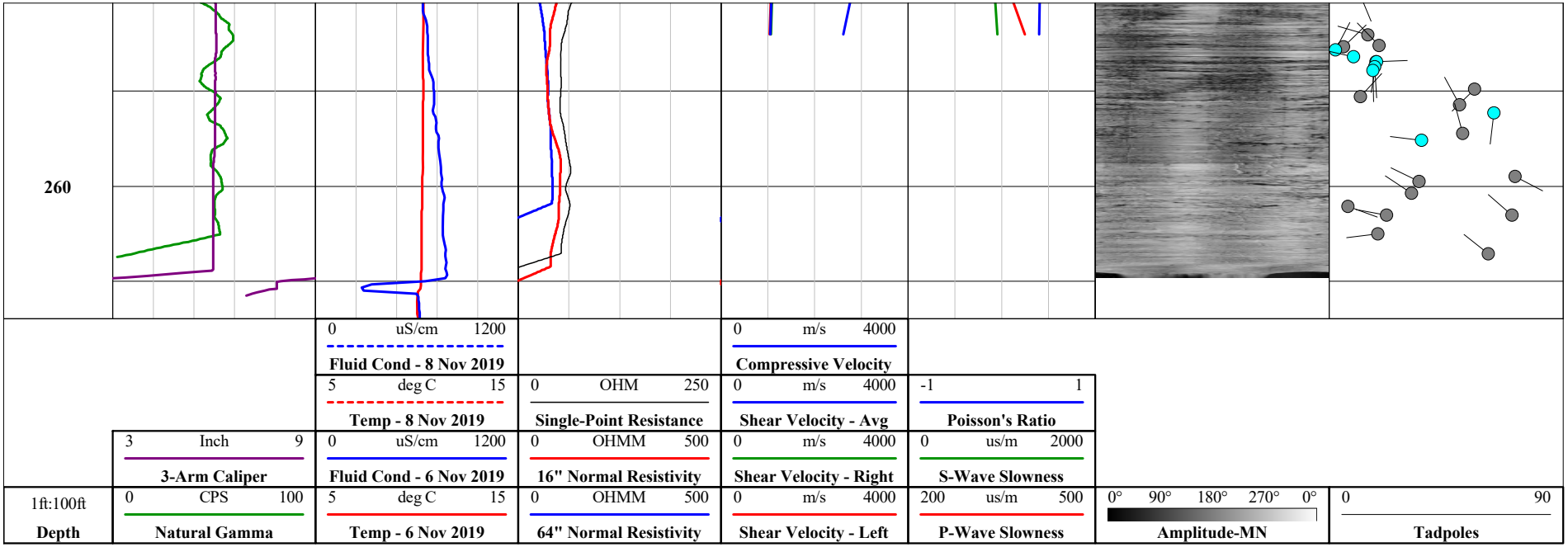

Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
2000
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
170
180
190
200
210
220
230
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
Depth
1ft:120ft
2000
m/s
4000
Compressive Velocity
-1
1
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness


COLOG
borehole geophysics / hydrophysics
Geophysical Summary Plot
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 6 & 8 Nov. 2019
WELL: BH19-31 - Mid Strait
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com
Depth
1ft:100ft
Natural Gamma
0 CPS 100
3-Arm Caliper
3 Inch 9
Temp - 6 Nov 2019
5 deg C 15
Fluid Cond - 6 Nov 2019
0 uS/cm 1200
Temp - 8 Nov 2019
5 deg C 15
Fluid Cond - 8 Nov 2019
0 uS/cm 1200
64" Normal Resistivity
0 OHMM 500
16" Normal Resistivity
0 OHMM 500
Single-Point Resistance
0 OHM 250
Shear Velocity - Left
0 m/s 4000
Shear Velocity - Right
0 m/s 4000
Shear Velocity - Avg
0 m/s 4000
Compressive Velocity
0 m/s 4000
P-Wave Slowness
200 us/m 500
S-Wave Slowness
0 us/m 2000
Poisson's Ratio
-1 1
Amplitude-MN
0° 90° 180° 270° 0°
Tadpoles
0 90
0
10
20
30
40


50
60
70
80
90
100
110


120
130
140
150
160
170
180


190
200
210
220
230
240
250


260
0 uS/cm 1200
Fluid Cond - 8 Nov 2019
0 m/s 4000
Compressive Velocity
5 deg C 15
Temp - 8 Nov 2019
0 OHM 250
Single-Point Resistance
0 m/s 4000
Shear Velocity - Avg
-1 1
Poisson's Ratio
3 Inch 9
3-Arm Caliper
0 uS/cm 1200
Fluid Cond - 6 Nov 2019
0 OHMM 500
16" Normal Resistivity
0 m/s 4000
Shear Velocity - Right
0 us/m 2000
S-Wave Slowness
1ft:100ft
Depth
0 CPS 100
Natural Gamma
5 deg C 15
Temp - 6 Nov 2019
0 OHMM 500
64" Normal Resistivity
0 m/s 4000
Shear Velocity - Left
200 us/m 500
P-Wave Slowness
0° 90° 180° 270° 0°
Amplitude-MN
0 90
Tadpoles

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-31
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-31
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81090 N
Longitude: 84.76751 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed Caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 462.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	6 & 8 Nov 2019			
RUN NUMBER	4,2			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	265.7'			
DEPTH-LOGGER	265'			
BTM LOG INTERVAL	264.8'			
TOP LOG INTERVAL	129.2'			
RECORDED BY	JBG			
WITNESSED BY	WSP			
PROBE TYPE, S/N	ABI/ALT #111018			
LOGGING SPEED	5 fpm			
A.S.D.E. / Sample Interval	0.2' / 0.008'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

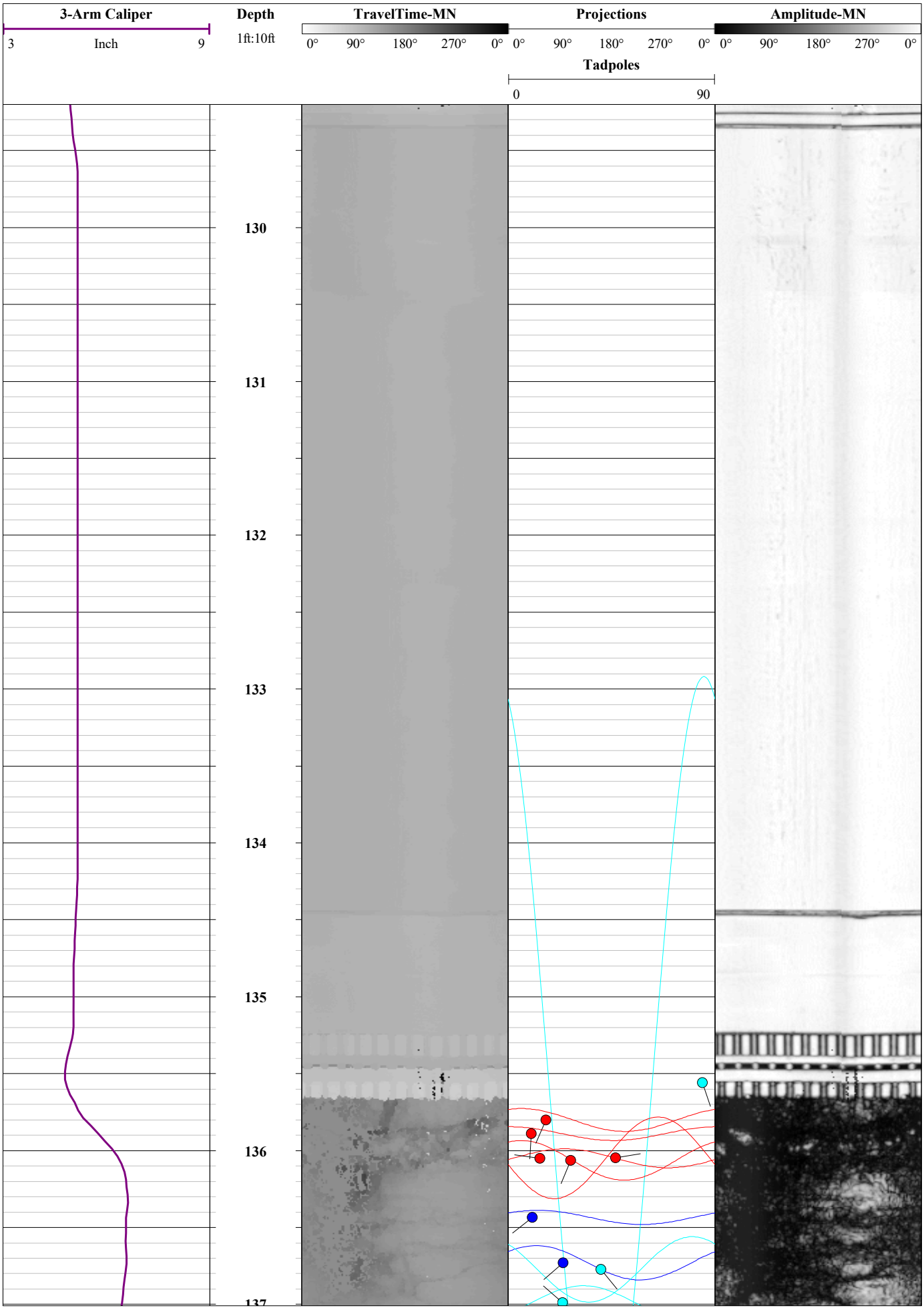
RUN No.	BIT	FROM	TO
1	7"	Mudline/TOC	75.4'
2	6"	Mudline/TOC	265.7'

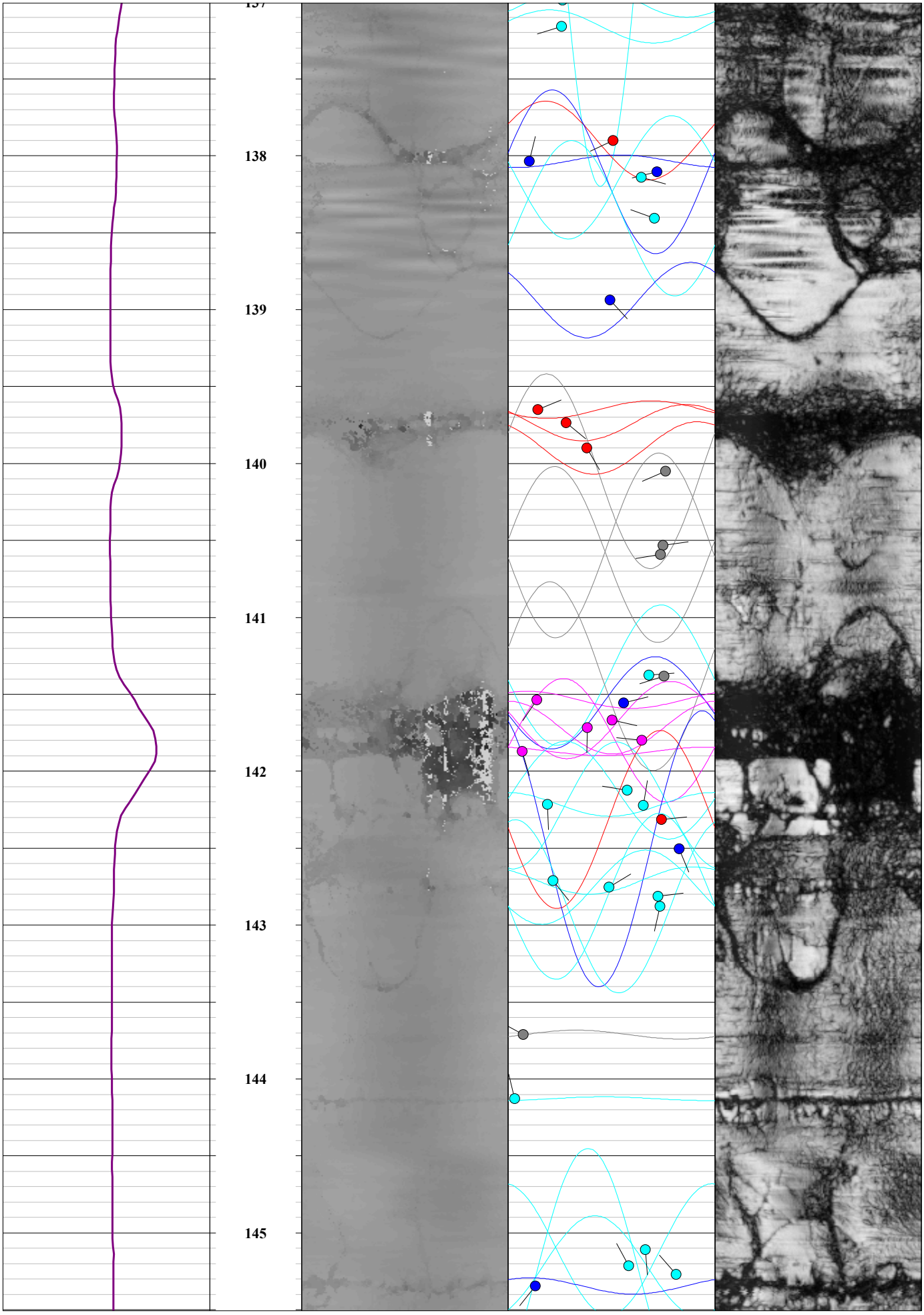
CASING RECORD

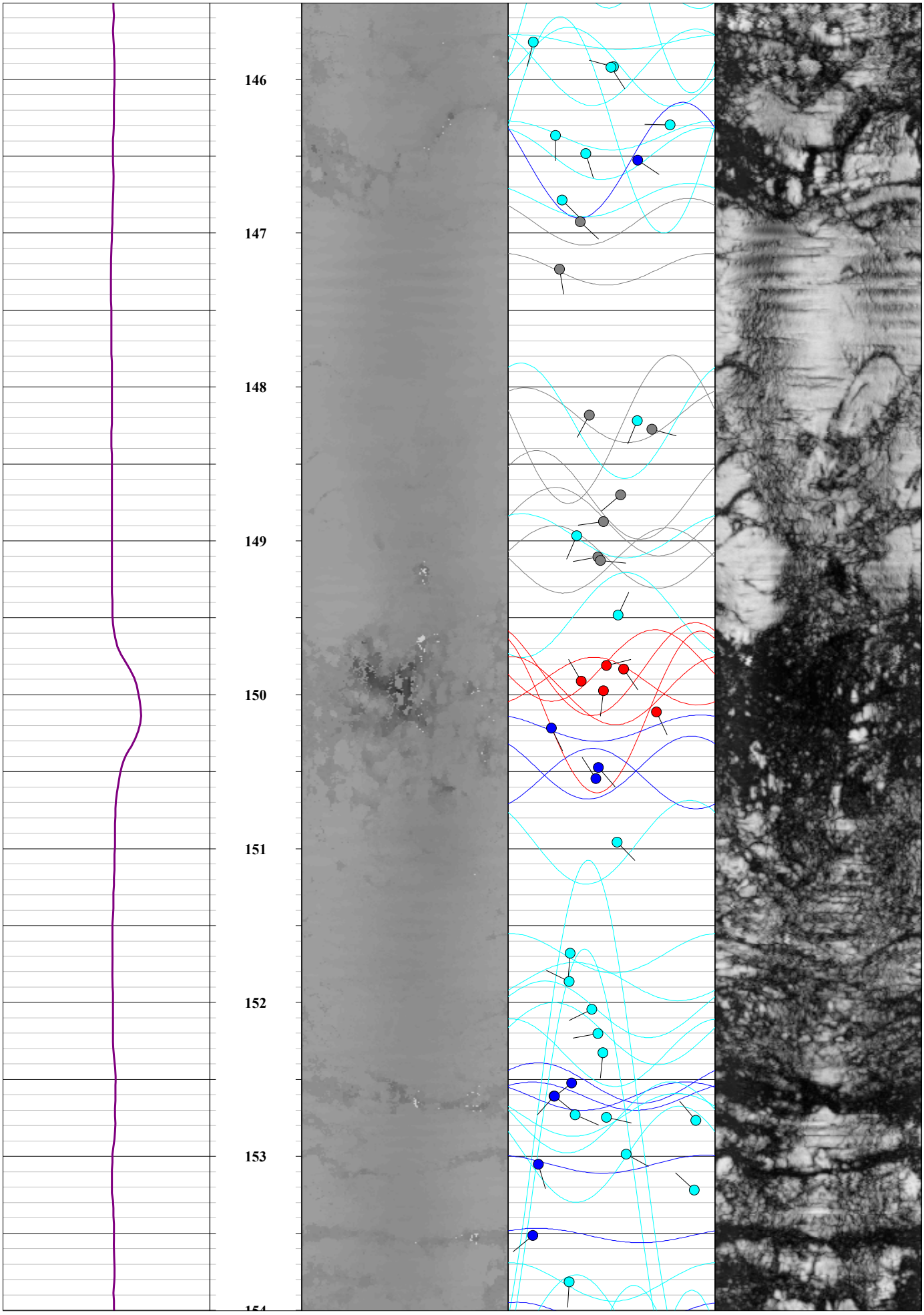
SIZE	WGT.	FROM	TO
6"	Steel	Mudline/TOC	135.5'

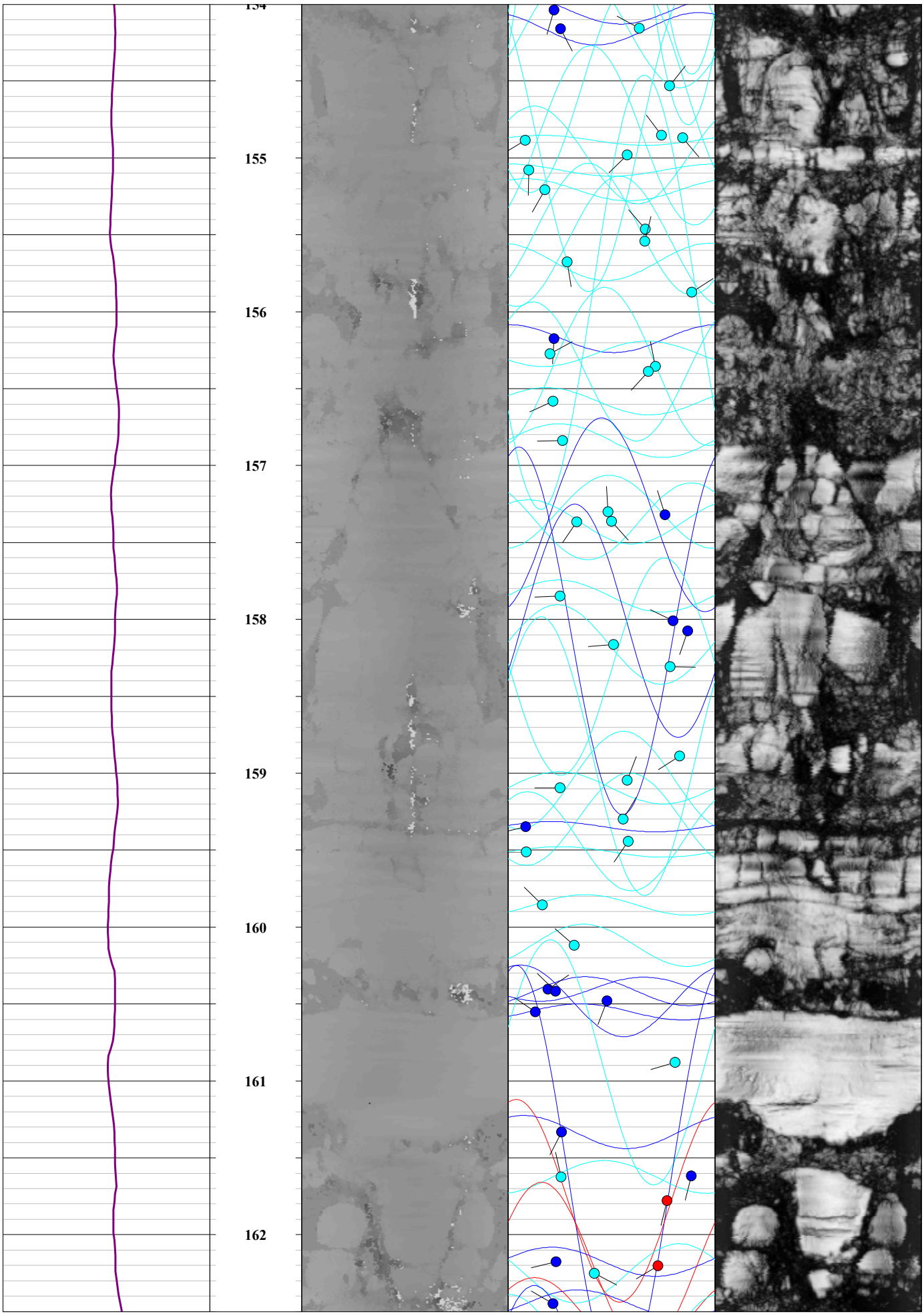
NA - Not Available, N/A - Not Applicable

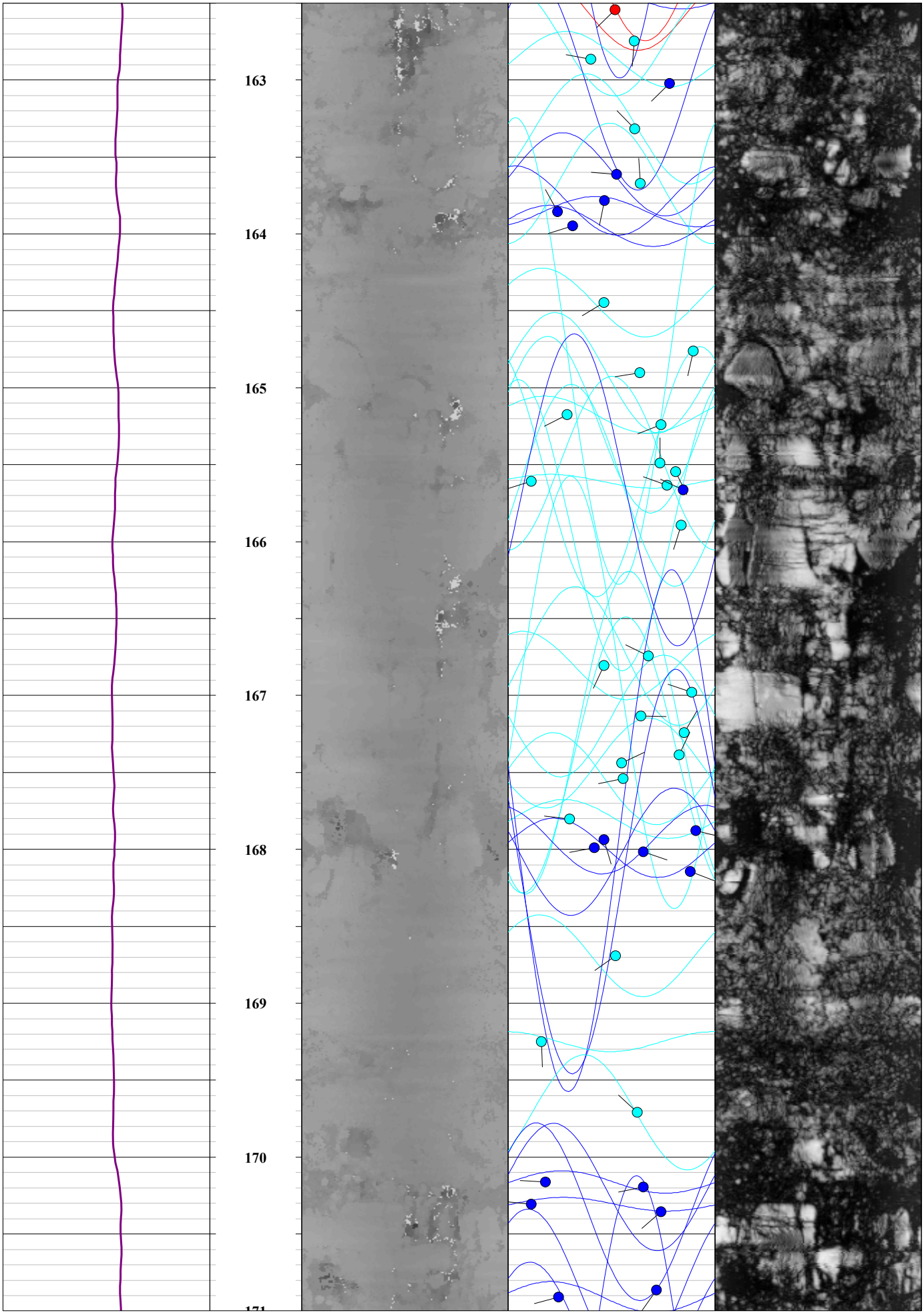
COMMENTS

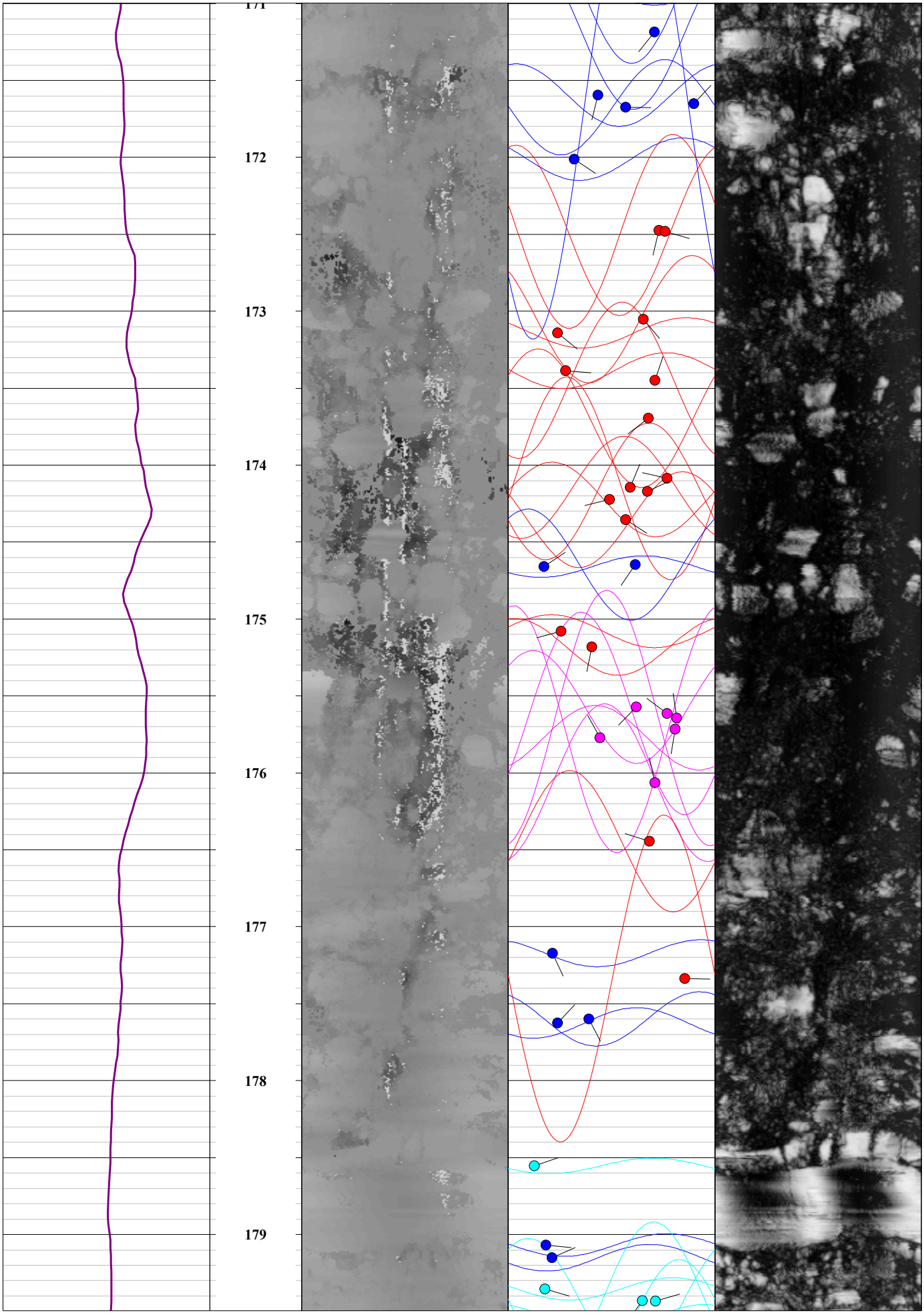

3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-MN
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude-MN
0°
90°
180°
270°
0°
130
131
132
133
134
135
136
137

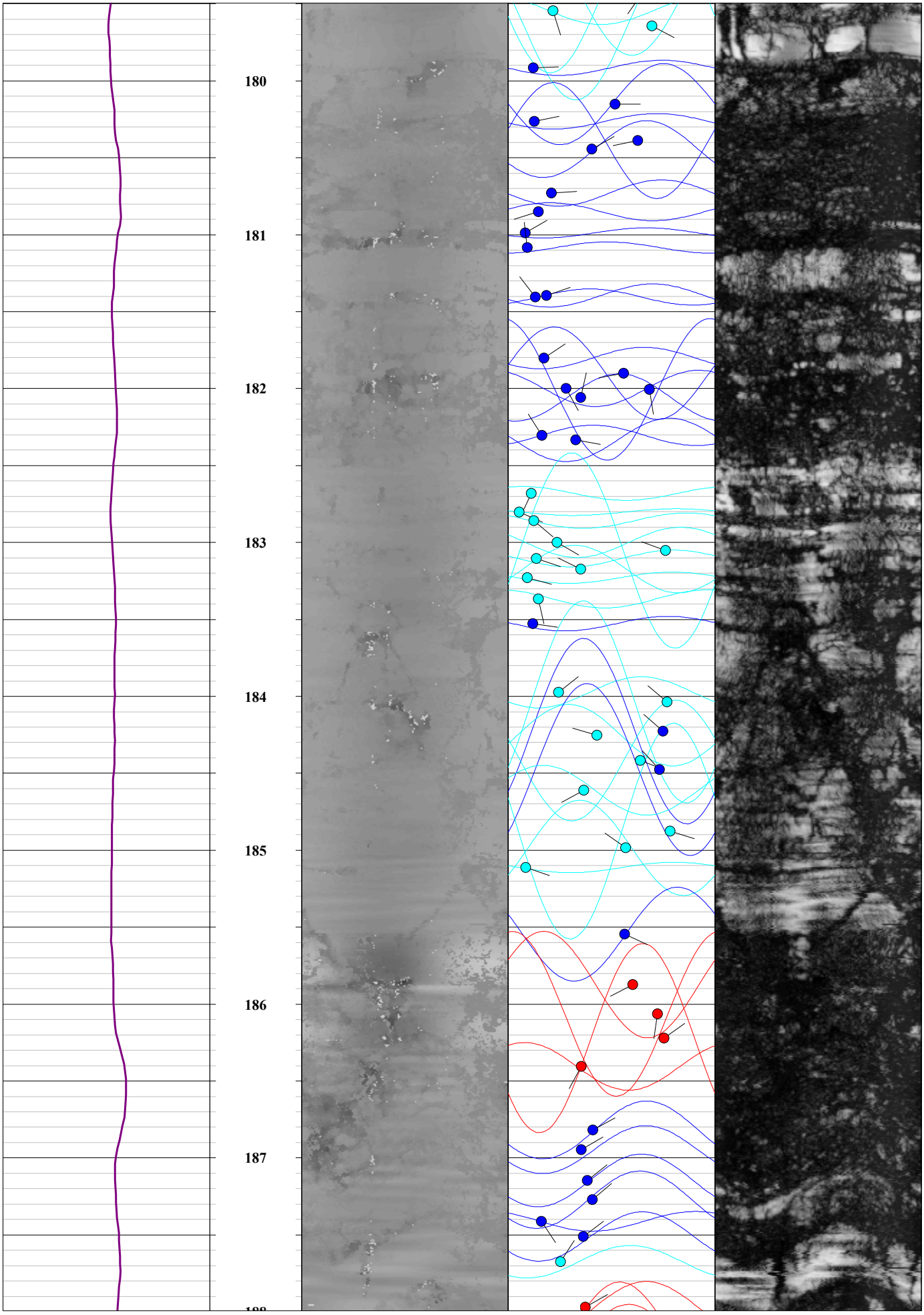

138
139
140
141
142
143
144
145

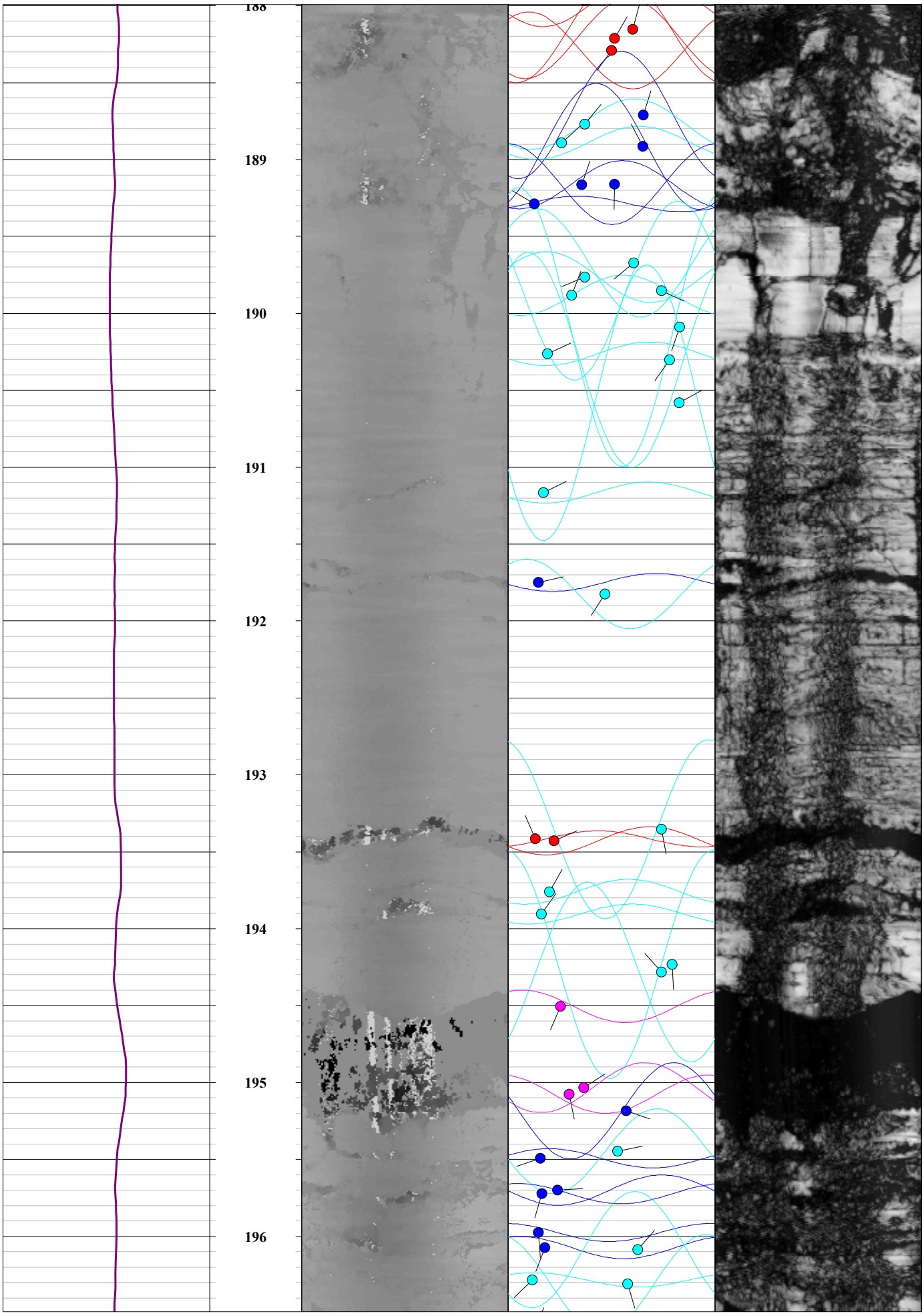

146
147
148
149
150
151
152
153
154

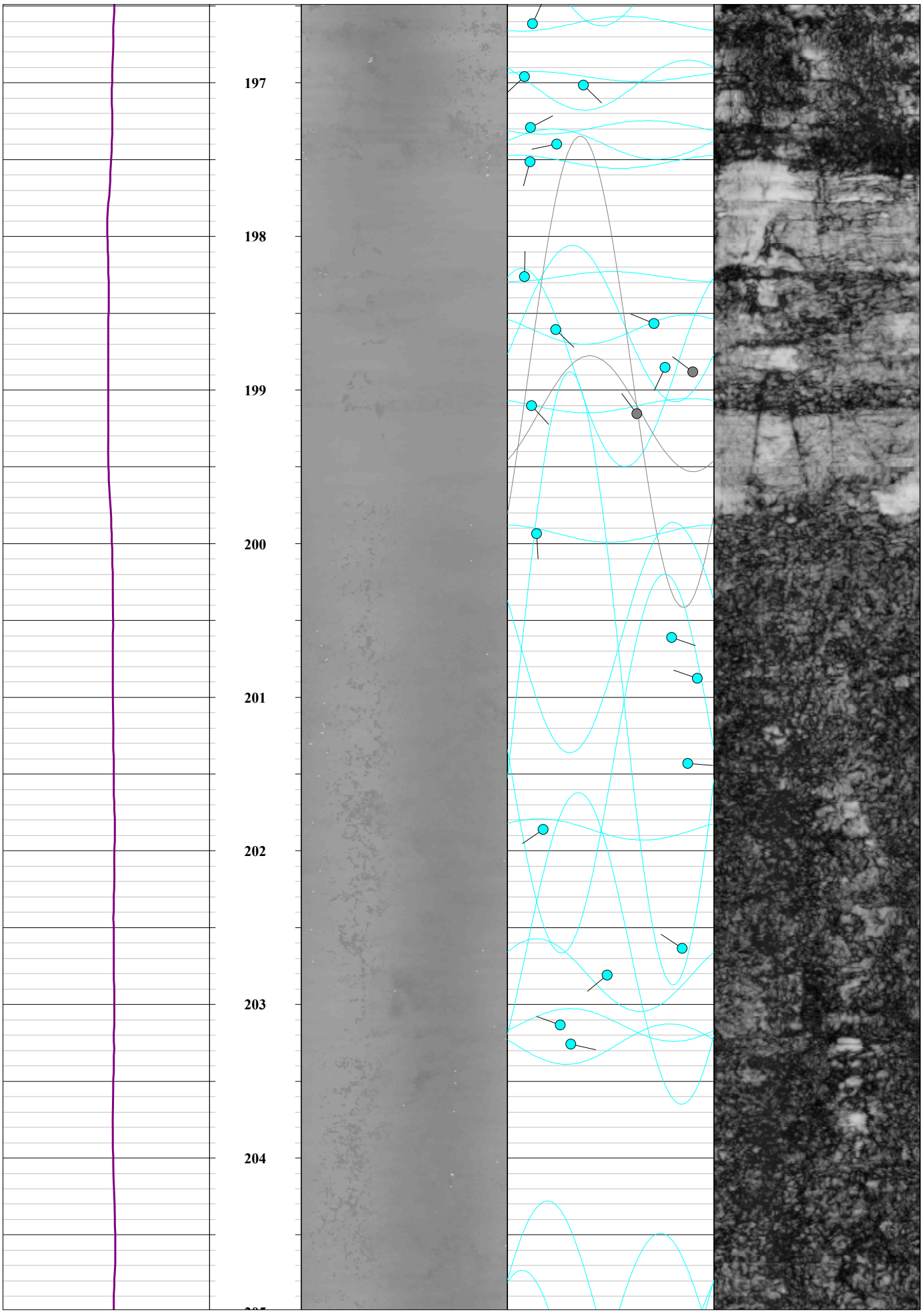

155
156
157
158
159
160
161
162

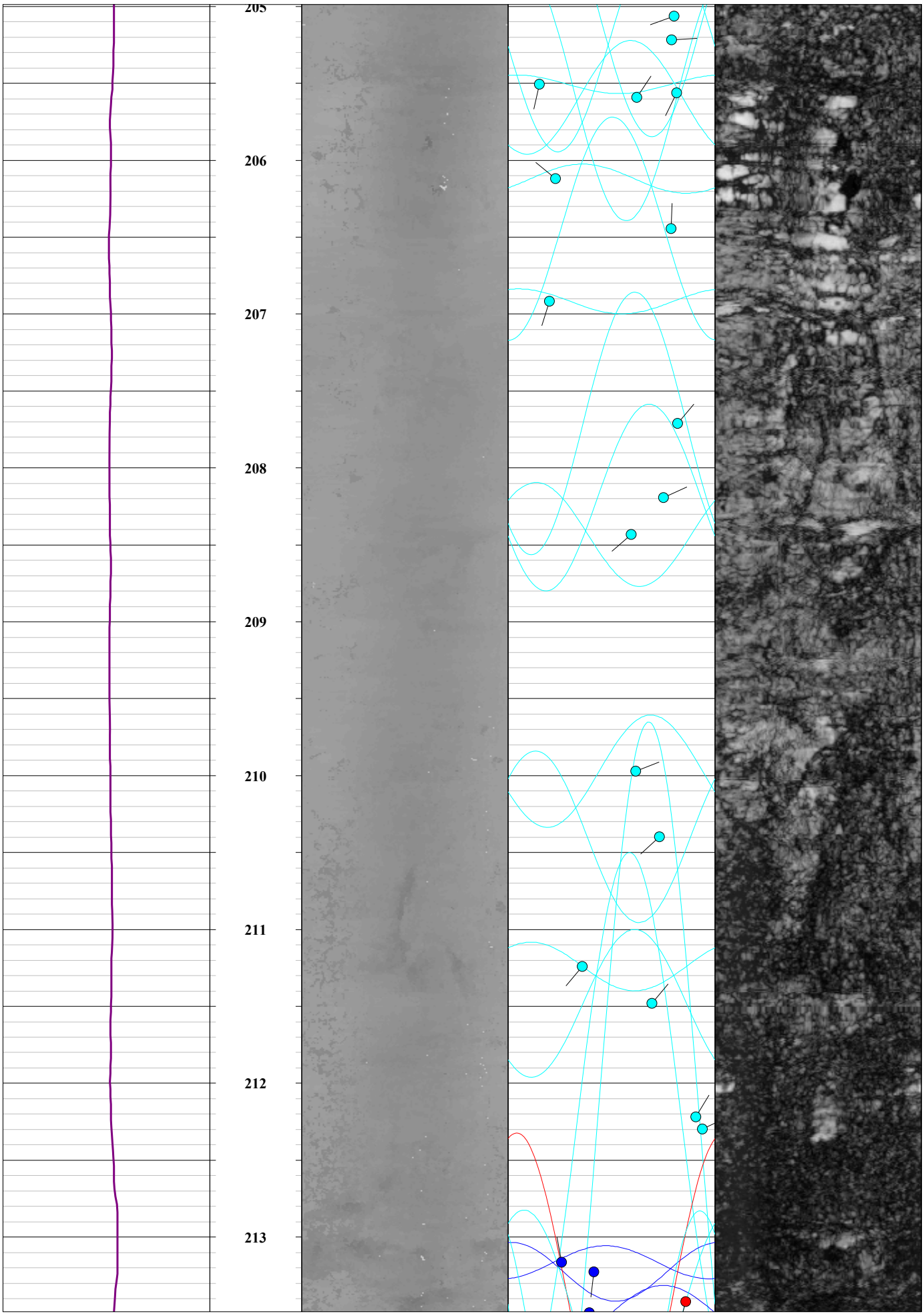

163
164
165
166
167
168
169
170
171

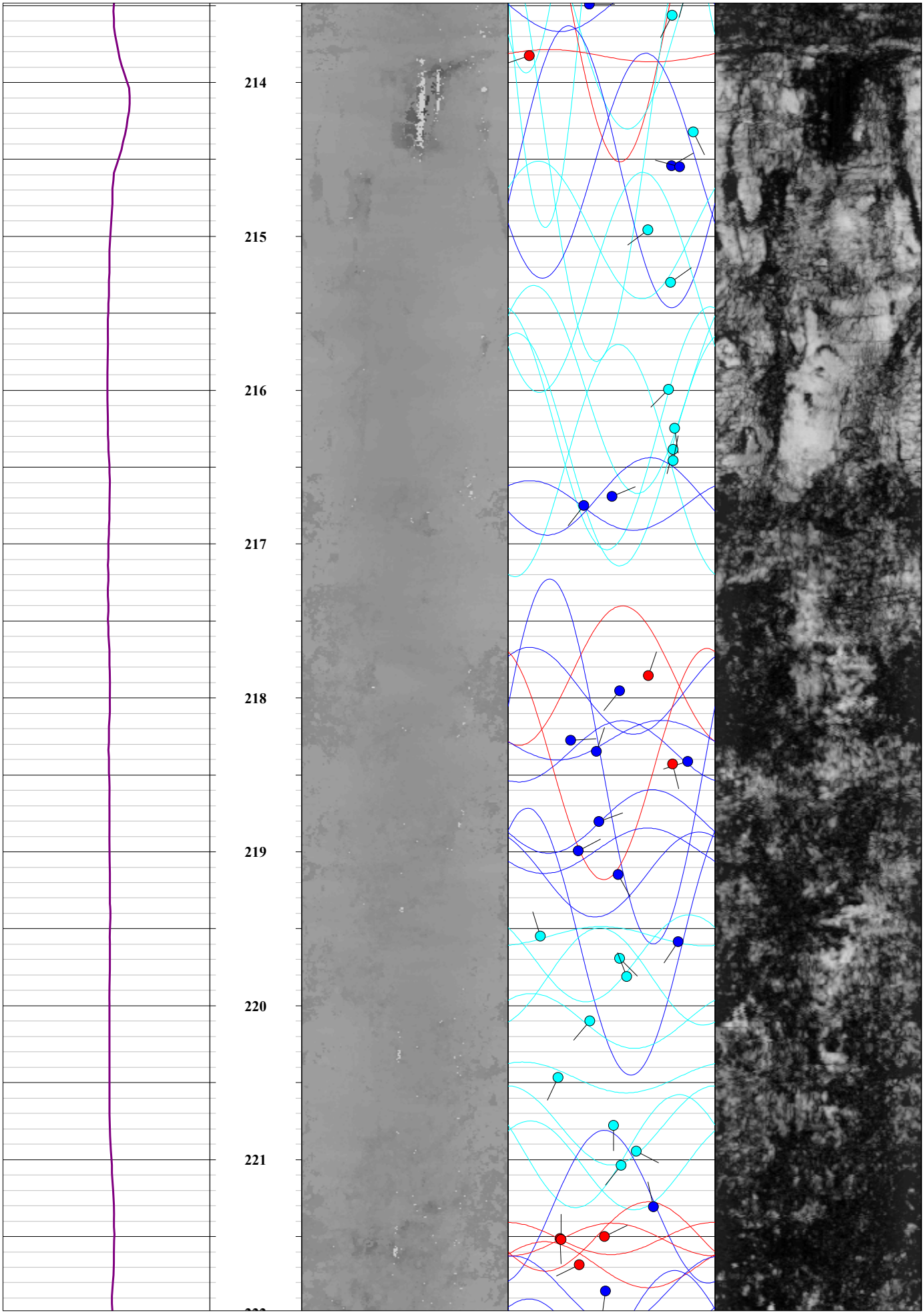

171
172
173
174
175
176
177
178
179

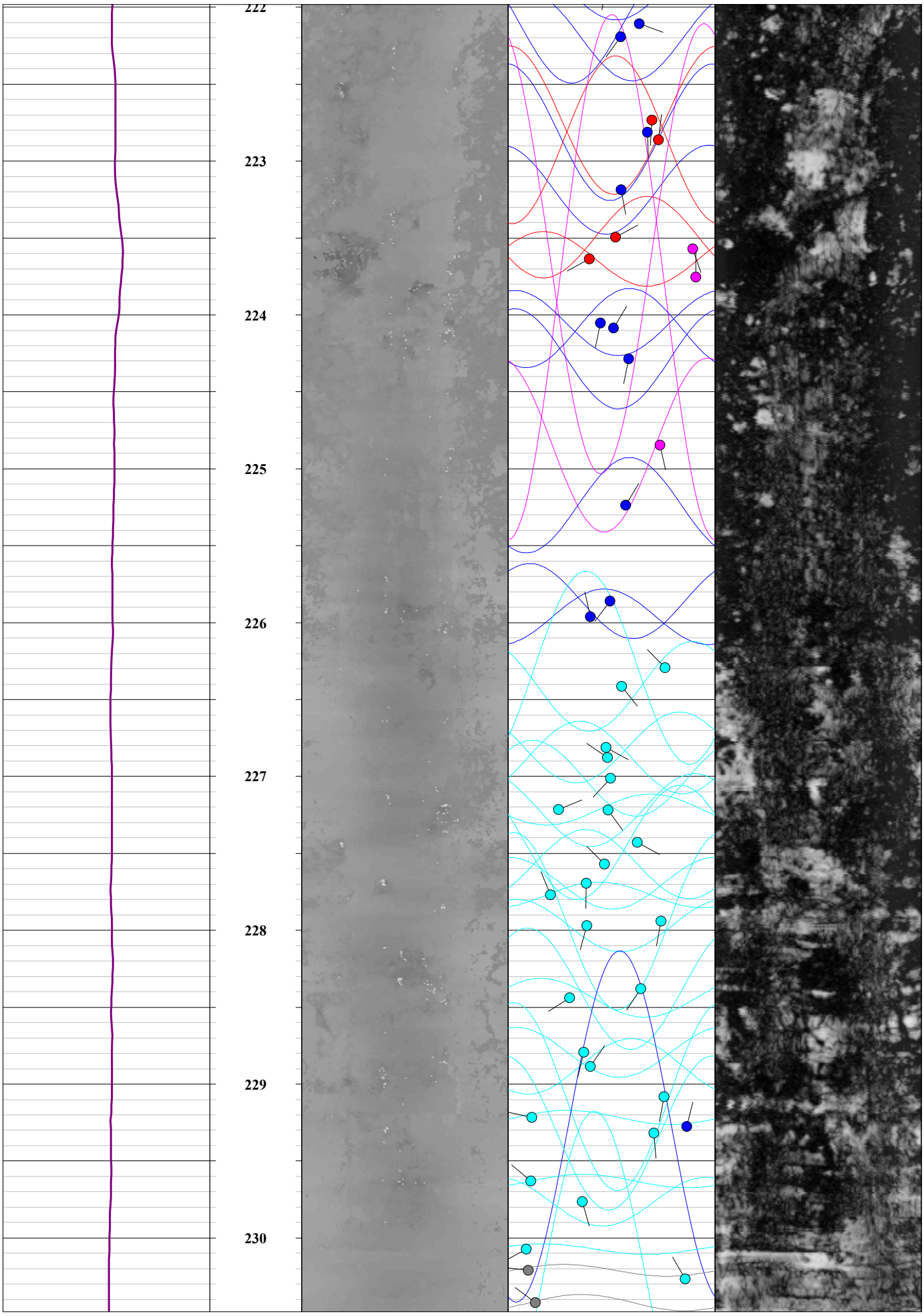

180
181
182
183
184
185
186
187

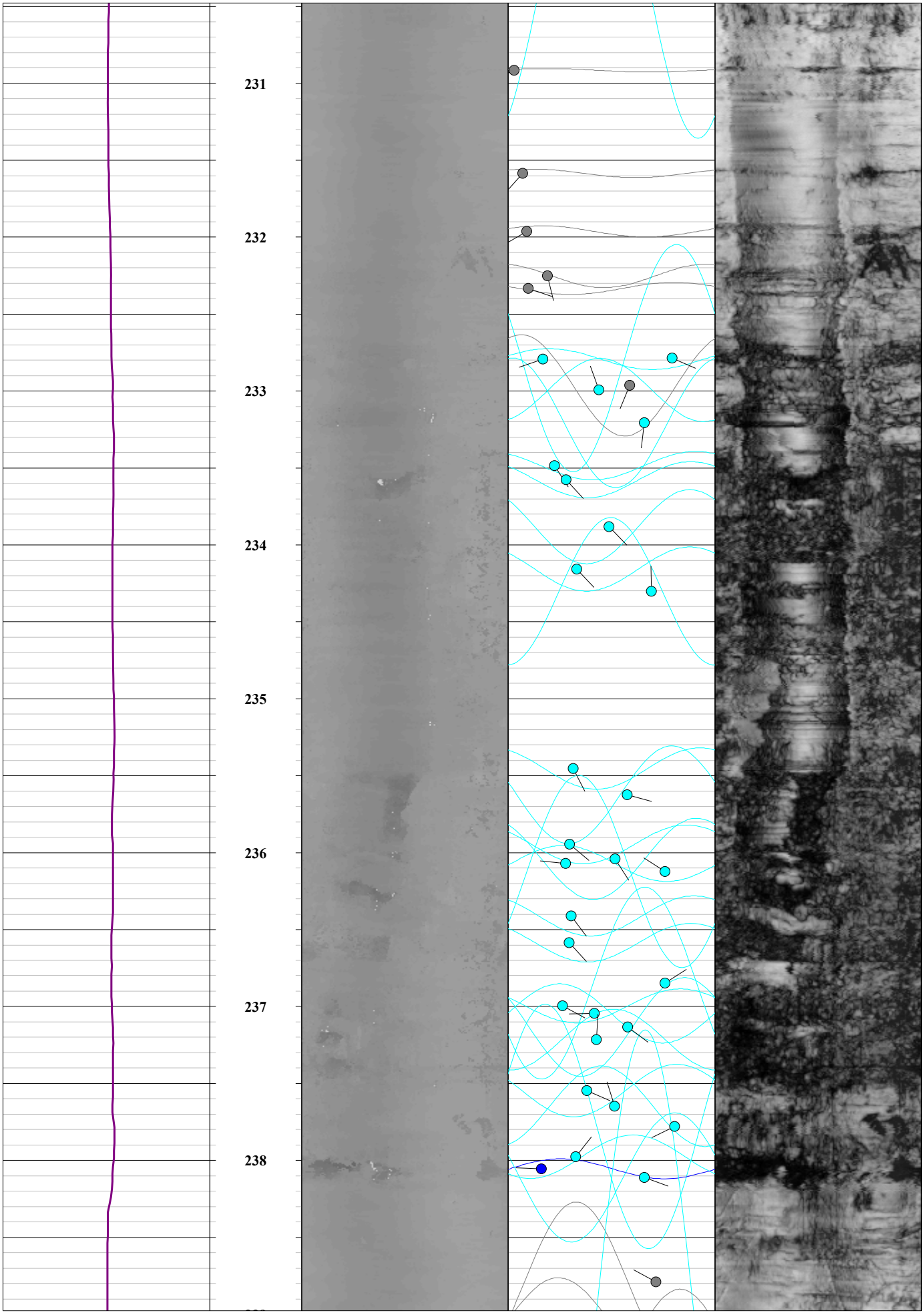

188
189
190
191
192
193
194
195
196

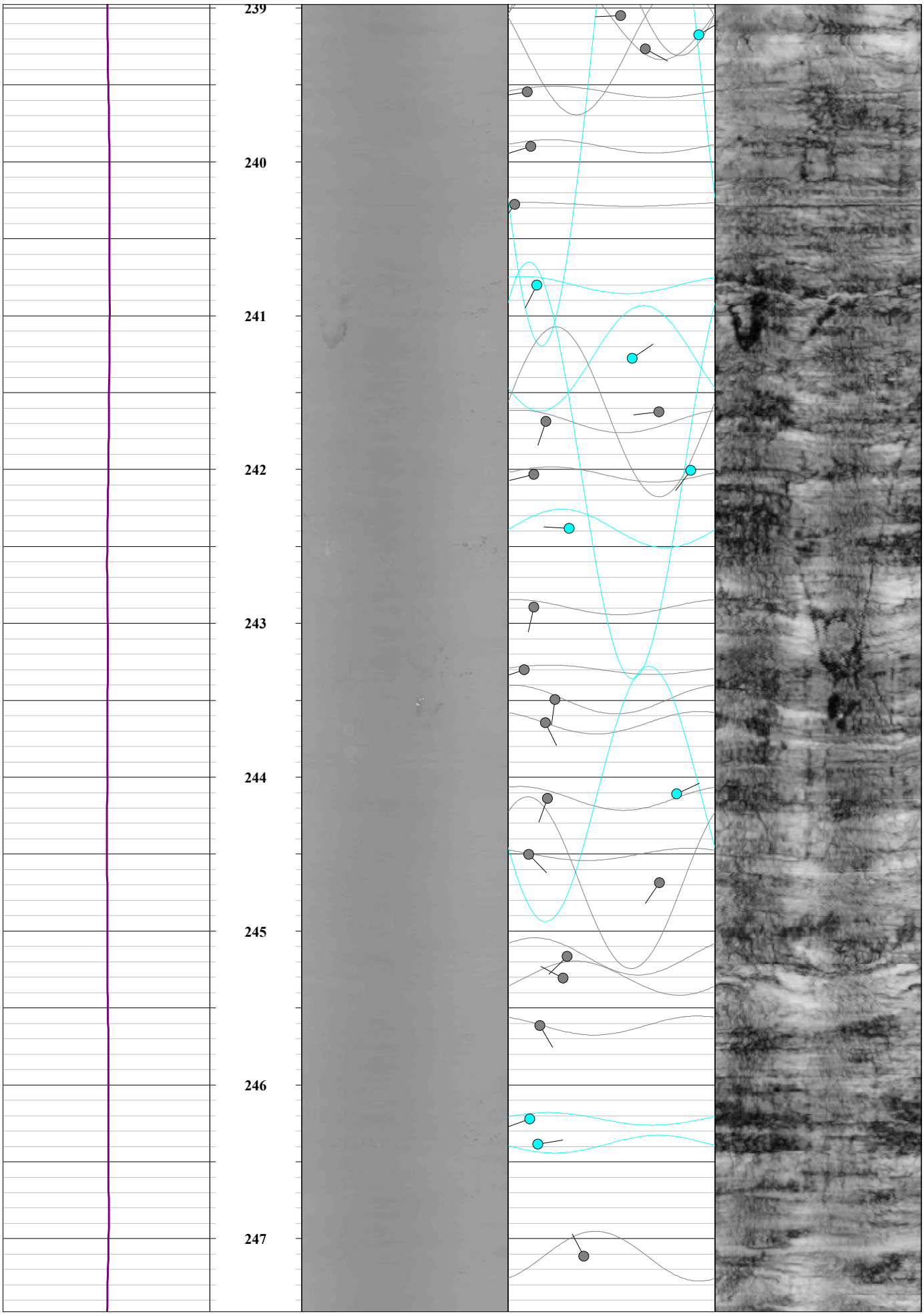

197
198
199
200
201
202
203
204

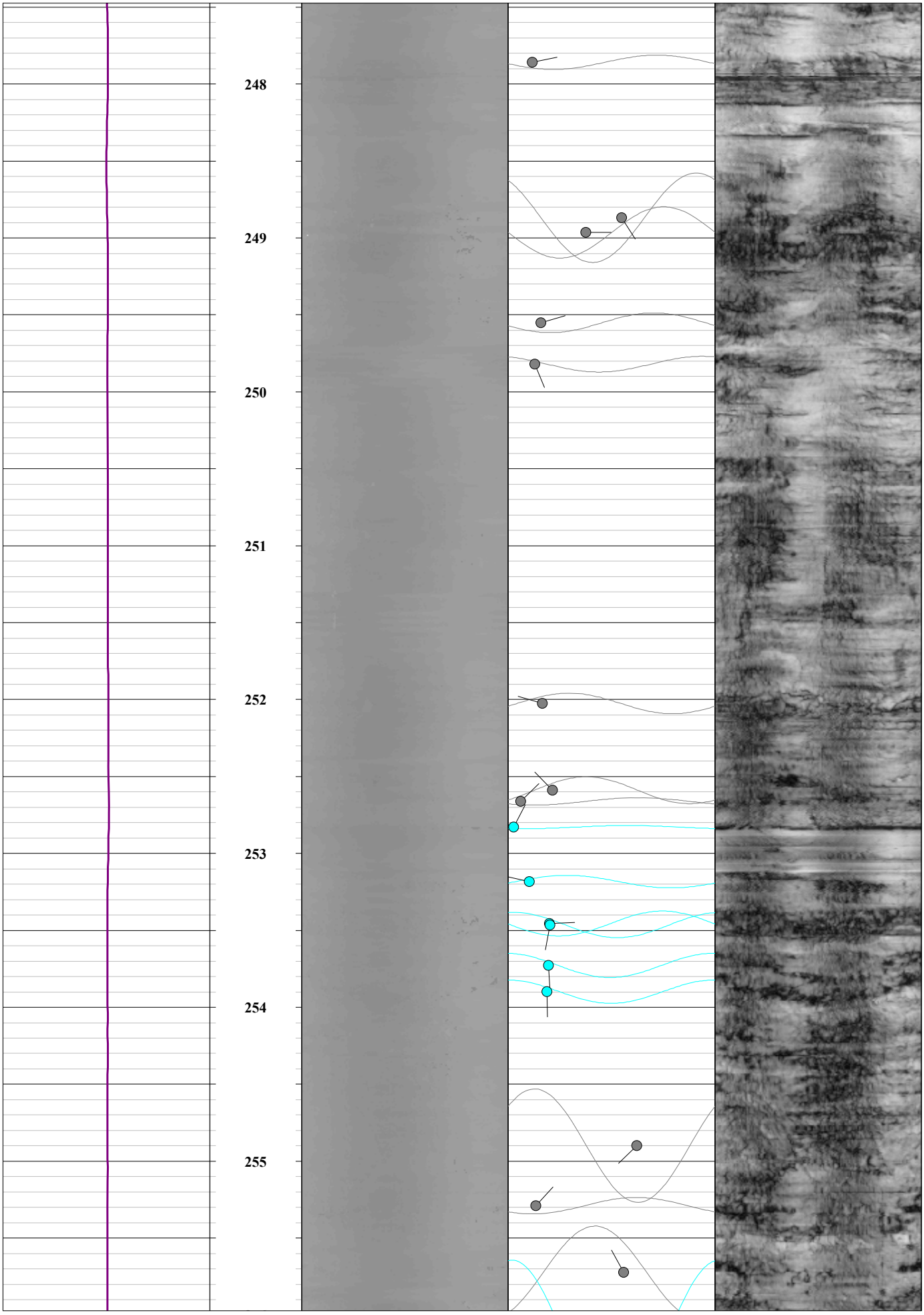

205
206
207
208
209
210
211
212
213

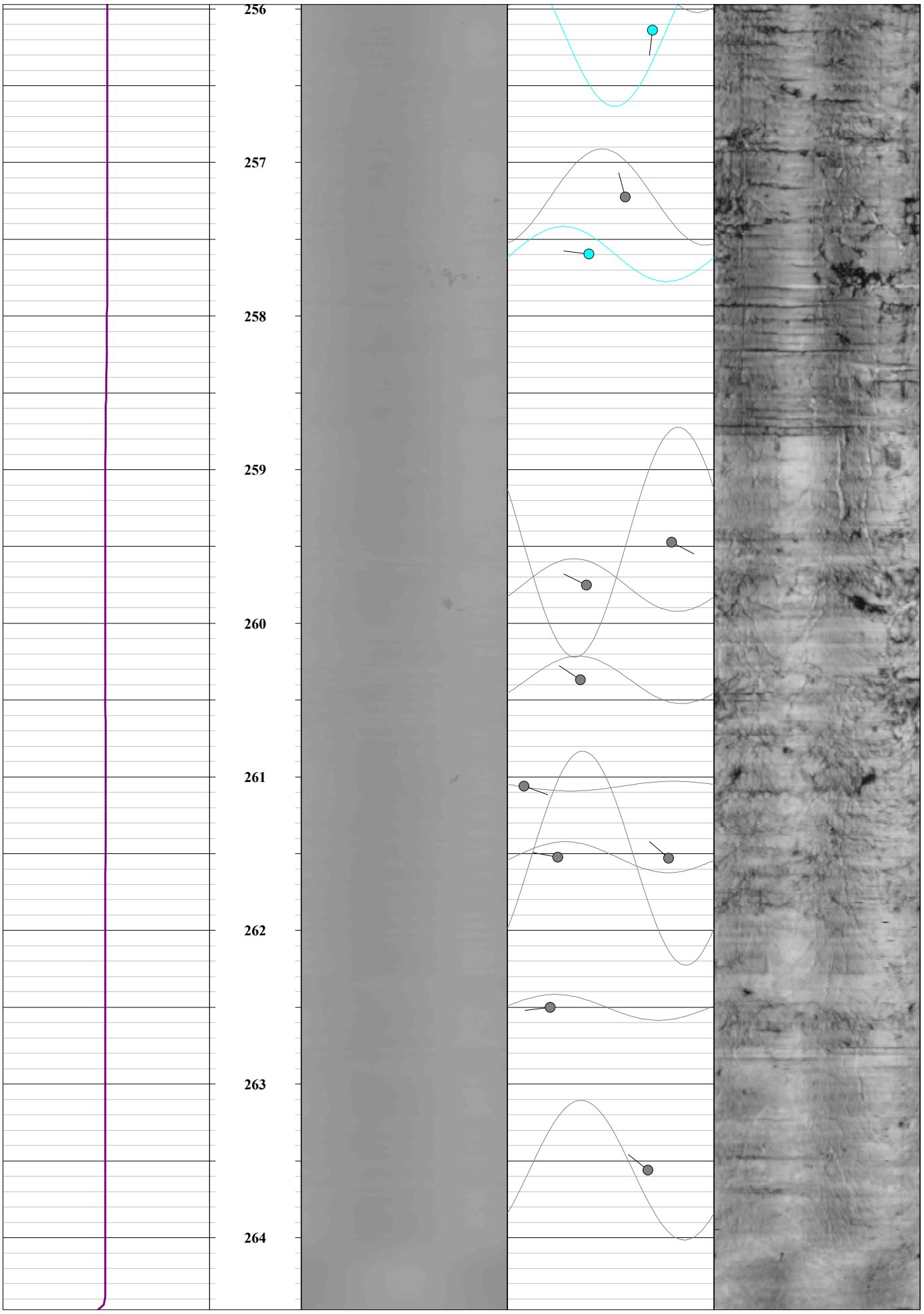

214
215
216
217
218
219
220
221

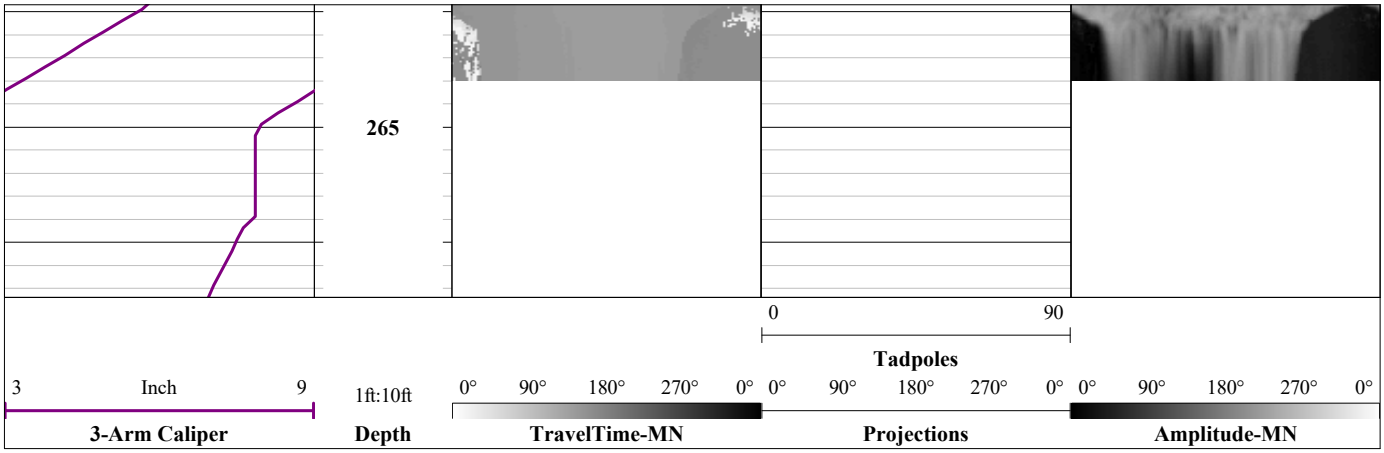

222
223
224
225
226
227
228
229
230


231
232
233
234
235
236
237
238

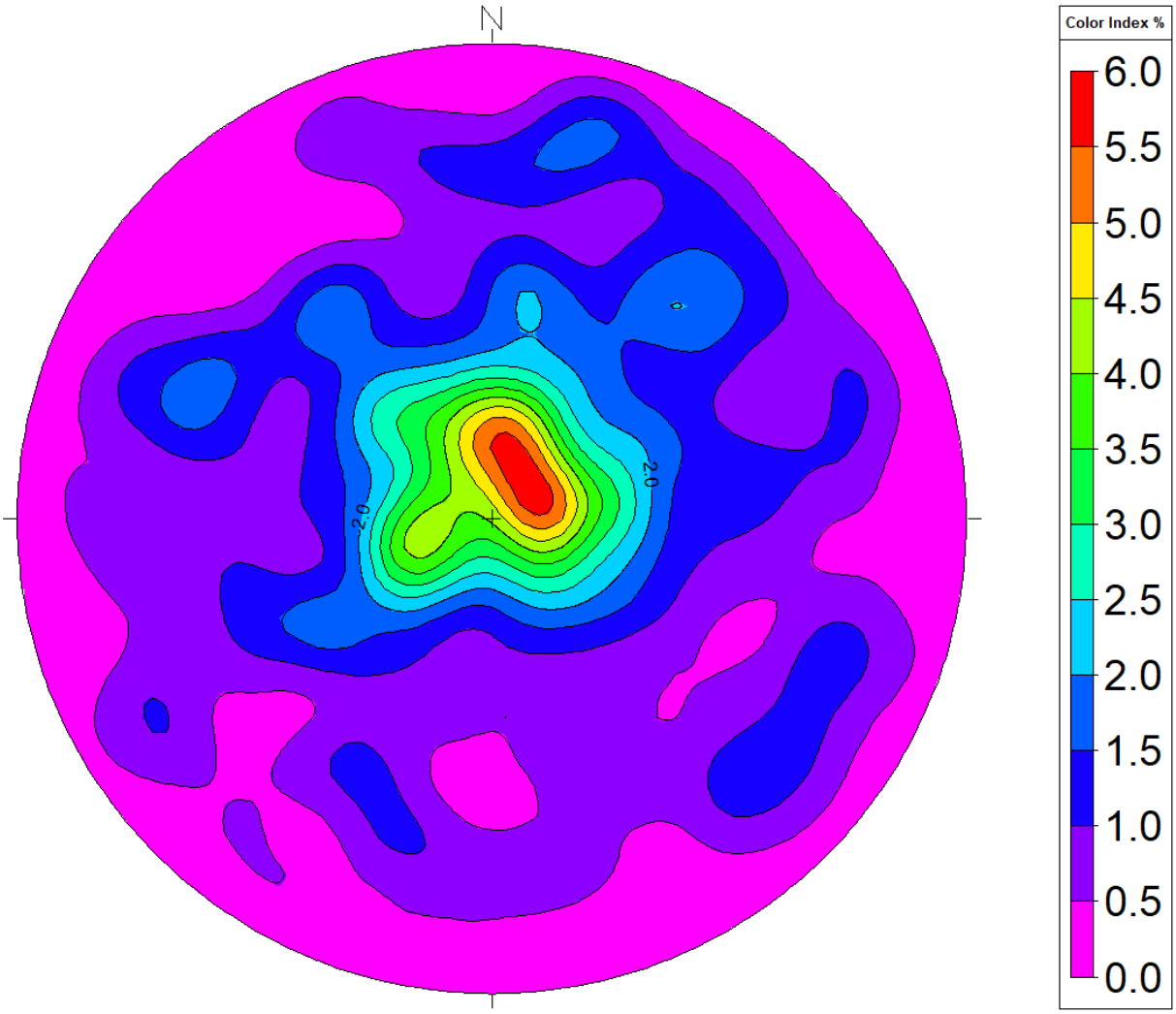

239
240
241
242
243
244
245
246
247


248
249
250
251
252
253
254
255


256
257
258
259
260
261
262
263
264

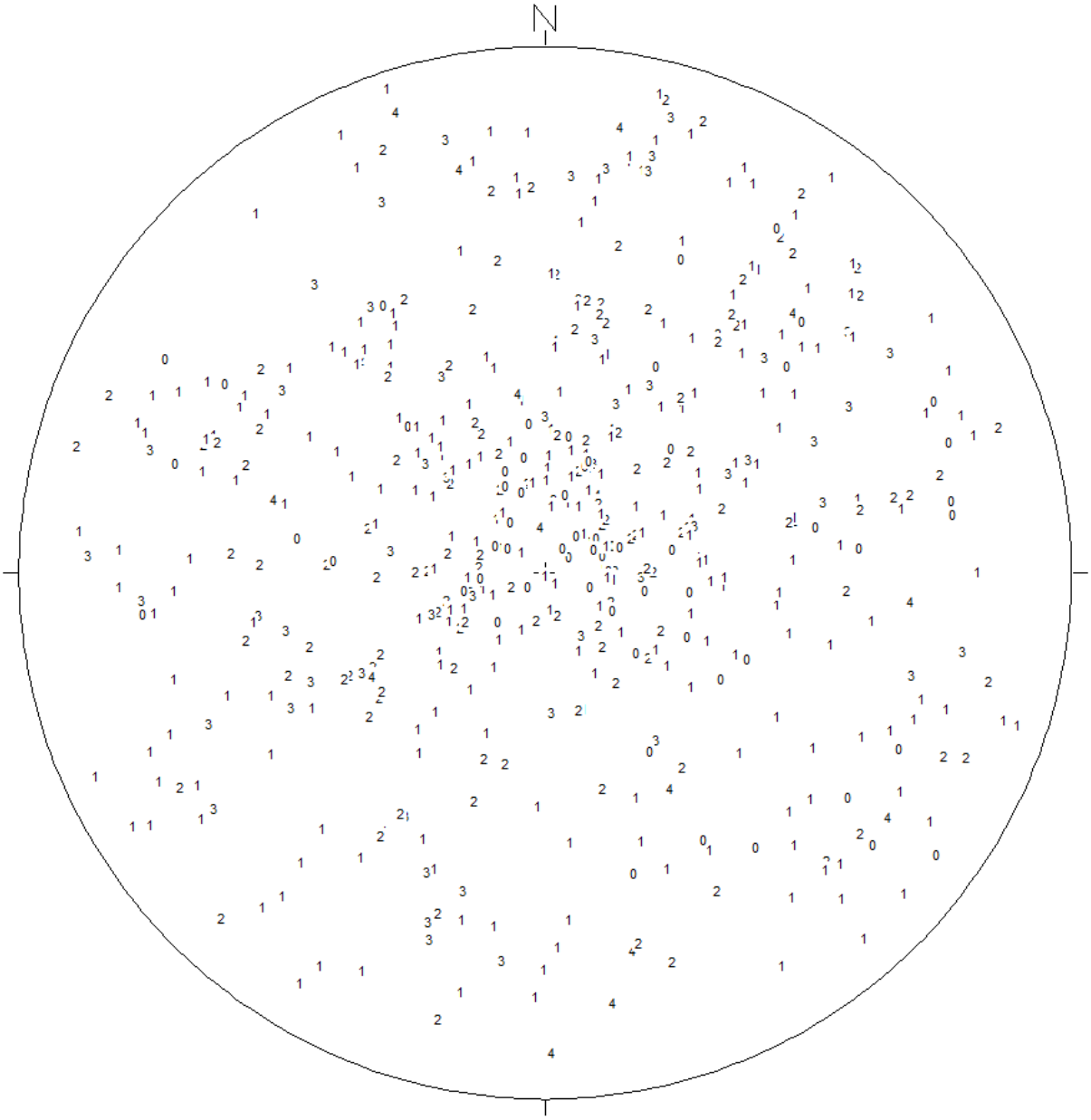

265
0
90
Tadpoles
3
Inch
9
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-31
6 & 8 November 2019



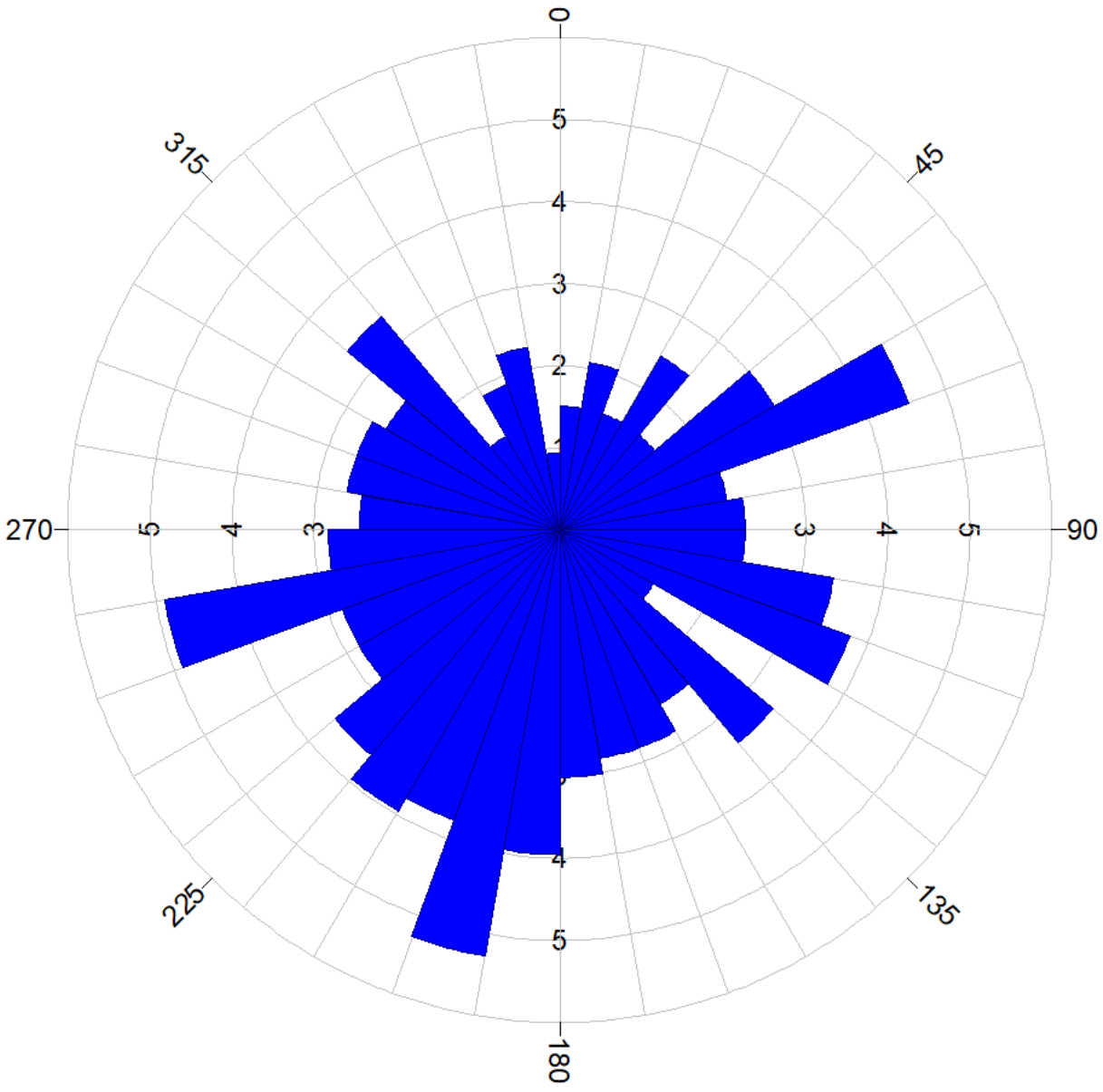
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-31
6 & 8 November 2019



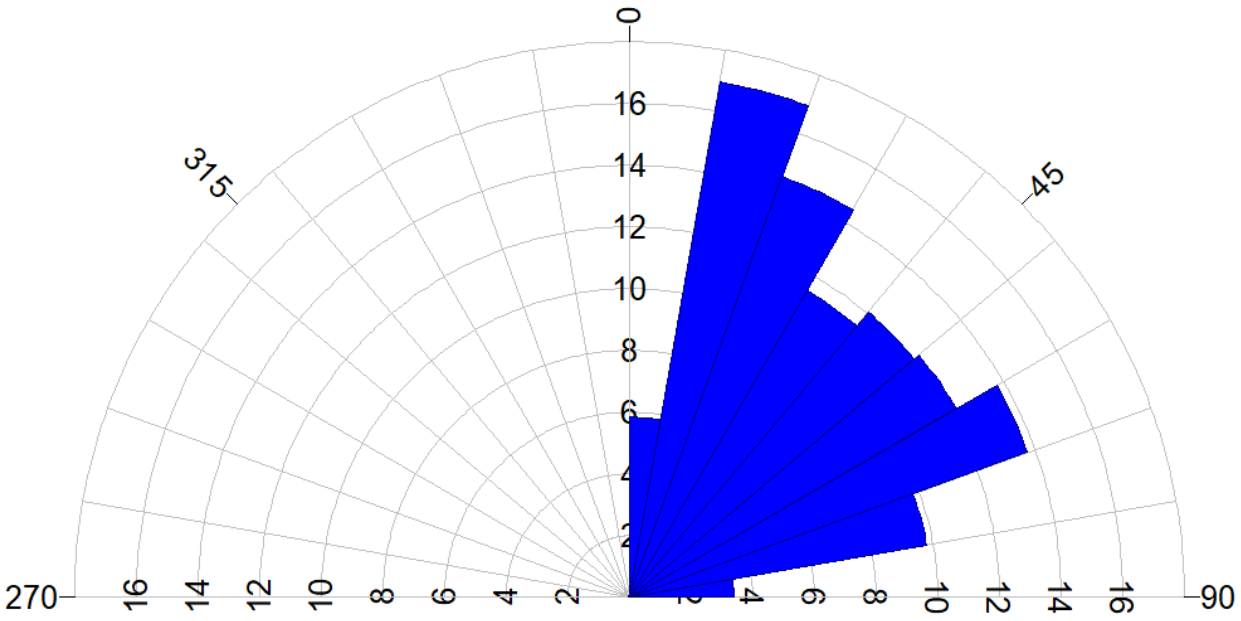
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-31
6 & 8 November 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-31
6 & 8 November 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	41.32	135.6	161	85	1
2	41.39	135.8	203	17	3
3	41.42	135.9	183	10	3
4	41.47	136.1	80	47	3
5	41.47	136.1	278	14	3
6	41.47	136.1	202	27	3
7	41.59	136.4	232	10	2
8	41.68	136.7	229	24	2
9	41.69	136.8	141	40	1
10	41.75	137.0	311	24	1
11	41.81	137.2	252	23	1
12	42.03	137.9	245	46	3
13	42.07	138.0	14	9	2
14	42.09	138.1	257	65	2
15	42.11	138.1	105	58	1
16	42.18	138.4	290	64	1
17	42.35	138.9	137	44	2
18	42.57	139.7	68	13	3
19	42.59	139.7	129	25	3
20	42.64	139.9	150	34	3
21	42.69	140.1	247	68	0
22	42.83	140.5	83	67	0
23	42.85	140.6	261	66	0
24	43.09	141.4	86	61	1
25	43.09	141.4	253	68	0
26	43.14	141.5	214	13	4
27	43.14	141.6	76	50	2
28	43.18	141.7	103	45	4
29	43.20	141.7	181	35	4
30	43.22	141.8	276	58	4
31	43.24	141.9	164	6	4
32	43.32	142.1	280	52	1
33	43.35	142.2	177	17	1
34	43.35	142.2	9	59	1
35	43.38	142.3	85	67	3
36	43.43	142.5	158	74	2
37	43.50	142.7	141	20	1
38	43.51	142.8	59	44	1
39	43.53	142.8	83	65	1
40	43.55	142.9	193	66	1
41	43.80	143.7	299	7	0
42	43.93	144.1	347	3	1
43	44.23	145.1	175	60	1
44	44.26	145.2	331	52	1
45	44.28	145.3	319	73	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	44.30	145.3	218	12	2
47	44.43	145.8	194	11	1
48	44.48	145.9	286	46	1
49	44.48	145.9	147	45	1
50	44.59	146.3	271	70	1
51	44.61	146.4	180	21	1
52	44.65	146.5	163	34	1
53	44.66	146.5	124	56	2
54	44.74	146.8	135	24	1
55	44.78	146.9	134	31	0
56	44.88	147.2	171	22	0
57	45.17	148.2	208	35	0
58	45.18	148.2	202	56	1
59	45.19	148.3	105	63	0
60	45.32	148.7	230	49	0
61	45.38	148.9	262	42	0
62	45.41	149.0	204	30	1
63	45.45	149.1	260	39	0
64	45.45	149.1	96	40	0
65	45.56	149.5	25	48	1
66	45.66	149.8	76	43	3
67	45.67	149.8	145	50	3
68	45.69	149.9	329	32	3
69	45.71	150.0	186	42	3
70	45.75	150.1	155	65	3
71	45.79	150.2	155	19	2
72	45.86	150.5	139	39	2
73	45.88	150.5	327	38	2
74	46.01	151.0	136	47	1
75	46.23	151.7	184	27	1
76	46.29	151.9	296	27	1
77	46.34	152.0	244	36	1
78	46.39	152.2	259	39	1
79	46.43	152.3	186	41	1
80	46.49	152.5	231	28	2
81	46.52	152.6	222	20	2
82	46.52	152.6	129	20	2
83	46.55	152.7	114	29	1
84	46.56	152.8	103	43	1
85	46.56	152.8	320	82	1
86	46.63	153.0	118	51	1
87	46.65	153.1	164	13	2
88	46.70	153.2	313	81	1
89	46.79	153.5	231	11	2
90	46.88	153.8	183	27	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	46.95	154.0	196	20	2
92	46.99	154.2	299	57	1
93	46.99	154.2	152	23	2
94	47.10	154.5	39	70	1
95	47.20	154.9	324	67	1
96	47.20	154.9	140	76	1
97	47.21	154.9	239	7	1
98	47.24	155.0	225	52	1
99	47.27	155.1	181	9	1
100	47.31	155.2	209	16	1
101	47.38	155.5	319	60	1
102	47.41	155.5	14	59	1
103	47.45	155.7	170	26	1
104	47.51	155.9	57	80	1
105	47.60	156.2	183	20	2
106	47.63	156.3	61	18	1
107	47.66	156.4	348	64	1
108	47.67	156.4	223	61	1
109	47.73	156.6	246	19	1
110	47.80	156.8	268	24	1
111	47.95	157.3	356	44	1
112	47.95	157.3	343	68	2
113	47.96	157.4	139	45	1
114	47.96	157.4	215	30	1
115	48.11	157.9	267	23	1
116	48.16	158.0	296	72	2
117	48.18	158.1	199	78	2
118	48.21	158.2	266	46	1
119	48.25	158.3	92	71	1
120	48.43	158.9	237	75	1
121	48.48	159.1	21	52	1
122	48.49	159.1	269	23	1
123	48.55	159.3	32	50	1
124	48.57	159.4	256	8	2
125	48.60	159.4	214	52	1
126	48.62	159.5	270	8	1
127	48.73	159.9	314	15	1
128	48.80	160.1	311	29	1
129	48.89	160.4	55	17	2
130	48.90	160.4	314	21	2
131	48.91	160.5	201	43	2
132	48.94	160.6	305	12	2
133	49.04	160.9	253	73	1
134	49.17	161.3	207	23	2
135	49.26	161.6	194	80	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	49.26	161.6	347	23	1
137	49.31	161.8	194	69	3
138	49.43	162.2	256	21	2
139	49.44	162.2	238	65	3
140	49.45	162.3	118	38	1
141	49.51	162.5	301	20	2
142	49.54	162.5	226	47	3
143	49.61	162.8	185	55	1
144	49.64	162.9	280	36	1
145	49.69	163.0	226	70	2
146	49.78	163.3	316	55	1
147	49.87	163.6	275	47	2
148	49.89	163.7	357	57	1
149	49.92	163.8	191	42	2
150	49.94	163.9	331	21	2
151	49.97	164.0	252	28	2
152	50.12	164.5	239	42	1
153	50.22	164.8	193	81	1
154	50.26	164.9	261	57	1
155	50.35	165.2	243	26	1
156	50.37	165.2	248	66	1
157	50.44	165.5	1	66	1
158	50.46	165.6	154	73	1
159	50.48	165.6	253	10	1
160	50.48	165.6	290	69	1
161	50.49	165.7	295	76	2
162	50.56	165.9	198	75	1
163	50.82	166.7	296	61	1
164	50.84	166.8	205	42	1
165	50.90	167.0	289	80	1
166	50.94	167.1	91	58	1
167	50.97	167.2	30	77	1
168	51.02	167.4	25	74	1
169	51.04	167.4	65	49	1
170	51.07	167.5	258	50	1
171	51.15	167.8	277	27	1
172	51.17	167.9	104	82	2
173	51.19	167.9	163	42	2
174	51.20	168.0	260	38	2
175	51.21	168.0	109	59	2
176	51.25	168.1	111	79	2
177	51.42	168.7	235	47	1
178	51.59	169.3	178	15	1
179	51.73	169.7	312	56	1
180	51.86	170.2	274	16	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	51.88	170.2	259	59	2
182	51.91	170.3	276	10	2
183	51.93	170.4	229	67	2
184	52.08	170.9	215	65	2
185	52.09	170.9	255	22	2
186	52.18	171.2	218	64	2
187	52.30	171.6	193	39	2
188	52.32	171.7	43	81	2
189	52.33	171.7	92	51	2
190	52.43	172.0	124	29	2
191	52.57	172.5	194	66	3
192	52.57	172.5	106	68	3
193	52.75	173.1	140	59	3
194	52.77	173.1	130	21	3
195	52.85	173.4	95	25	3
196	52.87	173.5	18	64	3
197	52.94	173.7	232	61	3
198	53.06	174.1	282	69	3
199	53.08	174.1	22	53	3
200	53.09	174.2	65	61	3
201	53.10	174.2	257	44	3
202	53.14	174.4	123	51	3
203	53.23	174.7	214	55	2
204	53.24	174.7	56	16	2
205	53.36	175.1	255	23	3
206	53.39	175.2	191	36	3
207	53.51	175.6	224	56	4
208	53.53	175.6	307	69	4
209	53.54	175.6	352	73	4
210	53.56	175.7	189	73	4
211	53.57	175.8	332	40	4
212	53.66	176.1	348	64	4
213	53.78	176.4	287	61	3
214	54.00	177.2	155	19	2
215	54.05	177.3	91	77	3
216	54.13	177.6	153	35	2
217	54.14	177.6	43	22	2
218	54.42	178.6	71	11	1
219	54.58	179.1	96	16	2
220	54.60	179.2	67	19	2
221	54.67	179.4	106	16	1
222	54.69	179.4	215	58	1
223	54.69	179.4	73	64	1
224	54.72	179.5	162	20	1
225	54.75	179.6	118	63	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	54.84	179.9	88	11	2
227	54.91	180.2	90	46	2
228	54.94	180.3	79	11	2
229	54.98	180.4	259	56	2
230	55.00	180.4	61	36	2
231	55.09	180.7	87	19	2
232	55.12	180.9	252	13	2
233	55.17	181.0	60	7	2
234	55.19	181.1	353	8	2
235	55.29	181.4	71	17	2
236	55.29	181.4	322	12	2
237	55.41	181.8	56	16	2
238	55.44	181.9	260	50	2
239	55.47	182.0	152	25	2
240	55.47	182.0	171	61	2
241	55.49	182.1	13	32	2
242	55.57	182.3	328	15	2
243	55.57	182.3	101	29	2
244	55.68	182.7	205	10	1
245	55.72	182.8	113	5	1
246	55.74	182.9	130	11	1
247	55.78	183.0	120	21	1
248	55.79	183.1	290	69	1
249	55.81	183.1	108	12	1
250	55.83	183.2	296	32	1
251	55.85	183.2	106	8	1
252	55.89	183.4	168	13	1
253	55.94	183.5	98	11	2
254	56.07	184.0	52	22	1
255	56.10	184.0	311	69	1
256	56.15	184.2	311	67	2
257	56.16	184.3	286	39	1
258	56.21	184.4	111	58	1
259	56.23	184.5	317	66	2
260	56.27	184.6	241	33	1
261	56.35	184.9	108	70	1
262	56.38	185.0	305	51	1
263	56.42	185.1	109	8	1
264	56.56	185.6	115	51	2
265	56.65	185.9	242	54	3
266	56.71	186.1	188	65	3
267	56.76	186.2	54	68	3
268	56.82	186.4	209	32	3
269	56.94	186.8	61	37	2
270	56.98	187.0	60	32	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	57.04	187.1	52	34	2
272	57.08	187.3	50	37	2
273	57.12	187.4	146	14	2
274	57.15	187.5	53	33	2
275	57.20	187.7	33	23	1
276	57.29	188.0	60	34	3
277	57.35	188.2	15	54	3
278	57.37	188.2	30	46	3
279	57.39	188.3	216	45	3
280	57.52	188.7	18	59	2
281	57.54	188.8	39	33	1
282	57.57	188.9	48	23	1
283	57.58	188.9	333	59	2
284	57.66	189.2	181	46	2
285	57.66	189.2	19	32	2
286	57.70	189.3	302	11	2
287	57.81	189.7	231	55	1
288	57.84	189.8	247	33	1
289	57.87	189.9	115	67	1
290	57.88	189.9	21	28	1
291	57.94	190.1	198	75	1
292	57.99	190.3	66	17	1
293	58.00	190.3	215	70	1
294	58.09	190.6	61	74	1
295	58.27	191.2	63	15	1
296	58.45	191.8	77	13	2
297	58.47	191.8	212	42	1
298	58.93	193.4	169	67	1
299	58.95	193.4	337	12	3
300	58.96	193.4	67	20	3
301	59.06	193.8	29	18	1
302	59.10	193.9	35	14	1
303	59.20	194.2	177	71	1
304	59.22	194.3	318	67	1
305	59.28	194.5	204	23	4
306	59.45	195.0	58	33	4
307	59.46	195.1	169	27	4
308	59.49	195.2	108	51	2
309	59.57	195.5	79	48	1
310	59.59	195.5	251	14	2
311	59.65	195.7	87	21	2
312	59.66	195.7	197	15	2
313	59.73	196.0	175	13	2
314	59.76	196.1	201	16	2
315	59.77	196.1	41	56	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
316	59.83	196.3	225	11	1
317	59.84	196.3	164	52	1
318	59.93	196.6	24	11	1
319	60.03	197.0	227	7	1
320	60.05	197.0	134	33	1
321	60.13	197.3	63	10	1
322	60.17	197.4	258	22	1
323	60.20	197.5	195	10	1
324	60.43	198.3	1	7	1
325	60.52	198.6	293	64	1
326	60.54	198.6	134	21	1
327	60.61	198.9	205	69	1
328	60.62	198.9	307	81	0
329	60.69	199.1	137	11	1
330	60.70	199.2	324	56	0
331	60.94	199.9	177	13	1
332	61.15	200.6	109	72	1
333	61.23	200.9	289	83	1
334	61.40	201.4	94	79	1
335	61.53	201.9	236	16	1
336	61.76	202.6	304	76	1
337	61.82	202.8	231	43	1
338	61.91	203.1	289	23	1
339	61.95	203.3	103	28	1
340	62.50	205.1	250	72	1
341	62.55	205.2	87	71	1
342	62.64	205.5	193	14	1
343	62.65	205.6	206	73	1
344	62.66	205.6	33	56	1
345	62.83	206.1	309	21	1
346	62.92	206.4	2	71	1
347	63.07	206.9	198	18	1
348	63.31	207.7	40	74	1
349	63.46	208.2	66	68	1
350	63.53	208.4	229	53	1
351	64.00	210.0	68	56	1
352	64.13	210.4	228	66	1
353	64.39	211.2	220	32	1
354	64.46	211.5	40	63	1
355	64.68	212.2	31	82	1
356	64.71	212.3	65	85	1
357	64.97	213.2	349	23	2
358	64.99	213.2	186	37	2
359	65.05	213.4	195	77	3
360	65.07	213.5	90	35	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
361	65.09	213.6	208	71	1
362	65.18	213.8	252	9	3
363	65.32	214.3	154	80	1
364	65.39	214.5	59	71	2
365	65.39	214.6	285	75	2
366	65.52	215.0	233	61	1
367	65.62	215.3	54	71	1
368	65.83	216.0	225	70	1
369	65.91	216.3	172	72	1
370	65.96	216.4	194	72	1
371	65.98	216.5	12	72	1
372	66.05	216.7	67	45	2
373	66.07	216.8	218	33	2
374	66.40	217.9	19	61	3
375	66.43	218.0	218	48	2
376	66.53	218.3	86	27	2
377	66.55	218.4	18	39	2
378	66.57	218.4	253	78	2
379	66.58	218.4	166	72	3
380	66.69	218.8	71	40	2
381	66.75	219.0	62	30	2
382	66.80	219.2	151	48	2
383	66.92	219.6	342	14	1
384	66.93	219.6	214	74	2
385	66.96	219.7	135	49	1
386	67.00	219.8	339	52	1
387	67.09	220.1	220	35	1
388	67.20	220.5	205	22	1
389	67.29	220.8	180	46	1
390	67.34	220.9	117	56	1
391	67.37	221.0	219	49	1
392	67.46	221.3	347	63	2
393	67.51	221.5	64	42	3
394	67.52	221.5	178	23	3
395	67.52	221.5	0	23	3
396	67.57	221.7	243	31	3
397	67.62	221.9	188	42	2
398	67.70	222.1	110	57	2
399	67.72	222.2	216	49	2
400	67.89	222.7	183	63	3
401	67.91	222.8	177	61	2
402	67.93	222.9	7	65	3
403	68.03	223.2	170	49	2
404	68.12	223.5	61	47	3
405	68.14	223.6	161	80	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
406	68.17	223.6	242	35	3
407	68.20	223.8	0	82	4
408	68.29	224.1	191	40	2
409	68.30	224.1	31	46	2
410	68.36	224.3	192	52	2
411	68.53	224.9	167	66	4
412	68.65	225.2	32	51	2
413	68.84	225.9	217	44	2
414	68.87	226.0	347	36	2
415	68.97	226.3	316	68	1
416	69.01	226.4	142	49	1
417	69.13	226.8	118	43	1
418	69.15	226.9	304	43	1
419	69.19	227.0	222	45	1
420	69.26	227.2	68	22	1
421	69.26	227.2	144	43	1
422	69.32	227.4	119	56	1
423	69.36	227.6	315	42	1
424	69.40	227.7	181	34	1
425	69.42	227.8	338	18	1
426	69.48	227.9	191	67	1
427	69.49	228.0	195	34	1
428	69.61	228.4	214	58	1
429	69.63	228.4	238	27	1
430	69.74	228.8	194	33	1
431	69.77	228.9	35	36	1
432	69.82	229.1	191	68	1
433	69.87	229.2	283	10	1
434	69.88	229.3	14	78	2
435	69.90	229.3	175	63	1
436	69.99	229.6	310	10	1
437	70.03	229.8	164	32	1
438	70.13	230.1	241	8	1
439	70.17	230.2	276	9	0
440	70.19	230.3	330	77	1
441	70.23	230.4	307	12	0
442	70.38	230.9	247	3	0
443	70.59	231.6	222	6	0
444	70.70	232.0	240	8	0
445	70.79	232.3	166	17	0
446	70.81	232.3	109	9	0
447	70.95	232.8	113	71	1
448	70.95	232.8	251	15	1
449	71.01	233.0	203	53	0
450	71.02	233.0	340	39	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
451	71.08	233.2	187	59	1
452	71.16	233.5	147	20	1
453	71.20	233.6	137	25	1
454	71.29	233.9	136	44	1
455	71.37	234.2	136	30	1
456	71.41	234.3	359	62	1
457	71.77	235.5	153	28	1
458	71.82	235.6	105	52	1
459	71.92	236.0	130	27	1
460	71.94	236.0	148	47	1
461	71.95	236.1	276	25	1
462	71.97	236.1	303	68	1
463	72.06	236.4	143	28	1
464	72.11	236.6	137	27	1
465	72.19	236.9	58	68	1
466	72.23	237.0	119	24	1
467	72.25	237.1	269	38	1
468	72.28	237.1	127	52	1
469	72.30	237.2	3	38	1
470	72.41	237.6	114	34	1
471	72.44	237.7	342	46	1
472	72.48	237.8	244	73	1
473	72.54	238.0	38	29	1
474	72.56	238.1	272	15	2
475	72.58	238.1	110	59	1
476	72.78	238.8	298	64	0
477	72.86	239.1	267	49	0
478	72.90	239.2	58	83	1
479	72.93	239.3	119	60	0
480	73.01	239.5	261	8	0
481	73.12	239.9	253	10	0
482	73.24	240.3	215	3	0
483	73.40	240.8	207	13	1
484	73.54	241.3	56	54	1
485	73.65	241.6	263	66	0
486	73.67	241.7	199	16	0
487	73.76	242.0	216	80	1
488	73.77	242.0	256	11	0
489	73.88	242.4	274	27	1
490	74.03	242.9	192	11	0
491	74.16	243.3	251	7	0
492	74.22	243.5	188	20	0
493	74.26	243.7	154	16	0
494	74.40	244.1	65	73	1
495	74.41	244.1	200	17	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-31

6 and 8 November 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
496	74.52	244.5	136	9	0
497	74.58	244.7	214	66	0
498	74.72	245.2	226	26	0
499	74.77	245.3	298	24	0
500	74.86	245.6	150	14	0
501	75.05	246.2	251	9	1
502	75.10	246.4	81	13	1
503	75.32	247.1	332	33	0
504	75.55	247.9	79	11	0
505	75.86	248.9	147	49	0
506	75.88	249.0	91	34	0
507	76.06	249.6	73	14	0
508	76.15	249.8	158	12	0
509	76.82	252.0	286	15	0
510	76.99	252.6	316	19	0
511	77.01	252.7	45	5	0
512	77.06	252.8	28	2	1
513	77.17	253.2	283	9	1
514	77.25	253.5	88	18	1
515	77.25	253.5	190	18	1
516	77.34	253.7	177	17	1
517	77.39	253.9	179	17	1
518	77.69	254.9	226	56	0
519	77.81	255.3	43	12	0
520	77.94	255.7	331	50	0
521	78.07	256.1	187	63	1
522	78.40	257.2	345	51	0
523	78.52	257.6	277	36	1
524	79.09	259.5	118	72	0
525	79.17	259.8	296	34	0
526	79.36	260.4	304	32	0
527	79.57	261.1	110	7	0
528	79.71	261.5	281	22	0
529	79.71	261.5	311	70	0
530	80.01	262.5	263	19	0
531	80.33	263.6	308	61	0

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-31
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-31
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81090 N
Longitude: 84.76751 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed Caliper
Acoustic Televiewer
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 462.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	6 & 8 Nov 2019	6 & 8 Nov 2019	6 & 8 Nov 2019	
RUN NUMBER	1	1	1	
LOG TYPE	Fluid Temp & Cond	3-Armed Caliper	Natural Gamma	
DEPTH-DRILLER	265.7'	265.7'	265.7'	
DEPTH-LOGGER	265.5'	265'	265'	
BTM LOG INTERVAL	265.5'	265'	263.7'	
TOP LOG INTERVAL	130.1'	0.0'	126.1'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	WSP	WSP	WSP	
PROBE TYPE, S/N	2PFA #5969	Comprobe #5238	ELXG #4314	
LOGGING SPEED	10 ft/min	10 ft/min	15 ft/min	
A.S.D.E. / Sample Interval	.0.06' / 0.10'	0.11' / 0.10'	0.1' / 0.25'	
Fluid Level / Fluid Type	NA/ water	NA/ water	NA/ water	

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	7"	Mudline/TOC	75.4'
2	6"	Mudline/TOC	265.7'

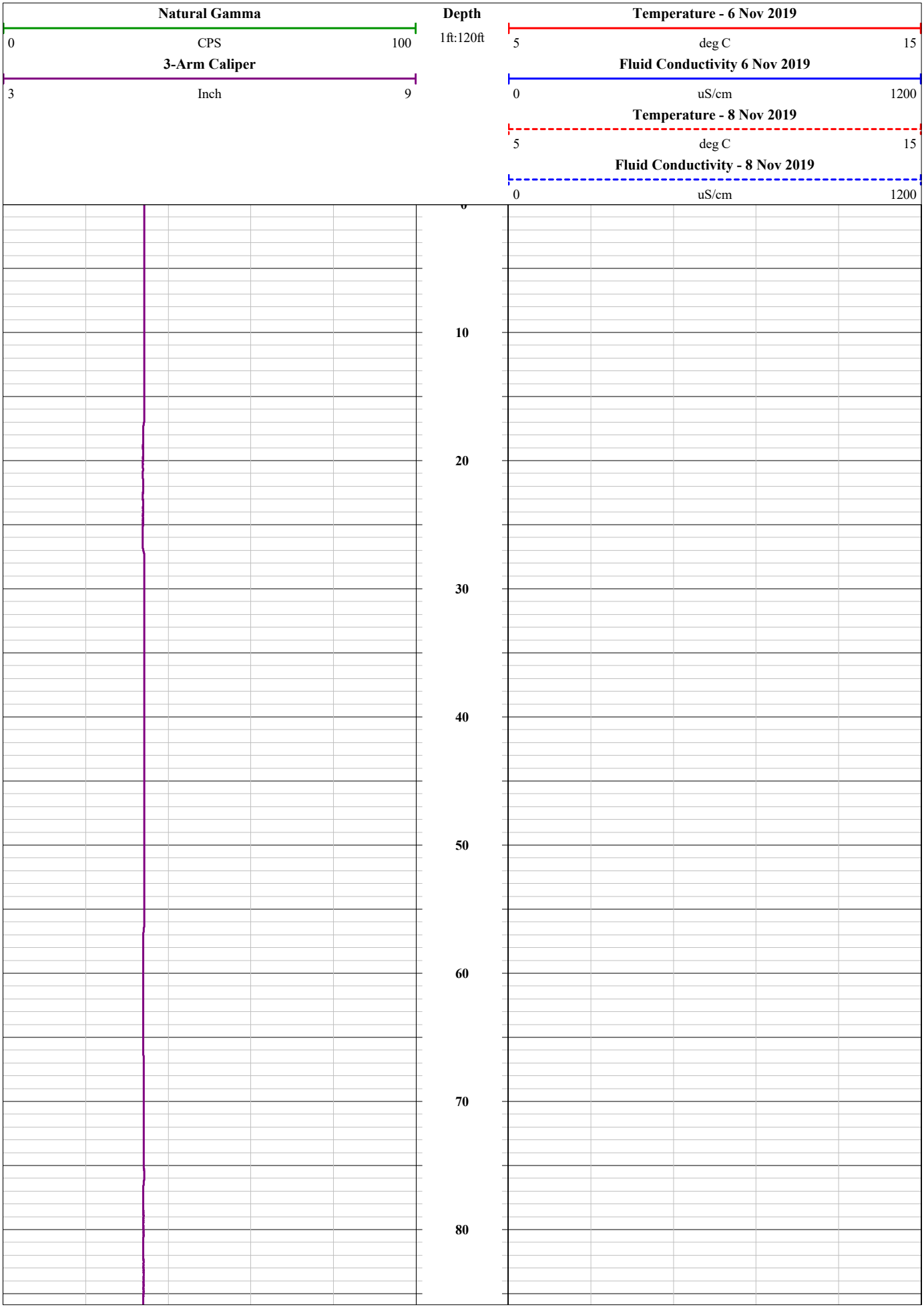
CASING RECORD

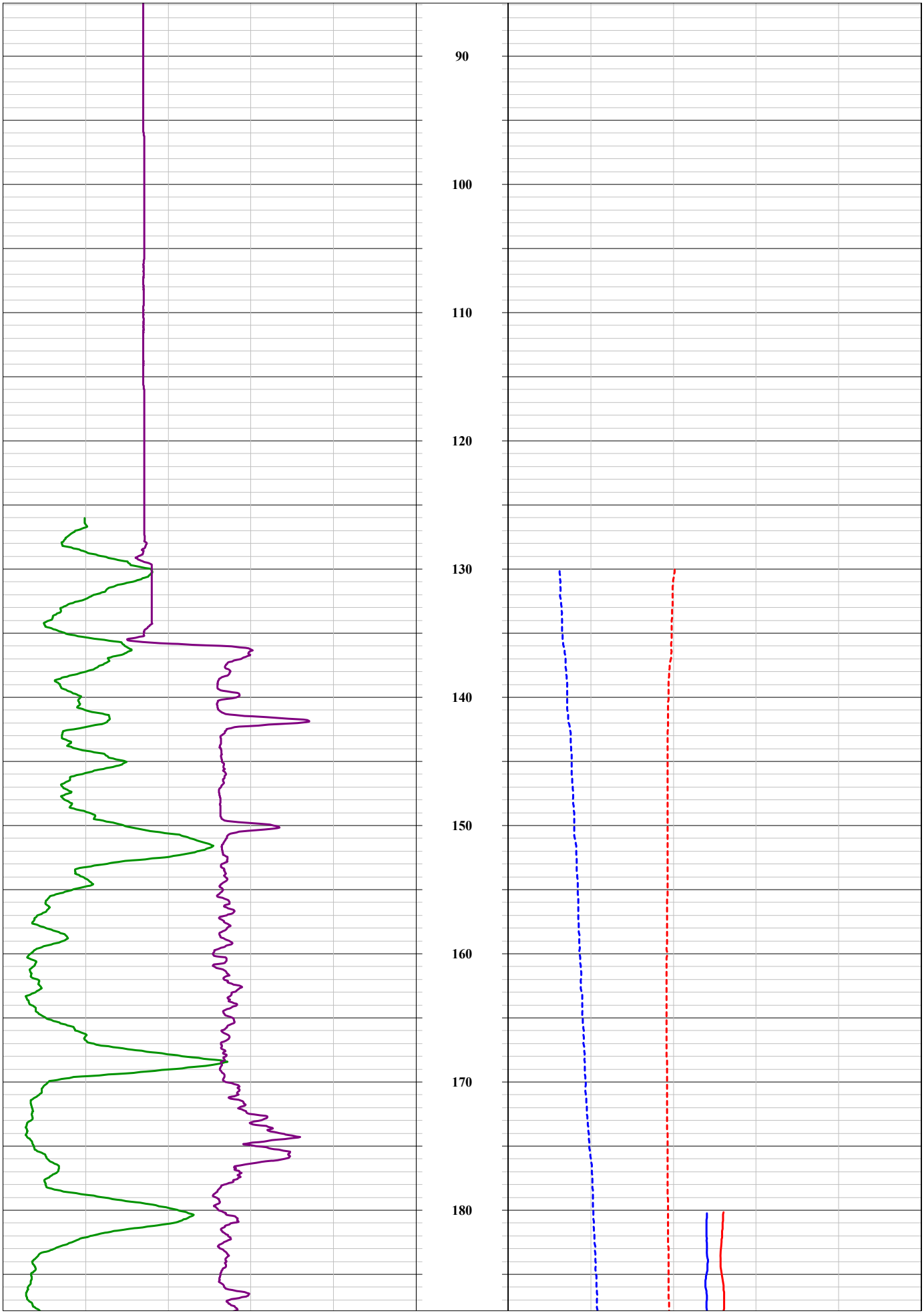
SIZE	WGT.	FROM	TO
6"	Steel	Mudline/TOC	135.5'

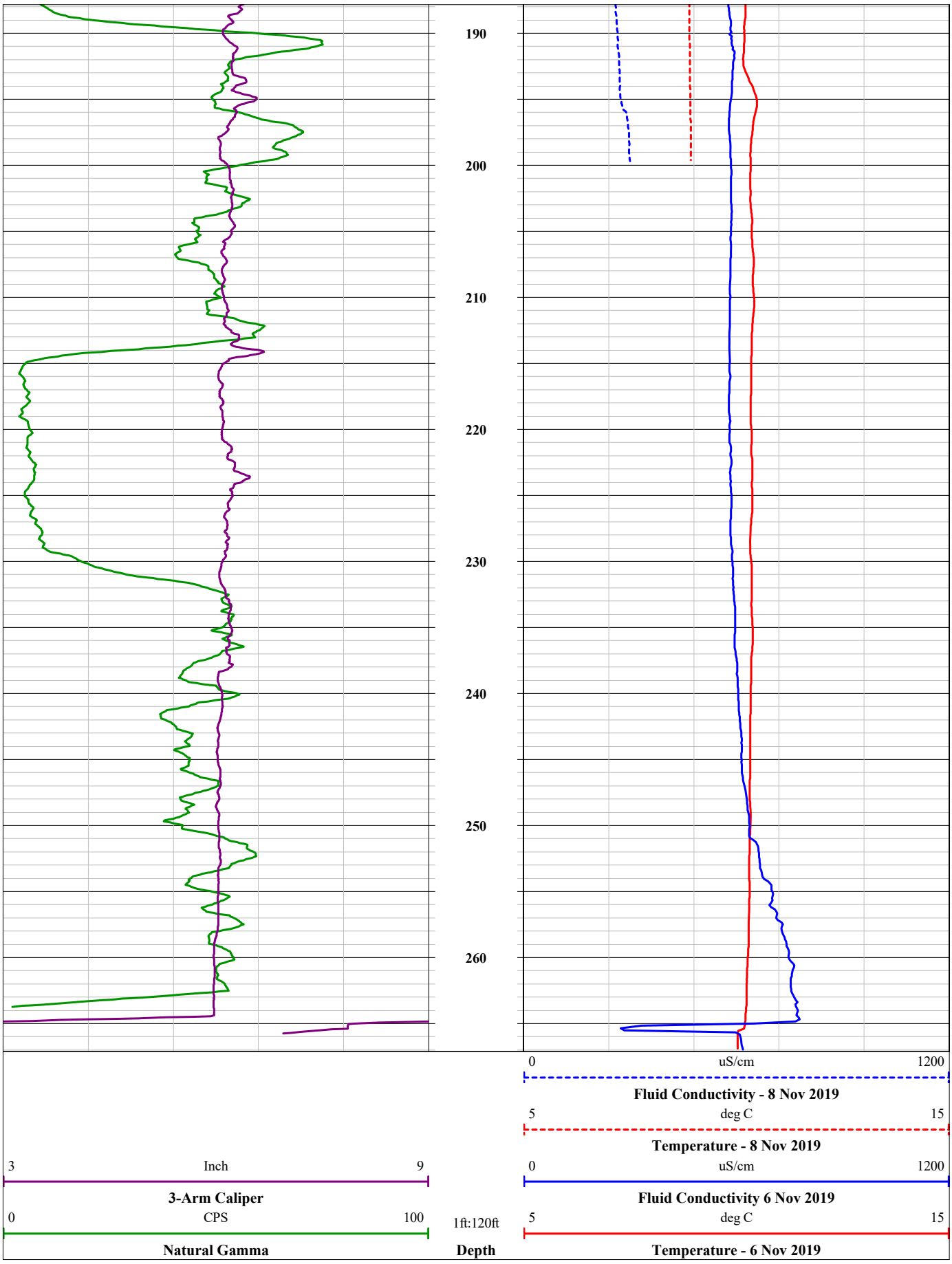
NA - Not Available, N/A - Not Applicable

COMMENTS

Note: Fluid Temperature and Conductivity slightly different values due to a day between logging phases & borehole conditions.


Natural Gamma
0
CPS
100
3-Arm Caliper
3
Inch
9
Depth
1ft:120ft
Temperature - 6 Nov 2019
5
deg C
15
Fluid Conductivity 6 Nov 2019
0
uS/cm
1200
Temperature - 8 Nov 2019
5
deg C
15
Fluid Conductivity - 8 Nov 2019
0
uS/cm
1200
0
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180


190
200
210
220
230
240
250
260
0
uS/cm
1200
Fluid Conductivity - 8 Nov 2019
5
deg C
15
Temperature - 8 Nov 2019
3
Inch
9
0
uS/cm
1200
3-Arm Caliper
Fluid Conductivity 6 Nov 2019
0
CPS
100
1ft:120ft
5
deg C
15
Natural Gamma
Depth
Temperature - 6 Nov 2019

Borehole Deviation

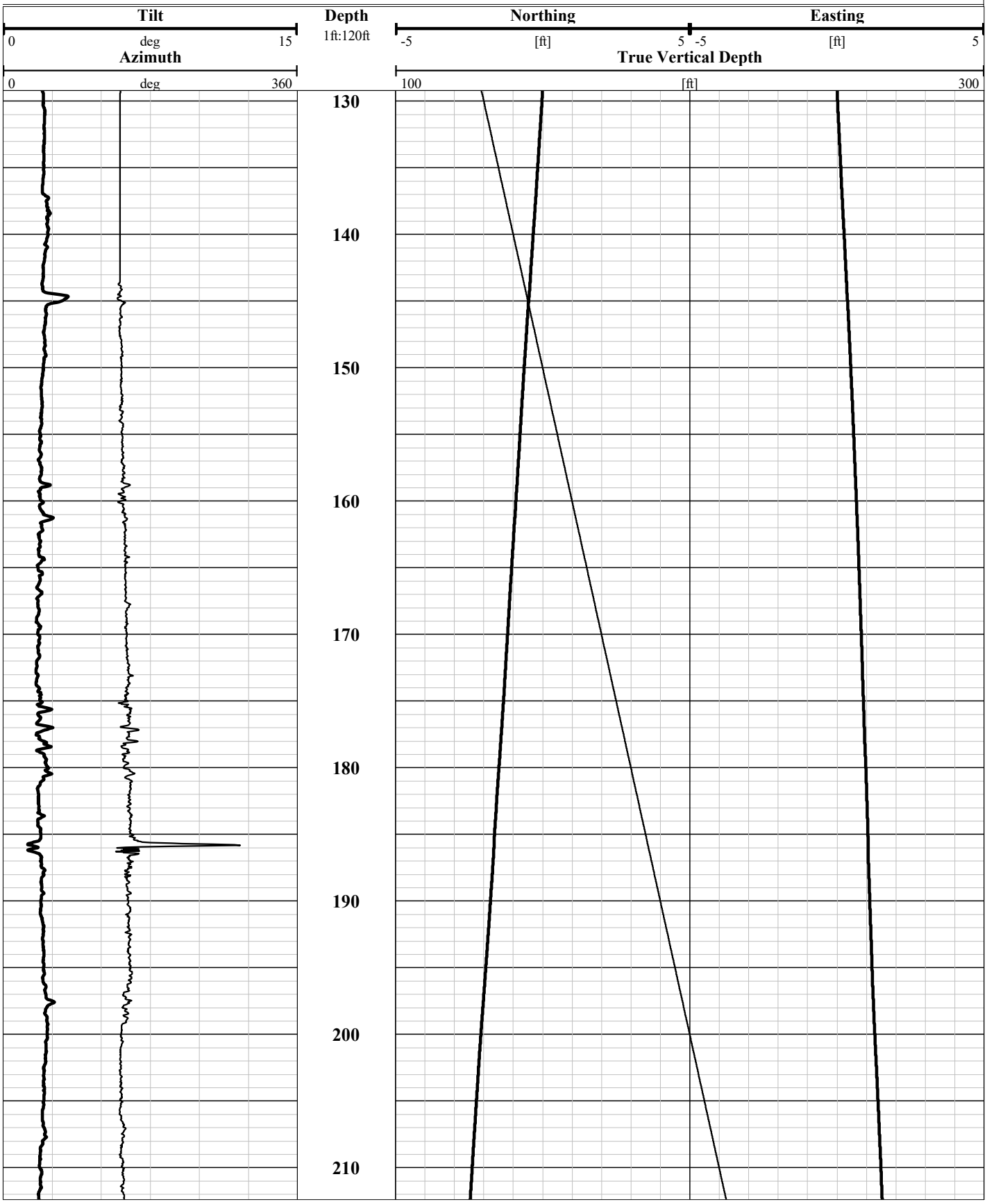
COLOG
borehole geophysics / hydrophysics

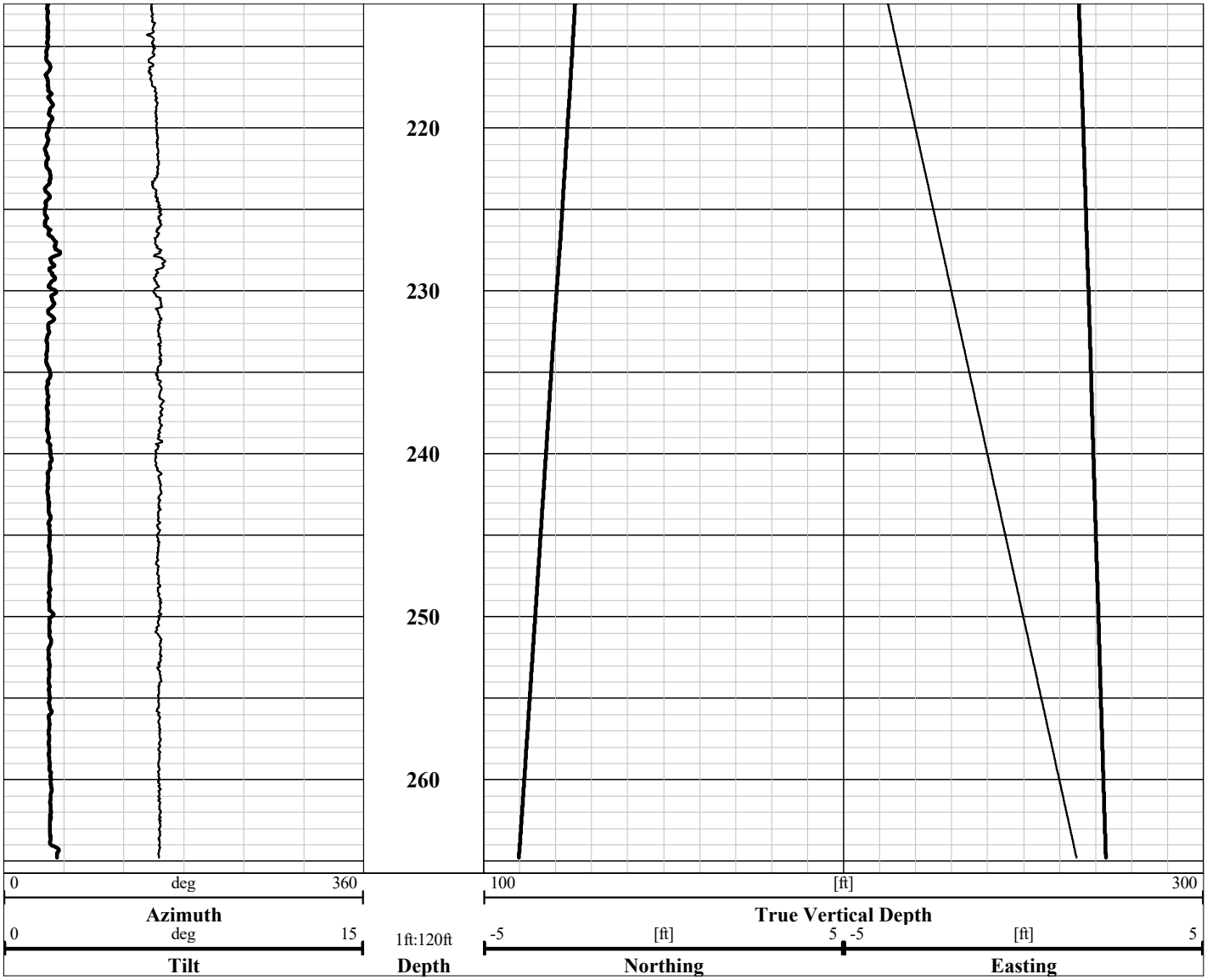
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 6 & 8 Nov. 2019	WELL: BH19-31 - Mid Strait

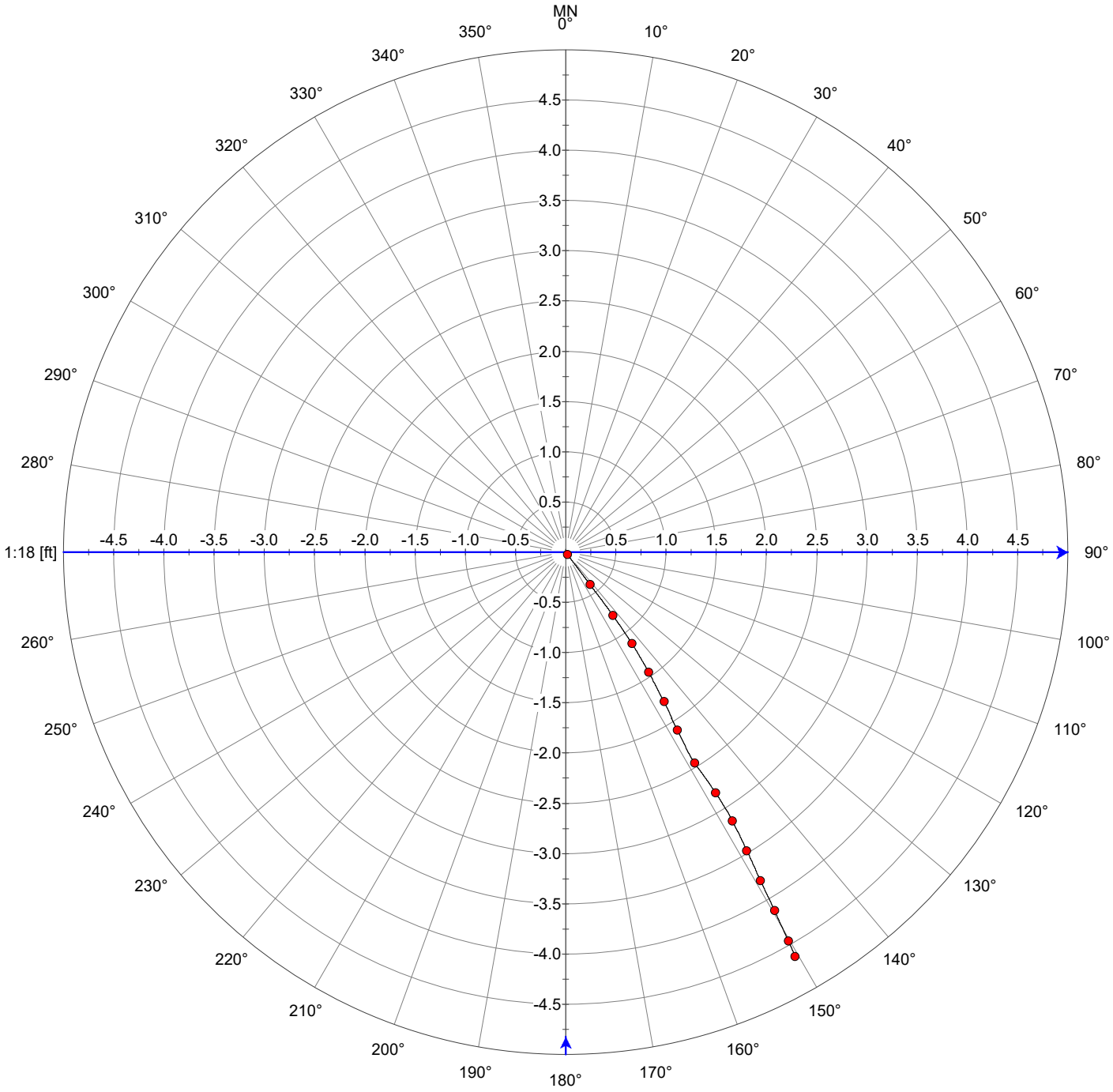
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 462.4'** **Latitude: 45.81090 N** **Longitude: 84.76751 W**




220
230
240
250
260
0
deg
360
Azimuth
0
deg
15
Tilt
1ft:120ft
Depth
100
[ft]
300
True Vertical Depth
-5
[ft]
5
Northing
-5
[ft]
5
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
1:18 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-31
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-31
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81090 N
Longitude: 84.76751 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
3-Armed Caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 462.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	6 & 8 Nov 2019	6 & 8 Nov 2019		
RUN NUMBER	2,3	2,3		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	265.7'	265.7'		
DEPTH-LOGGER	265'	265'		
BTM LOG INTERVAL	263.7'	264.9'		
TOP LOG INTERVAL	126.1'	124.3'		
RECORDED BY	JBG	JBG		
WITNESSED BY	WSP	WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	15 ft/min	15 ft/min		
A.S.D.E. / Sample Interval	0.1' / 0.25'	0.1' / 0.25'		
Fluid Level / Fluid Type	NA/ water	NA/ water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	7"	Mudline/TOC	75.4'
2	6"	Mudline/TOC	265.7'

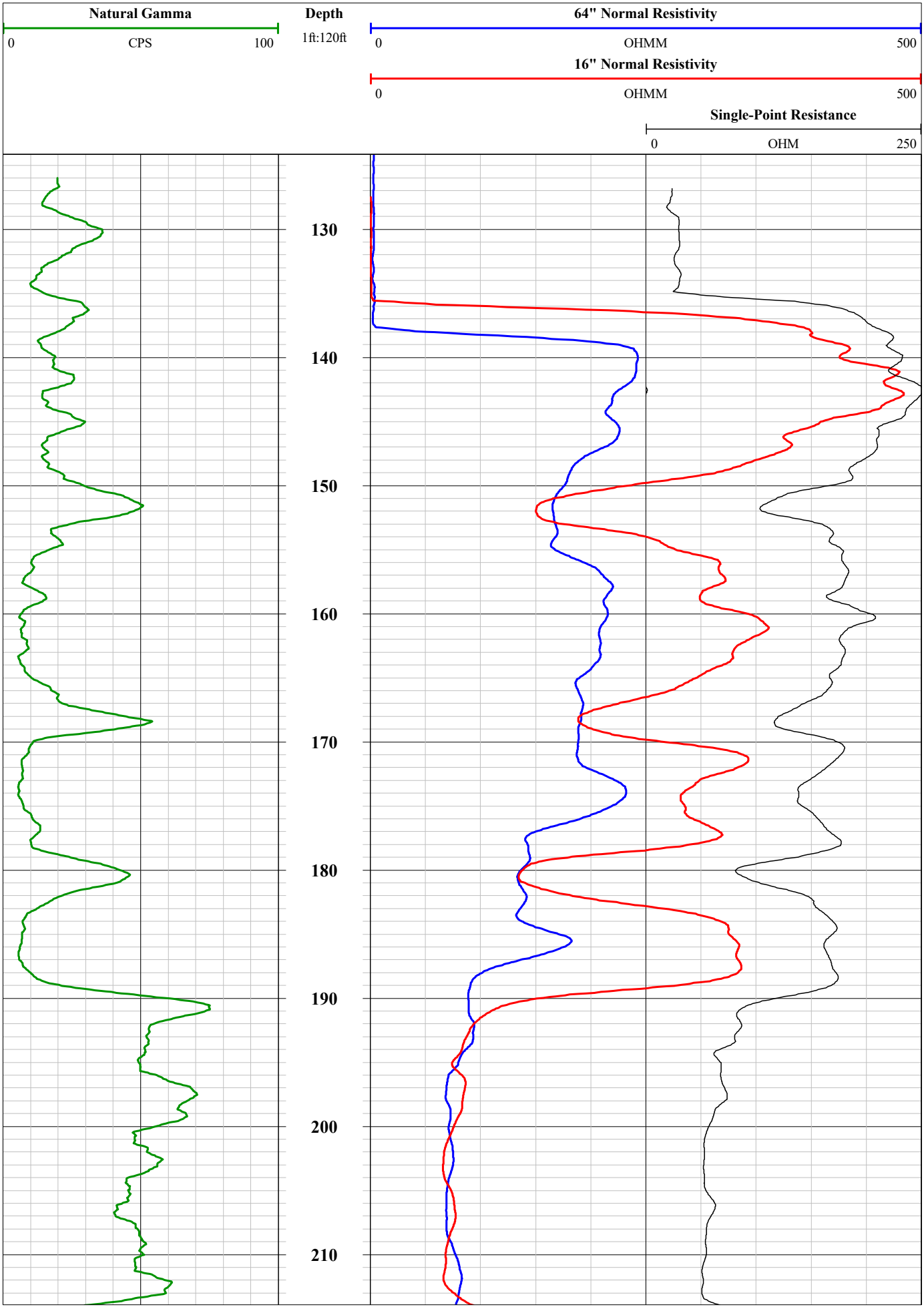
CASING RECORD

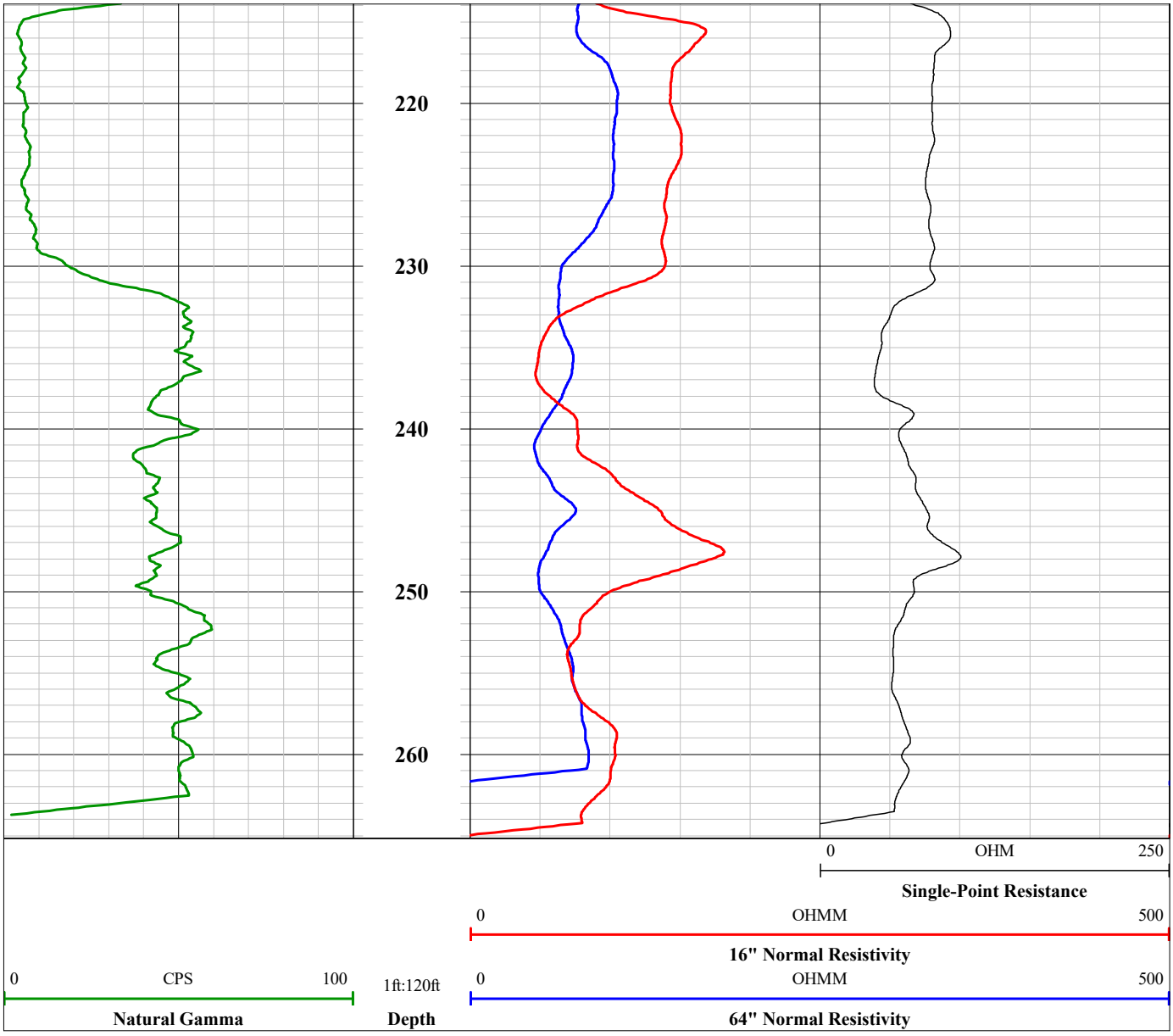
SIZE	WGT.	FROM	TO
6"	Steel	Mudline/TOC	135.5'

NA - Not Available, N/A - Not Applicable

COMMENTS

Spontaneous Potential omitted due to configuration error.


Natural Gamma
0
CPS
100
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
500
16" Normal Resistivity
0
OHMM
500
Single-Point Resistance
0
OHM
250
130
140
150
160
170
180
190
200
210


220
230
240
250
260
0
OHM
250
Single-Point Resistance
0
OHMM
500
16" Normal Resistivity
0
CPS
100
1ft:120ft
0
OHMM
500
Natural Gamma
Depth
64" Normal Resistivity

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-31
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-31
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.81090 N
Longitude: 84.76751 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed Caliper
Acoustic Televiewer
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 462.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	6 & 8 Nov 2019			
RUN NUMBER	1			
LOG TYPE	PSLog			
DEPTH-DRILLER	265.7'			
DEPTH-LOGGER	252'			
BTM LOG INTERVAL	252'			
TOP LOG INTERVAL	132'			
RECORDED BY	JBG			
WITNESSED BY	WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

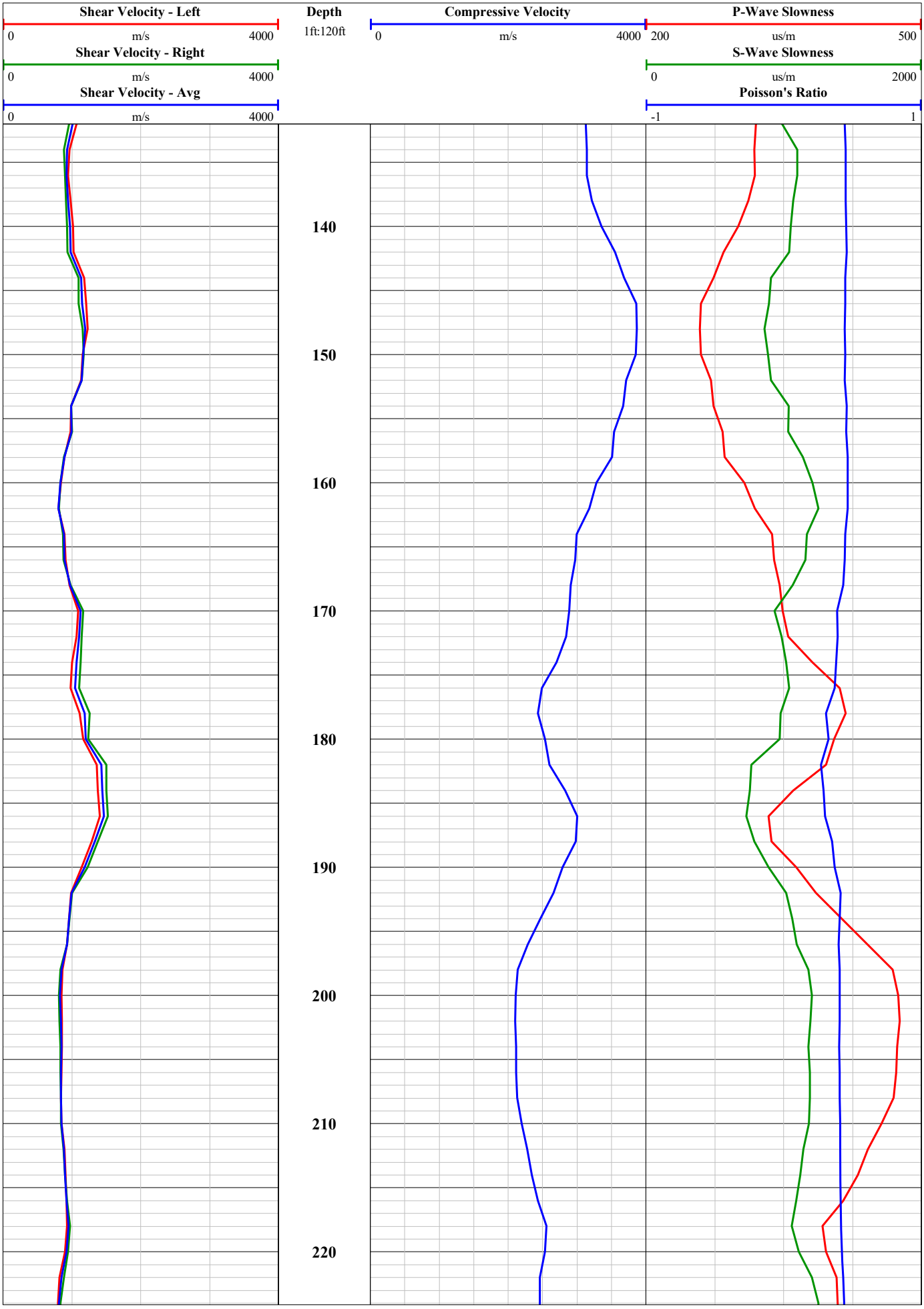
RUN No.	BIT	FROM	TO
1	7"	Mudline/TOC	75.4'
2	6"	Mudline/TOC	265.7'

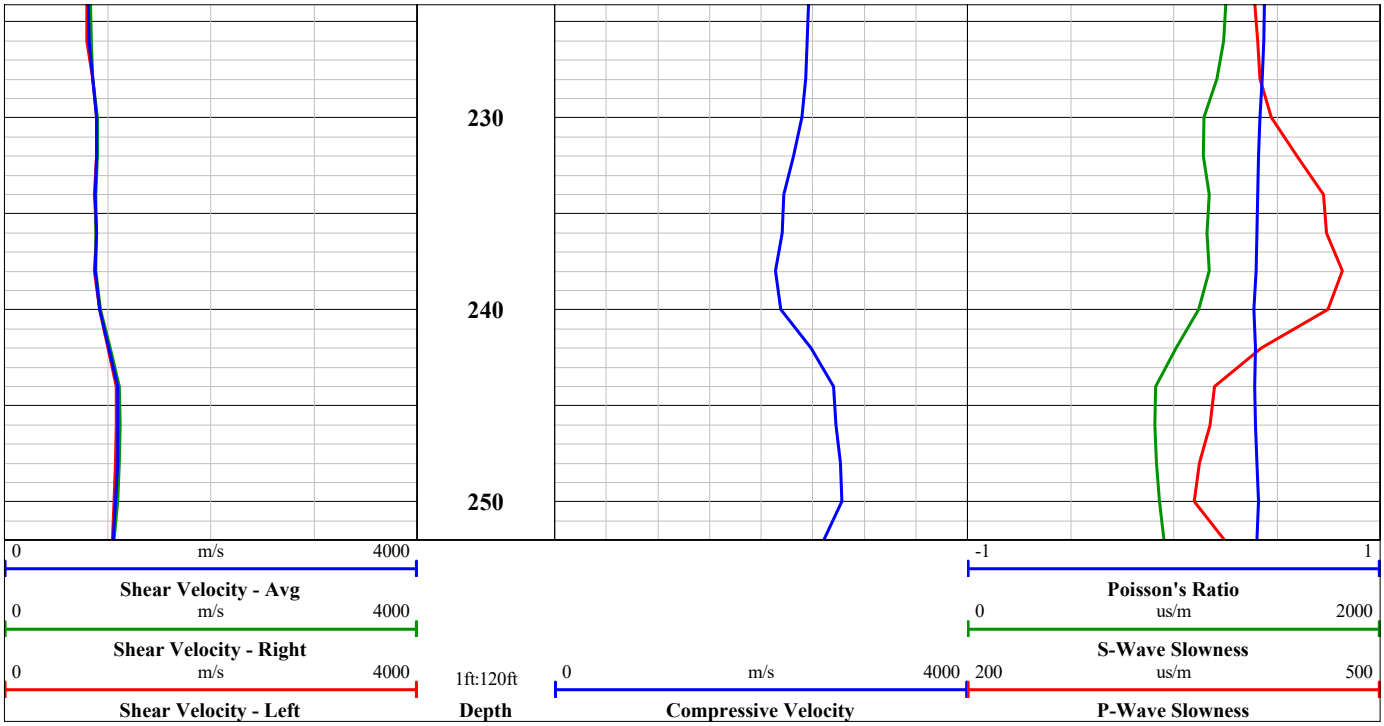
CASING RECORD

SIZE	WGT.	FROM	TO
6"	Steel	Mudline/TOC	135.5'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
0
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
140
150
160
170
180
190
200
210
220


230
240
250
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
0
m/s
4000
Compressive Velocity
-1
1
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness

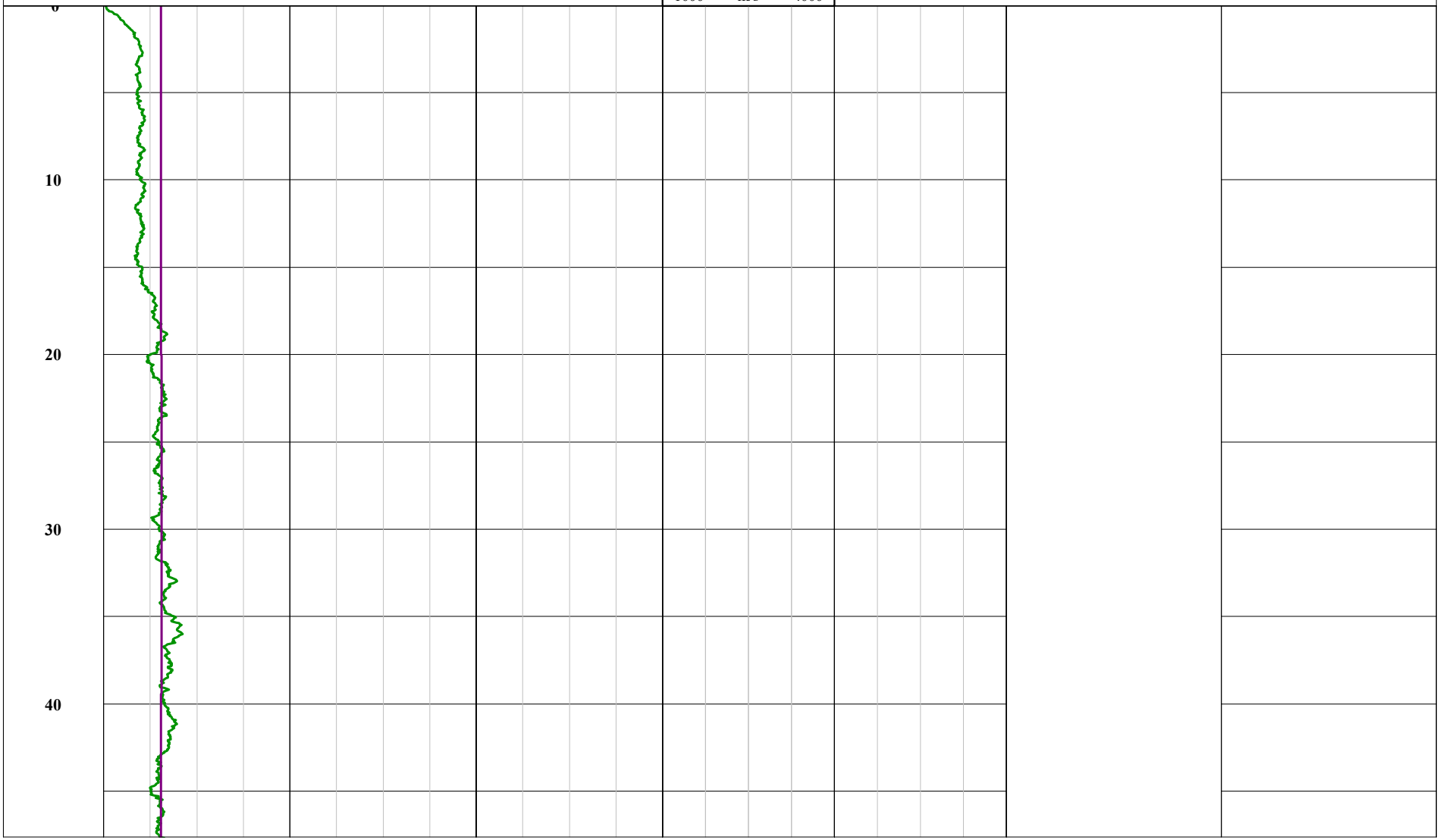
Geophysical Summary Plot

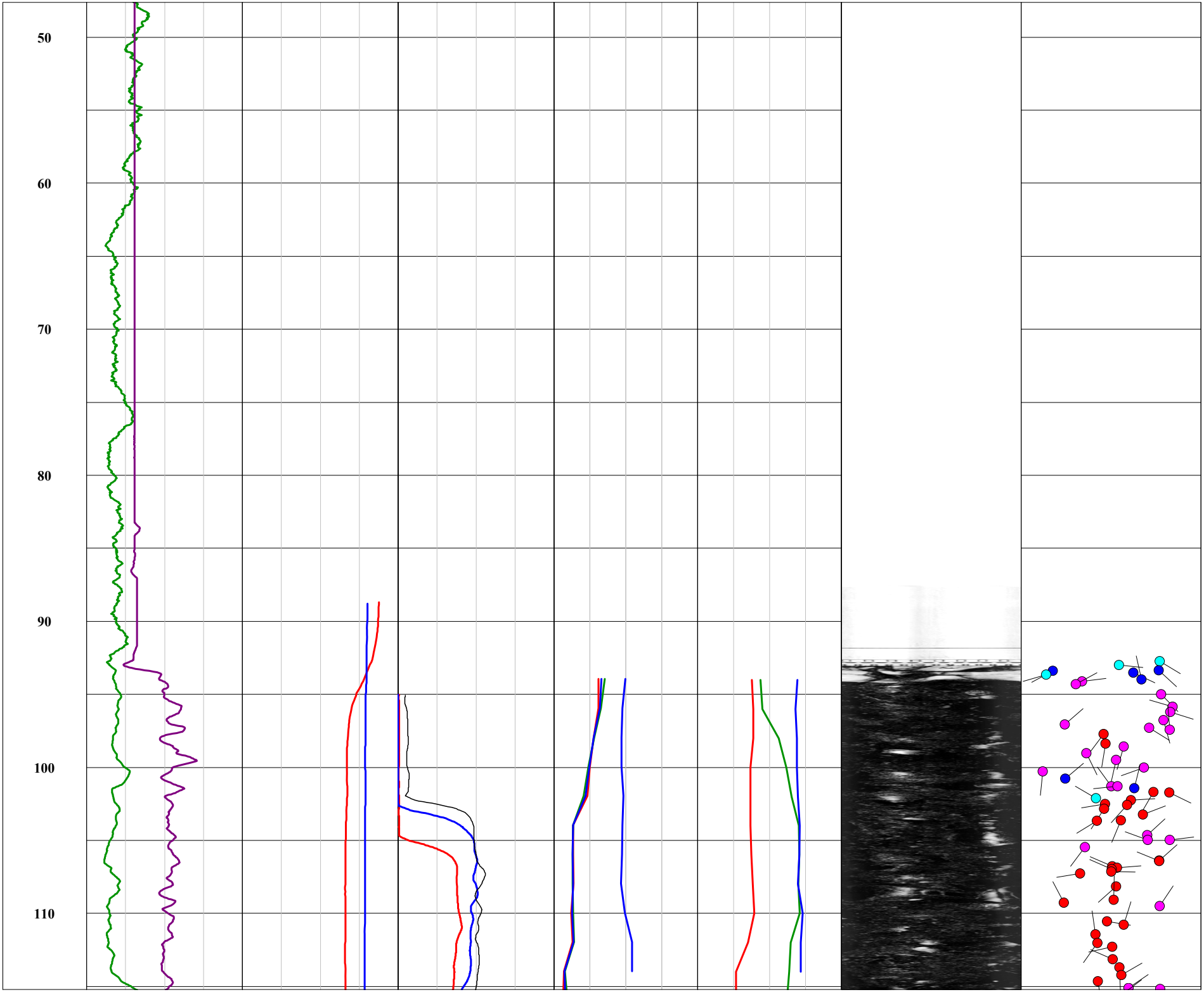
COLOG
borehole geophysics / hydrophysics

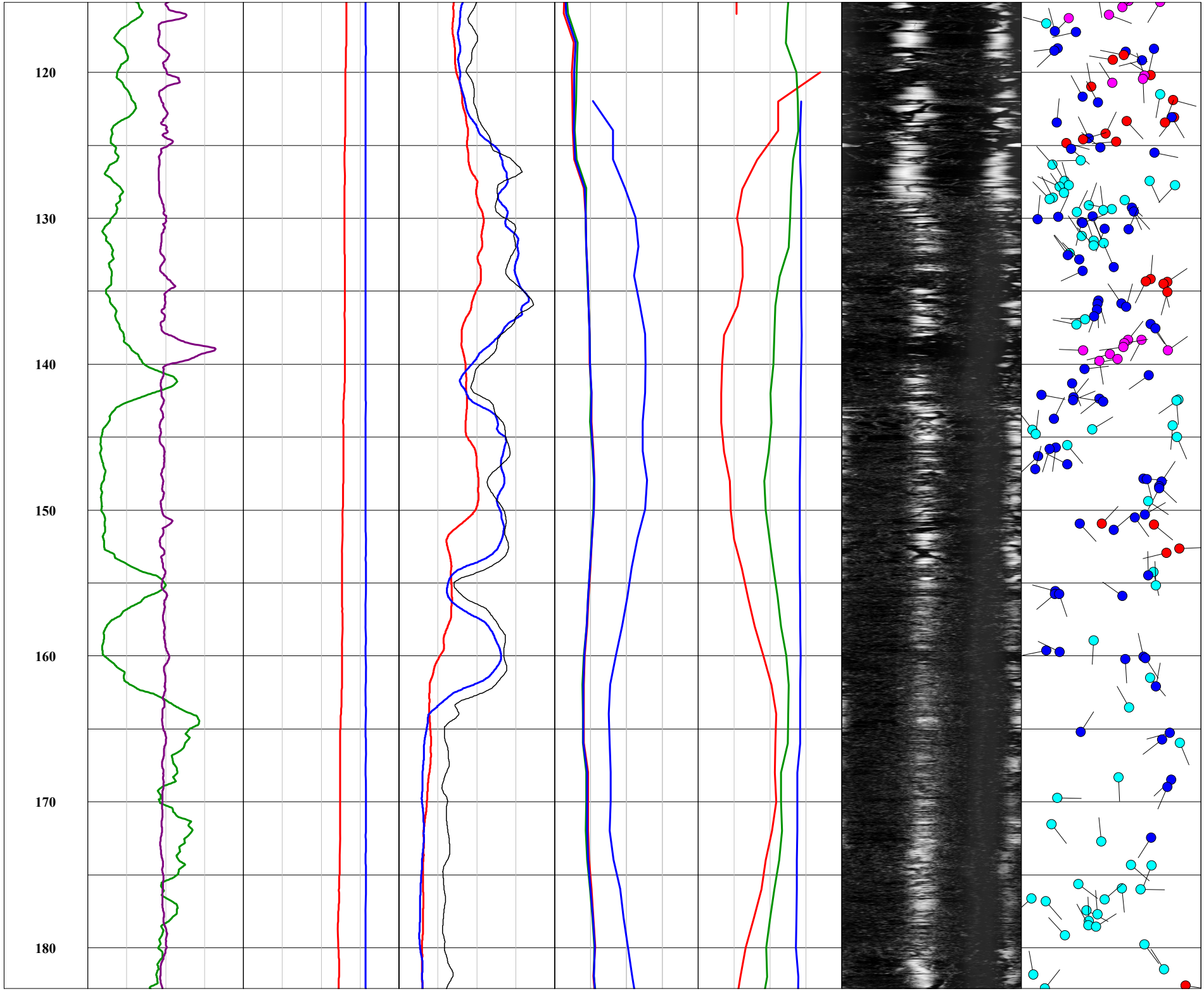
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 20 September 2019
WELL: BH19-32 - Mid Strait

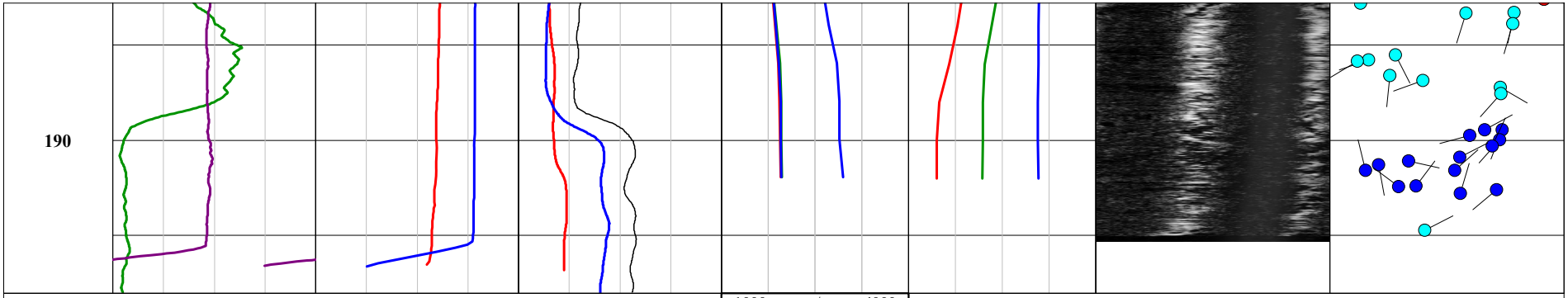
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	Temperature	64" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Amplitude - MN	Tadpoles
1ft:100ft	0 CPS 100	10 deg C 20	0 Ohm-m 500	0 m/s 4000	300 us/m 600	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	**Fluid Conductivity**	**16" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**		
	3 Inch 9	0 uS/cm 1000	0 Ohm-m 500	0 m/s 4000	0 us/m 2000		
			Single-Point Resistance	**Shear Velocity - Avg**	**Poisson's Ratio**		
			0 Ohm 200	0 m/s 4000	-1 1		
				Compressive Velocity			
				1000 m/s 4000			




50
60
70
80
90
100
110


120
130
140
150
160
170
180



					1000 m/s 4000 **Compressive Velocity**			
				0 Ohm 200 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-1 1 **Poisson's Ratio**		
	3 Inch 9 **3-Arm Caliper**	0 uS/cm 1000 **Fluid Conductivity**		0 Ohm-m 500 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**		
1ft:100ft	0 CPS 100	10 deg C 20		0 Ohm-m 500	0 m/s 4000	300 us/m 600	0° 90° 180° 270° 0°	0 90
Depth	**Natural Gamma**	**Temperature**		**64" Normal Resistivity**	**Shear Velocity - Left**	**P-Wave Slowness**	**Amplitude - MN**	**Tadpoles**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-32
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-32
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80755 N
Longitude: 84.76880 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 451.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 September 2019			
RUN NUMBER	5			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	197.1'			
DEPTH-LOGGER	196'			
BTM LOG INTERVAL	195.3'			
TOP LOG INTERVAL	87.5'			
RECORDED BY	DRE			
WITNESSED BY	WSP			
PROBE TYPE, S/N	ALT ABI/#111018			
LOGGING SPEED	5 fpm			
A.S.D.E. / Sample Interval	0.35'/.008			
Fluid Level / Fluid Type	NA/water			

BOREHOLE RECORD

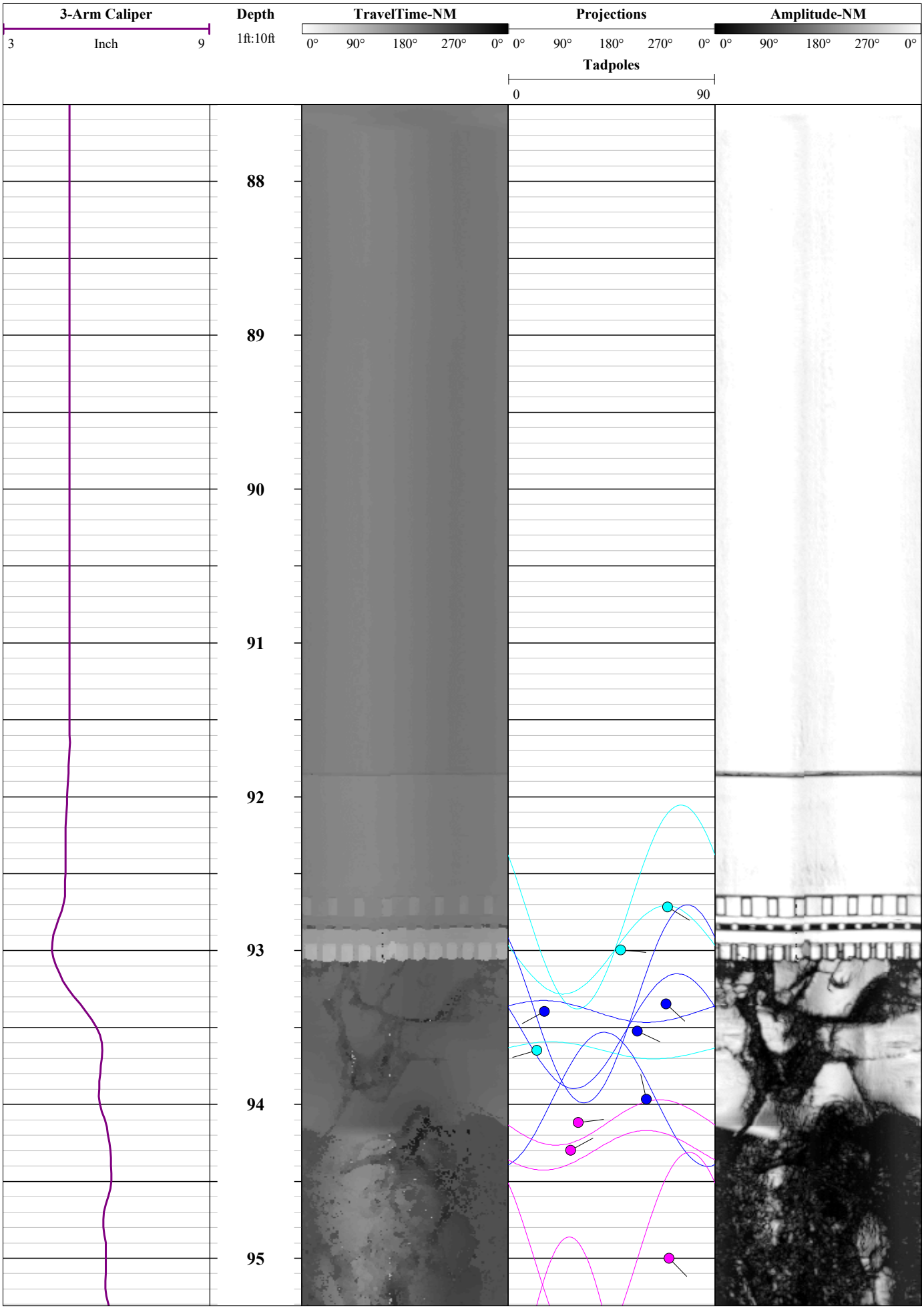
RUN No.	BIT	FROM	TO
1	7"	Deck	94.8'
2	6"	Mudline	197'

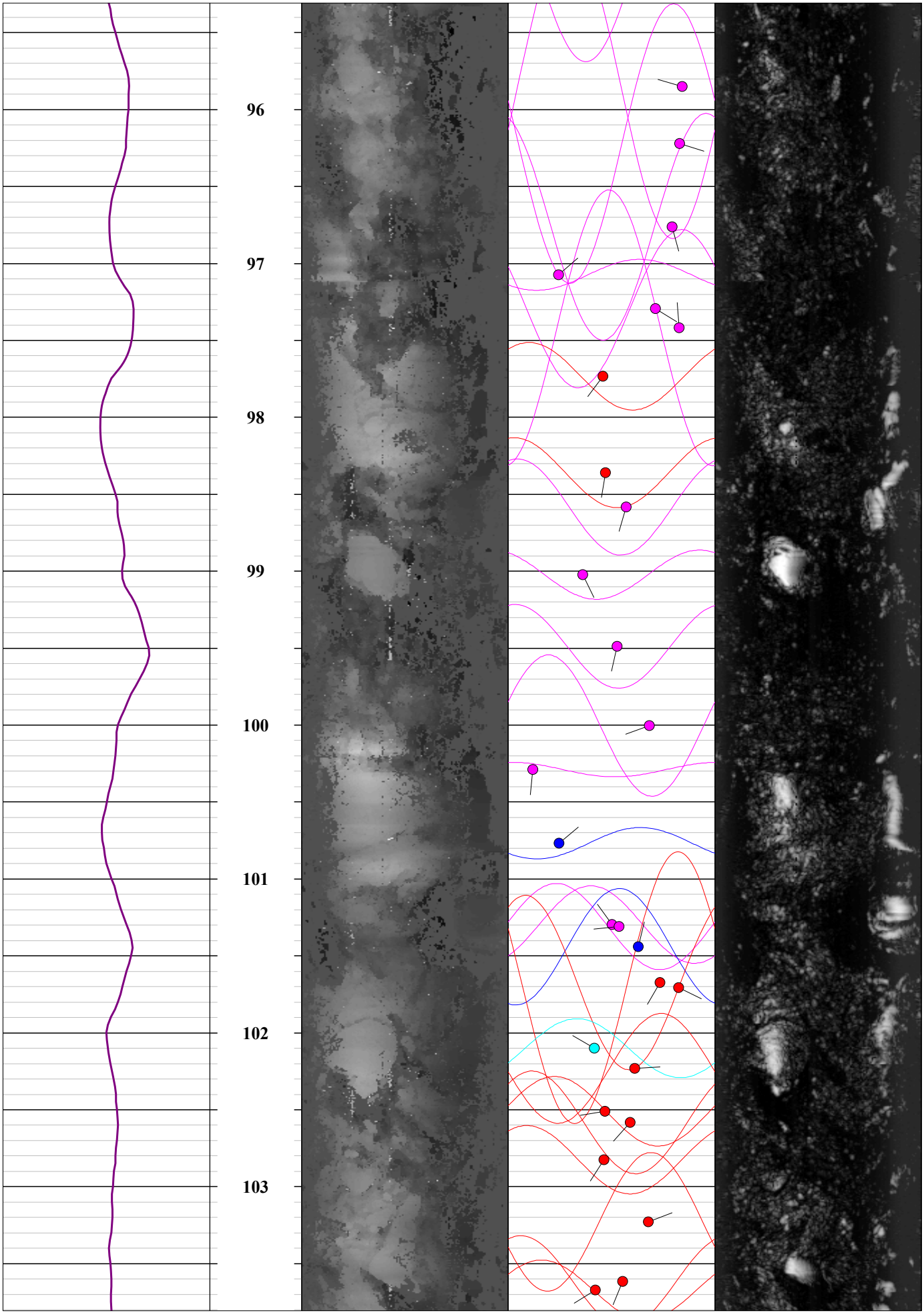
CASING RECORD

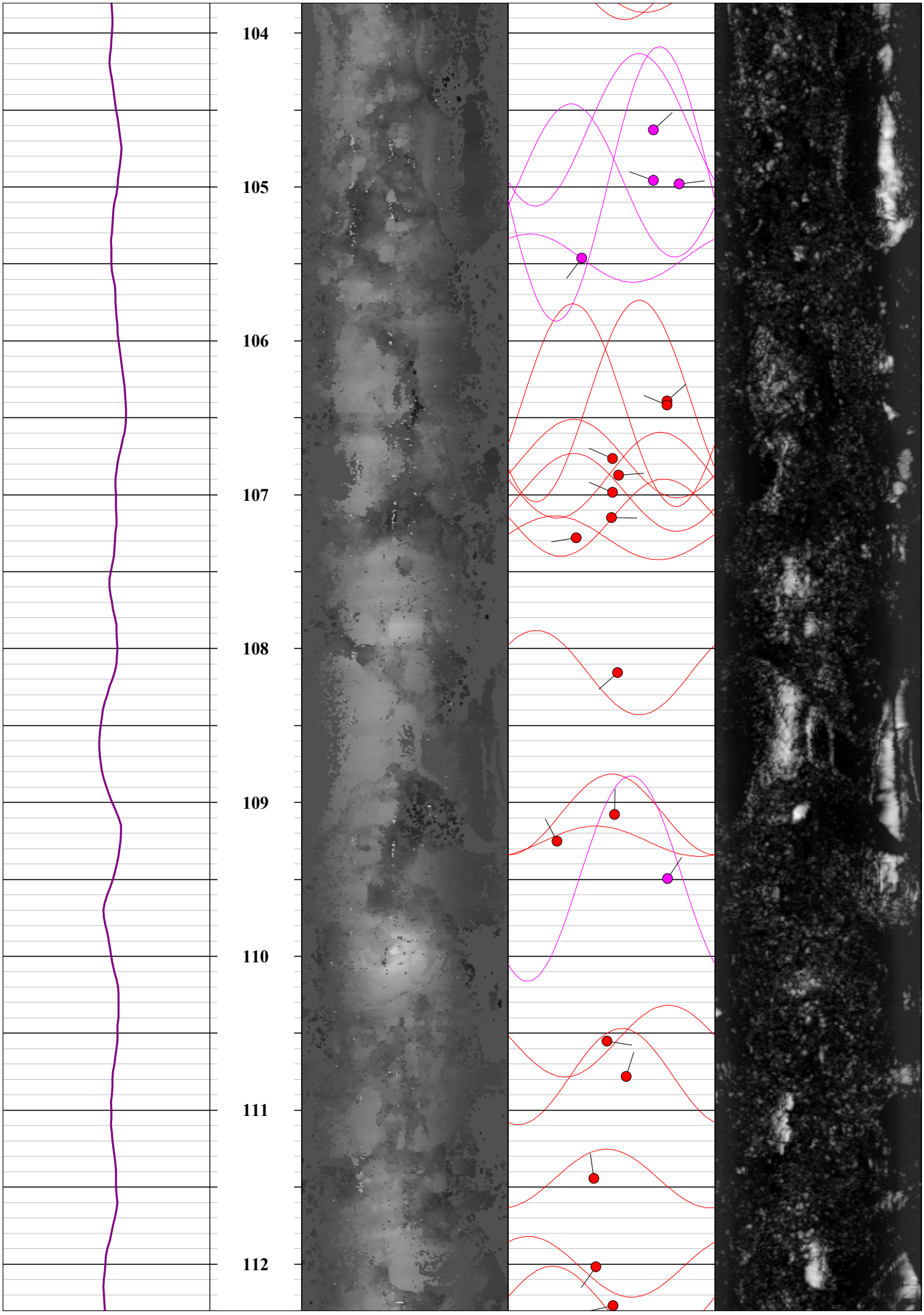
SIZE	WGT.	FROM	TO
7"	Steel	Deck	94.8'
6"	Steel	Mudline	197'

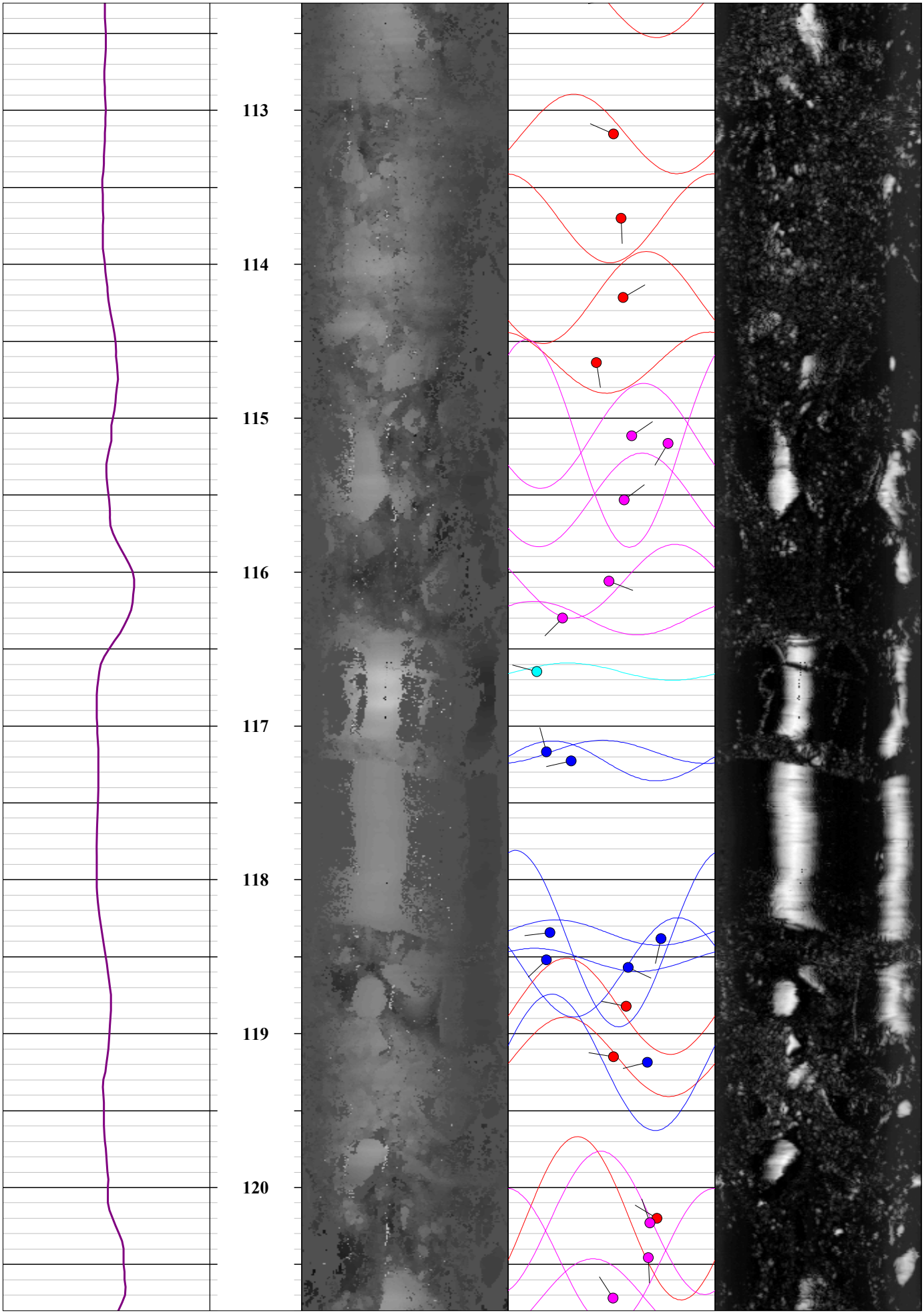
NA - Not Available, N/A - Not Applicable

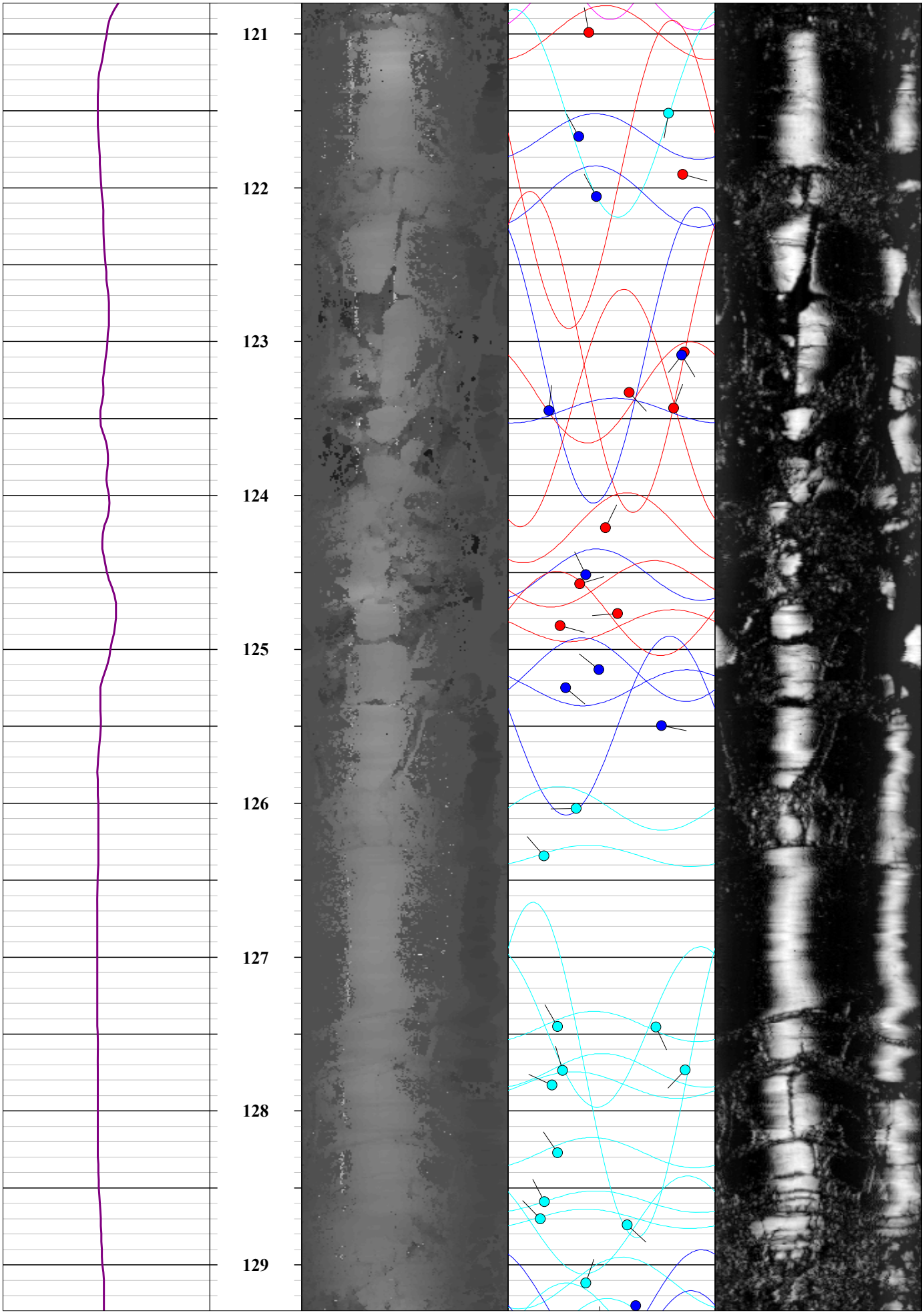
COMMENTS

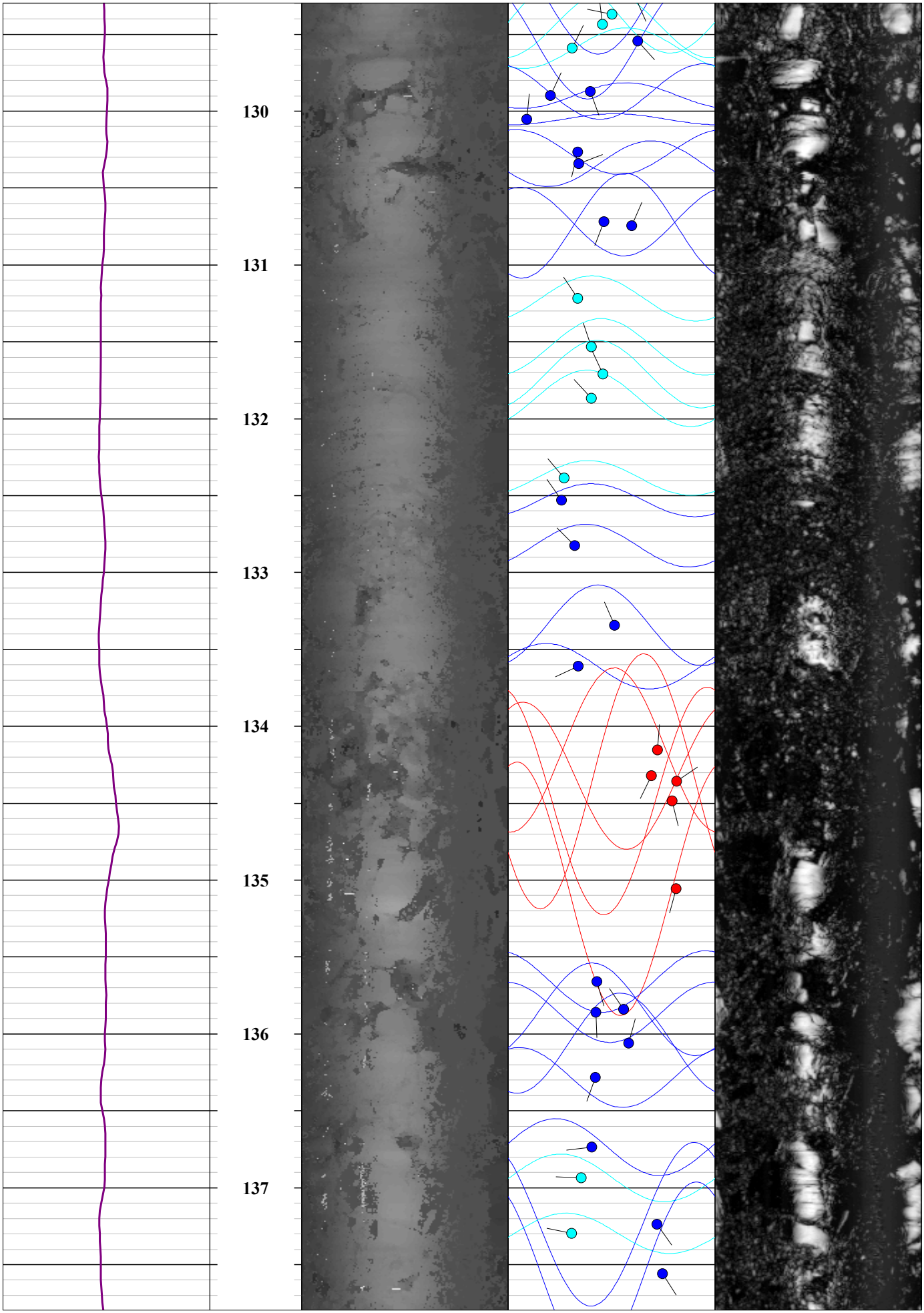

3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-NM
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude-NM
0°
90°
180°
270°
0°
88
89
90
91
92
93
94
95

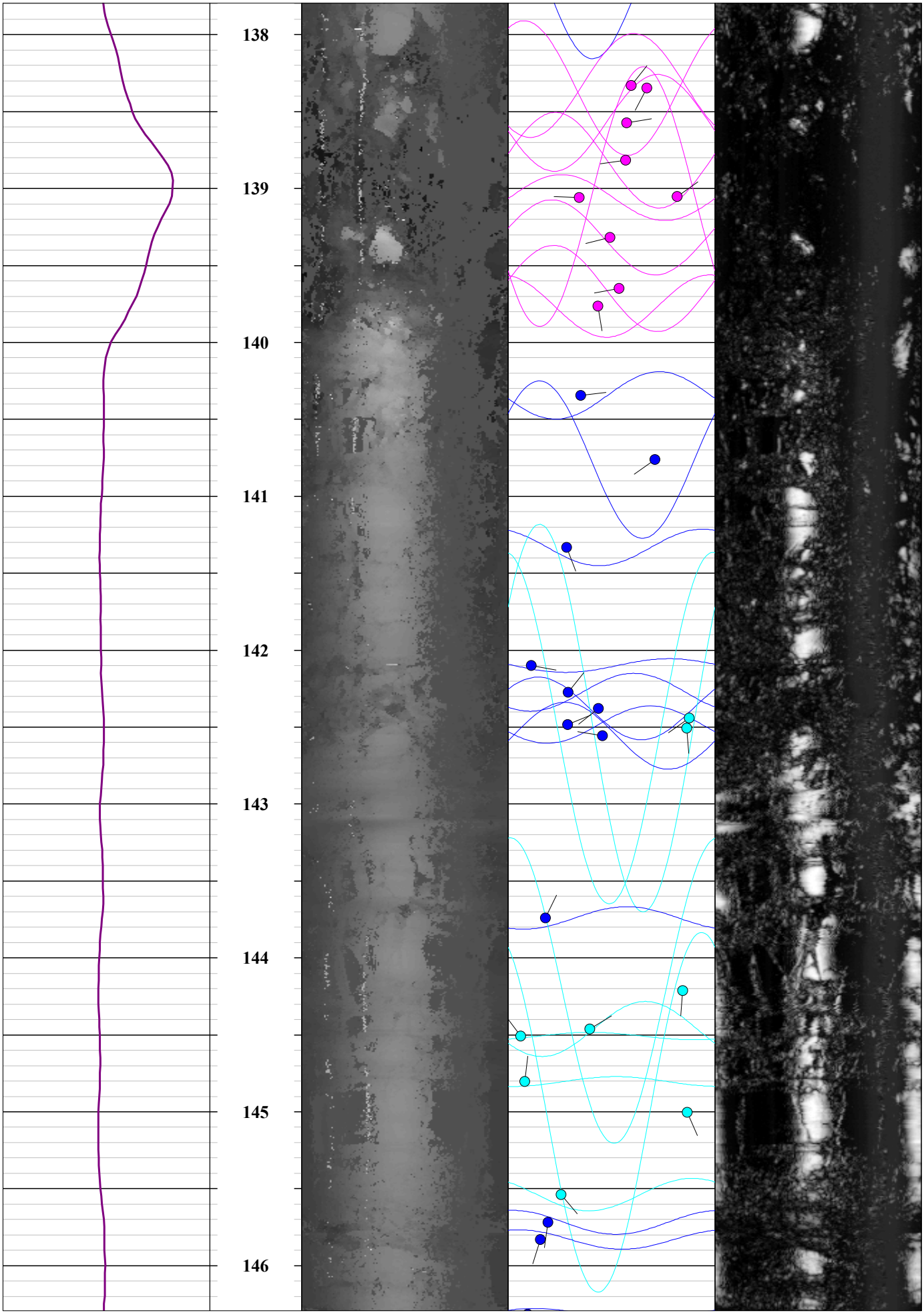

96
97
98
99
100
101
102
103

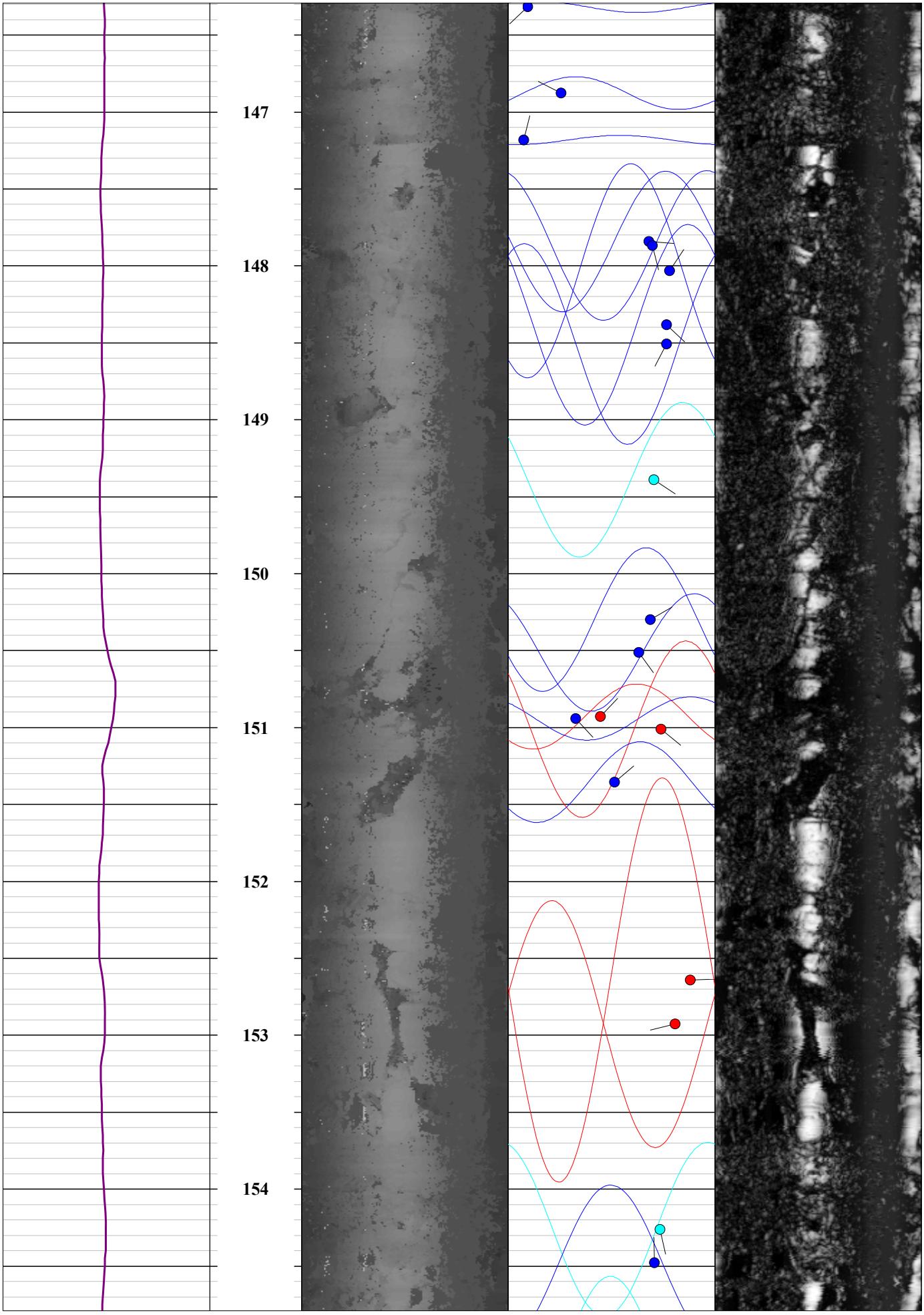

104
105
106
107
108
109
110
111
112

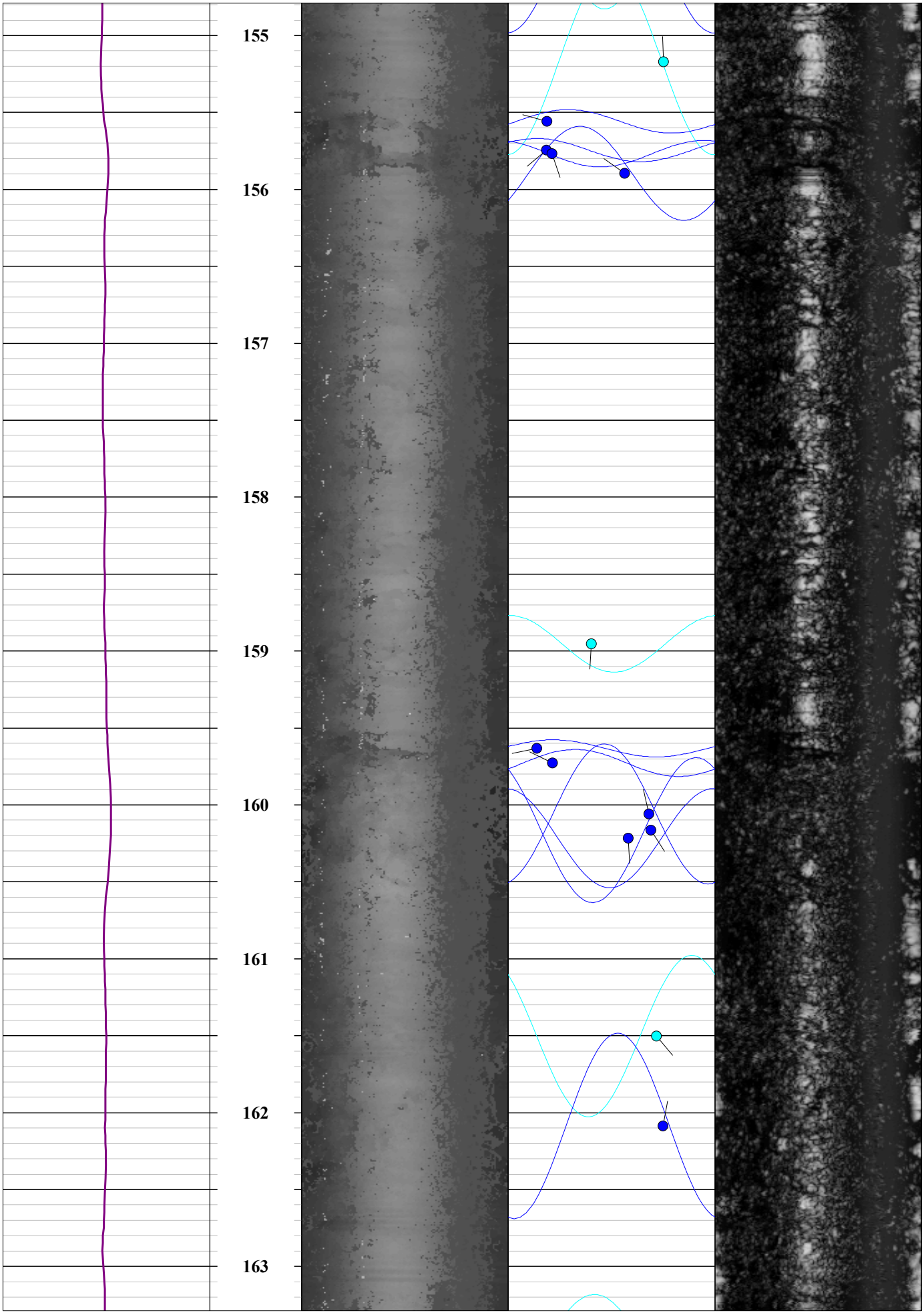

113
114
115
116
117
118
119
120

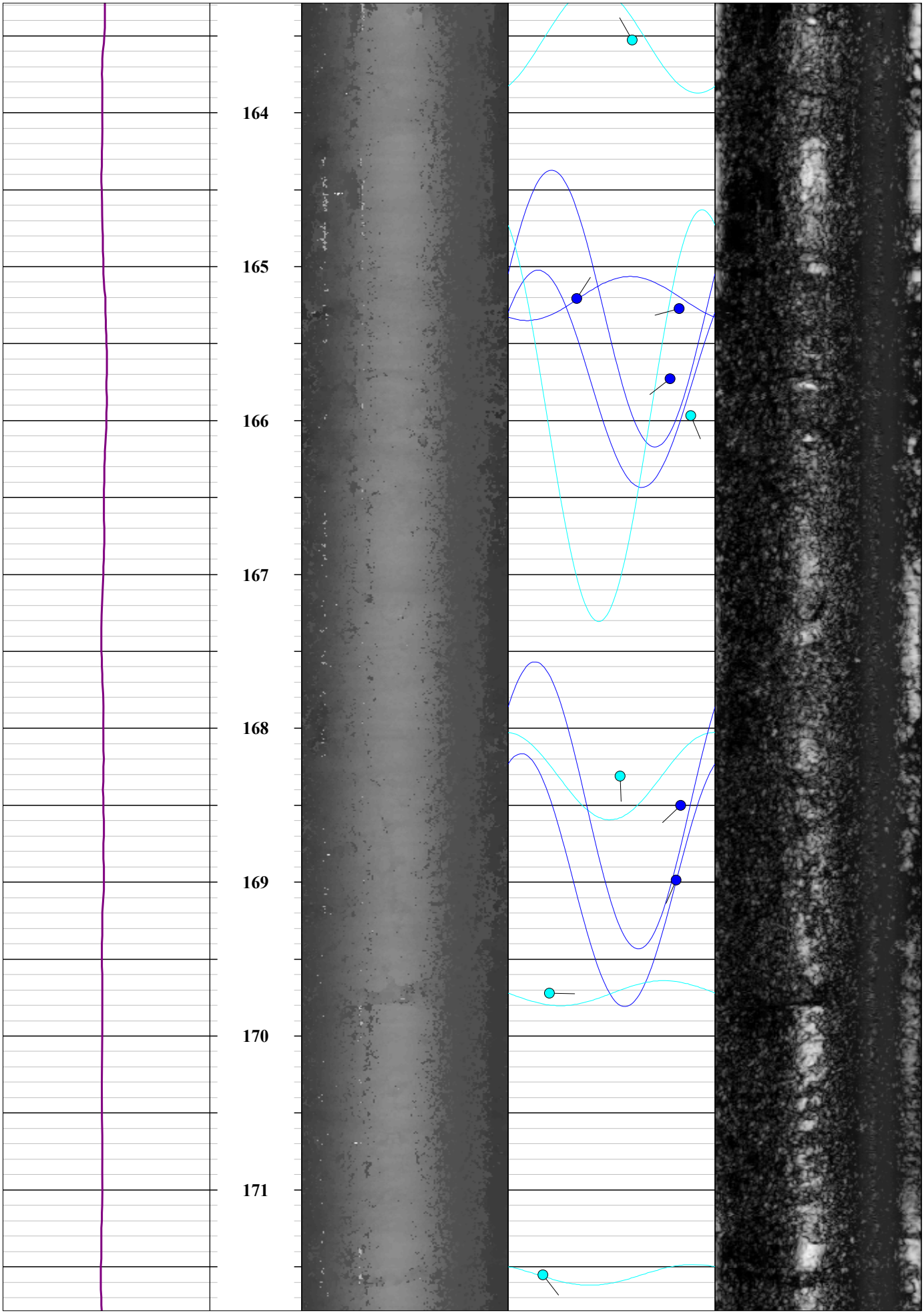

121
122
123
124
125
126
127
128
129

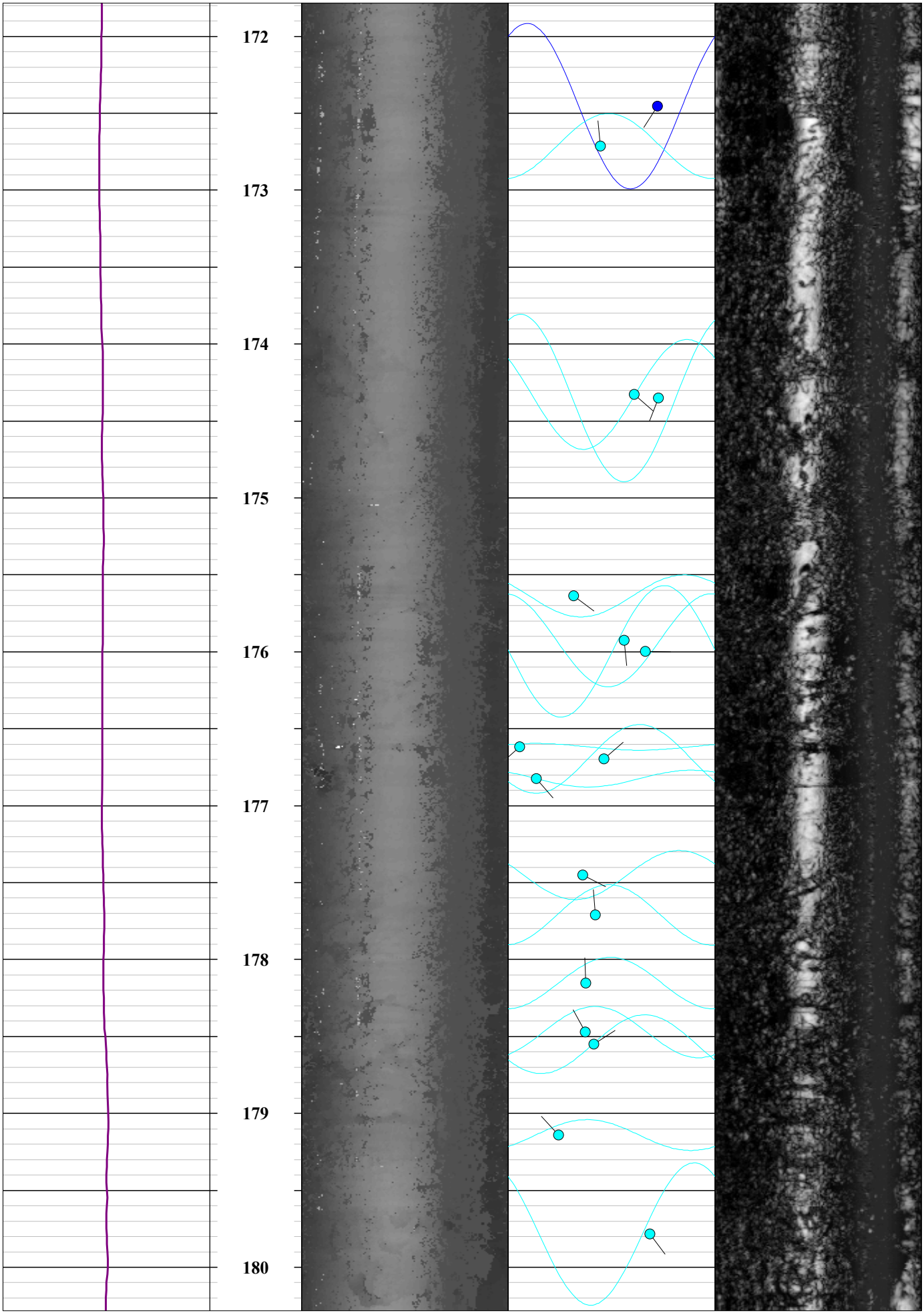

130
131
132
133
134
135
136
137

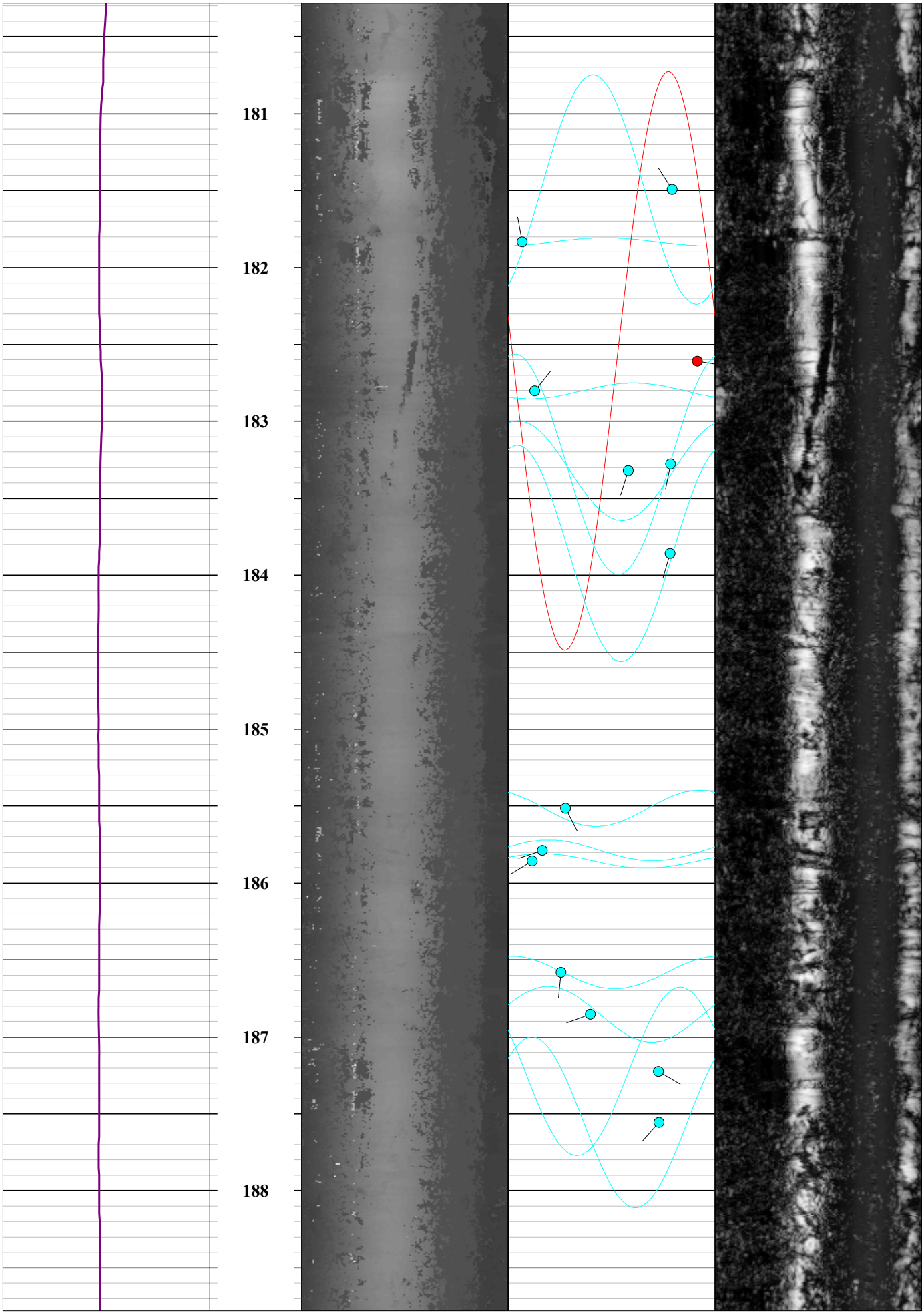

138
139
140
141
142
143
144
145
146

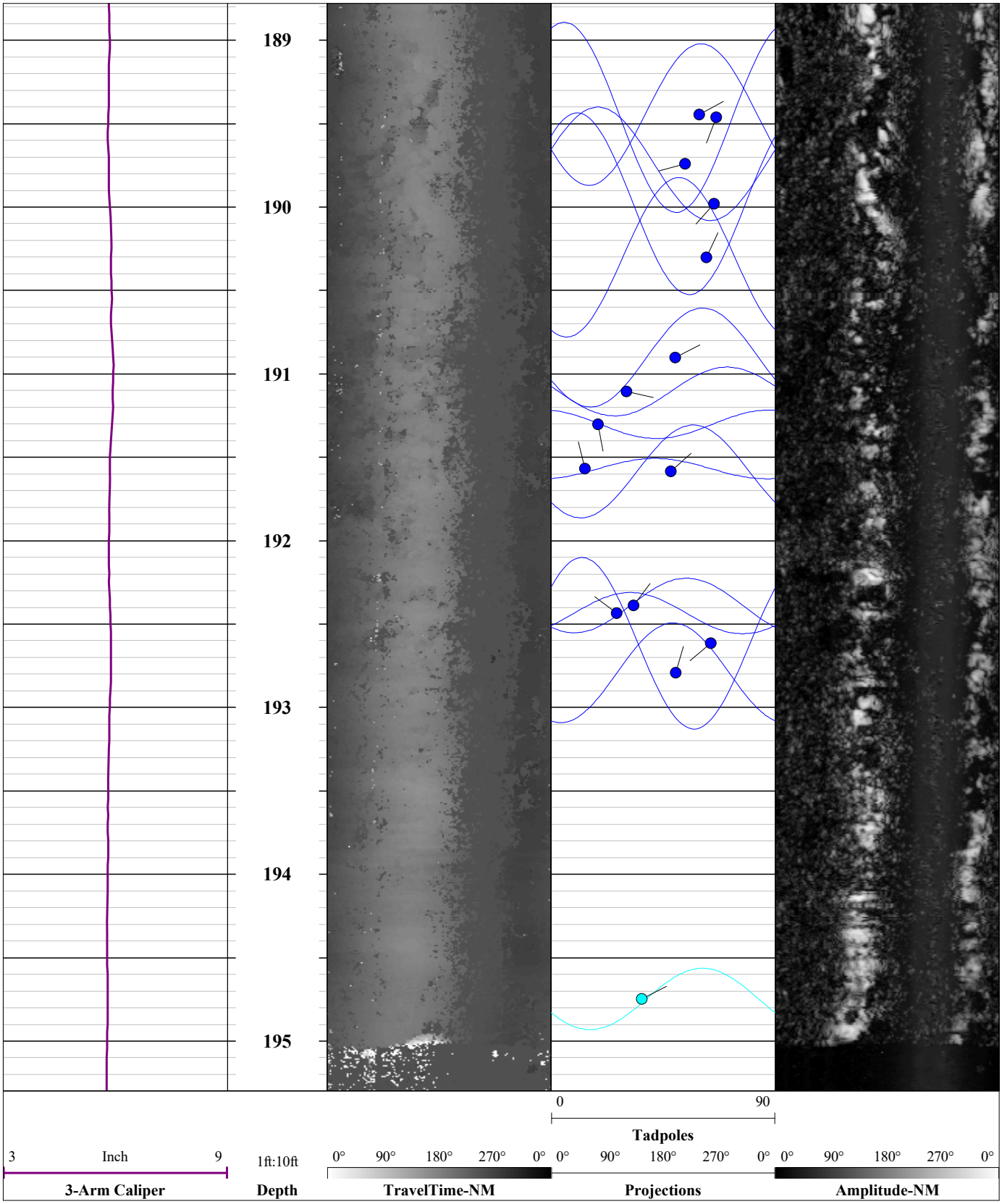

147
148
149
150
151
152
153
154


155
156
157
158
159
160
161
162
163

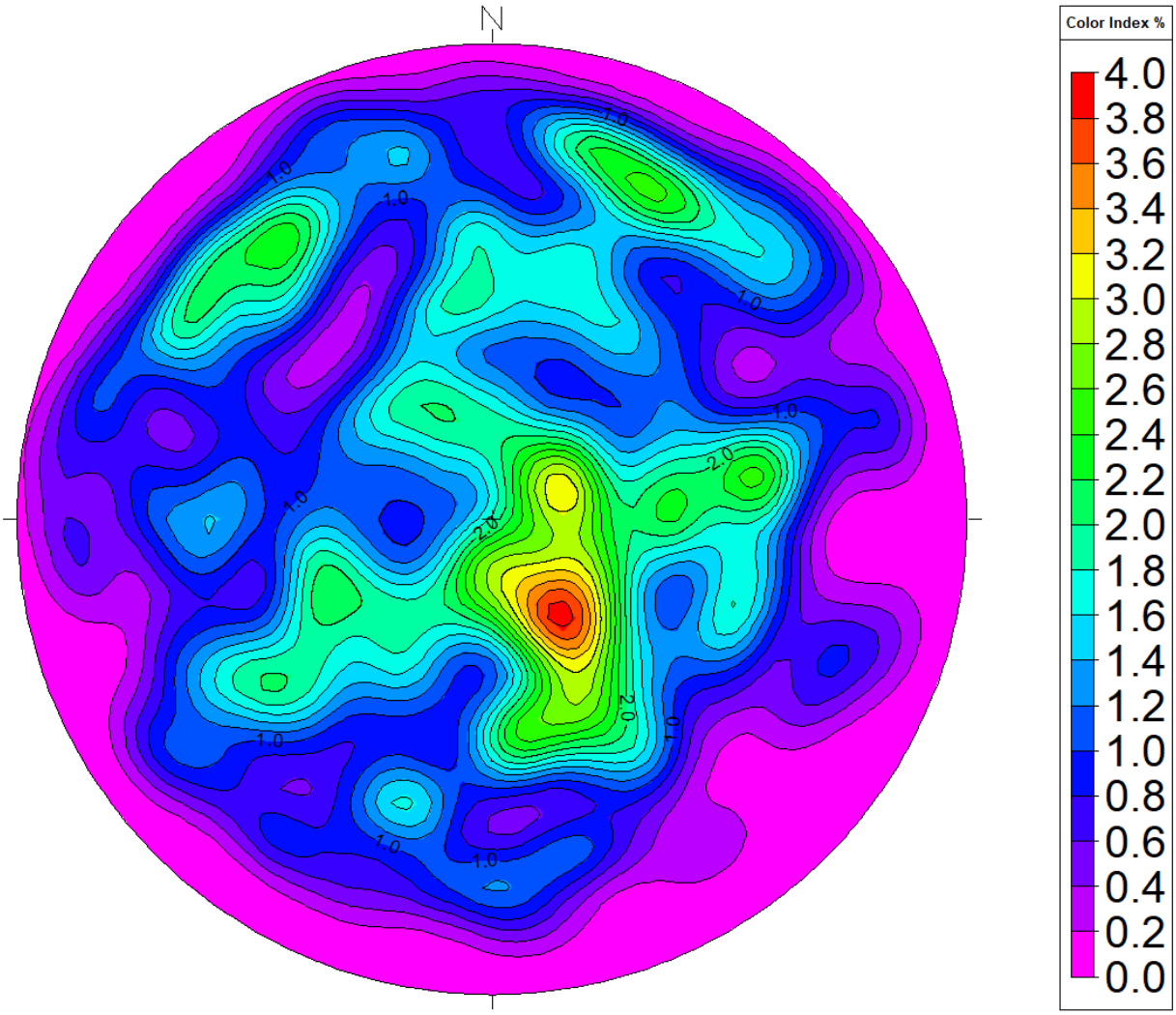

164
165
166
167
168
169
170
171


172
173
174
175
176
177
178
179
180


181
182
183
184
185
186
187
188

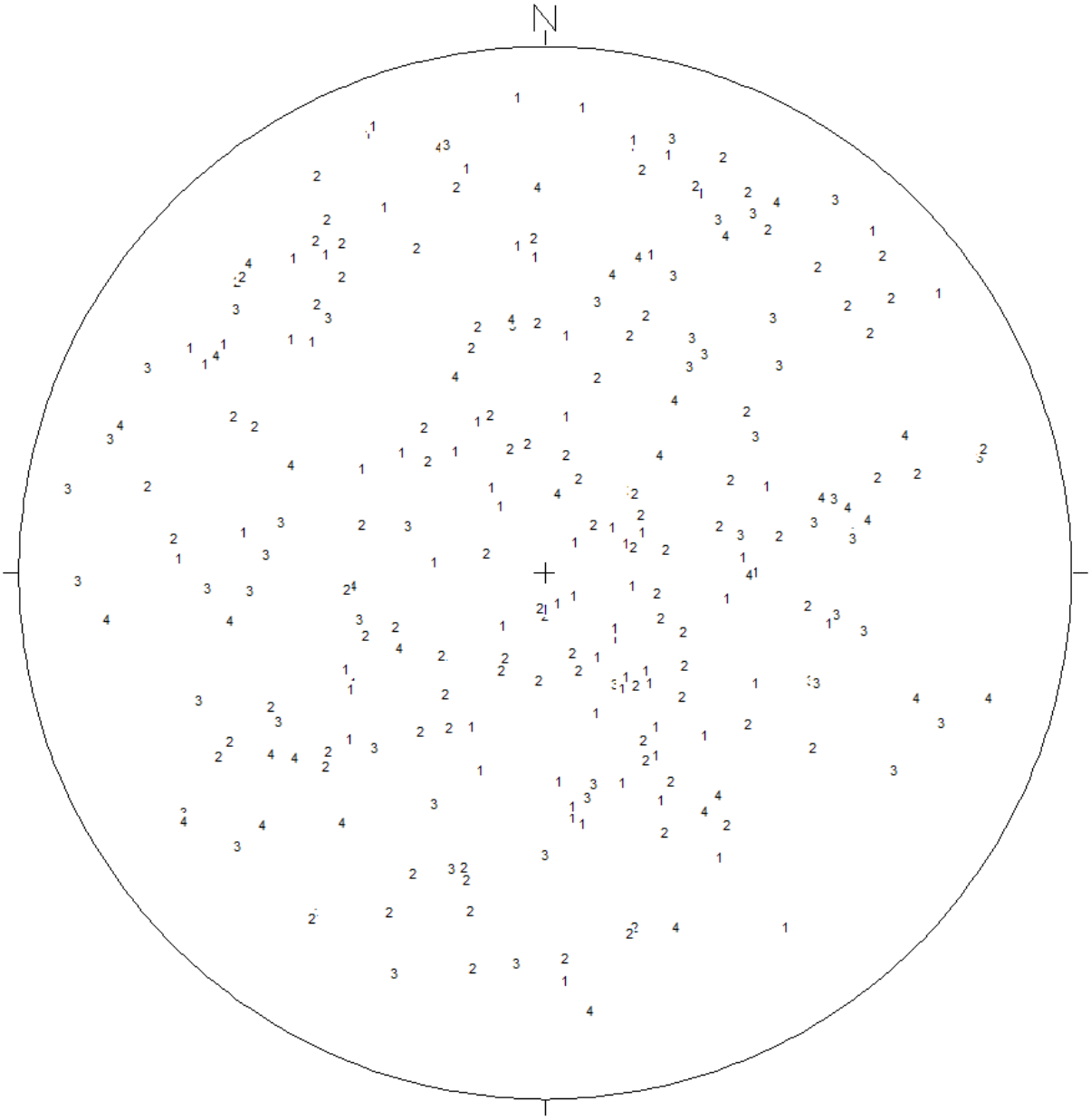

189
190
191
192
193
194
195
0
90
Tadpoles
3
Inch
9
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
TravelTime-NM
Projections
Amplitude-NM

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-32
20 September 2019



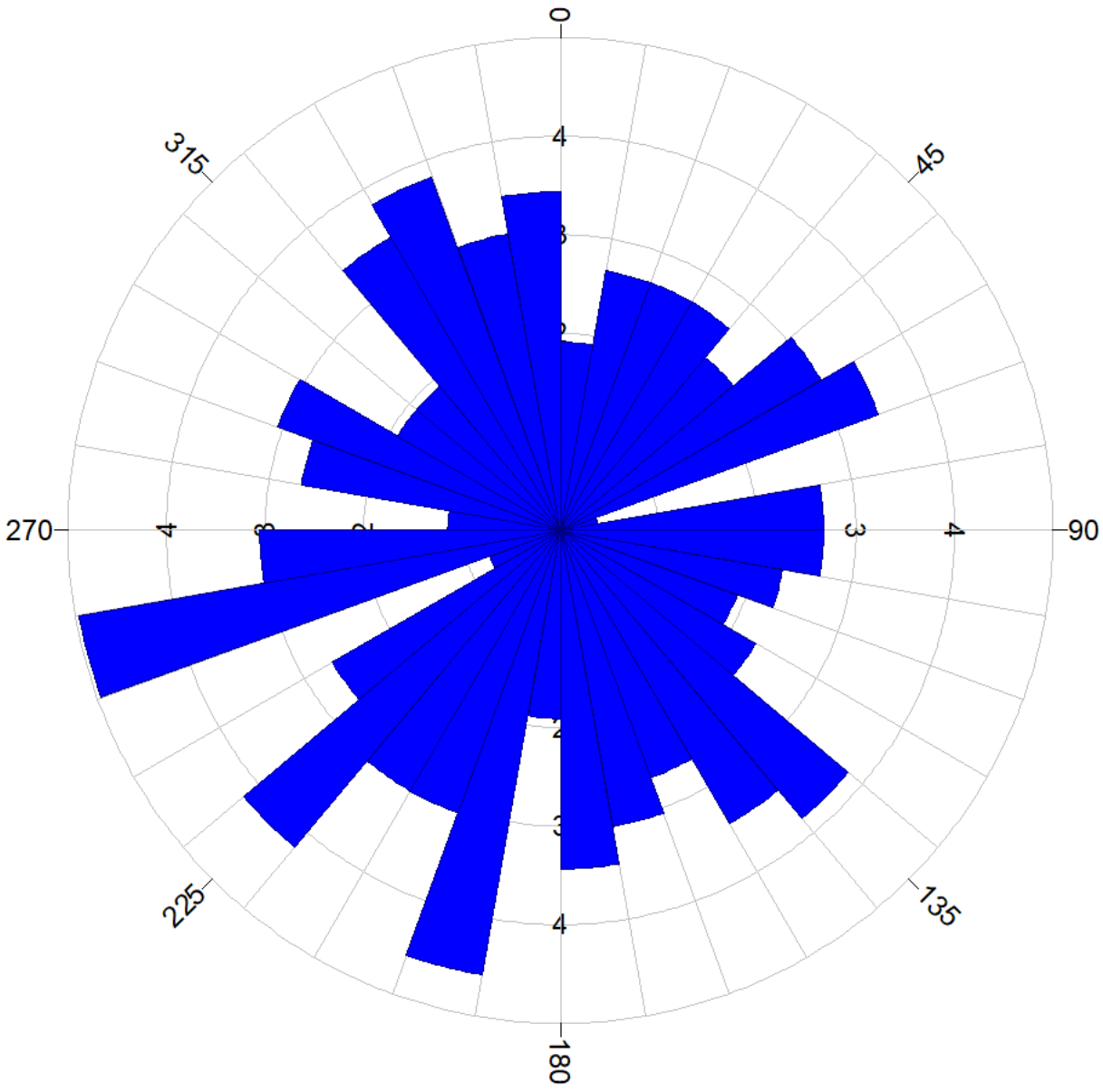
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-32
20 September 2019



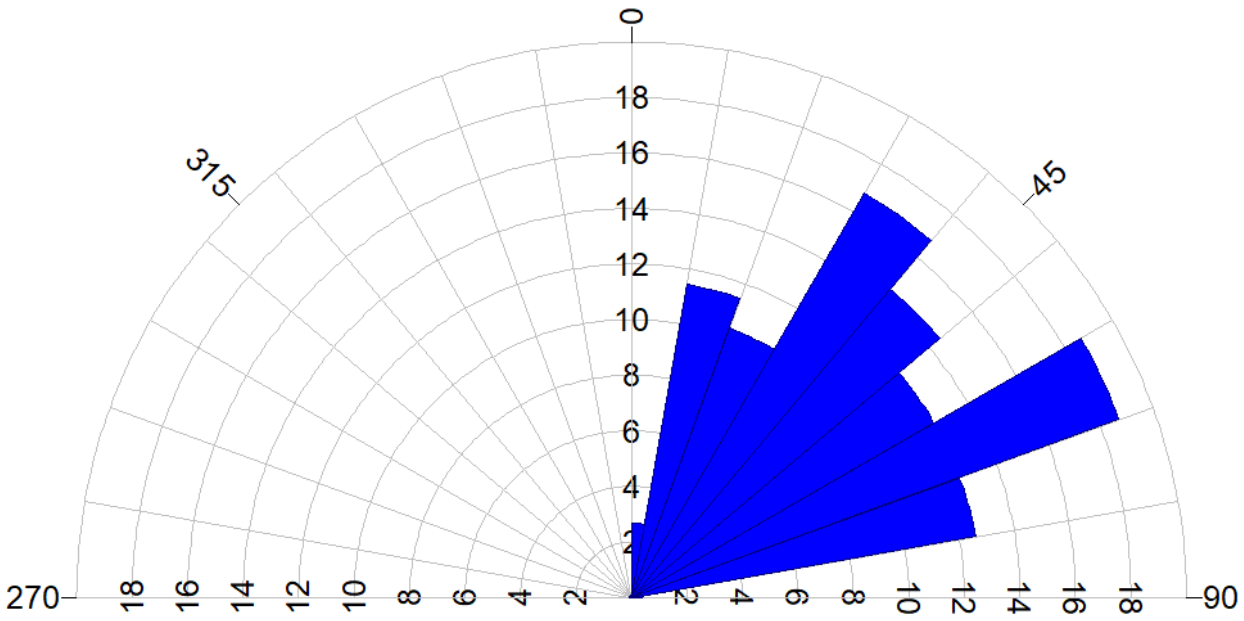
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-32
20 September 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-32
20 September 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-32

20 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	28.26	92.7	121	69	1
2	28.34	93.0	96	49	1
3	28.45	93.4	132	69	2
4	28.47	93.4	241	16	2
5	28.50	93.5	115	56	2
6	28.54	93.7	254	12	1
7	28.64	94.0	347	60	2
8	28.69	94.1	84	31	4
9	28.74	94.3	61	27	4
10	28.96	95.0	135	70	4
11	29.22	95.9	287	76	4
12	29.33	96.2	108	75	4
13	29.49	96.8	165	71	4
14	29.59	97.1	49	22	4
15	29.65	97.3	122	64	4
16	29.69	97.4	355	74	4
17	29.79	97.7	216	41	3
18	29.98	98.4	190	42	3
19	30.05	98.6	196	51	4
20	30.18	99.0	153	33	4
21	30.32	99.5	192	47	4
22	30.48	100.0	250	61	4
23	30.57	100.3	185	11	4
24	30.71	100.8	50	22	2
25	30.88	101.3	324	45	4
26	30.88	101.3	264	48	4
27	30.92	101.4	13	57	2
28	30.99	101.7	210	66	3
29	31.00	101.7	116	74	3
30	31.12	102.1	300	37	1
31	31.16	102.2	86	55	3
32	31.25	102.5	261	42	3
33	31.27	102.6	222	53	3
34	31.34	102.8	212	42	3
35	31.46	103.2	69	61	3
36	31.58	103.6	203	50	3
37	31.60	103.7	238	38	3
38	31.89	104.6	48	63	4
39	31.99	105.0	290	63	4
40	32.00	105.0	83	74	4
41	32.14	105.5	217	32	4
42	32.43	106.4	48	69	3
43	32.44	106.4	292	69	3
44	32.54	106.8	294	46	3
45	32.57	106.9	85	48	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-32

20 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	32.61	107.0	294	45	3
47	32.66	107.2	92	45	3
48	32.70	107.3	261	30	3
49	32.97	108.2	229	48	3
50	33.25	109.1	1	46	3
51	33.30	109.3	332	21	3
52	33.37	109.5	34	69	4
53	33.70	110.6	99	43	3
54	33.77	110.8	18	51	3
55	33.97	111.4	351	37	3
56	34.14	112.0	215	38	3
57	34.22	112.3	257	46	3
58	34.49	113.2	294	46	3
59	34.66	113.7	177	49	3
60	34.81	114.2	60	50	3
61	34.94	114.6	171	38	3
62	35.09	115.1	56	54	4
63	35.10	115.2	212	70	4
64	35.21	115.5	53	51	4
65	35.38	116.1	111	44	4
66	35.45	116.3	225	24	4
67	35.55	116.7	285	13	1
68	35.71	117.2	345	17	2
69	35.73	117.2	257	27	2
70	36.07	118.3	263	18	2
71	36.08	118.4	193	66	2
72	36.12	118.5	227	17	2
73	36.14	118.6	115	52	2
74	36.22	118.8	282	51	3
75	36.32	119.2	280	46	3
76	36.33	119.2	256	61	2
77	36.64	120.2	301	65	3
78	36.65	120.2	341	62	4
79	36.71	120.5	178	61	4
80	36.80	120.7	328	46	4
81	36.88	121.0	349	35	3
82	37.04	121.5	191	70	1
83	37.09	121.7	332	31	2
84	37.16	121.9	106	76	3
85	37.20	122.1	331	39	2
86	37.51	123.1	218	77	3
87	37.52	123.1	149	75	2
88	37.59	123.3	138	53	3
89	37.62	123.4	21	72	3
90	37.63	123.5	6	18	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-32

20 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	37.86	124.2	26	42	3
92	37.95	124.5	334	34	2
93	37.97	124.6	74	31	3
94	38.03	124.8	265	48	3
95	38.05	124.8	105	23	3
96	38.14	125.1	309	40	2
97	38.18	125.3	130	25	2
98	38.25	125.5	101	67	2
99	38.41	126.0	268	30	1
100	38.51	126.3	319	15	1
101	38.85	127.5	330	22	1
102	38.85	127.5	155	64	1
103	38.93	127.7	224	77	1
104	38.94	127.7	343	24	1
105	38.96	127.8	294	19	1
106	39.10	128.3	326	21	1
107	39.19	128.6	333	16	1
108	39.23	128.7	315	14	1
109	39.24	128.7	133	52	1
110	39.36	129.1	19	34	1
111	39.40	129.3	157	55	2
112	39.43	129.4	282	45	1
113	39.45	129.4	353	41	1
114	39.48	129.5	138	56	2
115	39.50	129.6	26	28	1
116	39.58	129.9	160	36	2
117	39.59	129.9	25	18	2
118	39.64	130.1	6	8	2
119	39.71	130.3	194	30	2
120	39.73	130.3	69	31	2
121	39.84	130.7	201	42	2
122	39.85	130.8	24	54	2
123	40.00	131.2	327	30	1
124	40.09	131.5	342	36	1
125	40.15	131.7	335	41	1
126	40.19	131.9	318	36	1
127	40.35	132.4	320	24	1
128	40.40	132.5	325	23	2
129	40.48	132.8	315	29	2
130	40.64	133.3	337	46	2
131	40.72	133.6	245	31	2
132	40.89	134.2	5	65	3
133	40.94	134.3	206	62	3
134	40.95	134.4	56	73	3
135	40.99	134.5	166	71	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-32

20 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	41.17	135.1	196	73	3
137	41.35	135.7	163	39	2
138	41.40	135.8	326	50	2
139	41.41	135.9	177	38	2
140	41.47	136.1	15	52	2
141	41.54	136.3	199	38	2
142	41.68	136.7	263	36	2
143	41.74	136.9	272	32	1
144	41.83	137.2	144	65	2
145	41.85	137.3	281	28	1
146	41.93	137.6	147	67	2
147	42.16	138.3	39	53	4
148	42.17	138.4	208	60	4
149	42.24	138.6	80	52	4
150	42.31	138.8	262	51	4
151	42.38	139.1	55	74	4
152	42.39	139.1	273	31	4
153	42.46	139.3	256	44	4
154	42.57	139.7	259	48	4
155	42.60	139.8	171	39	4
156	42.78	140.4	83	32	2
157	42.90	140.8	234	64	2
158	43.08	141.3	158	25	2
159	43.31	142.1	100	10	2
160	43.36	142.3	39	26	2
161	43.40	142.4	232	39	2
162	43.42	142.4	235	79	1
163	43.43	142.5	68	26	2
164	43.44	142.5	176	78	1
165	43.45	142.6	279	41	2
166	43.81	143.7	26	16	2
167	43.96	144.2	184	76	1
168	44.03	144.5	59	36	1
169	44.05	144.5	323	6	1
170	44.14	144.8	7	7	1
171	44.20	145.0	157	78	1
172	44.36	145.5	140	23	1
173	44.42	145.7	188	17	2
174	44.45	145.8	198	14	2
175	44.60	146.3	227	9	2
176	44.77	146.9	297	23	2
177	44.86	147.2	14	7	2
178	45.06	147.8	94	61	2
179	45.07	147.9	166	63	2
180	45.12	148.0	34	70	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-32

20 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	45.23	148.4	133	69	2
182	45.27	148.5	208	69	2
183	45.53	149.4	124	64	1
184	45.81	150.3	60	62	2
185	45.88	150.5	144	57	2
186	46.00	150.9	44	40	3
187	46.01	150.9	137	29	2
188	46.03	151.0	129	66	3
189	46.13	151.4	50	46	2
190	46.52	152.6	88	79	3
191	46.61	152.9	256	73	3
192	47.02	154.3	168	66	1
193	47.09	154.5	358	64	2
194	47.30	155.2	358	68	1
195	47.41	155.6	285	17	2
196	47.47	155.8	230	17	2
197	47.48	155.8	161	19	2
198	47.52	155.9	305	51	2
199	48.45	159.0	184	36	1
200	48.66	159.6	258	13	2
201	48.69	159.7	296	19	2
202	48.79	160.1	348	61	2
203	48.82	160.2	147	62	2
204	48.84	160.2	177	52	2
205	49.23	161.5	140	65	1
206	49.41	162.1	11	67	2
207	49.84	163.5	330	54	1
208	50.36	165.2	32	30	2
209	50.37	165.3	255	74	2
210	50.51	165.7	232	71	2
211	50.59	166.0	158	79	1
212	51.30	168.3	177	49	1
213	51.36	168.5	227	75	2
214	51.51	169.0	203	73	2
215	51.73	169.7	91	18	1
216	52.29	171.6	142	15	1
217	52.56	172.5	213	65	2
218	52.64	172.7	355	40	1
219	53.14	174.3	131	55	1
220	53.14	174.4	202	65	1
221	53.54	175.6	127	29	1
222	53.62	175.9	174	51	1
223	53.64	176.0	91	60	1
224	53.83	176.6	228	5	1
225	53.86	176.7	49	42	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-32

20 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	53.89	176.8	139	12	1
227	54.09	177.5	117	33	1
228	54.17	177.7	355	38	1
229	54.30	178.2	358	34	1
230	54.40	178.5	331	34	1
231	54.42	178.6	58	37	1
232	54.60	179.1	318	22	1
233	54.80	179.8	144	62	1
234	55.32	181.5	327	71	1
235	55.42	181.8	350	6	1
236	55.66	182.6	99	82	3
237	55.72	182.8	38	12	1
238	55.86	183.3	191	71	1
239	55.88	183.3	198	52	1
240	56.04	183.9	196	70	1
241	56.54	185.5	153	25	1
242	56.63	185.8	251	15	1
243	56.65	185.9	239	11	1
244	56.87	186.6	186	23	1
245	56.95	186.9	250	36	1
246	57.07	187.2	120	65	1
247	57.17	187.6	222	66	1
248	57.74	189.4	61	59	2
249	57.75	189.5	201	66	2
250	57.83	189.7	255	54	2
251	57.91	190.0	222	65	2
252	58.00	190.3	25	62	2
253	58.19	190.9	63	50	2
254	58.25	191.1	102	30	2
255	58.31	191.3	169	19	2
256	58.39	191.6	346	14	2
257	58.39	191.6	48	48	2
258	58.64	192.4	38	33	2
259	58.65	192.4	307	26	2
260	58.71	192.6	229	64	2
261	58.76	192.8	16	50	2
262	59.36	194.8	63	36	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-32
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-32
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80755 N
Longitude: 84.76880 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 451.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 September 2019	20 September 2019	20 September 2019	
RUN NUMBER	3	2	1	
LOG TYPE	FTC	Natural Gamma	Caliper	
DEPTH-DRILLER	197.1'	197.1'	197.1'	
DEPTH-LOGGER	197'	197'	197'	
BTM LOG INTERVAL	196.6'	197.9'	196.2'	
TOP LOG INTERVAL	88.8'	0.0'	0.0'	
RECORDED BY	DRE	DRE	DRE	
WITNESSED BY	WSP	WSP	WSP	
PROBE TYPE, S/N	2PFA #3656	ELXG #4314	3ACS#5596	
LOGGING SPEED	20 fpm	20 fpm	20 fpm	
A.S.D.E. / Sample Interval	.0.07' / 0.10'	0.50' / 0.25'	0.30' / 0.10'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

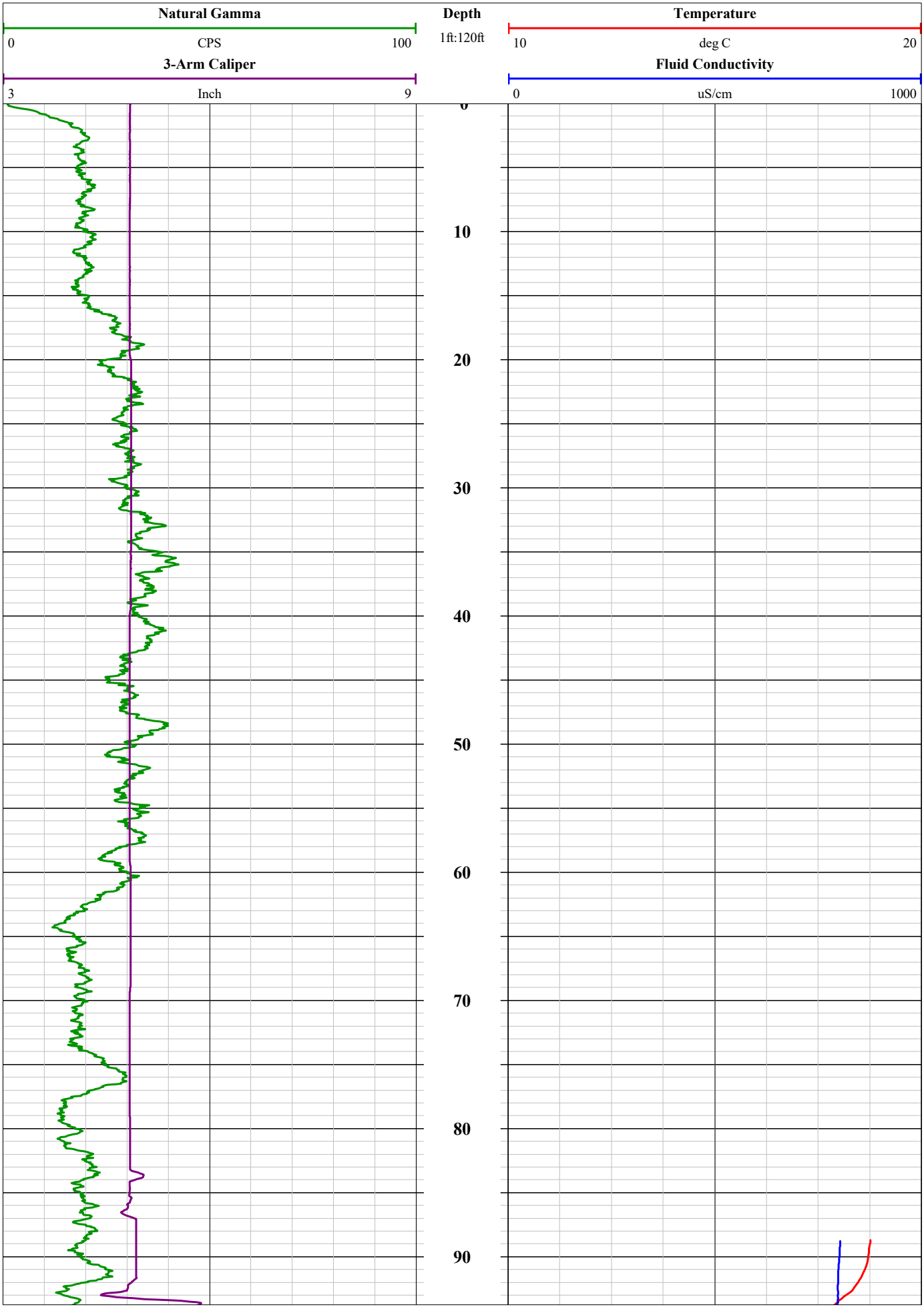
RUN No.	BIT	FROM	TO
1	7"	Deck	94.8'
2	6"	Mudline	197'

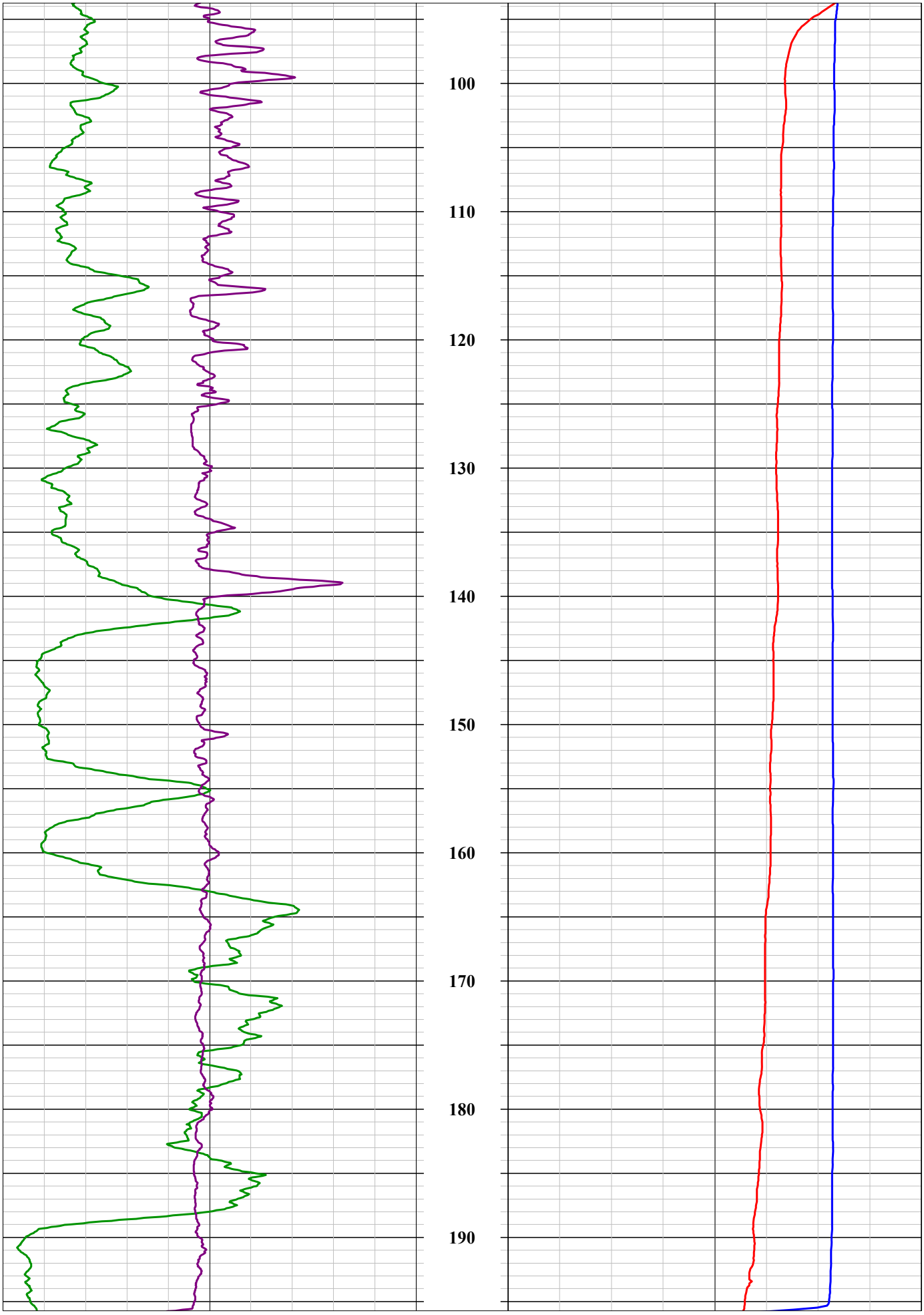
CASING RECORD

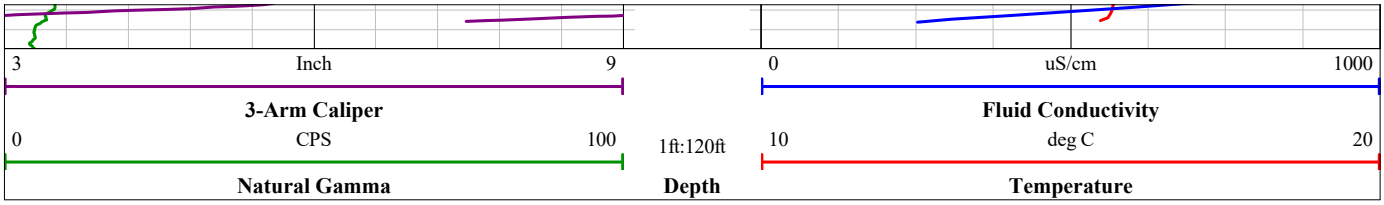
SIZE	WGT.	FROM	TO
7"	Steel	Deck	94.8'
6"	Steel	Mudline	197'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
3
Inch
9
Depth
1ft:120ft
0
10
20
30
40
50
60
70
80
90
Temperature
10
deg C
20
Fluid Conductivity
0
uS/cm
1000


100
110
120
130
140
150
160
170
180
190


3
Inch
9
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
10
deg C
20
Temperature

Borehole Deviation

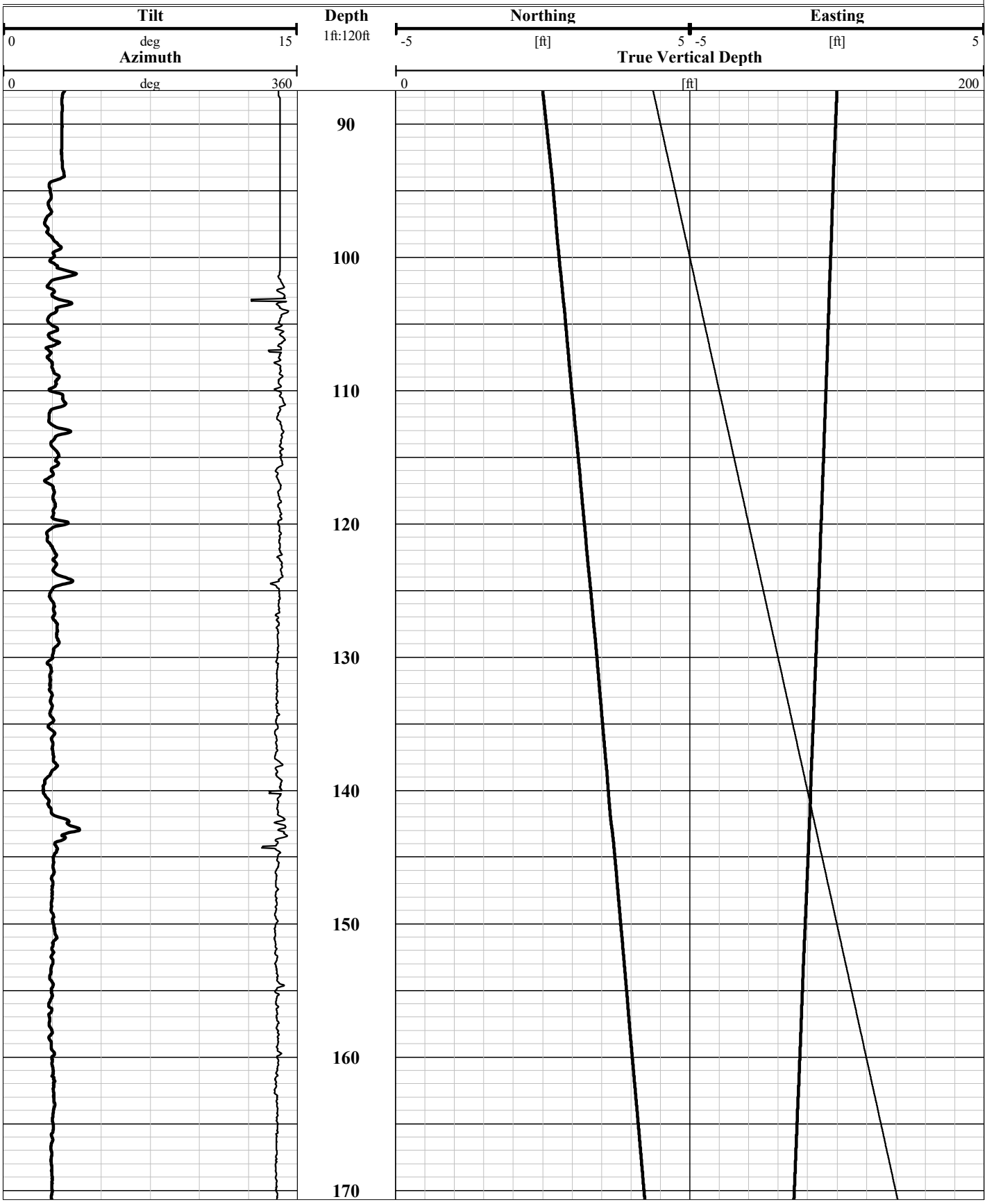
COLOG
borehole geophysics / hydrophysics

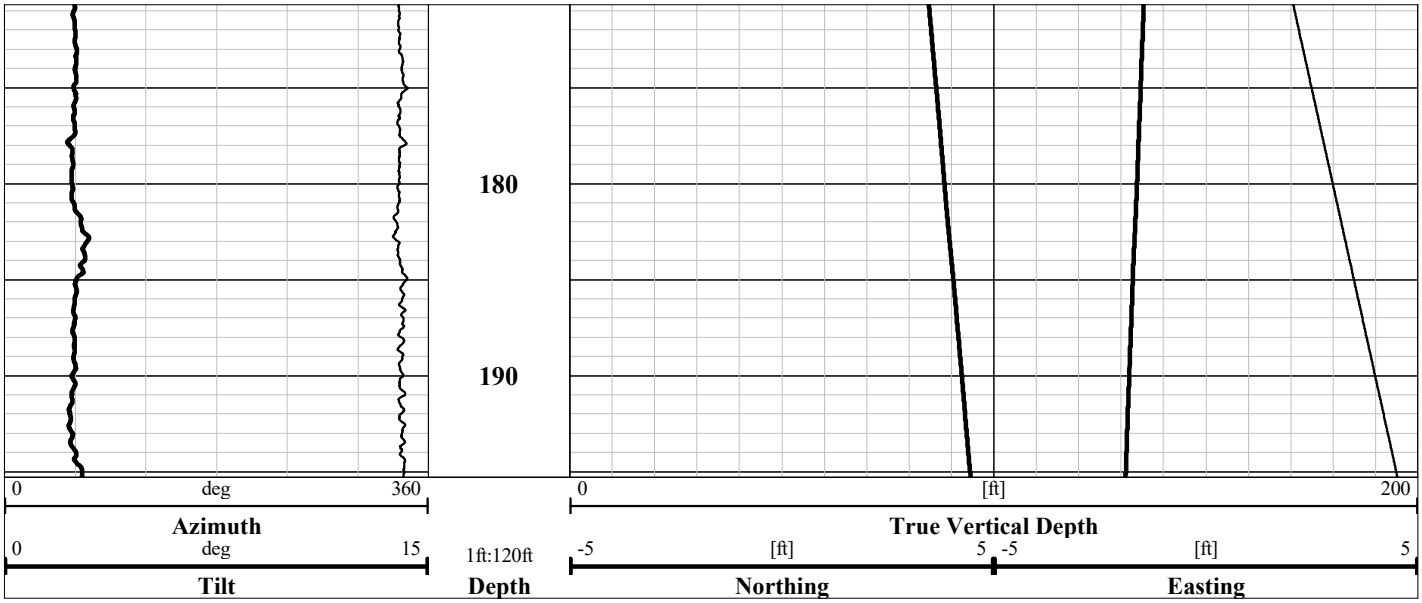
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 20 Sept. 2019	WELL: BH19-32 - Mid Strait

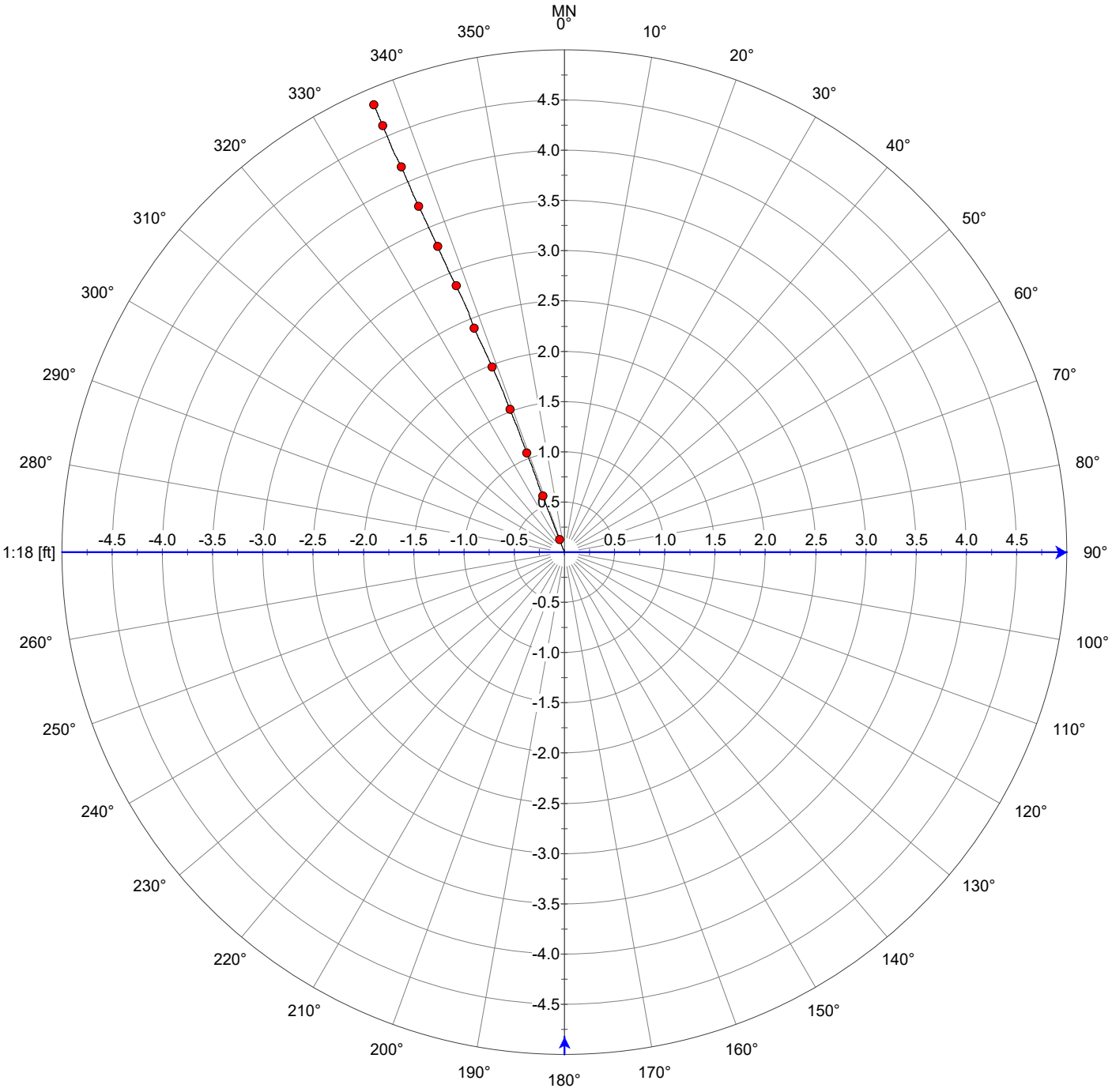
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 451.4'** **Latitude: 45.80755 N** **Longitude: 84.76880 W**




180
190
0
deg
360
Azimuth
0
deg
15
Tilt
1ft:120ft
Depth
0
[ft]
200
True Vertical Depth
-5
[ft]
5
Northing
-5
[ft]
5
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1:18 [ft]
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-32
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-32
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80755 N
Longitude: 84.76880 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 451.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 September 2019	20 September 2019		
RUN NUMBER	2	2		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	197.1'	197.1'		
DEPTH-LOGGER	197'	197'		
BTM LOG INTERVAL	197.9'	197.9'		
TOP LOG INTERVAL	0.0'	95.1'		
RECORDED BY	DRE	DRE		
WITNESSED BY	WSP	WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 fpm	20 fpm		
A.S.D.E. / Sample Interval	0.5' / 0.25'	0.5' / 0.25'		
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

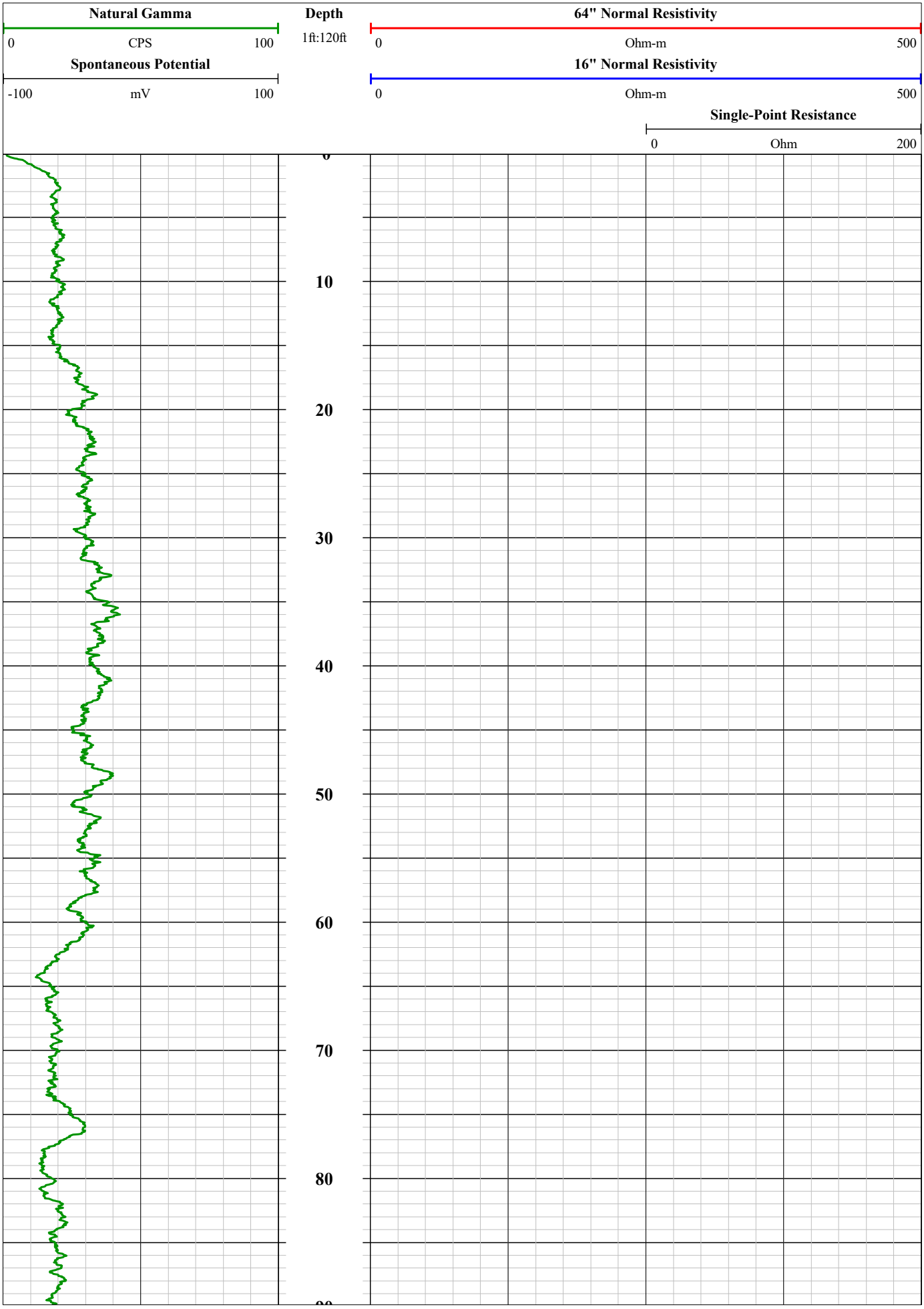
RUN No.	BIT	FROM	TO
1	7"	Deck	94.8'
2	6"	Mudline	197'

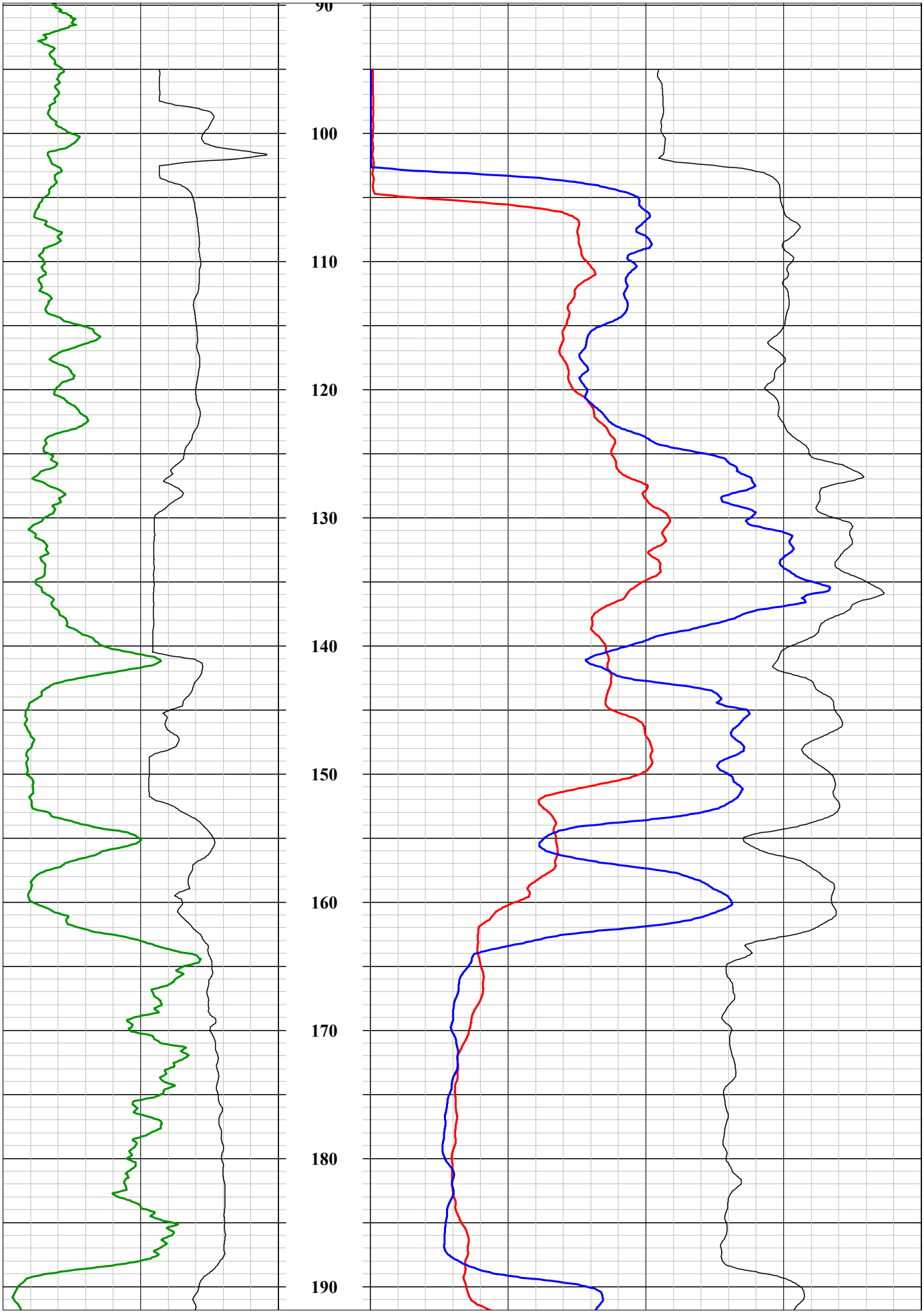
CASING RECORD

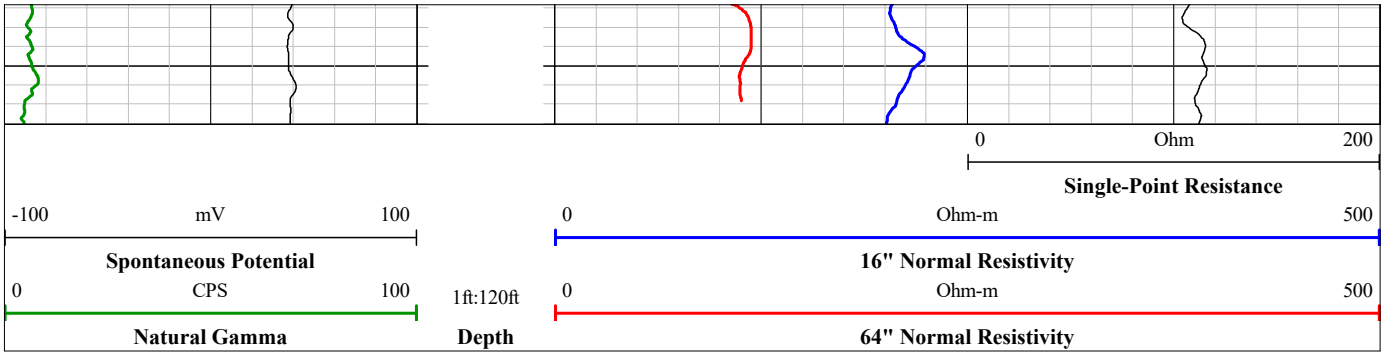
SIZE	WGT.	FROM	TO
7"	Steel	Deck	94.8'
6"	Steel	Mudline	197'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-100
mV
100
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
500
16" Normal Resistivity
0
Ohm-m
500
Single-Point Resistance
0
Ohm
200
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


0
Ohm
200
Single-Point Resistance
-100
mV
100
Spontaneous Potential
0
Ohm-m
500
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
500
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-32
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-32
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80755 N
Longitude: 84.76880 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 451.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	20 September 2019			
RUN NUMBER	10			
LOG TYPE	PSLog			
DEPTH-DRILLER	197.1'			
DEPTH-LOGGER	192'			
BTM LOG INTERVAL	192'			
TOP LOG INTERVAL	94'			
RECORDED BY	DRE			
WITNESSED BY	WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	0.01'/2.0'			
Fluid Level / Fluid Type	NA'/Water			

BOREHOLE RECORD

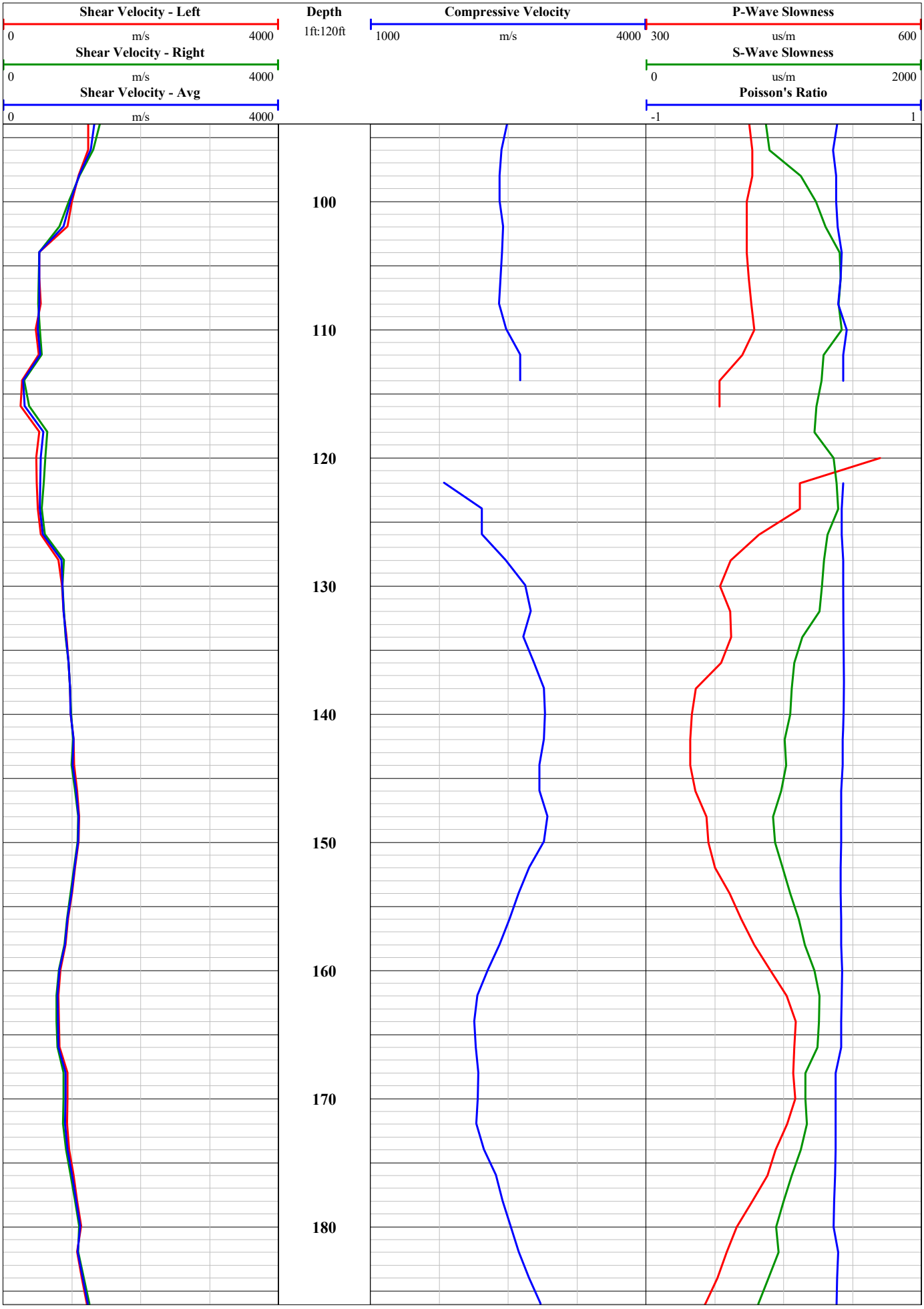
RUN No.	BIT	FROM	TO
1	7"	Deck	94.8'
2	6"	Mudline	197'

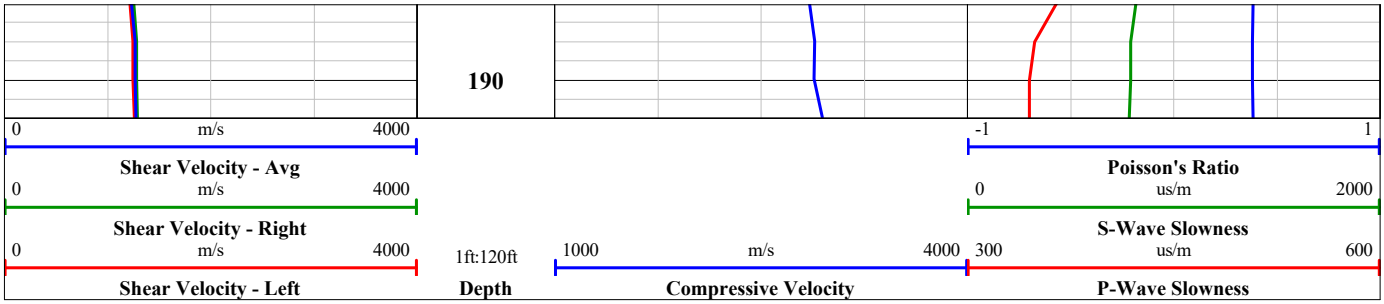
CASING RECORD

SIZE	WGT.	FROM	TO
7"	Steel	Deck	94.8'
6"	Steel	Mudline	197'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
1000
m/s
4000
P-Wave Slowness
300
us/m
600
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
100
110
120
130
140
150
160
170
180


190
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
1ft:120ft
Depth
1000
m/s
4000
Compressive Velocity
-1
1
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
300
us/m
600
P-Wave Slowness

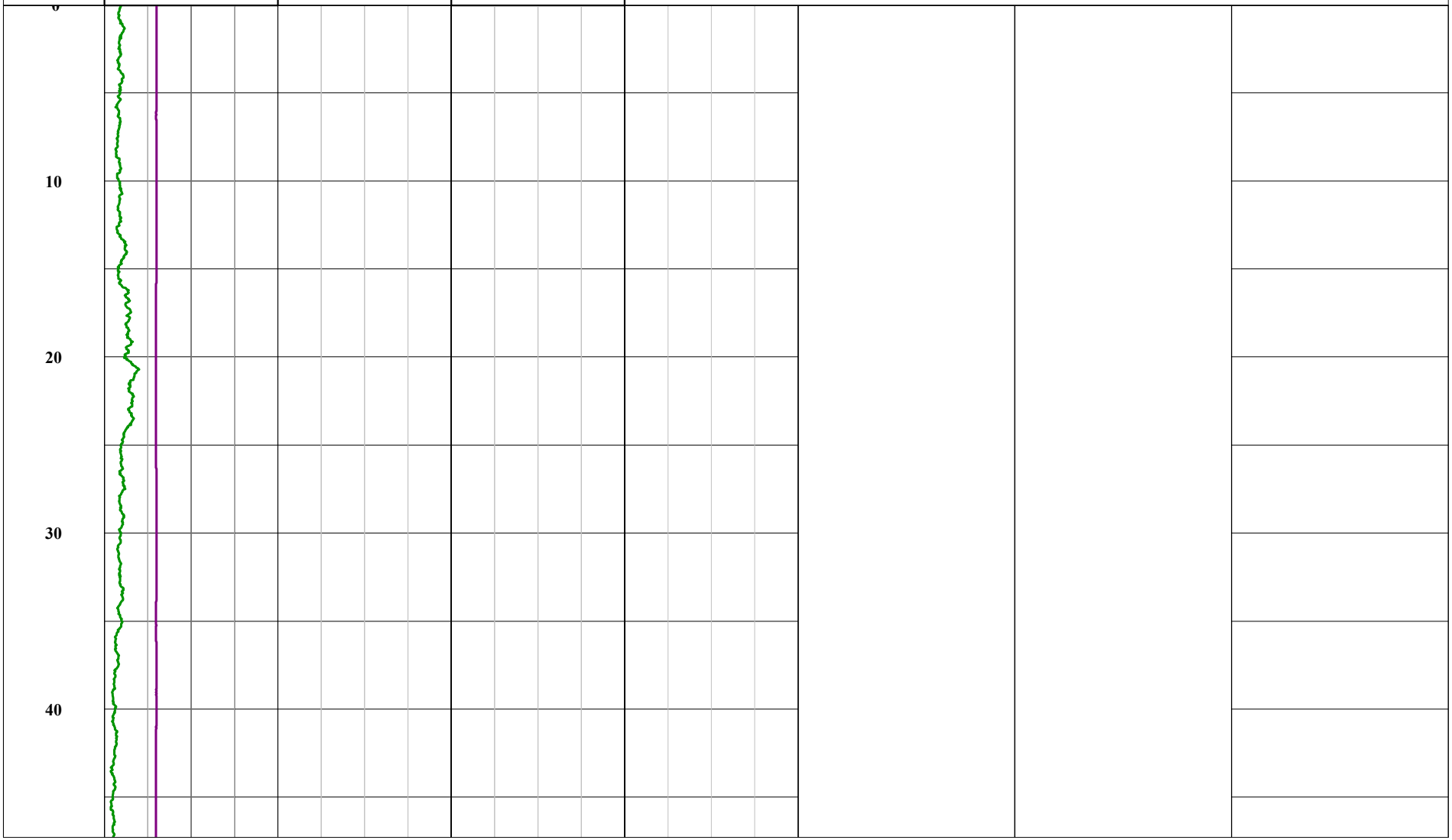
Geophysical Summary Plot

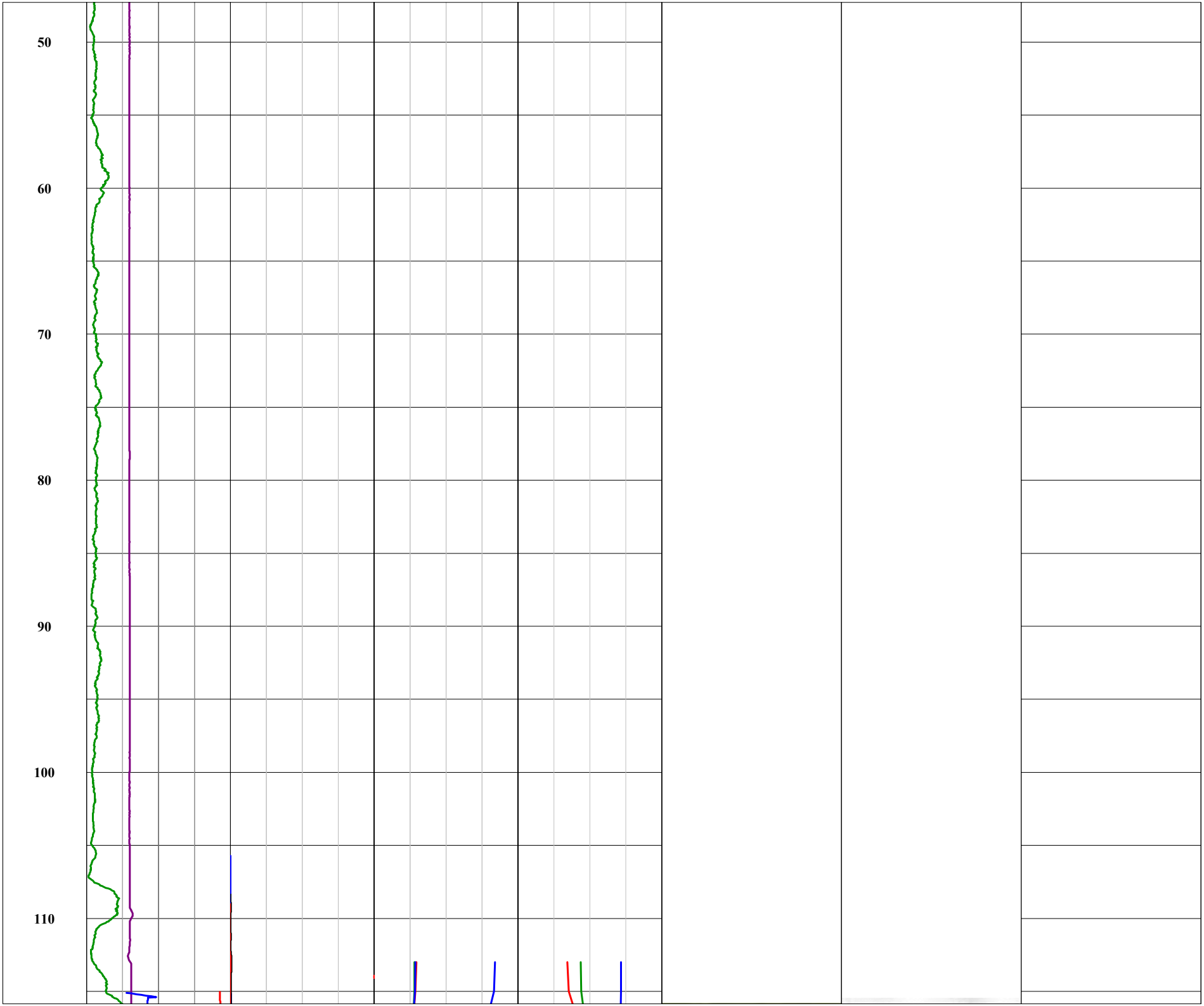
COLOG
borehole geophysics / hydrophysics

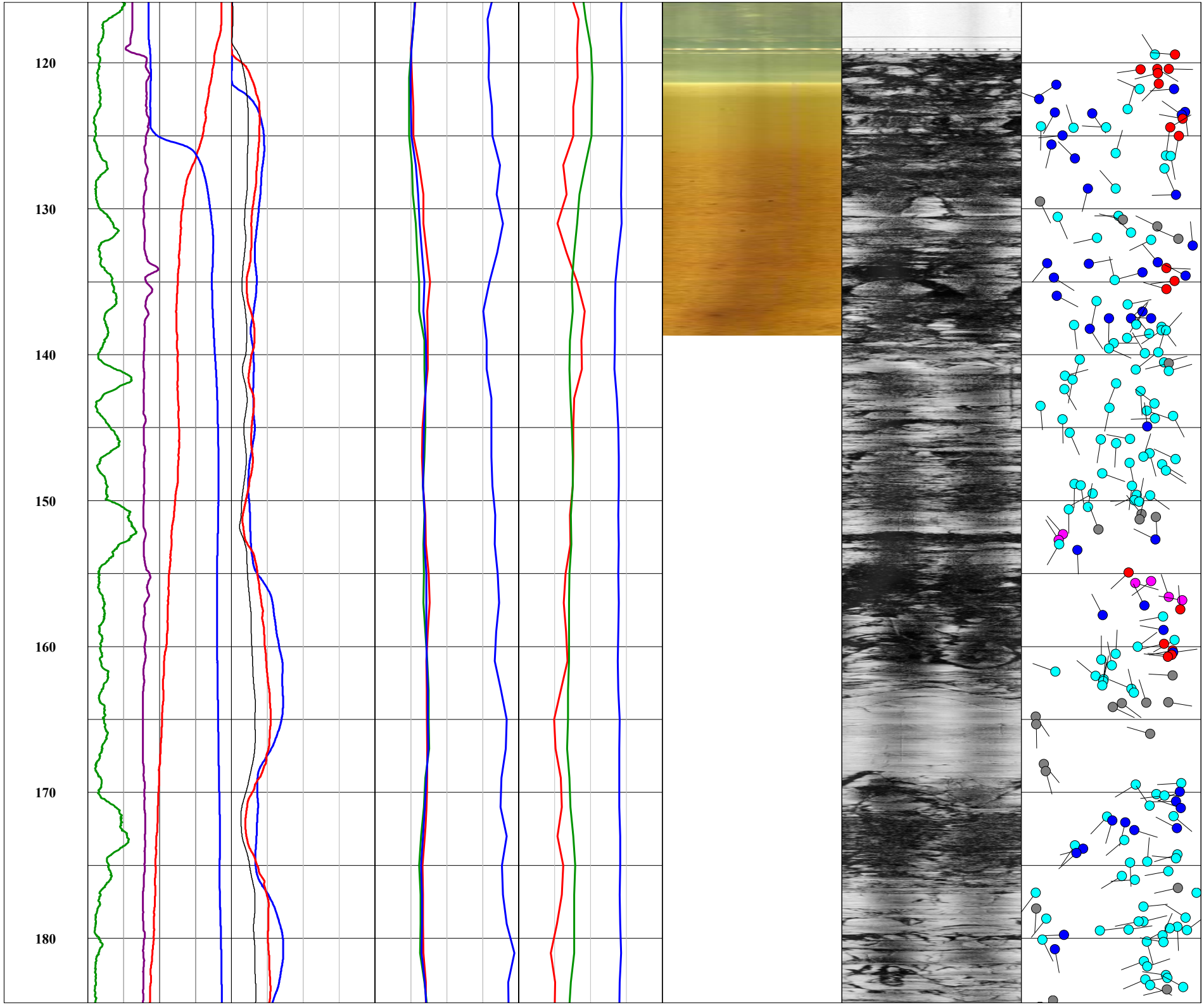
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 21 July 2019
WELL: BH19-33 - Mid Strait

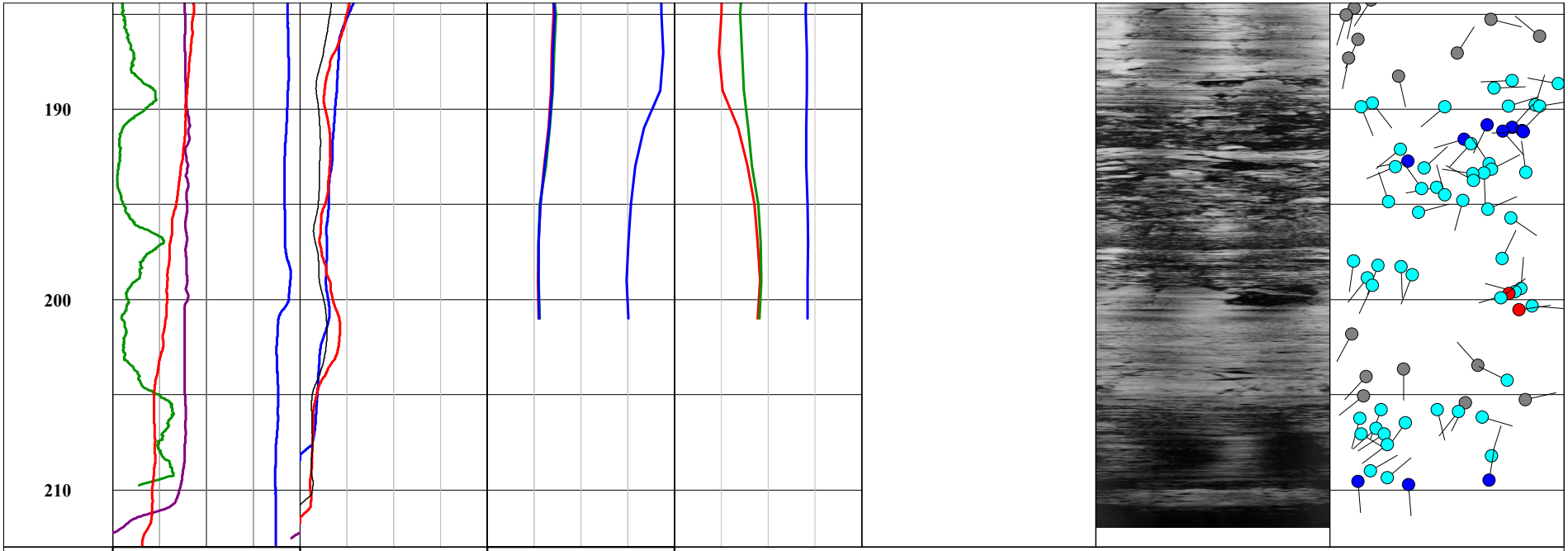
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	64" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude-MN	Tadpoles
1ft:100ft	0 CPS 200	0 Ohm-m 2000	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	16" Normal Resistivity	Shear Velocity - Right	S-Wave Slowness			
	2 Inch 12	0 Ohm-m 2000	0 m/s 4000	0 us/m 2000			
	Temperature	Single-Point Resistance	Shear Velocity - Avg	Poisson's Ratio			
	2 deg C 12	0 Ohm 1000	0 m/s 4000	-1 1			
	Fluid Conductivity		Compressive Velocity				
	0 uScm 1200		0 m/s 4000				




50
60
70
80
90
100
110


120
130
140
150
160
170
180



	0 uScm 1200 **Fluid Conductivity**		0 m/s 4000 **Compressive Velocity**				
	2 deg C 12 **Temperature**	0 Ohm 1000 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-1 1 **Poisson's Ratio**			
	2 Inch 12 **3-Arm Caliper**	0 Ohm-m 2000 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**			
1ft:100ft **Depth**	0 CPS 200 **Natural Gamma**	0 Ohm-m 2000 **64" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Left**	200 us/m 500 **P-Wave Slowness**	0° 90° 180° 270° 0° **Optical Image - MN**	0° 90° 180° 270° 0° **Amplitude-MN**	0 90 **Tadpoles**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-33
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-33
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80489 N
Longitude: 84.76979 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 486.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	21 July 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	217.6'			
DEPTH-LOGGER	217.5'			
BTM LOG INTERVAL	212'			
TOP LOG INTERVAL	116'			
RECORDED BY	JBG,KMG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	ABI #111018			
LOGGING SPEED	6' ft/min			
A.S.D.E. / Sample Interval	0.13' / 0.0024'			
Fluid Level / Fluid Type	NA/water			

BOREHOLE RECORD

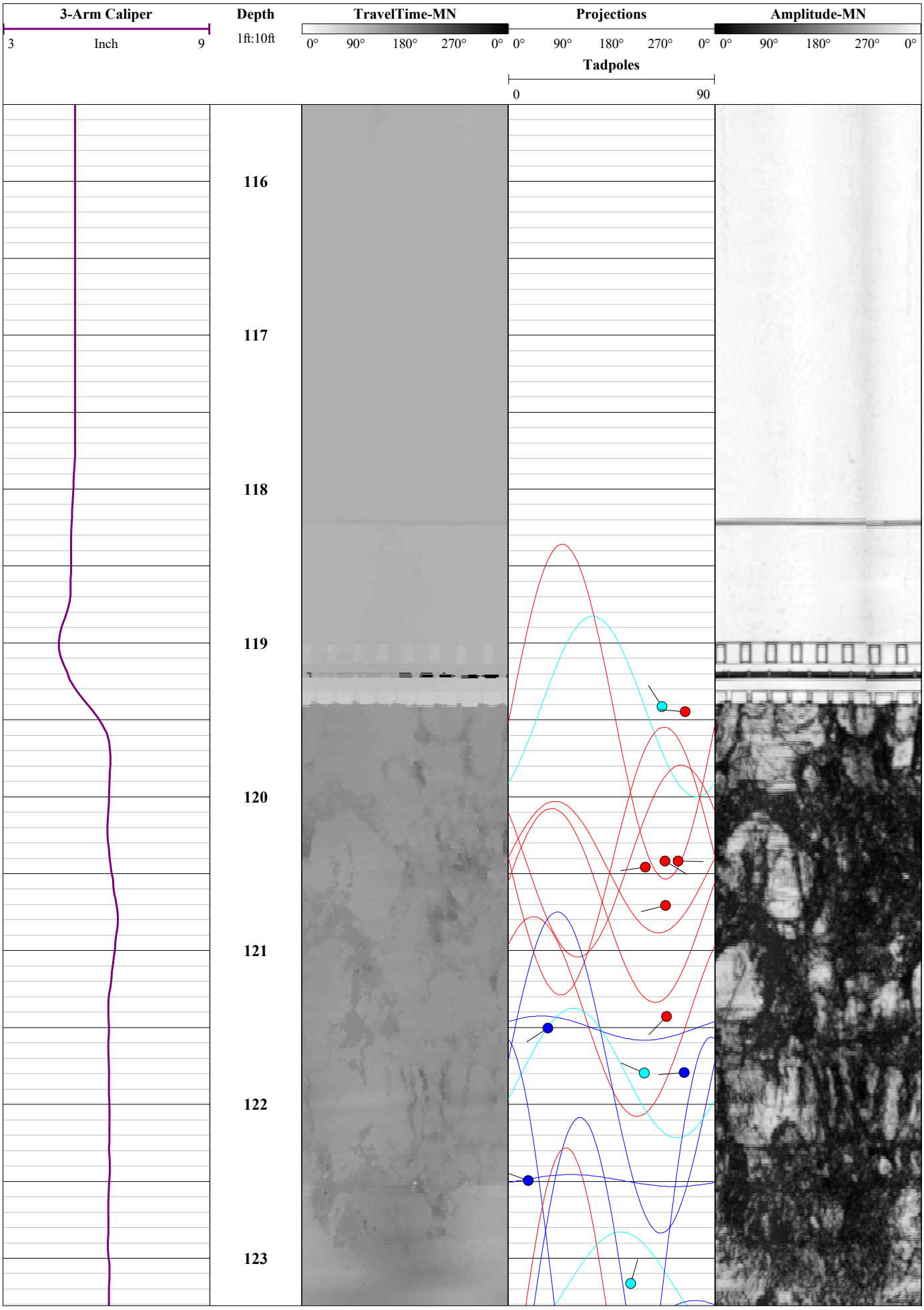
RUN No.	BIT	FROM	TO
1	7"	SU	Mudline 16.4'
2	6"	SU	217.6'

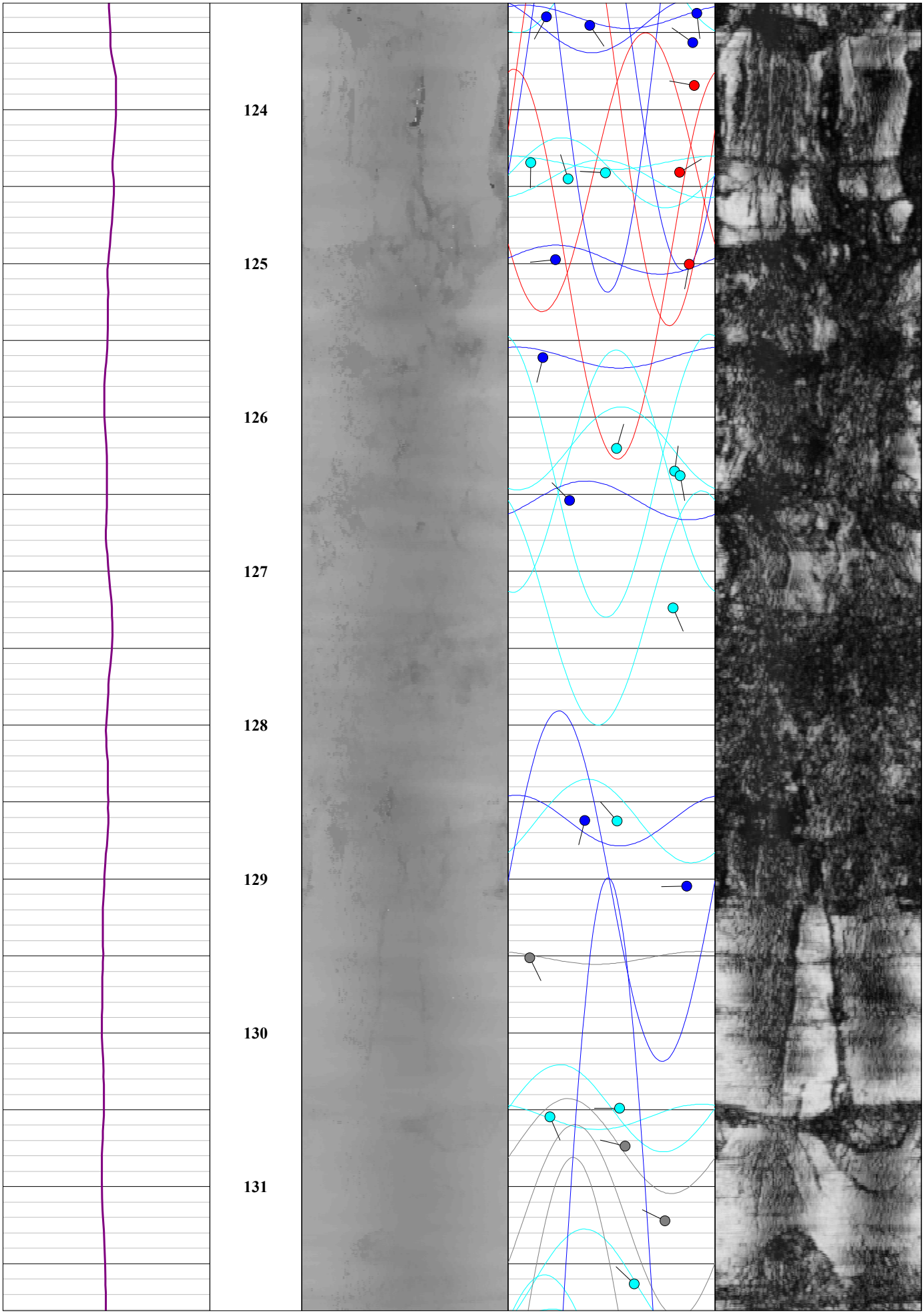
CASING RECORD

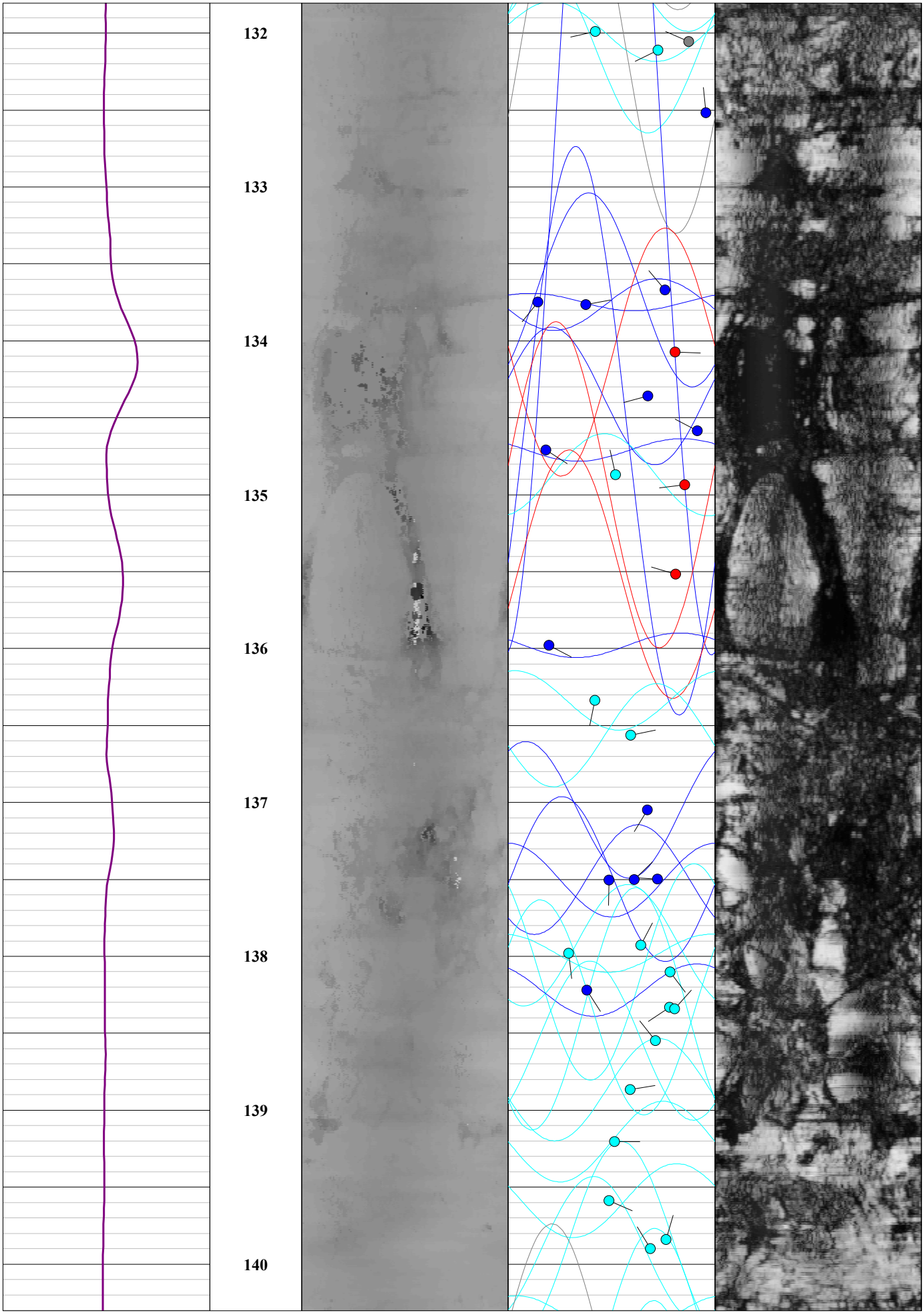
SIZE	WGT.	FROM	TO
7"	Steel	SU	118.1'
		SU	

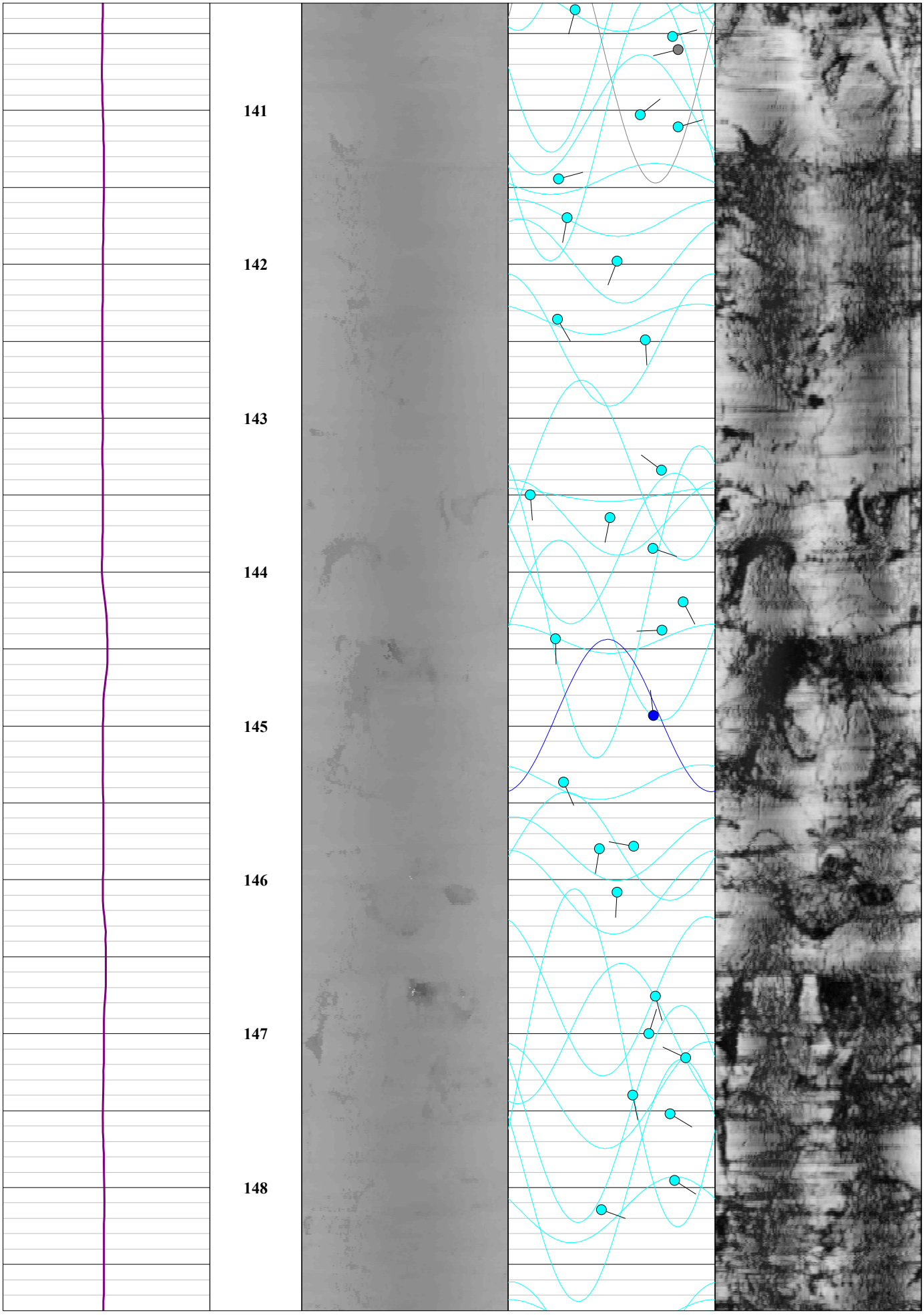
NA - Not Available, N/A - Not Applicable

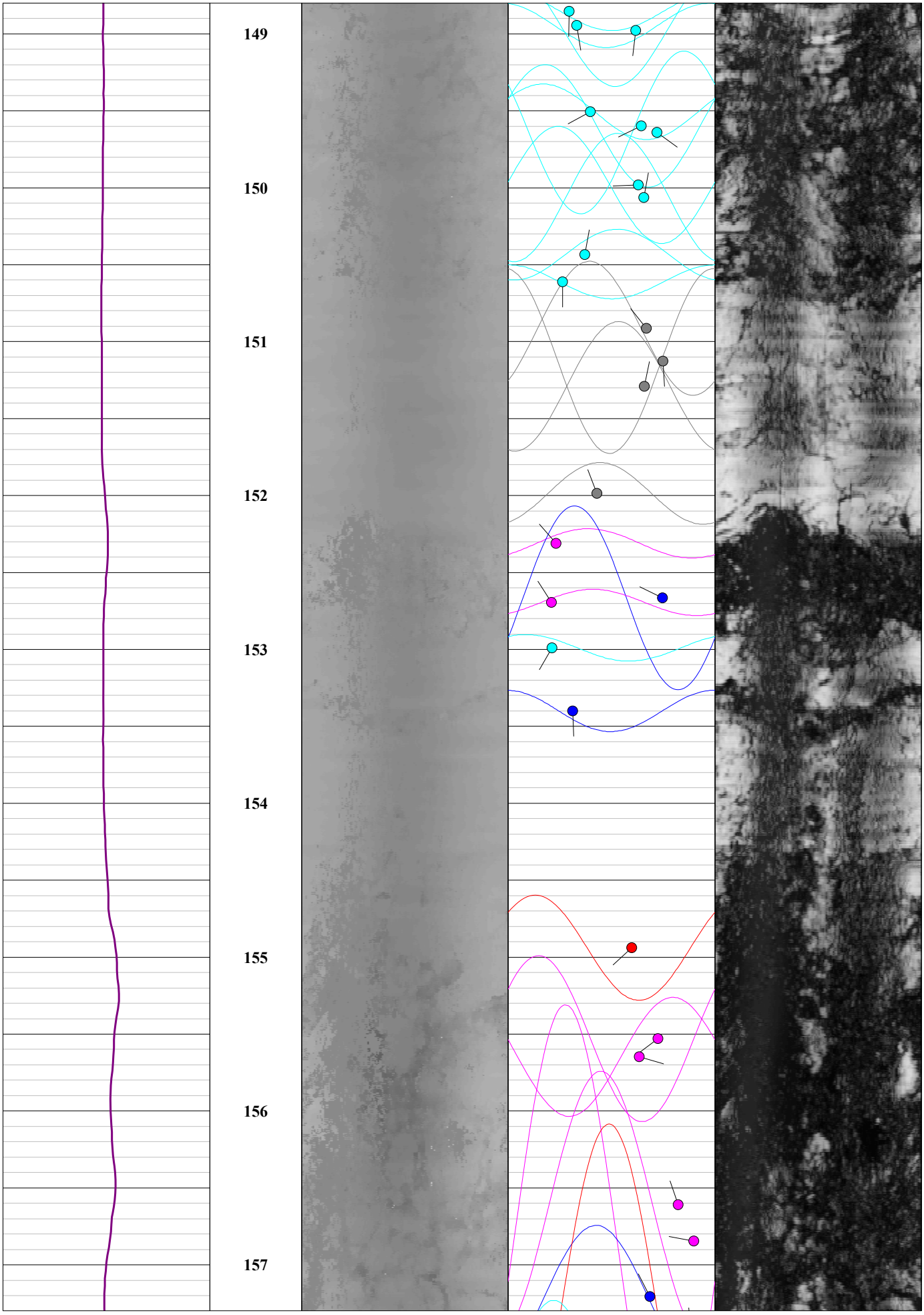
COMMENTS

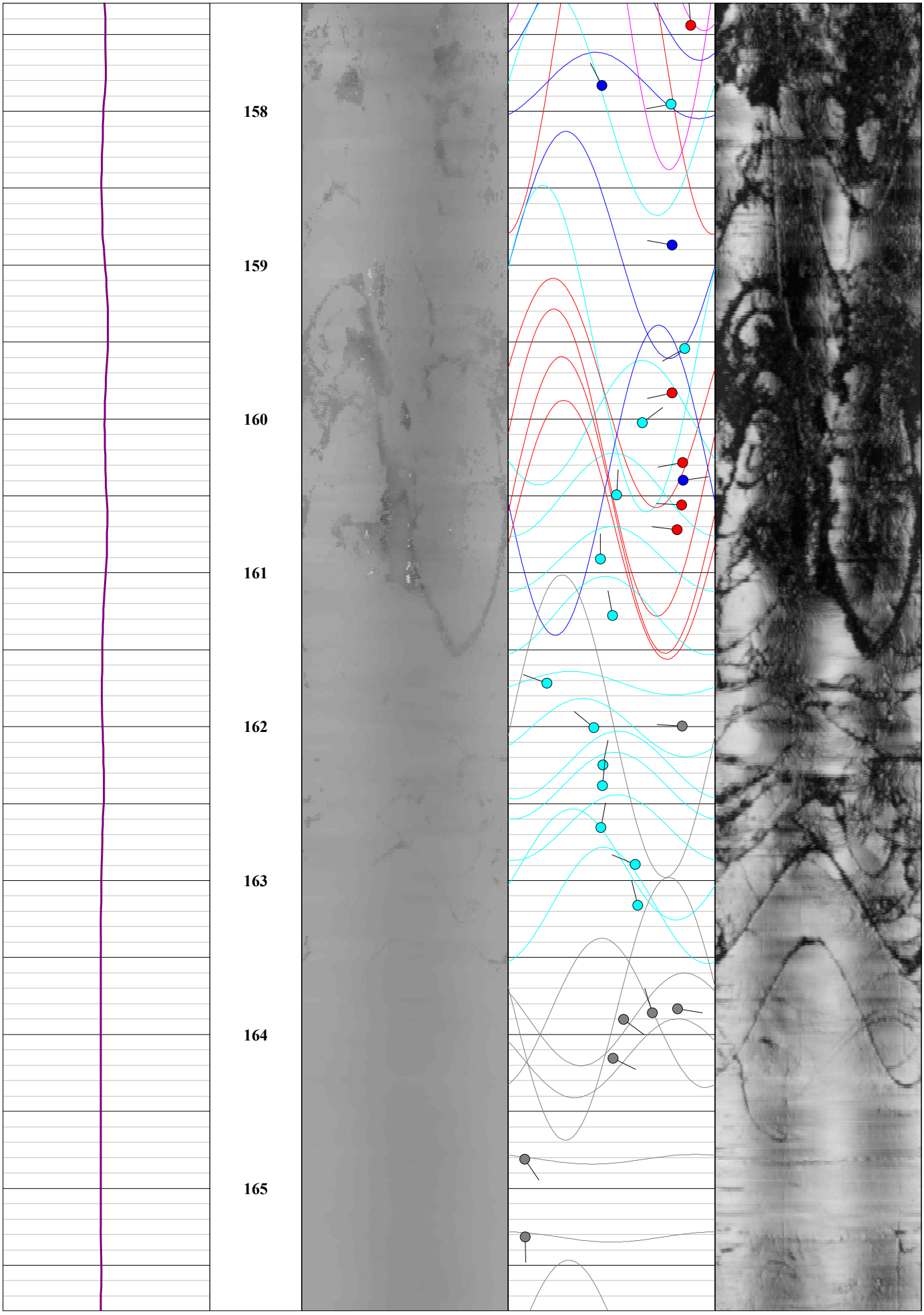

3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-MN
0° 90° 180° 270° 0°
Projections
0° 90° 180° 270° 0°
Tadpoles
0
90
Amplitude-MN
0° 90° 180° 270° 0°
116
117
118
119
120
121
122
123

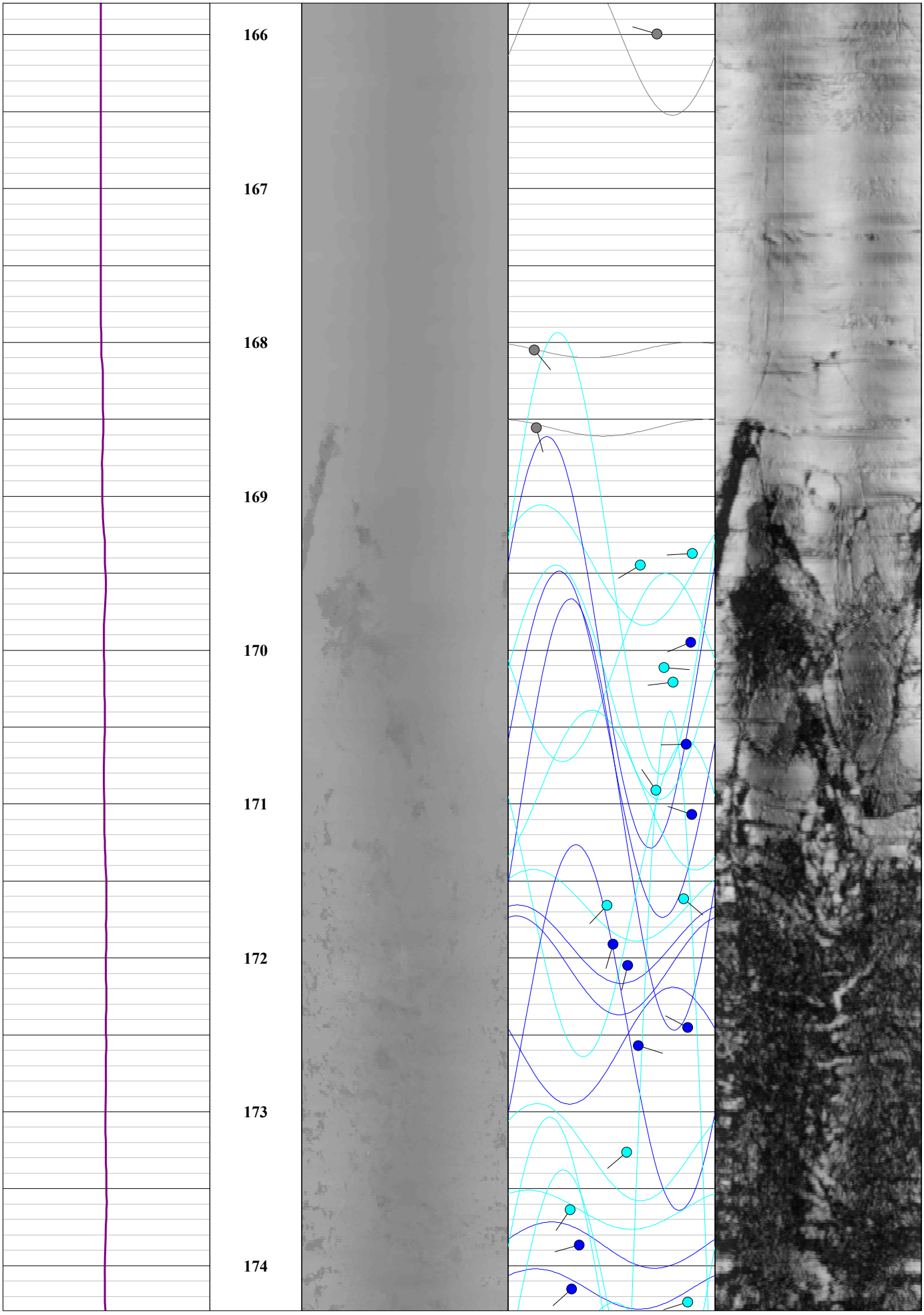

124
125
126
127
128
129
130
131

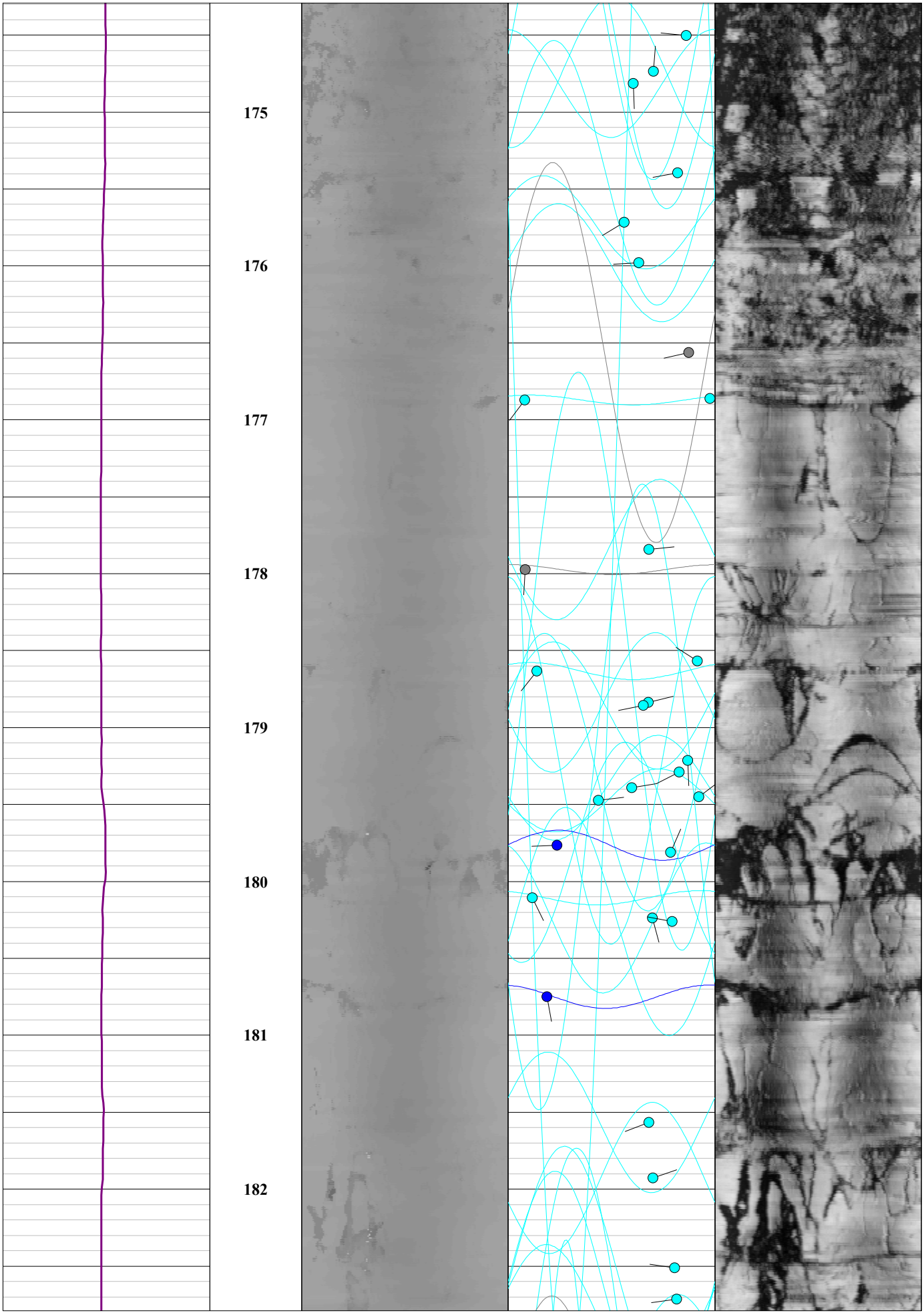

132
133
134
135
136
137
138
139
140

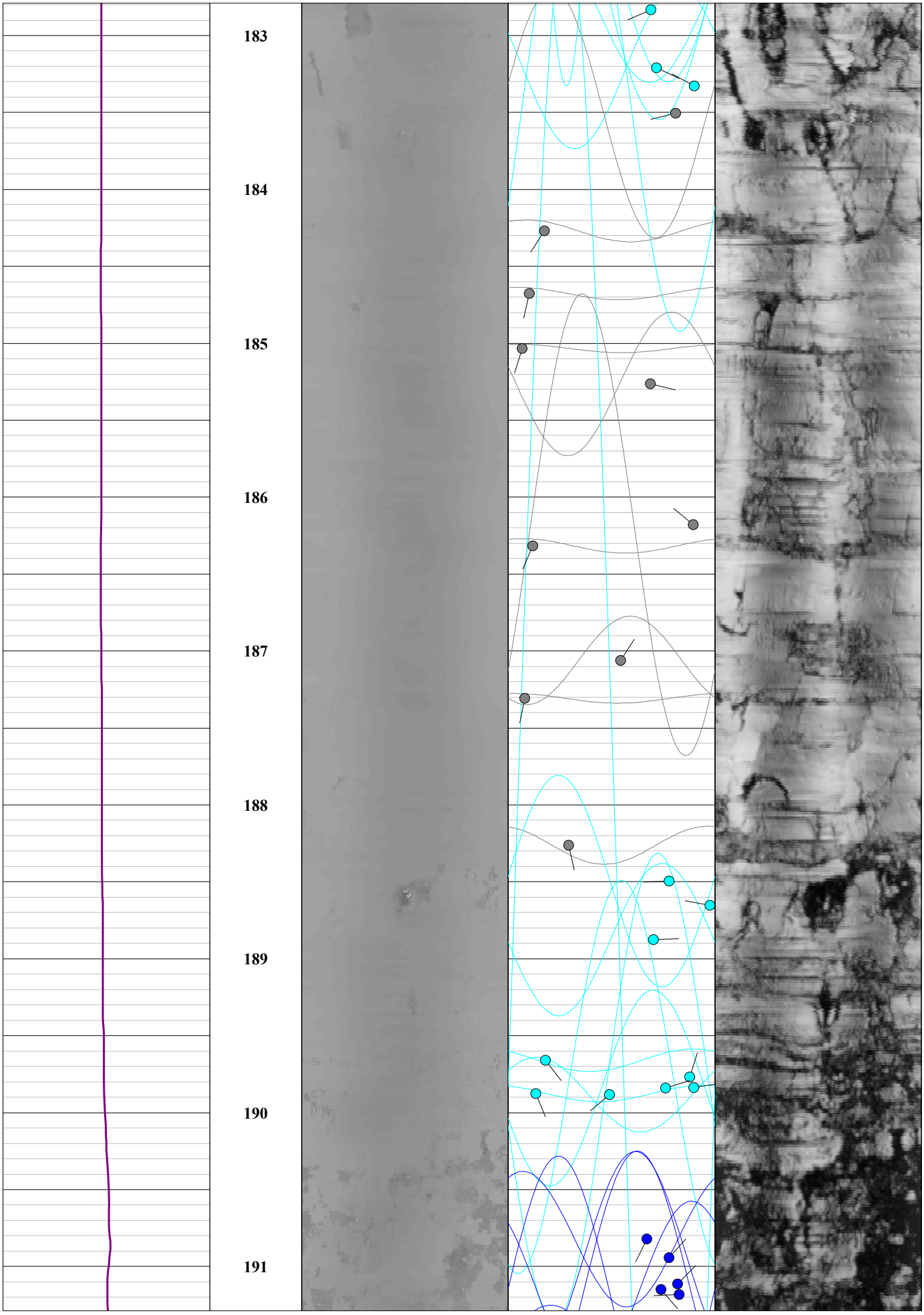

141
142
143
144
145
146
147
148

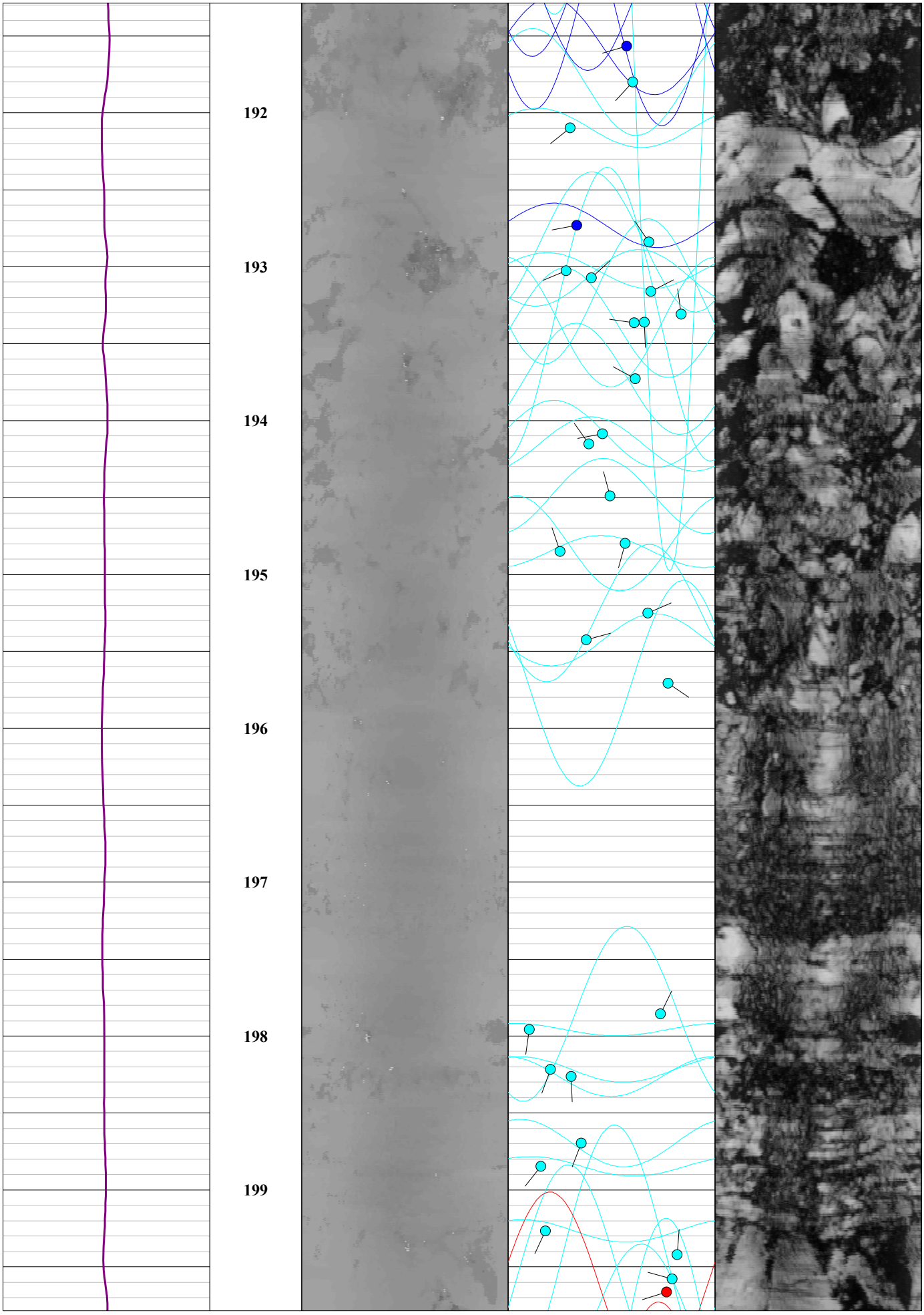

149
150
151
152
153
154
155
156
157

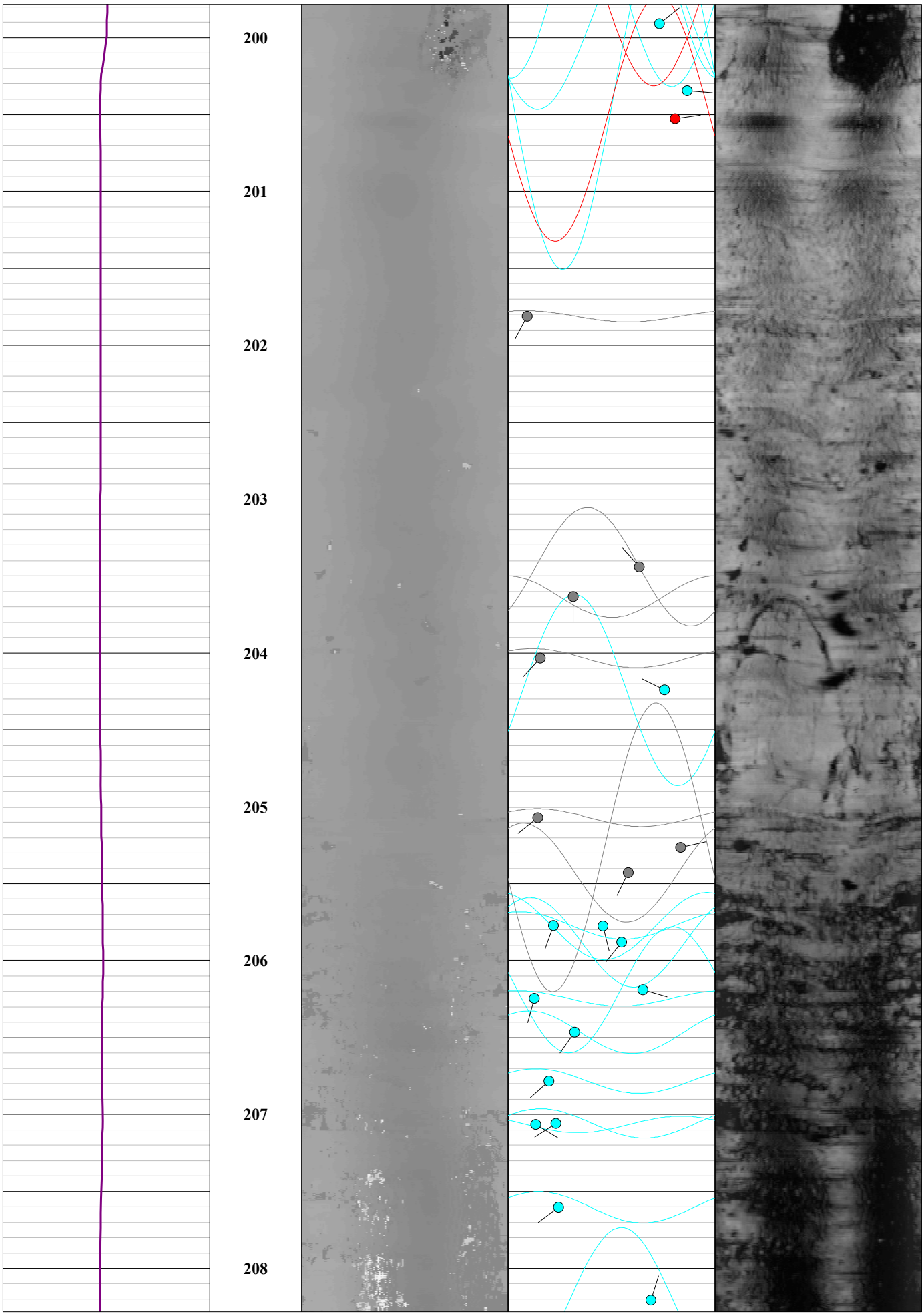

158
159
160
161
162
163
164
165

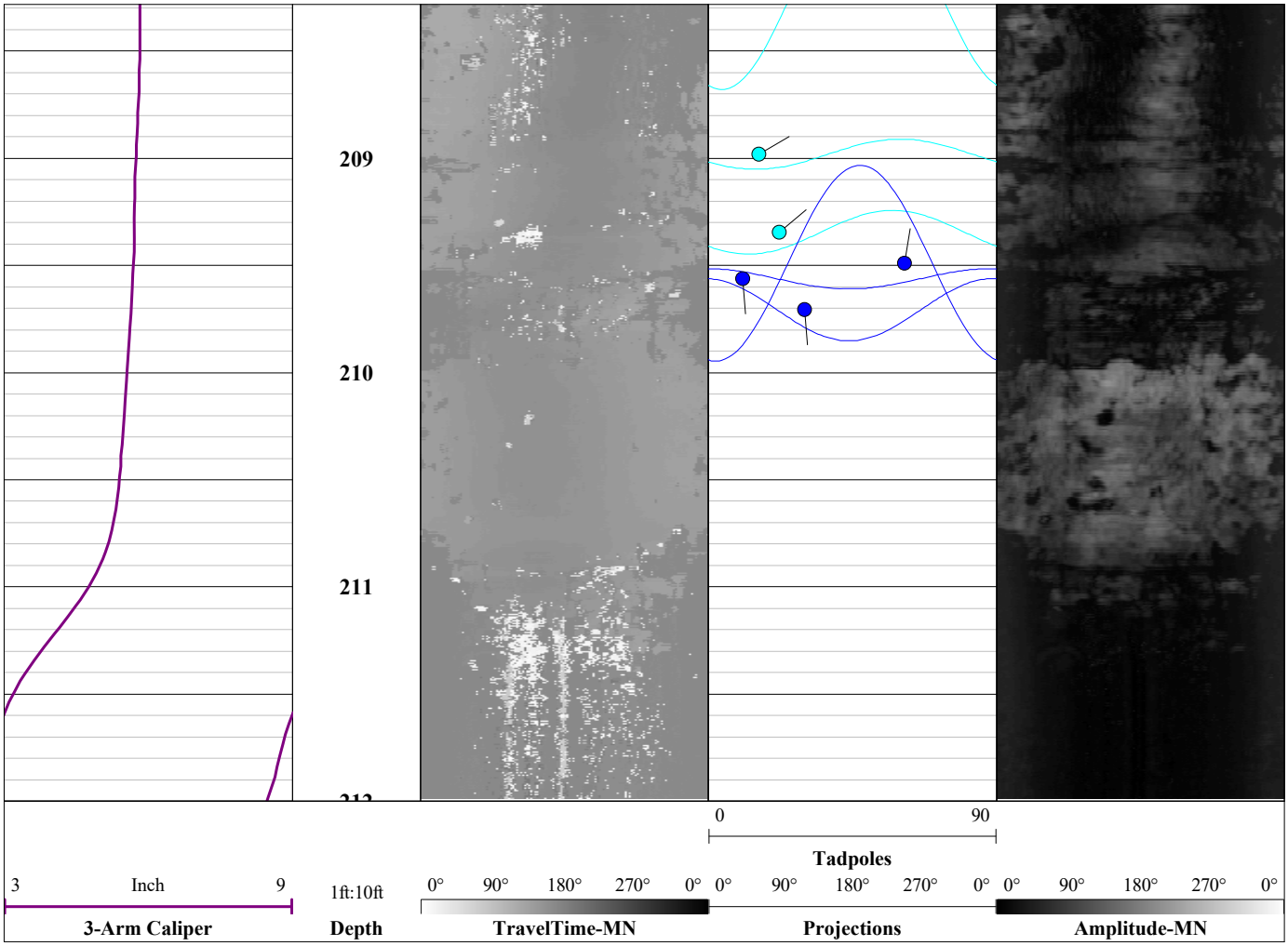

166
167
168
169
170
171
172
173
174


175
176
177
178
179
180
181
182


183
184
185
186
187
188
189
190
191


192
193
194
195
196
197
198
199


200
201
202
203
204
205
206
207
208


209
210
211
0
90
Tadpoles
3
Inch
9
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-33
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-33
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80489 N
Longitude: 84.76979 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 486.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	21 July 2019			
RUN NUMBER	4			
LOG TYPE	Optical Televiewer			
DEPTH-DRILLER	217.6'			
DEPTH-LOGGER	139'			
BTM LOG INTERVAL	138.7'			
TOP LOG INTERVAL	115.9'			
RECORDED BY	JBG,KMG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	OBI #121406			
LOGGING SPEED	4 ft/min			
A.S.D.E. / Sample Interval	0.006			
Fluid Level / Fluid Type	NA'/water			

BOREHOLE RECORD

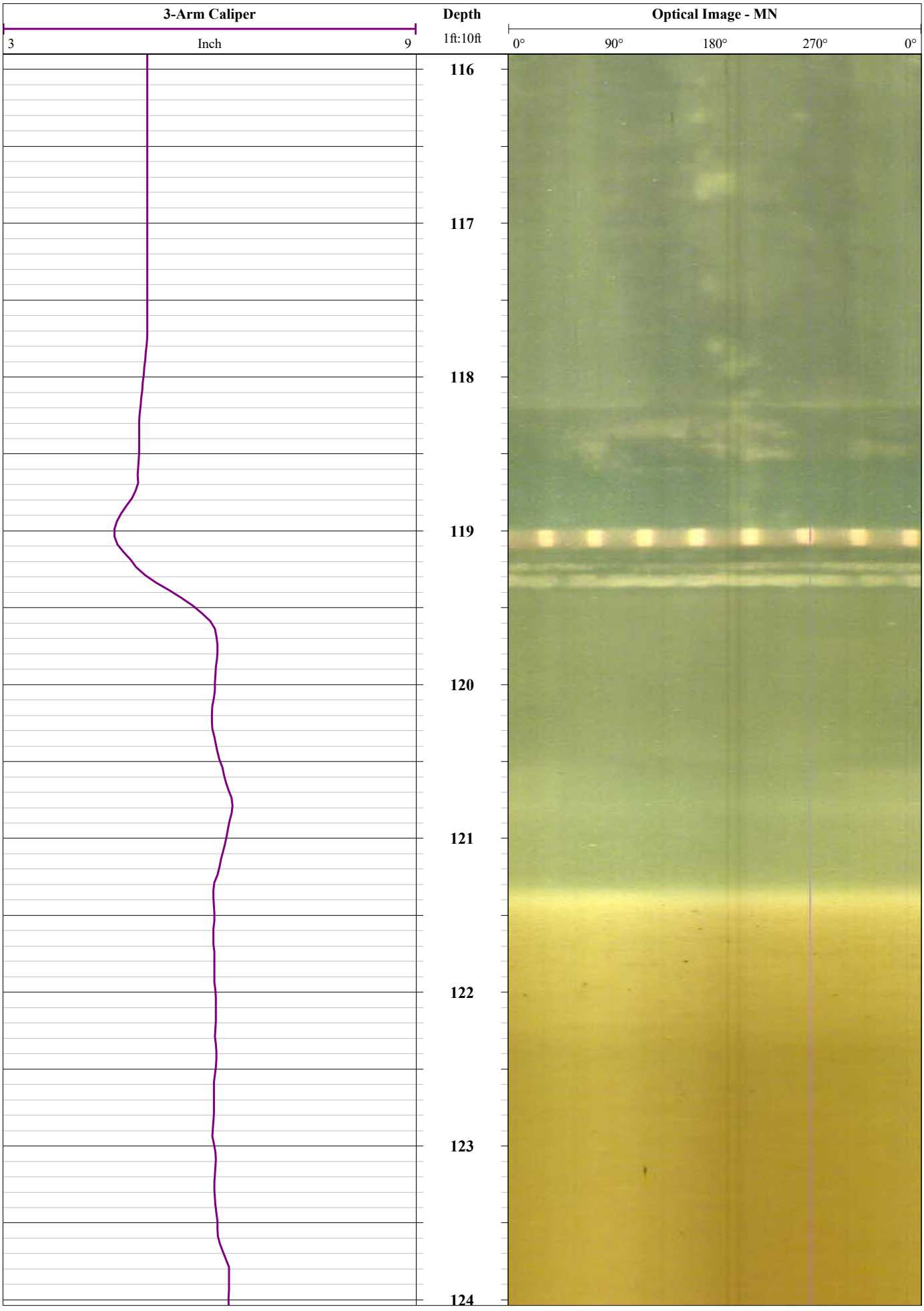
RUN No.	BIT	FROM	TO
1	7"	SU	Mudline 16.4'
2	6"	SU	217.6'

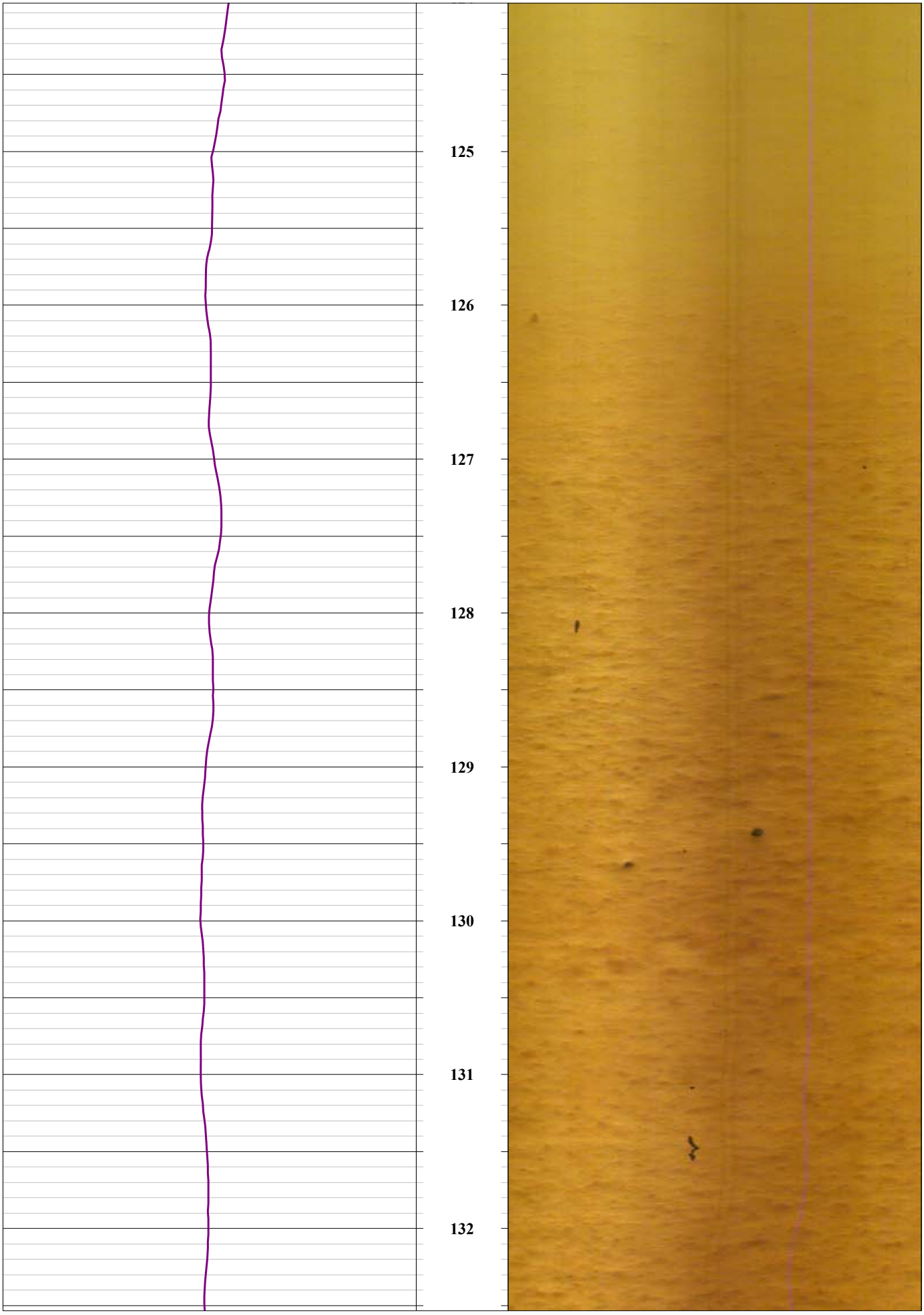
CASING RECORD

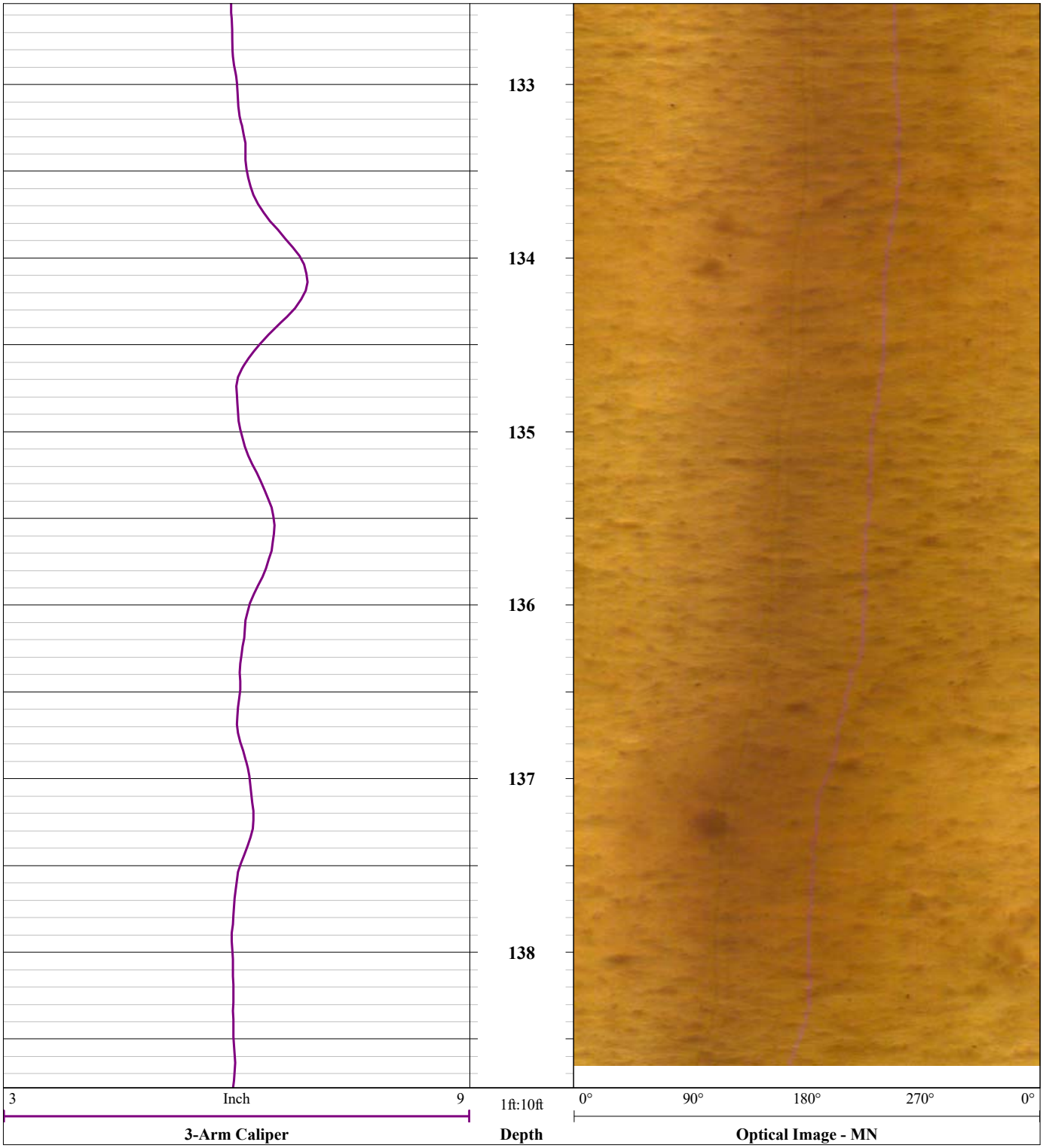
SIZE	WGT.	FROM	TO
7"	Steel	SU	118.1'

NA - Not Available, N/A - Not Applicable

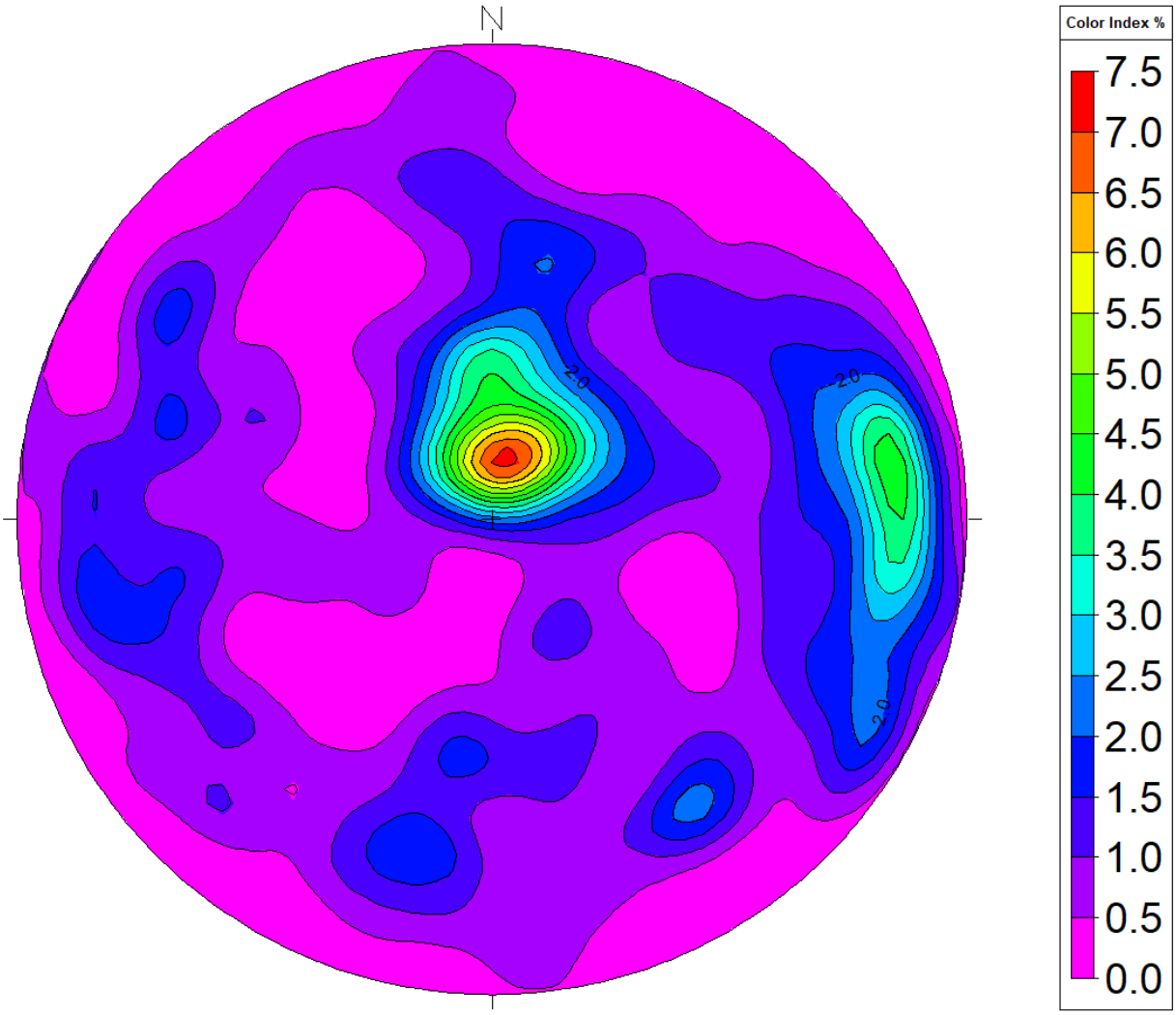
COMMENTS


3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
Optical Image - MN
0°
90°
180°
270°
0°
116
117
118
119
120
121
122
123
124


125
126
127
128
129
130
131
132

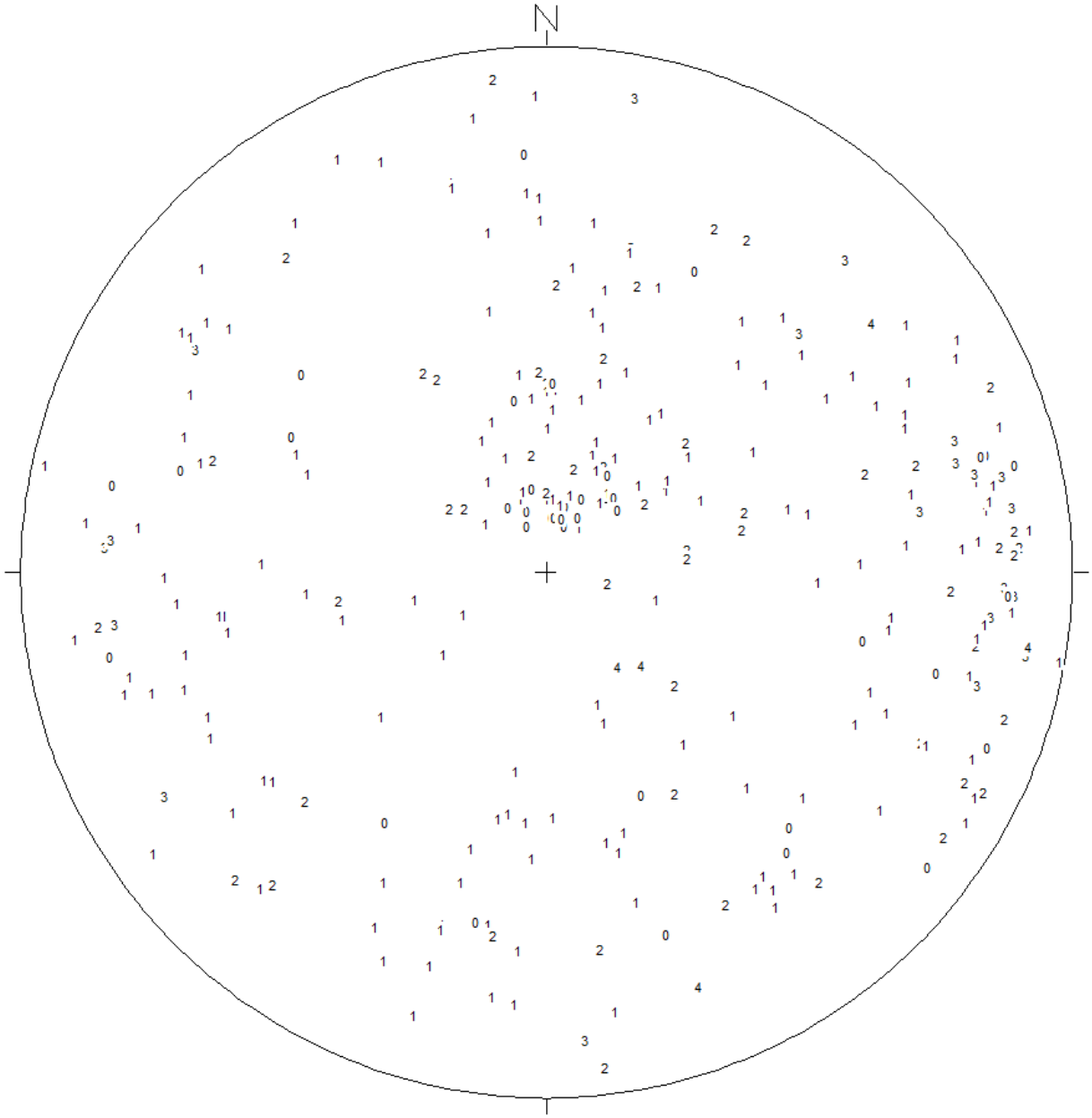

133
134
135
136
137
138
3
Inch
9
1ft:10ft
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-33
21 July 2019



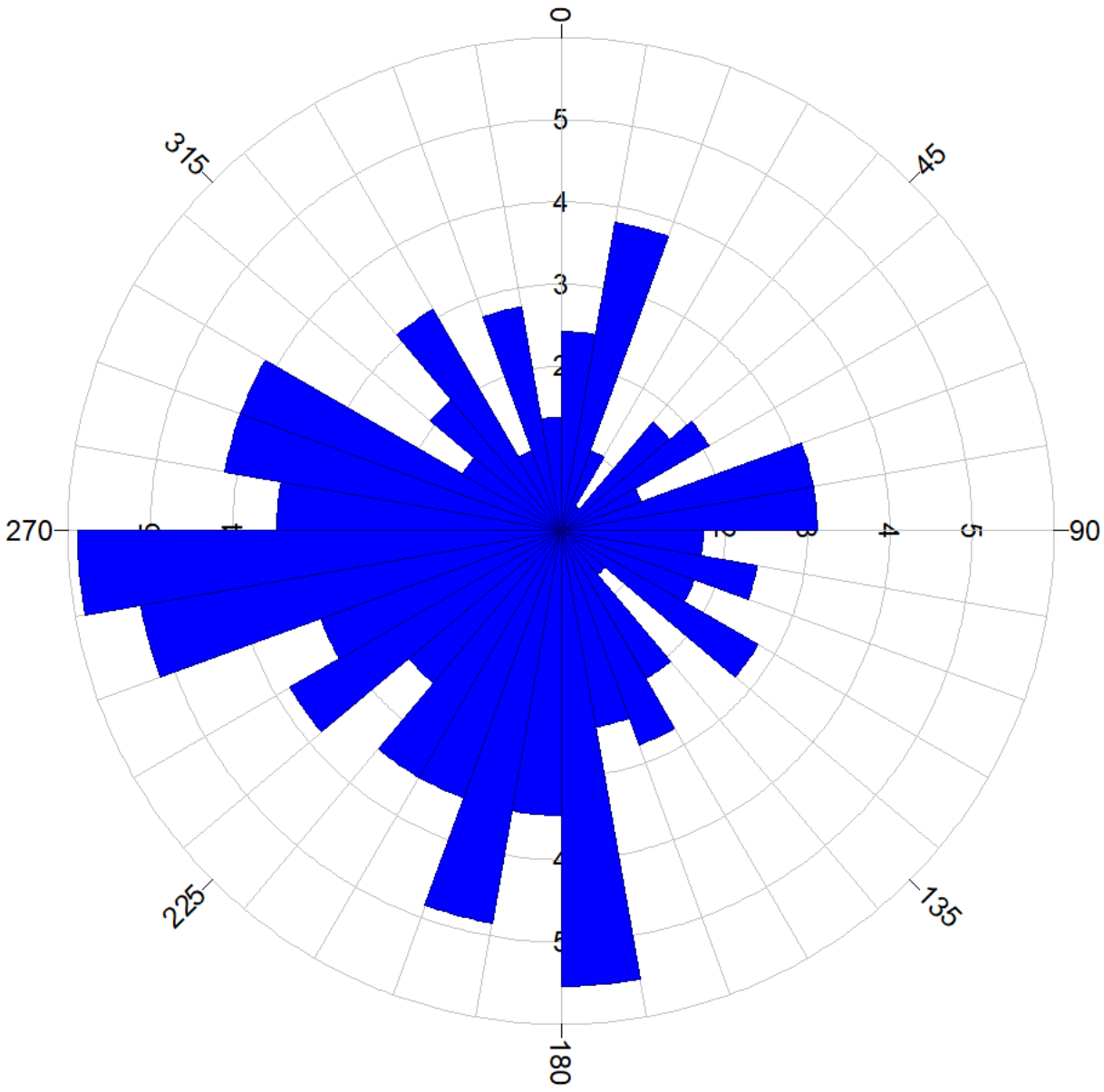
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-33
21 July 2019



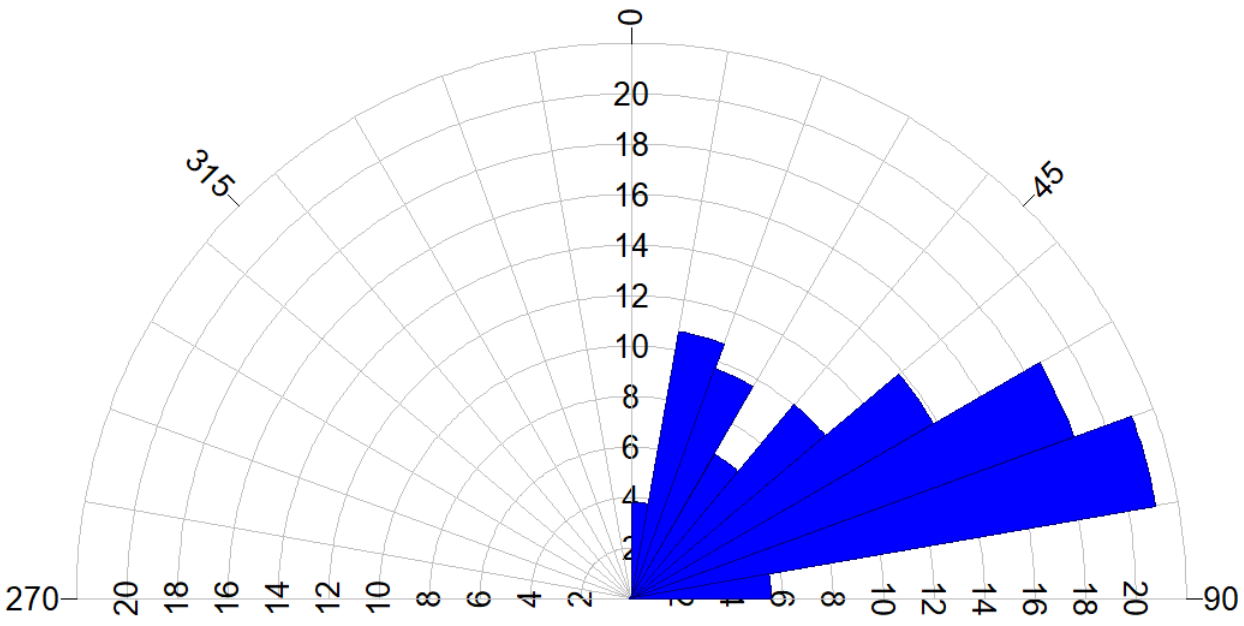
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-33
21 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-33
21 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	36.40	119.4	327	67	1
2	36.41	119.5	274	77	3
3	36.70	120.4	121	68	3
4	36.70	120.4	92	74	3
5	36.72	120.5	262	60	3
6	36.79	120.7	256	68	3
7	37.01	121.4	224	69	3
8	37.04	121.5	237	17	2
9	37.12	121.8	266	77	2
10	37.12	121.8	294	59	1
11	37.33	122.5	290	9	2
12	37.54	123.2	16	53	1
13	37.60	123.4	173	82	2
14	37.61	123.4	208	17	2
15	37.63	123.5	146	36	2
16	37.66	123.6	305	80	2
17	37.75	123.8	281	81	3
18	37.90	124.4	181	10	1
19	37.92	124.4	59	75	3
20	37.92	124.4	274	42	1
21	37.93	124.5	342	26	1
22	38.09	125.0	264	21	2
23	38.10	125.0	190	79	3
24	38.29	125.6	193	15	2
25	38.47	126.2	16	47	1
26	38.51	126.4	8	72	1
27	38.52	126.4	170	75	1
28	38.57	126.5	315	27	2
29	38.78	127.2	157	72	1
30	39.20	128.6	194	33	2
31	39.20	128.6	319	47	1
32	39.33	129.1	268	78	2
33	39.47	129.5	154	9	0
34	39.77	130.5	270	49	1
35	39.79	130.6	156	18	1
36	39.85	130.7	284	51	0
37	40.00	131.2	296	68	0
38	40.12	131.6	313	55	1
39	40.23	132.0	257	38	1
40	40.25	132.1	293	79	0
41	40.27	132.1	243	65	1
42	40.39	132.5	354	86	2
43	40.74	133.7	320	68	2
44	40.77	133.8	219	13	2
45	40.77	133.8	80	34	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	40.86	134.1	93	73	3
47	40.95	134.4	255	61	2
48	41.02	134.6	298	82	2
49	41.06	134.7	122	16	2
50	41.11	134.9	347	47	1
51	41.13	134.9	263	77	3
52	41.31	135.5	286	73	3
53	41.45	136.0	118	18	2
54	41.56	136.3	192	38	1
55	41.62	136.6	78	53	1
56	41.77	137.1	211	61	2
57	41.91	137.5	274	65	2
58	41.91	137.5	46	55	2
59	41.91	137.5	181	44	2
60	42.04	137.9	28	58	1
61	42.06	138.0	173	26	1
62	42.09	138.1	143	70	1
63	42.13	138.2	148	34	2
64	42.16	138.3	236	70	1
65	42.17	138.3	42	72	1
66	42.23	138.6	322	64	1
67	42.33	138.9	81	53	1
68	42.43	139.2	90	46	1
69	42.55	139.6	113	44	1
70	42.62	139.8	17	69	1
71	42.64	139.9	328	62	1
72	42.78	140.3	195	29	1
73	42.83	140.5	75	72	1
74	42.85	140.6	256	74	0
75	42.99	141.0	52	57	1
76	43.01	141.1	73	74	1
77	43.11	141.5	75	22	1
78	43.19	141.7	190	26	1
79	43.28	142.0	201	47	1
80	43.39	142.4	150	22	1
81	43.43	142.5	176	60	1
82	43.69	143.3	307	67	1
83	43.74	143.5	175	10	1
84	43.78	143.7	191	44	1
85	43.85	143.9	109	63	1
86	43.95	144.2	152	76	1
87	44.01	144.4	268	67	1
88	44.02	144.4	178	21	1
89	44.17	144.9	353	63	2
90	44.31	145.4	157	24	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	44.43	145.8	281	55	1
92	44.44	145.8	189	40	1
93	44.53	146.1	184	47	1
94	44.73	146.8	165	64	1
95	44.81	147.0	17	61	1
96	44.85	147.2	295	77	1
97	44.93	147.4	169	54	1
98	44.96	147.5	122	70	1
99	45.10	148.0	122	72	1
100	45.15	148.1	110	41	1
101	45.37	148.9	181	27	1
102	45.40	148.9	170	30	1
103	45.41	149.0	187	55	1
104	45.57	149.5	241	36	1
105	45.60	149.6	244	58	1
106	45.61	149.6	126	65	1
107	45.71	150.0	267	57	1
108	45.74	150.1	10	59	1
109	45.85	150.4	10	33	1
110	45.91	150.6	180	24	1
111	46.00	150.9	321	60	0
112	46.06	151.1	176	67	0
113	46.11	151.3	12	59	0
114	46.33	152.0	339	39	0
115	46.42	152.3	319	21	4
116	46.53	152.7	296	67	2
117	46.54	152.7	328	19	4
118	46.63	153.0	211	19	1
119	46.76	153.4	178	28	2
120	47.23	154.9	227	54	3
121	47.41	155.5	233	65	4
122	47.44	155.7	107	57	4
123	47.73	156.6	341	74	4
124	47.81	156.9	280	81	4
125	47.92	157.2	333	62	2
126	47.99	157.4	356	80	3
127	48.11	157.8	332	41	2
128	48.14	158.0	259	71	1
129	48.42	158.9	281	71	2
130	48.63	159.5	241	77	1
131	48.72	159.8	258	71	3
132	48.78	160.0	53	58	1
133	48.85	160.3	259	76	3
134	48.89	160.4	82	76	2
135	48.92	160.5	4	47	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	48.94	160.6	273	75	3
137	48.99	160.7	277	73	3
138	49.05	160.9	0	40	1
139	49.16	161.3	349	45	1
140	49.29	161.7	289	17	1
141	49.38	162.0	274	76	0
142	49.38	162.0	310	37	1
143	49.45	162.3	12	41	1
144	49.49	162.4	6	41	1
145	49.58	162.7	10	40	1
146	49.65	162.9	292	55	1
147	49.73	163.2	346	56	1
148	49.94	163.8	100	74	0
149	49.94	163.9	343	63	0
150	49.96	163.9	127	50	0
151	50.03	164.2	116	46	0
152	50.23	164.8	146	7	0
153	50.39	165.3	179	7	0
154	50.59	166.0	286	65	0
155	51.22	168.1	141	11	0
156	51.38	168.6	165	12	0
157	51.62	169.4	266	80	1
158	51.65	169.5	238	57	1
159	51.80	170.0	248	79	2
160	51.85	170.1	95	68	1
161	51.88	170.2	263	72	1
162	52.00	170.6	269	77	2
163	52.09	170.9	326	64	1
164	52.14	171.1	289	80	2
165	52.31	171.6	130	76	1
166	52.32	171.7	223	43	1
167	52.40	171.9	197	46	2
168	52.44	172.1	194	52	2
169	52.56	172.5	298	78	2
170	52.60	172.6	107	57	2
171	52.81	173.3	230	52	1
172	52.93	173.6	214	27	1
173	53.00	173.9	255	31	2
174	53.08	174.2	228	28	2
175	53.11	174.2	253	78	1
176	53.19	174.5	276	77	1
177	53.26	174.7	5	63	1
178	53.28	174.8	178	55	1
179	53.46	175.4	260	74	1
180	53.56	175.7	239	51	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	53.64	176.0	267	57	1
182	53.82	176.6	258	79	0
183	53.91	176.9	101	88	1
184	53.91	176.9	217	7	1
185	54.21	177.8	84	61	1
186	54.25	178.0	183	7	0
187	54.43	178.6	302	82	1
188	54.45	178.6	218	12	1
189	54.51	178.8	76	61	1
190	54.52	178.9	259	59	1
191	54.62	179.2	178	78	1
192	54.65	179.3	243	75	1
193	54.68	179.4	81	54	1
194	54.70	179.5	54	83	1
195	54.70	179.5	83	39	1
196	54.79	179.8	268	21	2
197	54.81	179.8	23	71	1
198	54.90	180.1	154	11	1
199	54.94	180.2	165	63	1
200	54.94	180.3	280	71	1
201	55.09	180.8	169	17	2
202	55.34	181.6	249	61	1
203	55.45	181.9	71	63	1
204	55.63	182.5	278	72	1
205	55.69	182.7	262	73	1
206	55.73	182.8	247	62	1
207	55.84	183.2	115	65	1
208	55.88	183.3	299	81	1
209	55.93	183.5	256	73	0
210	56.17	184.3	212	16	0
211	56.29	184.7	193	9	0
212	56.40	185.0	197	6	0
213	56.47	185.3	104	62	0
214	56.75	186.2	309	81	0
215	56.79	186.3	204	11	0
216	57.02	187.1	33	49	0
217	57.09	187.3	191	7	0
218	57.38	188.3	167	26	0
219	57.45	188.5	267	70	1
220	57.50	188.7	281	88	1
221	57.57	188.9	88	63	1
222	57.81	189.7	142	16	1
223	57.84	189.8	17	79	1
224	57.86	189.8	81	81	1
225	57.86	189.8	72	69	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	57.88	189.9	158	12	1
227	57.88	189.9	230	44	1
228	58.16	190.8	206	60	2
229	58.20	190.9	41	70	2
230	58.25	191.1	45	74	2
231	58.26	191.2	139	66	2
232	58.27	191.2	268	74	2
233	58.39	191.6	254	52	2
234	58.46	191.8	223	54	1
235	58.55	192.1	232	27	1
236	58.74	192.7	260	30	2
237	58.78	192.8	326	61	1
238	58.84	193.0	247	25	1
239	58.85	193.1	48	36	1
240	58.88	193.2	63	62	1
241	58.92	193.3	352	75	1
242	58.94	193.4	178	59	1
243	58.94	193.4	279	55	1
244	59.05	193.7	298	55	1
245	59.16	194.1	259	41	1
246	59.18	194.2	324	35	1
247	59.28	194.5	345	44	1
248	59.38	194.8	194	51	1
249	59.39	194.9	342	23	1
250	59.51	195.3	66	61	1
251	59.56	195.4	75	34	1
252	59.65	195.7	125	69	1
253	60.31	197.9	26	66	1
254	60.34	198.0	188	9	1
255	60.42	198.2	200	18	1
256	60.43	198.3	178	27	1
257	60.56	198.7	201	32	1
258	60.61	198.9	218	14	1
259	60.74	199.3	205	16	1
260	60.78	199.4	5	73	1
261	60.83	199.6	285	71	1
262	60.86	199.7	253	69	3
263	60.93	199.9	52	66	1
264	61.06	200.3	95	78	1
265	61.12	200.5	82	73	3
266	61.51	201.8	209	8	0
267	62.01	203.4	318	57	0
268	62.07	203.6	180	28	0
269	62.19	204.0	223	14	0
270	62.25	204.2	296	68	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-33

21 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	62.51	205.1	231	13	0
272	62.56	205.3	78	75	0
273	62.62	205.4	206	52	0
274	62.72	205.8	200	20	1
275	62.72	205.8	166	41	1
276	62.75	205.9	218	49	1
277	62.85	206.2	106	59	1
278	62.87	206.3	195	11	1
279	62.93	206.5	216	29	1
280	63.03	206.8	228	18	1
281	63.11	207.1	237	21	1
282	63.11	207.1	121	12	1
283	63.28	207.6	234	22	1
284	63.46	208.2	17	62	1
285	63.70	209.0	60	16	1
286	63.81	209.4	50	22	1
287	63.85	209.5	9	61	2
288	63.87	209.6	175	11	2
289	63.92	209.7	176	30	2

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-33
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-33
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80489 N
Longitude: 84.76979 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 486.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	21 July 2019	21 July 2019	21 July 2019	
RUN NUMBER	6	1	2	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	217.6'	217.6'	217.6'	
DEPTH-LOGGER	213'	213'	212'	
BTM LOG INTERVAL	212.9'	212.5'	211.5'	
TOP LOG INTERVAL	115.1'	0.0'	0.0'	
RECORDED BY	JBG,KMG	JBG,KMG	JBG,KMG	
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP	
PROBE TYPE, S/N	TCDS #3463	3ACS #3596	ELXG #4314	
LOGGING SPEED	15 ft/min	10 ft/min	20 ft/min	
A.S.D.E. / Sample Interval	.0.06' / 0.10'	0.11' / 0.10'	0.28' / 0.25'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

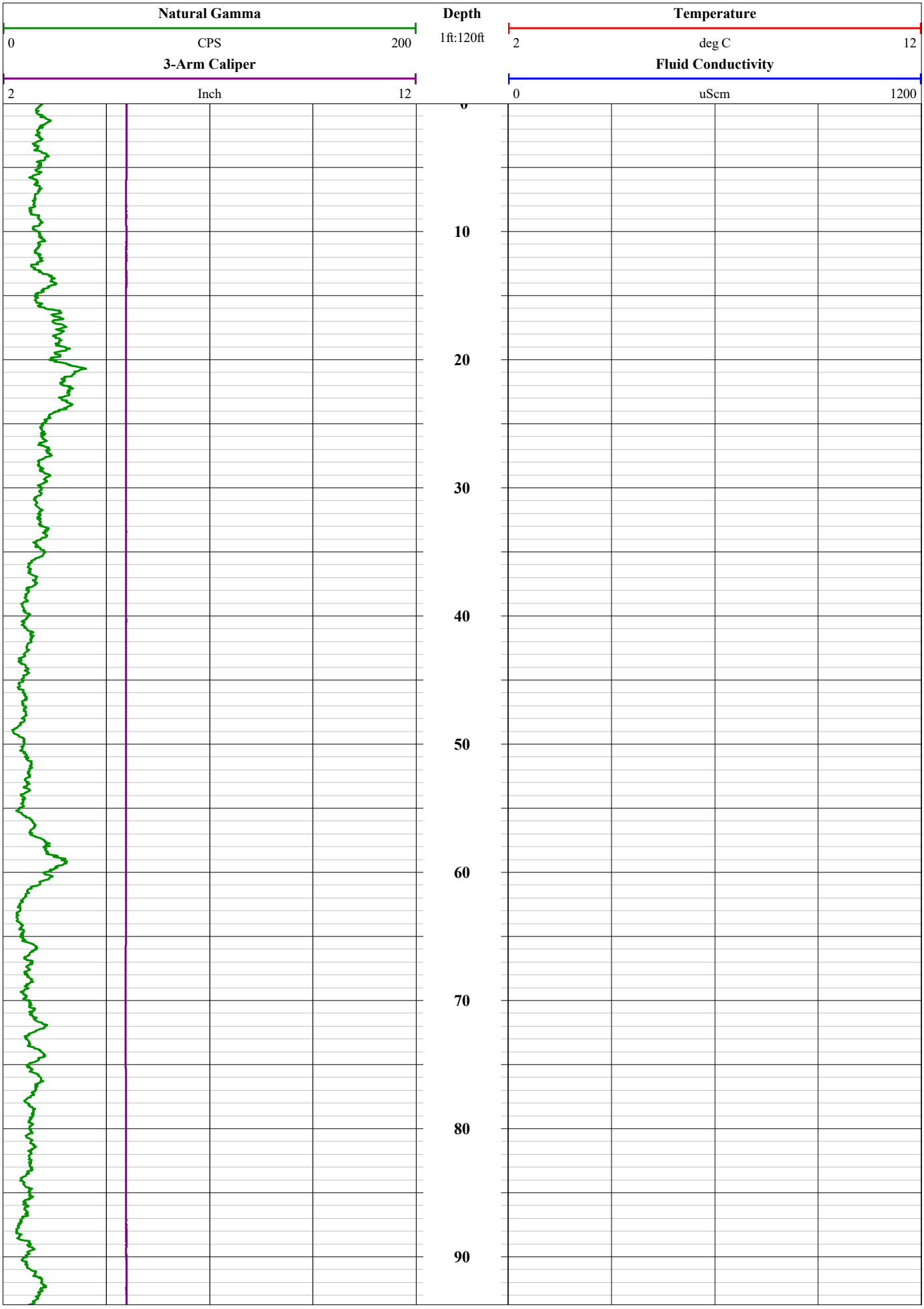
RUN No.	BIT	FROM	TO
1	7"	SU	Mudline 16.4'
2	6"	SU	217.6'

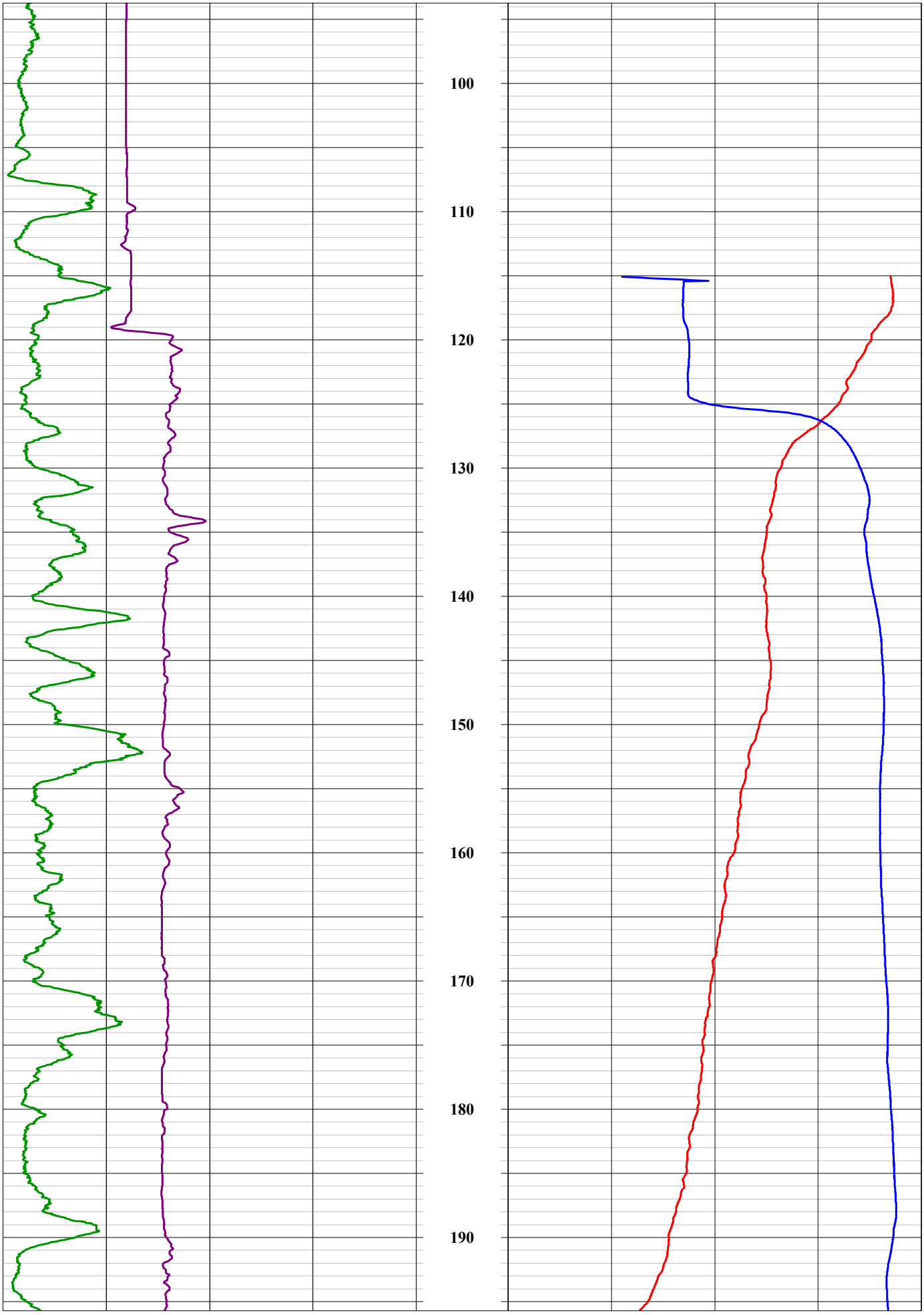
CASING RECORD

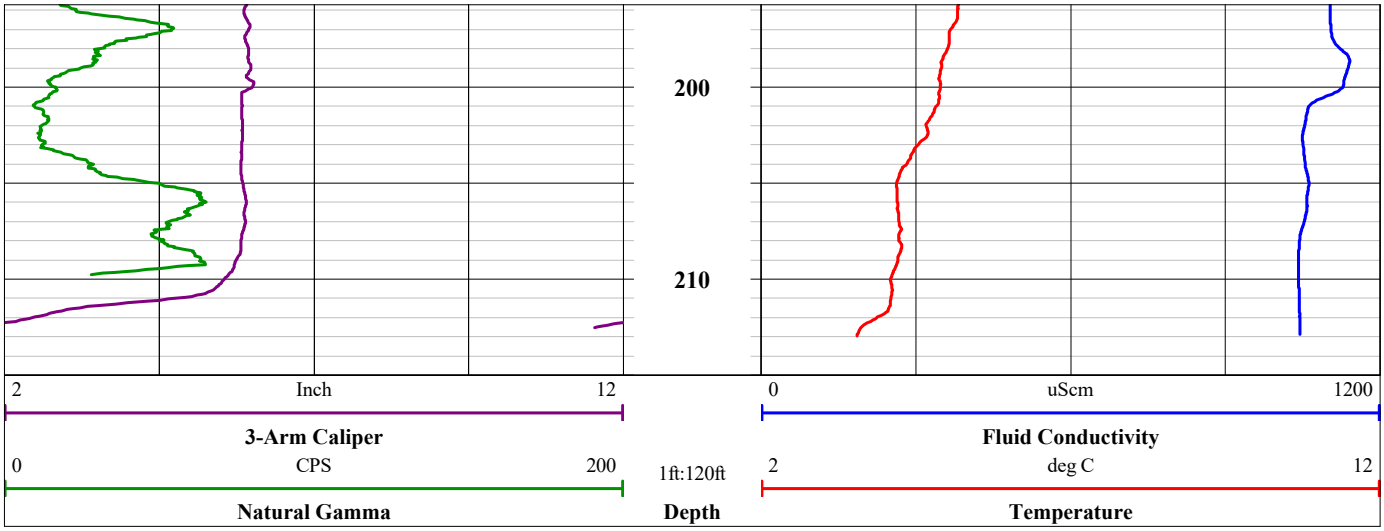
SIZE	WGT.	FROM	TO
7"	Steel	SU	118.1'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
200
3-Arm Caliper
2
Inch
12
Depth
1ft:120ft
Temperature
2
deg C
12
Fluid Conductivity
0
uScm
1200
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
2
Inch
12
3-Arm Caliper
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
uScm
1200
Fluid Conductivity
2
deg C
12
Temperature

Borehole Deviation

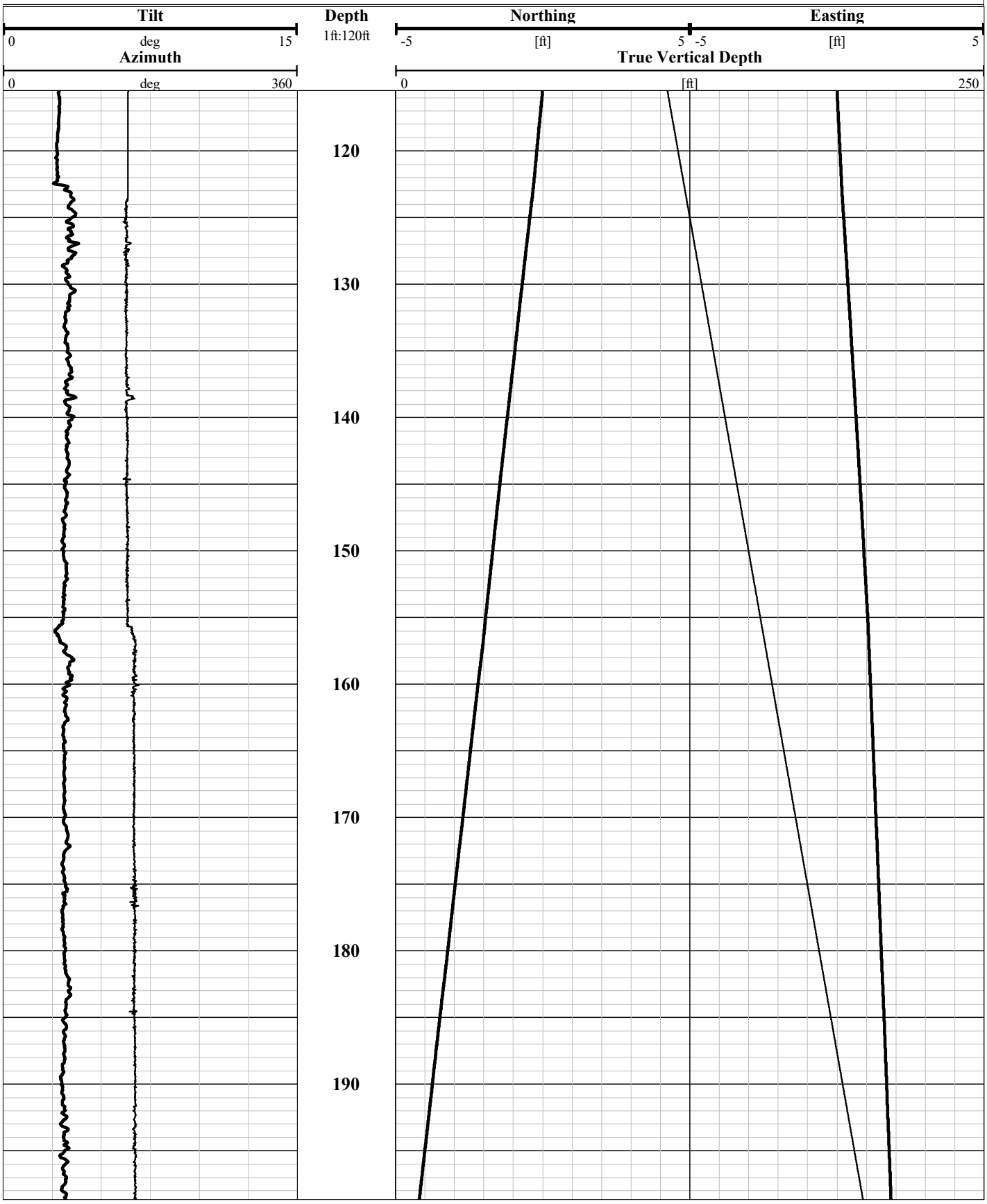
COLOG
borehole geophysics / hydrophysics

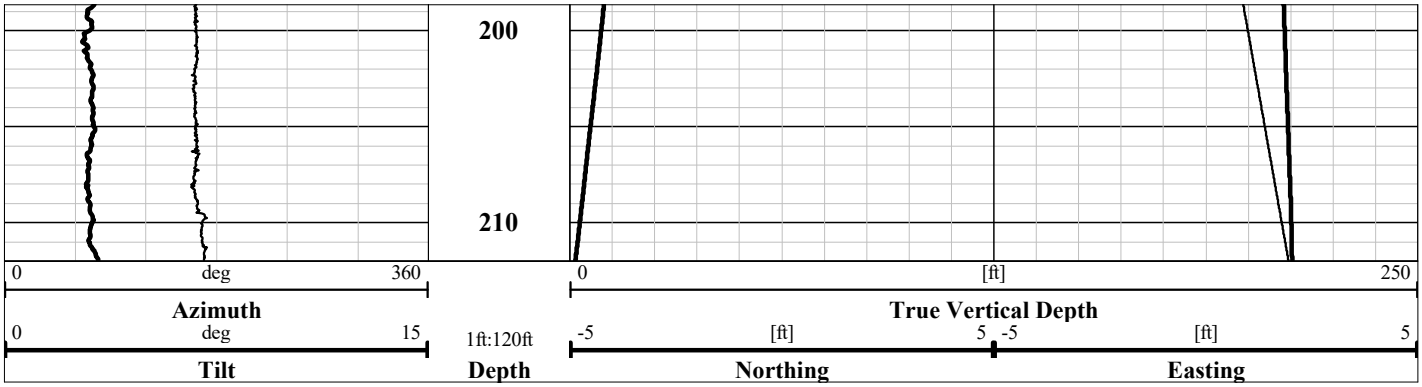
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 21 July 2019	WELL: BH19-33 - Mid Strait

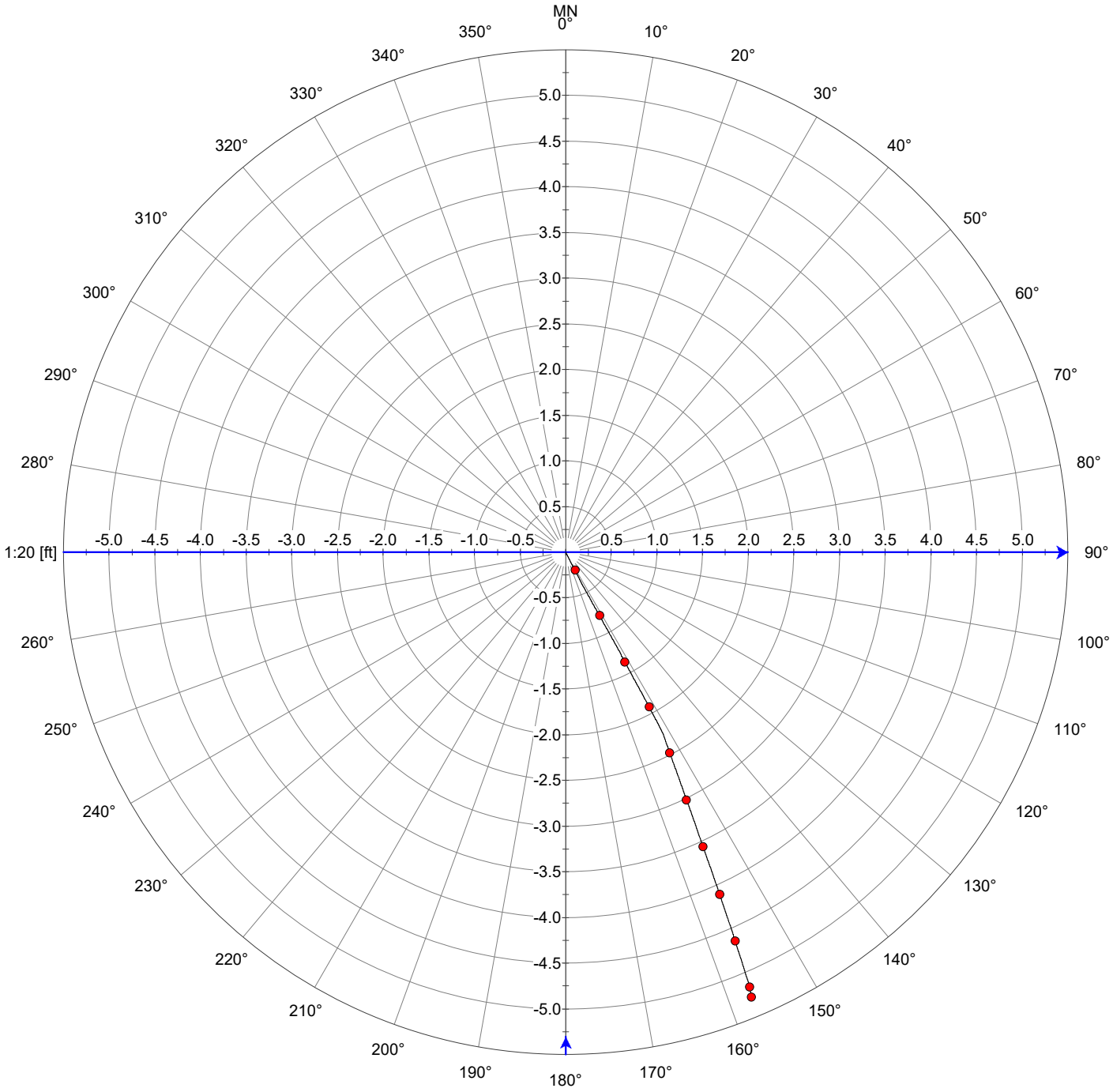
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 486.5'** **Latitude: 45.80489 N** **Longitude: 84.76979 W**




200
210
0
deg
360
Azimuth
0
deg
15
Tilt
1ft:120ft
Depth
0
[ft]
250
True Vertical Depth
-5
[ft]
5
Northing
-5
[ft]
5
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
1:20 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-33
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-33
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80489 N
Longitude: 84.76979 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
3-Arm Caliper

PERMANENT DATUM Mudline **ELEVATION** 486.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	21 July 2019	21 July 2019		
RUN NUMBER	2	2		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	217'	217'		
DEPTH-LOGGER	212'	212'		
BTM LOG INTERVAL	211.5'	211.5'		
TOP LOG INTERVAL	0.0'	105.7'		
RECORDED BY	JBG,KMG	JBG,KMG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 ft/min	20 ft/min		
A.S.D.E. / Sample Interval	0.28' / 0.25'	0.28' / 0.25'		
Fluid Level / Fluid Type	NA/water	NA/water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	7"	SU	Mudline 16.4'
2	6"	SU	217.6'

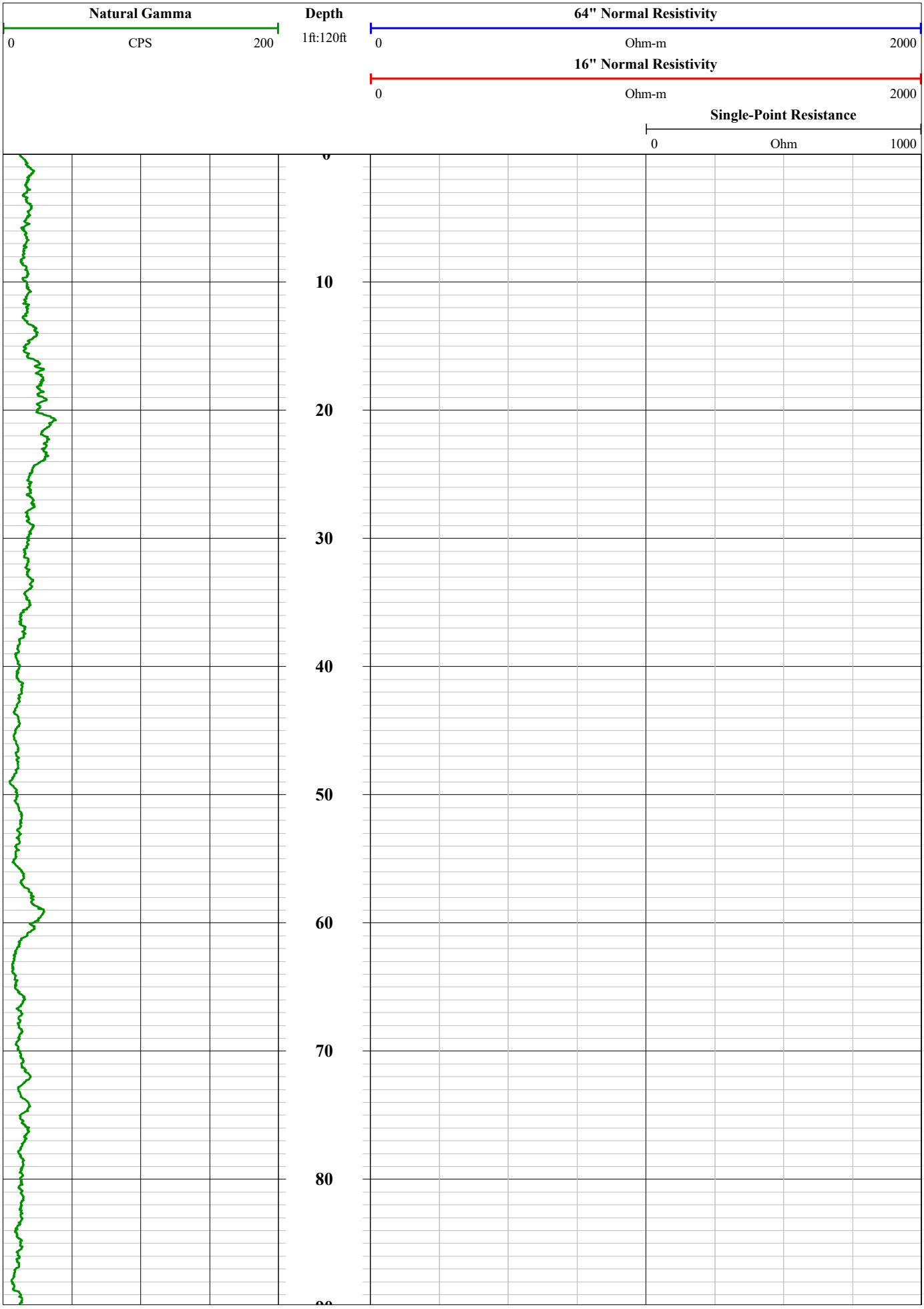
CASING RECORD

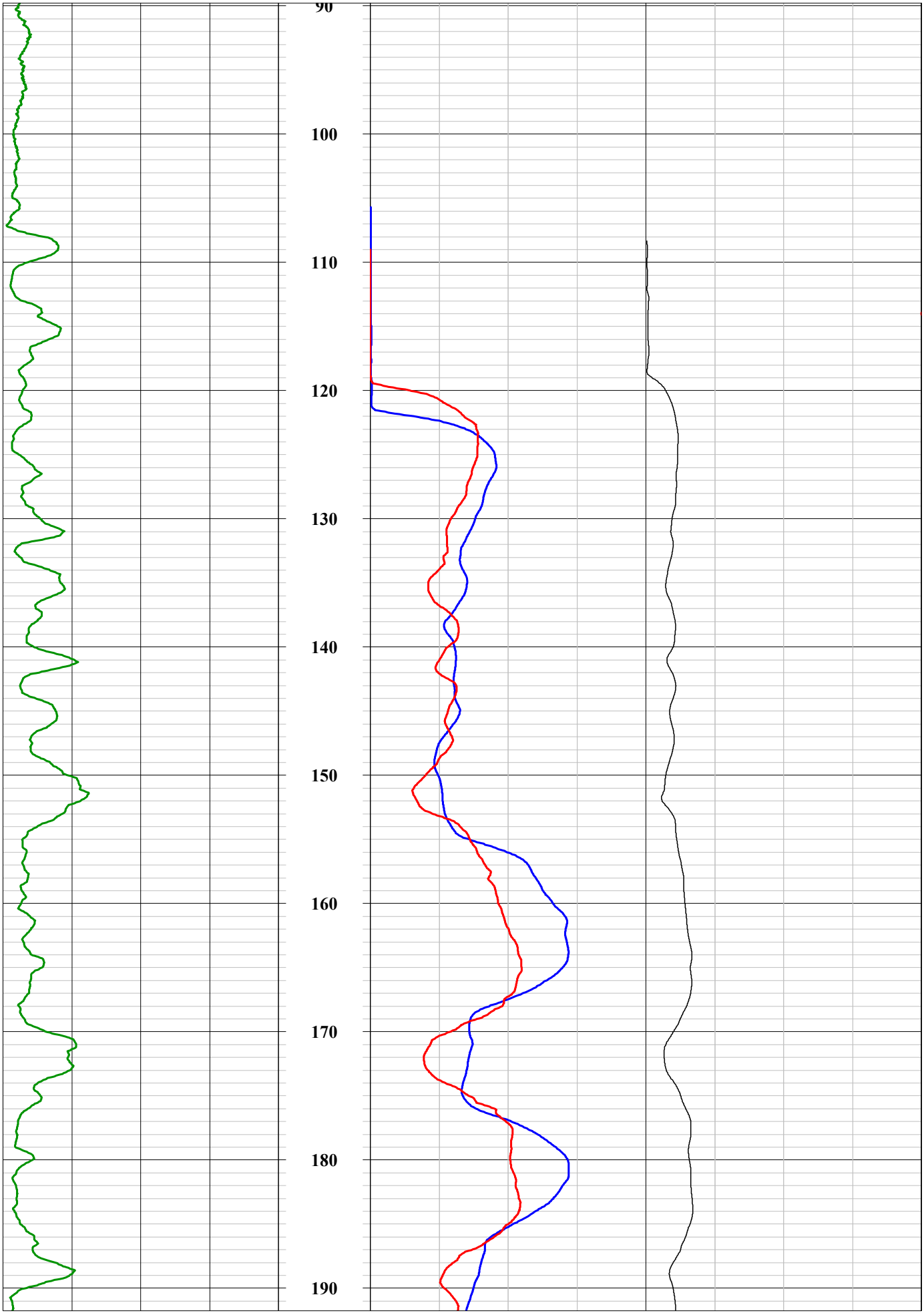
SIZE	WGT.	FROM	TO
7"	Steel	SU	118.1'

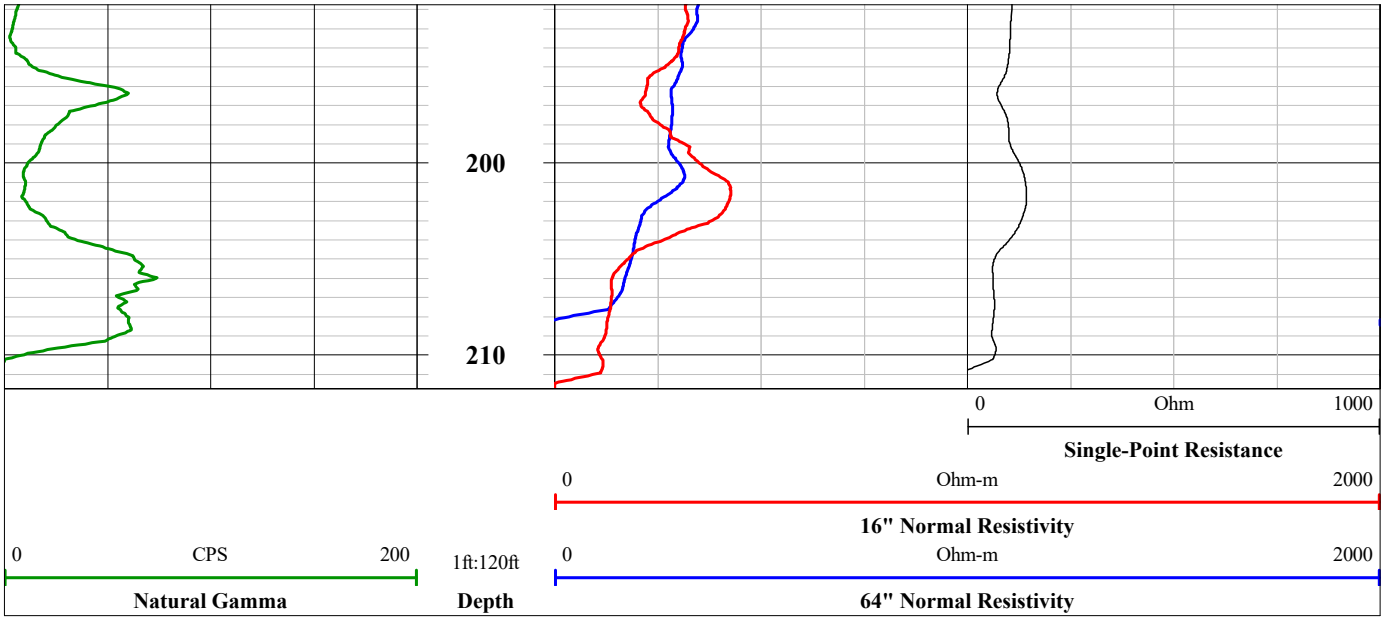
NA - Not Available, N/A - Not Applicable

COMMENTS

Spontaneous Potential omitted due to configuration error.


Natural Gamma
0
CPS
200
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
2000
16" Normal Resistivity
0
Ohm-m
2000
Single-Point Resistance
0
Ohm
1000
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
0
Ohm
1000
Single-Point Resistance
0
Ohm-m
2000
16" Normal Resistivity
0
CPS
200
1ft:120ft
0
Ohm-m
2000
Natural Gamma
Depth
64" Normal Resistivity

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-33
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-33
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.80489 N
Longitude: 84.76979 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Acoustic Televiewer
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 486.5'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	21 July 2019			
RUN NUMBER	3			
LOG TYPE	PSLog			
DEPTH-DRILLER	217.6'			
DEPTH-LOGGER	201'			
BTM LOG INTERVAL	201'			
TOP LOG INTERVAL	113'			
RECORDED BY	JBG,KMG			
WITNESSED BY	WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

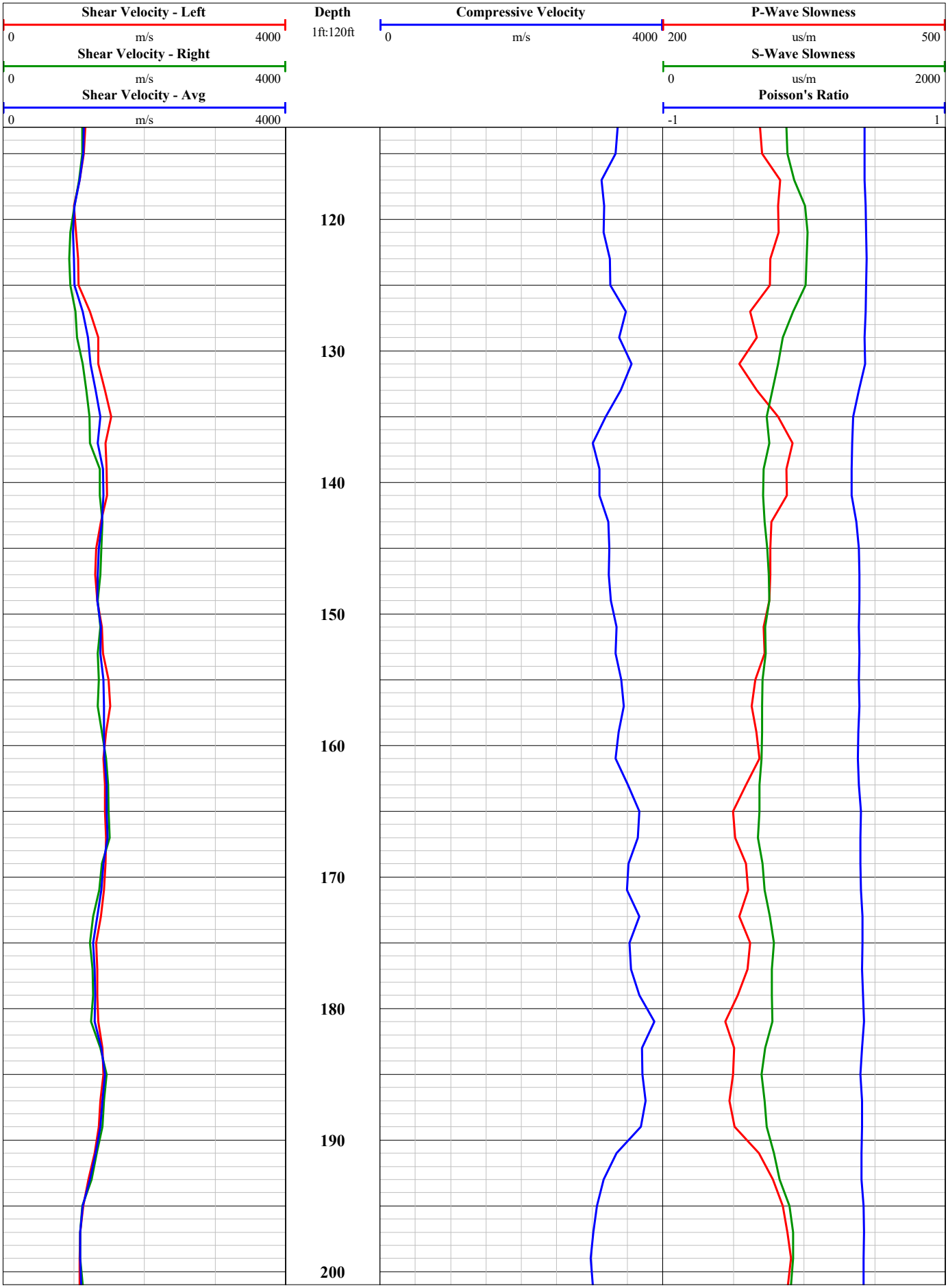
RUN No.	BIT	FROM	TO
1	7"	SU	Mudline 16.4'
2	6"	SU	217.6'

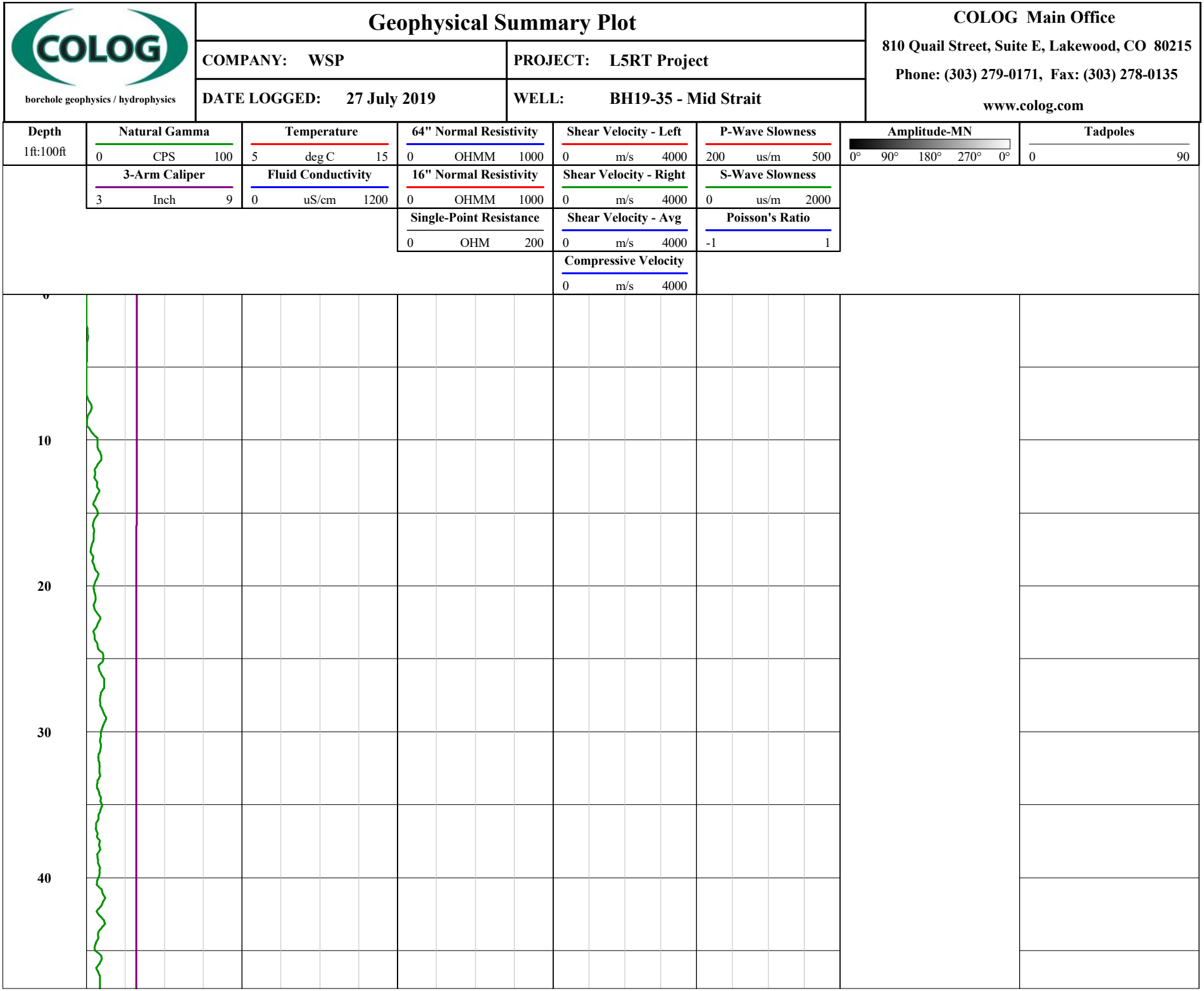
CASING RECORD

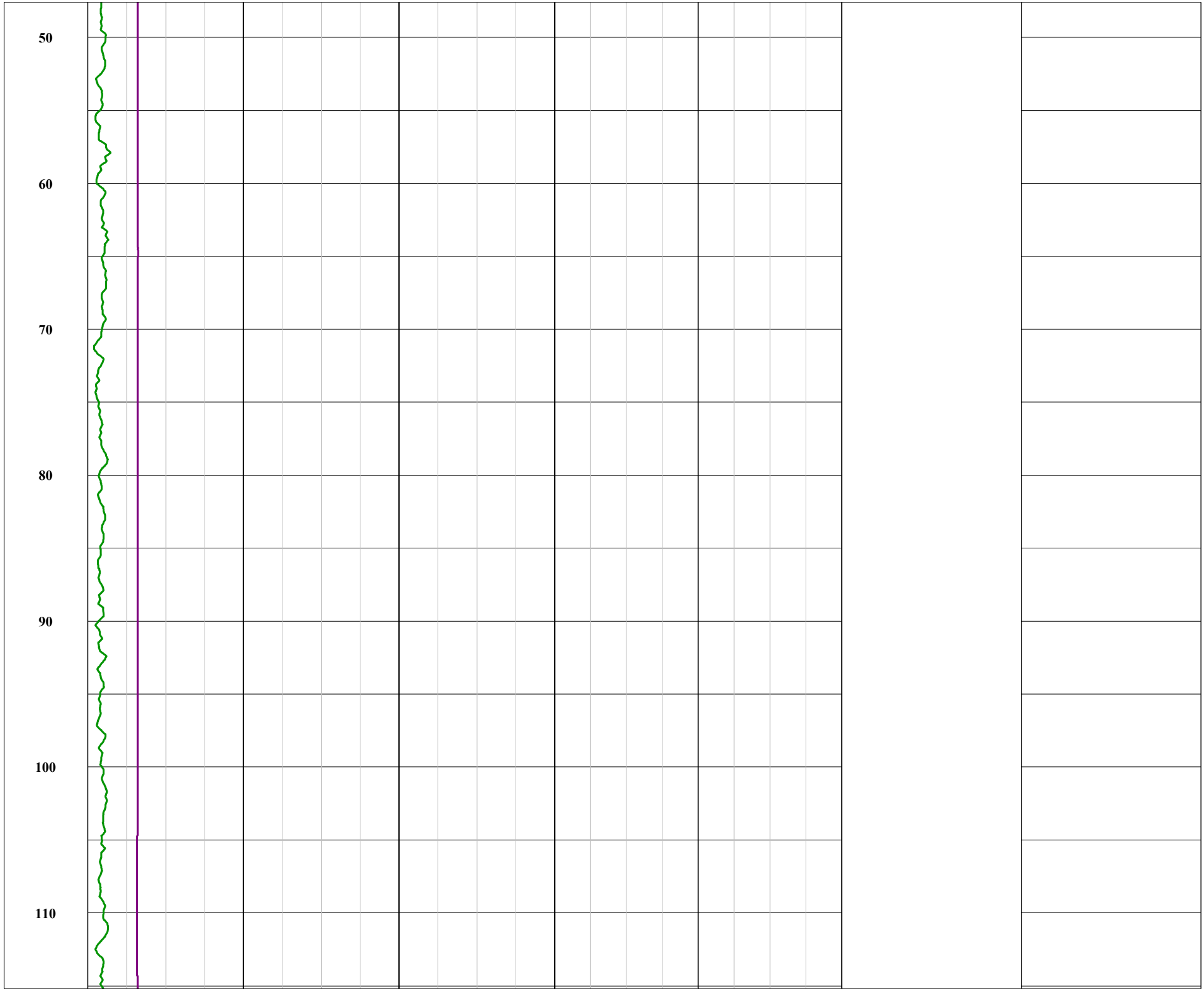
SIZE	WGT.	FROM	TO
7"	Steel	SU	118.1'

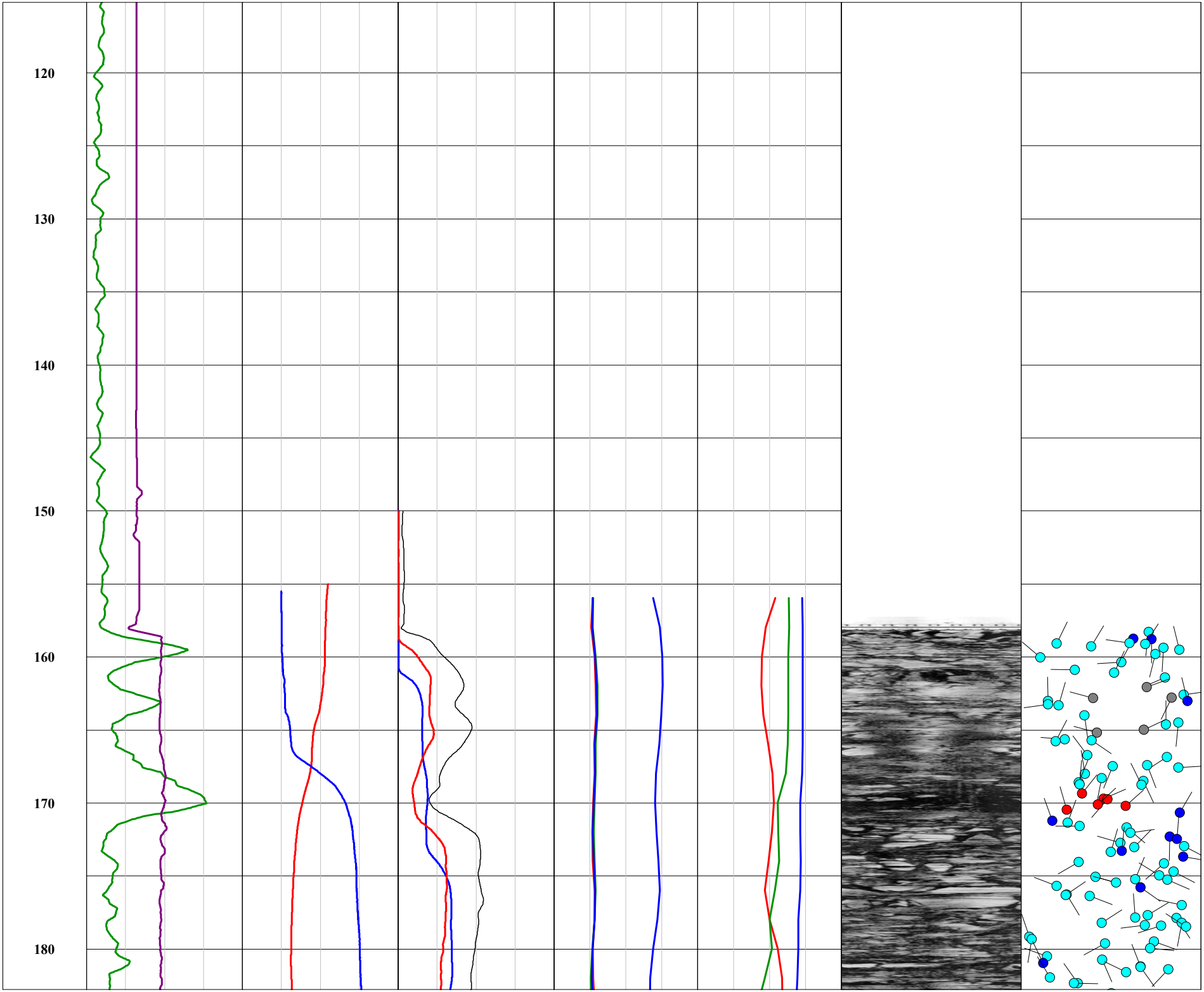
NA - Not Available, N/A - Not Applicable

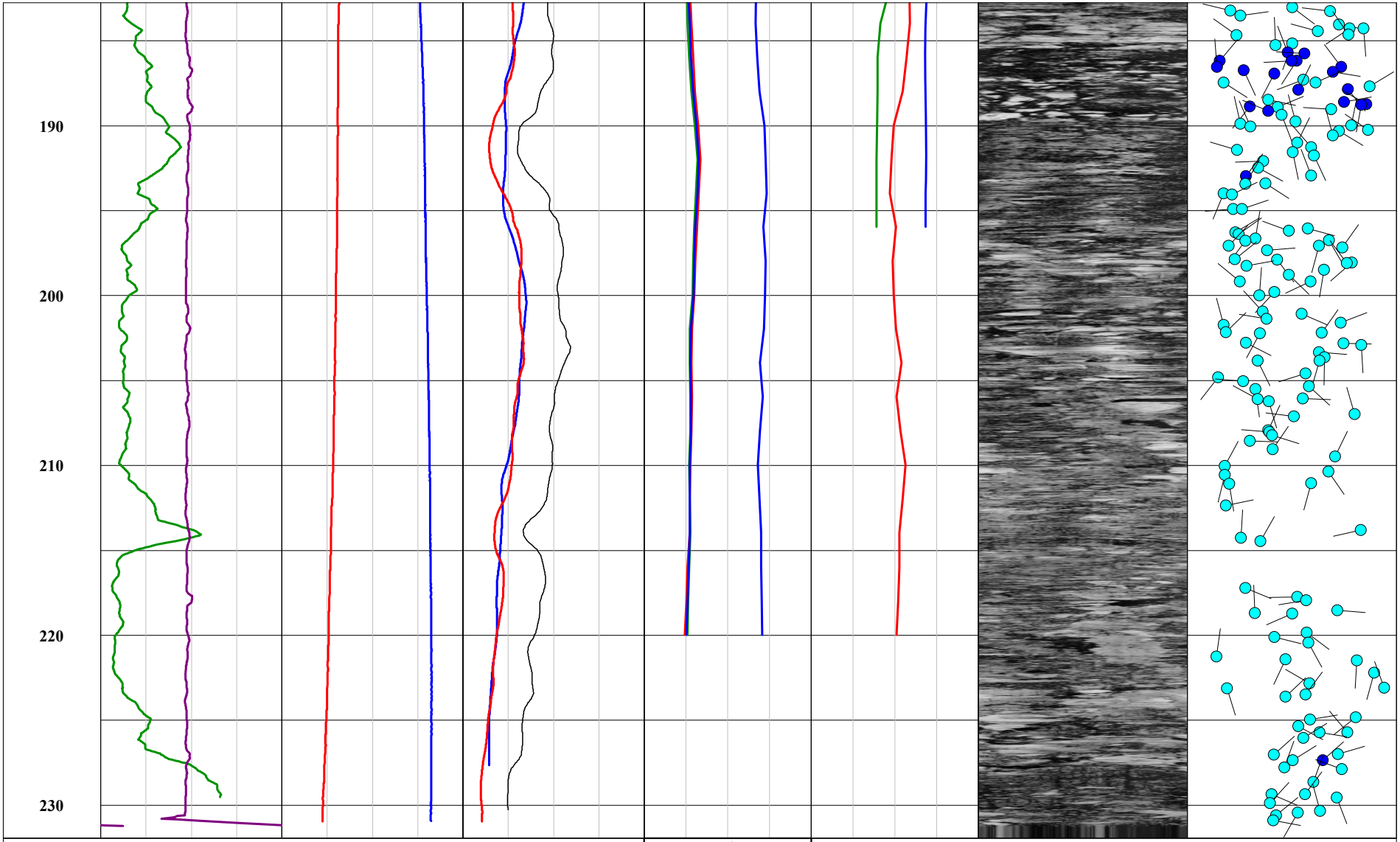
COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
0
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
120
130
140
150
160
170
180
190
200


COLOG
borehole geophysics / hydrophysics
Geophysical Summary Plot
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 27 July 2019
WELL: BH19-35 - Mid Strait
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com
Depth
1ft:100ft
Natural Gamma
0 CPS 100
3-Arm Caliper
3 Inch 9
Temperature
5 deg C 15
Fluid Conductivity
0 uS/cm 1200
64" Normal Resistivity
0 OHMM 1000
16" Normal Resistivity
0 OHMM 1000
Single-Point Resistance
0 OHM 200
Shear Velocity - Left
0 m/s 4000
Shear Velocity - Right
0 m/s 4000
Shear Velocity - Avg
0 m/s 4000
Compressive Velocity
0 m/s 4000
P-Wave Slowness
200 us/m 500
S-Wave Slowness
0 us/m 2000
Poisson's Ratio
-1 1
Amplitude-MN
0° 90° 180° 270° 0°
Tadpoles
0 90
10
20
30
40


50
60
70
80
90
100
110


120
130
140
150
160
170
180



					0 m/s 4000 **Compressive Velocity**			
			0 OHM 200 **Single-Point Resistance**		0 m/s 4000 **Shear Velocity - Avg**	-1 1 **Poisson's Ratio**		
	3 Inch 9 **3-Arm Caliper**	0 uS/cm 1200 **Fluid Conductivity**	0 OHMM 1000 **16" Normal Resistivity**		0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**		
1ft:100ft **Depth**	0 CPS 100 **Natural Gamma**	5 deg C 15 **Temperature**	0 OHMM 1000 **64" Normal Resistivity**		0 m/s 4000 **Shear Velocity - Left**	200 us/m 500 **P-Wave Slowness**	0° 90° 180° 270° 0° **Amplitude-MN**	0 90 **Tadpoles**

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-35
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-35
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79960 N
Longitude: 84.77182 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 499.2'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	27 July 2019			
RUN NUMBER	5			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	231.24'			
DEPTH-LOGGER	231.3'			
BTM LOG INTERVAL	231.3'			
TOP LOG INTERVAL	157.2'			
RECORDED BY	JBG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	ABI #111018			
LOGGING SPEED	4.5 fpm			
A.S.D.E. / Sample Interval	0.8' / 0.0024'			
Fluid Level / Fluid Type	NA'/water			

BOREHOLE RECORD

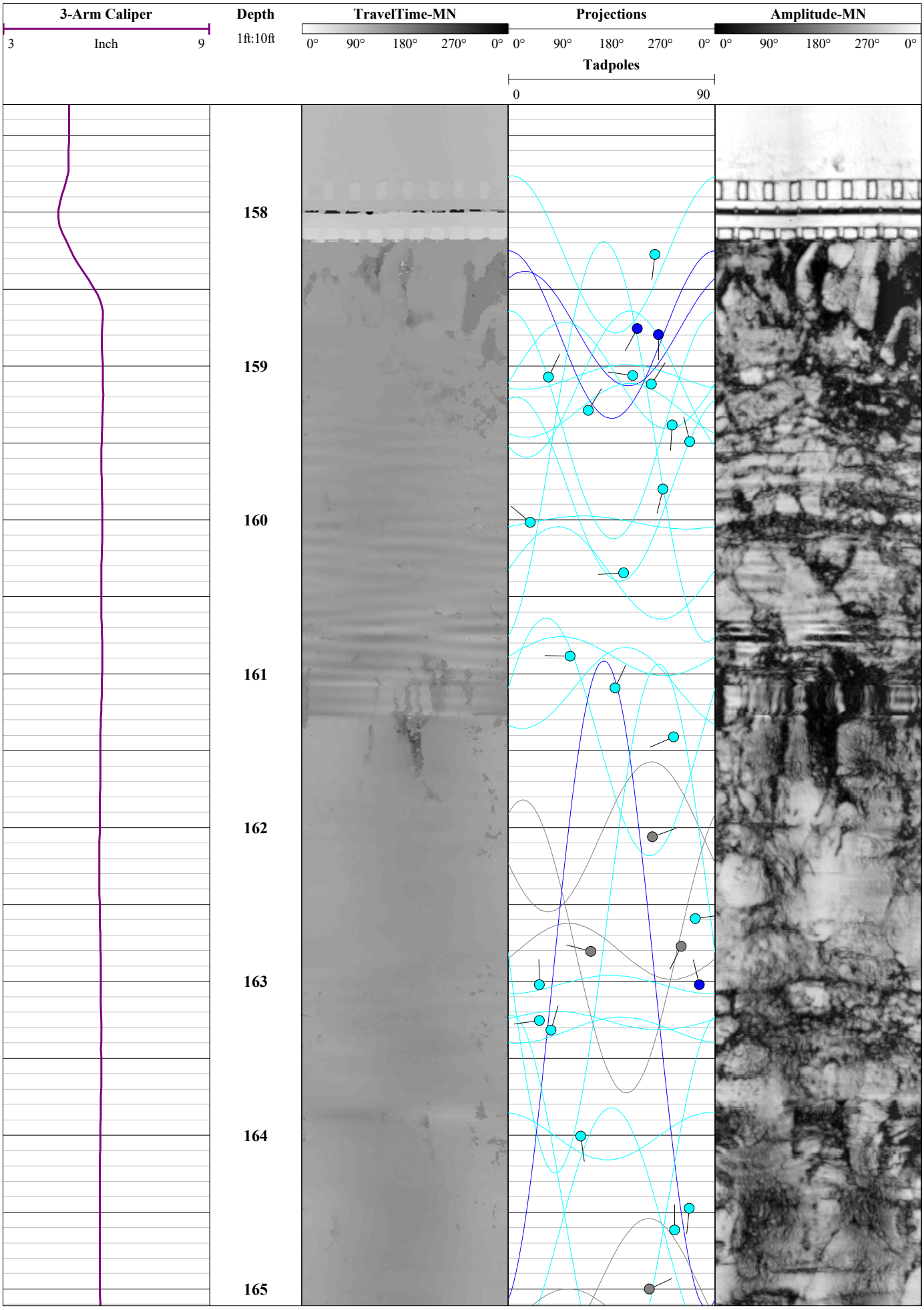
RUN No.	BIT	FROM	TO
1	7"	Mudline	13.45'
2	6"	13.45'	TD

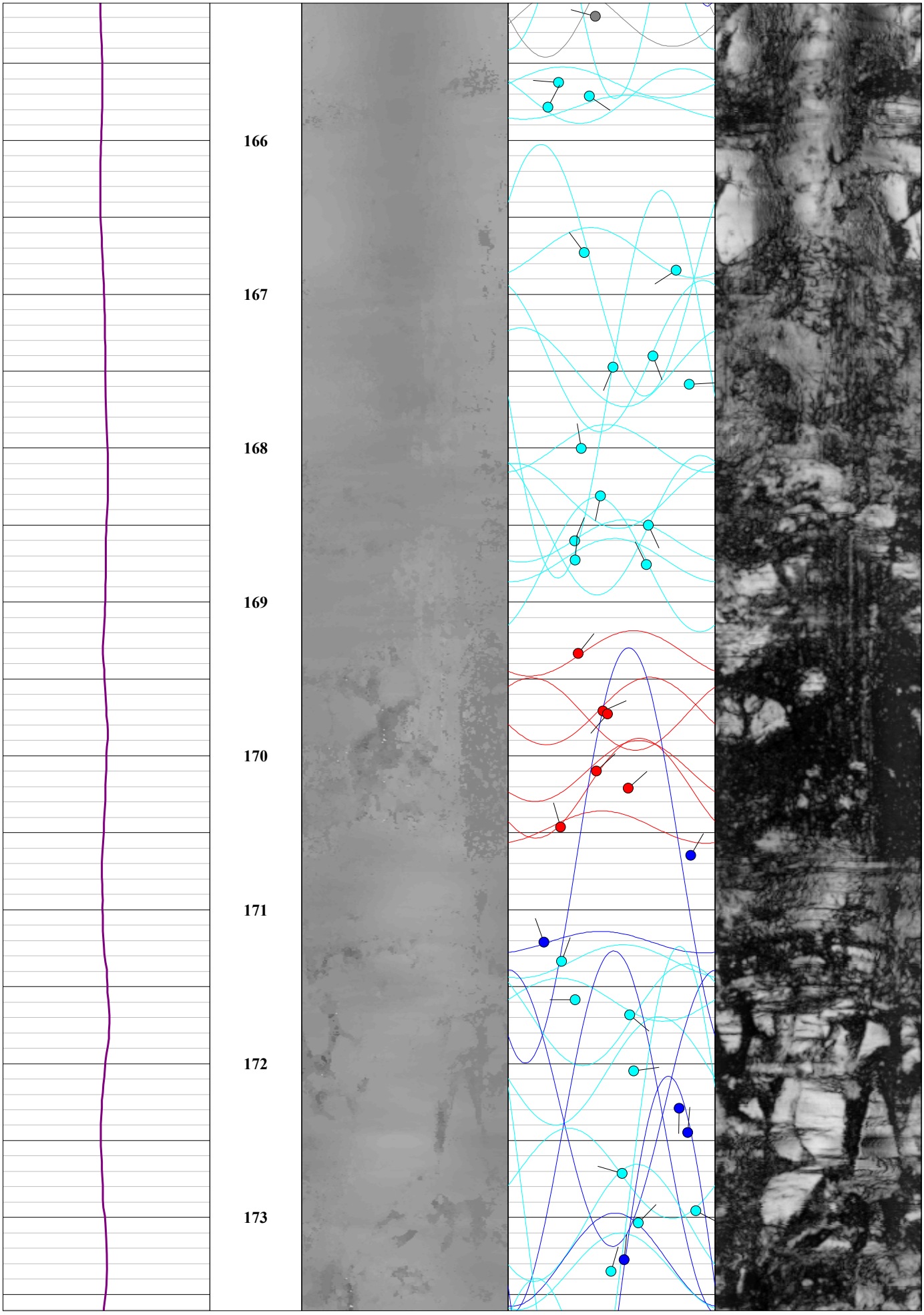
CASING RECORD

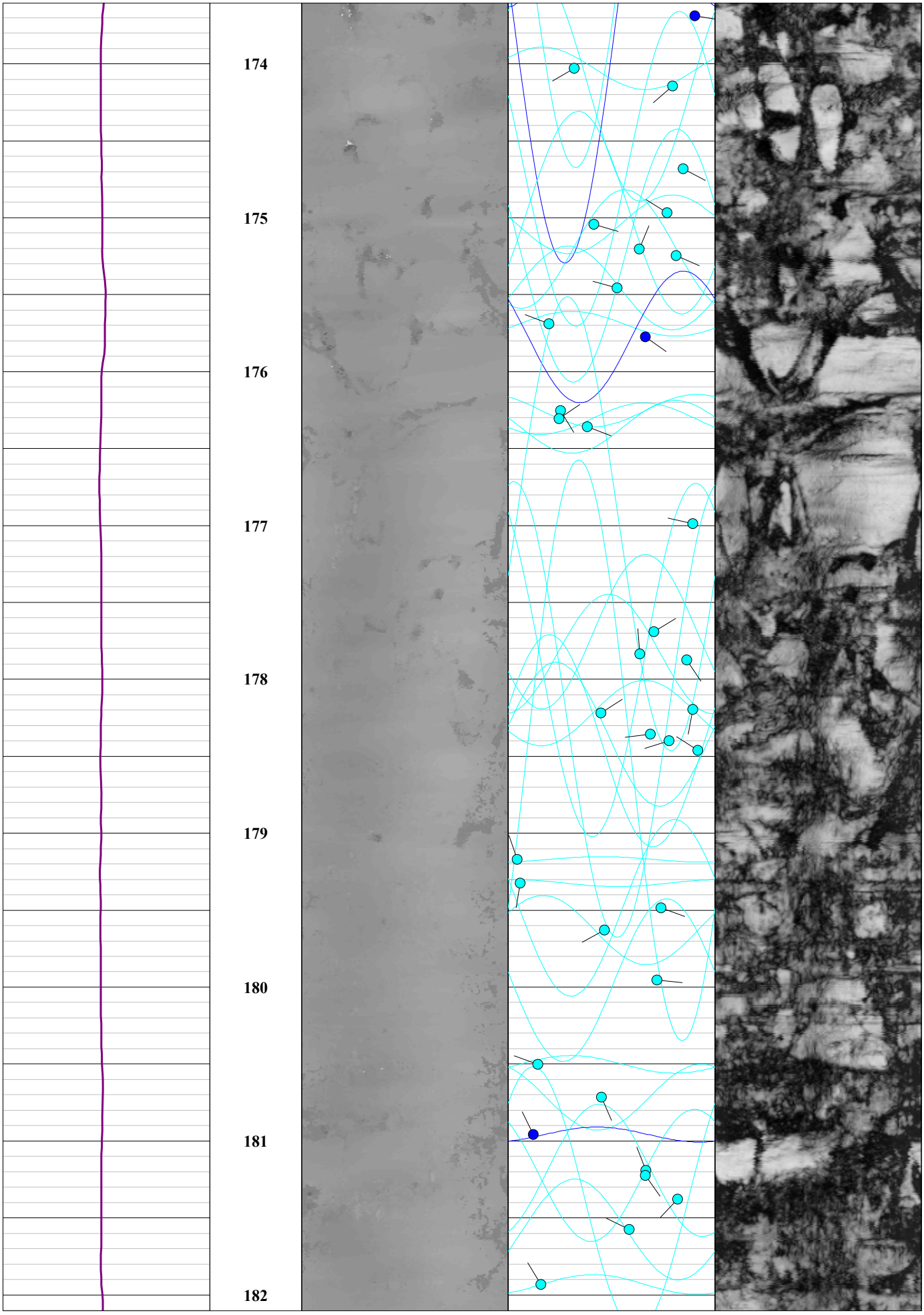
SIZE	WGT.	FROM	TO
7"	Steel	SU	13.45'
6"	Steel	SU	158.8'

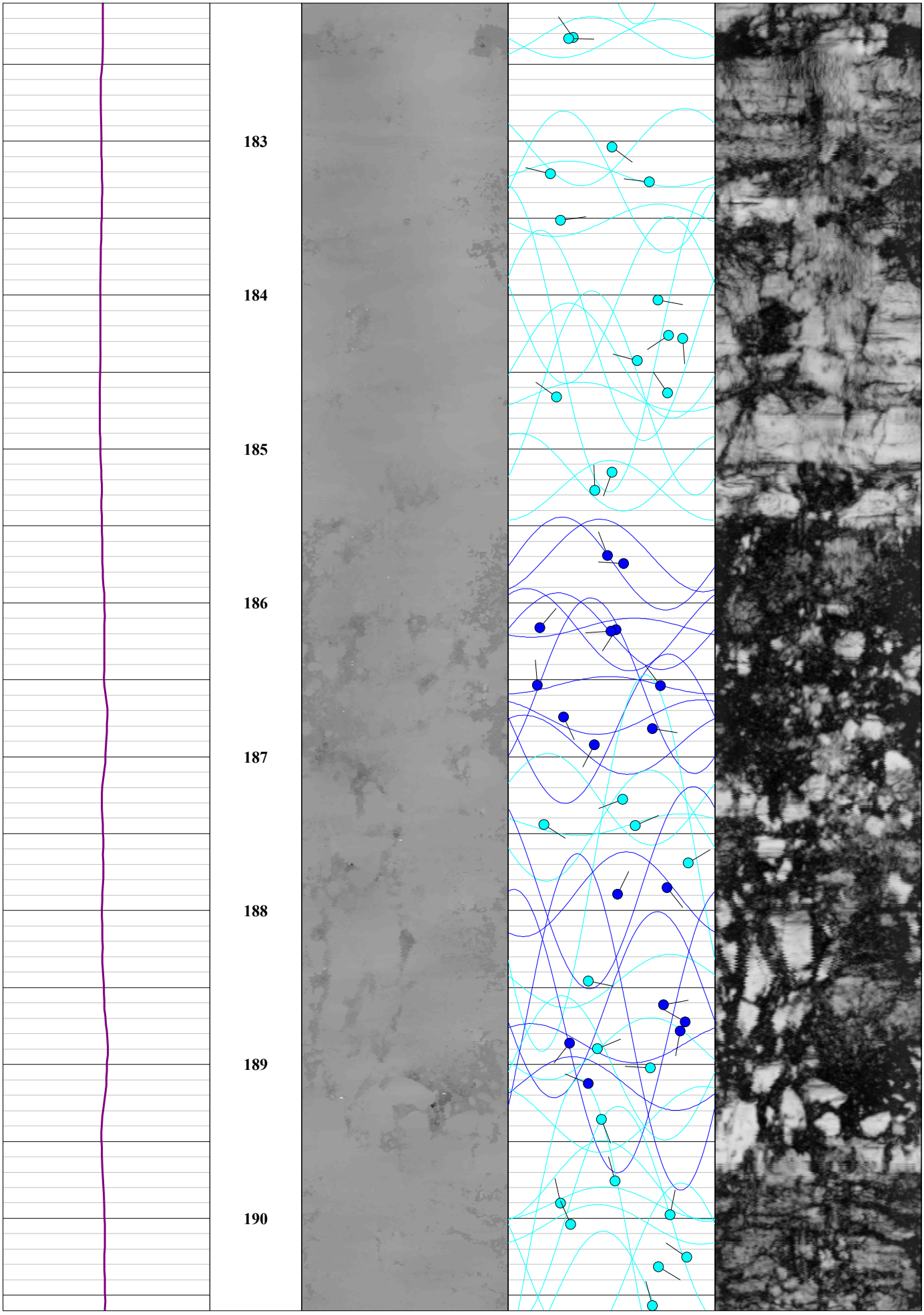
NA - Not Available, N/A - Not Applicable

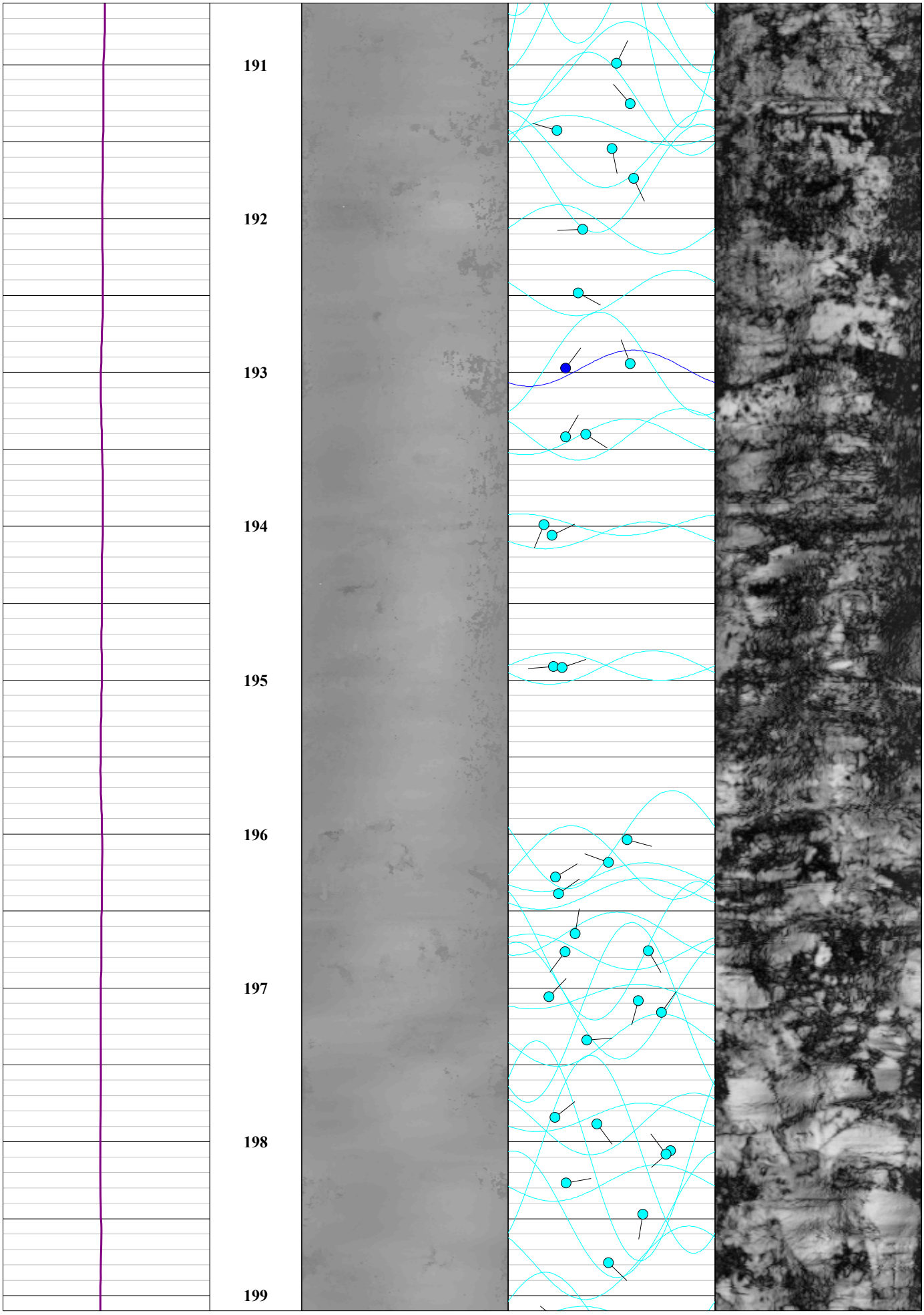
COMMENTS

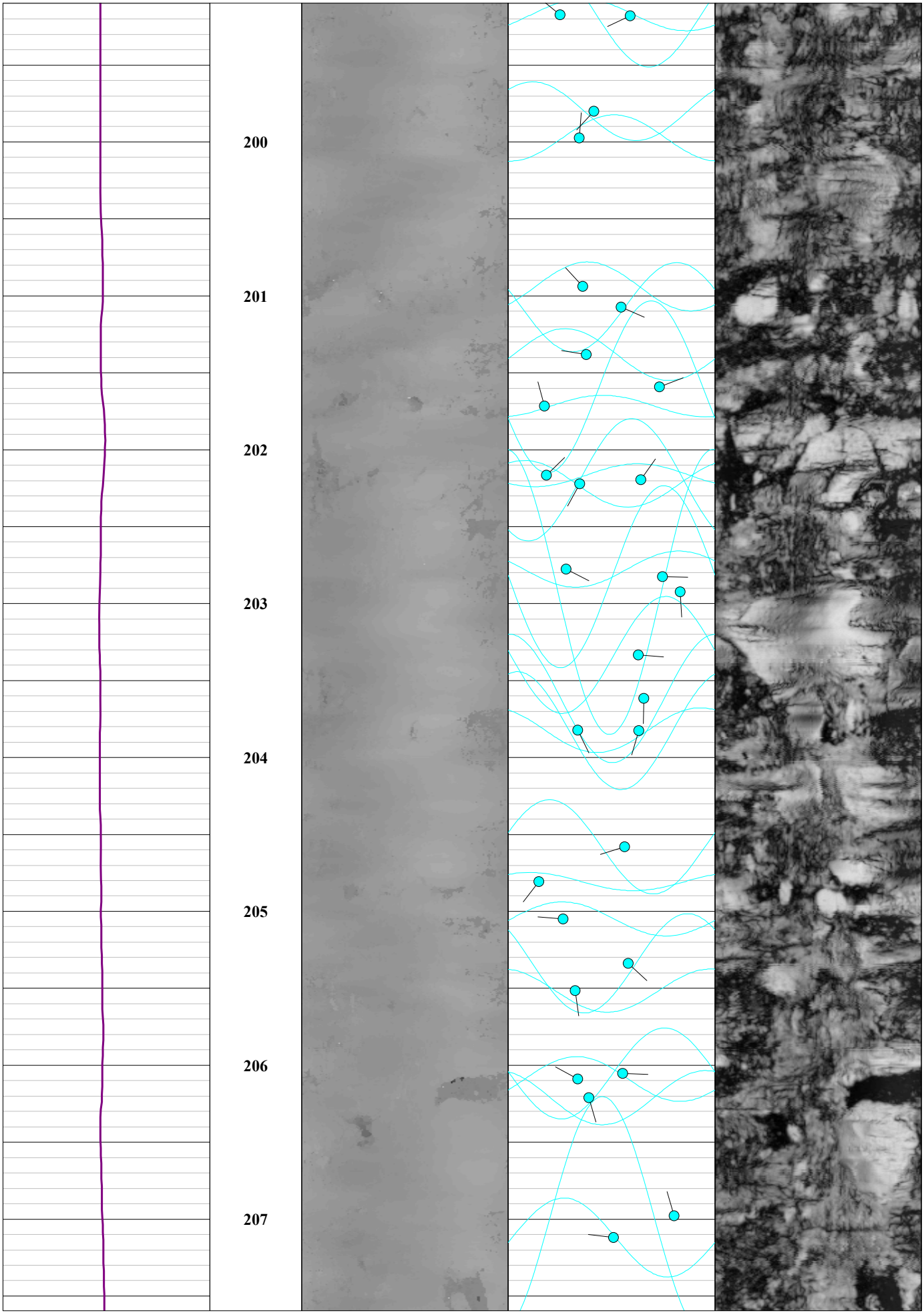

3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-MN
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude-MN
0°
90°
180°
270°
0°
158
159
160
161
162
163
164
165

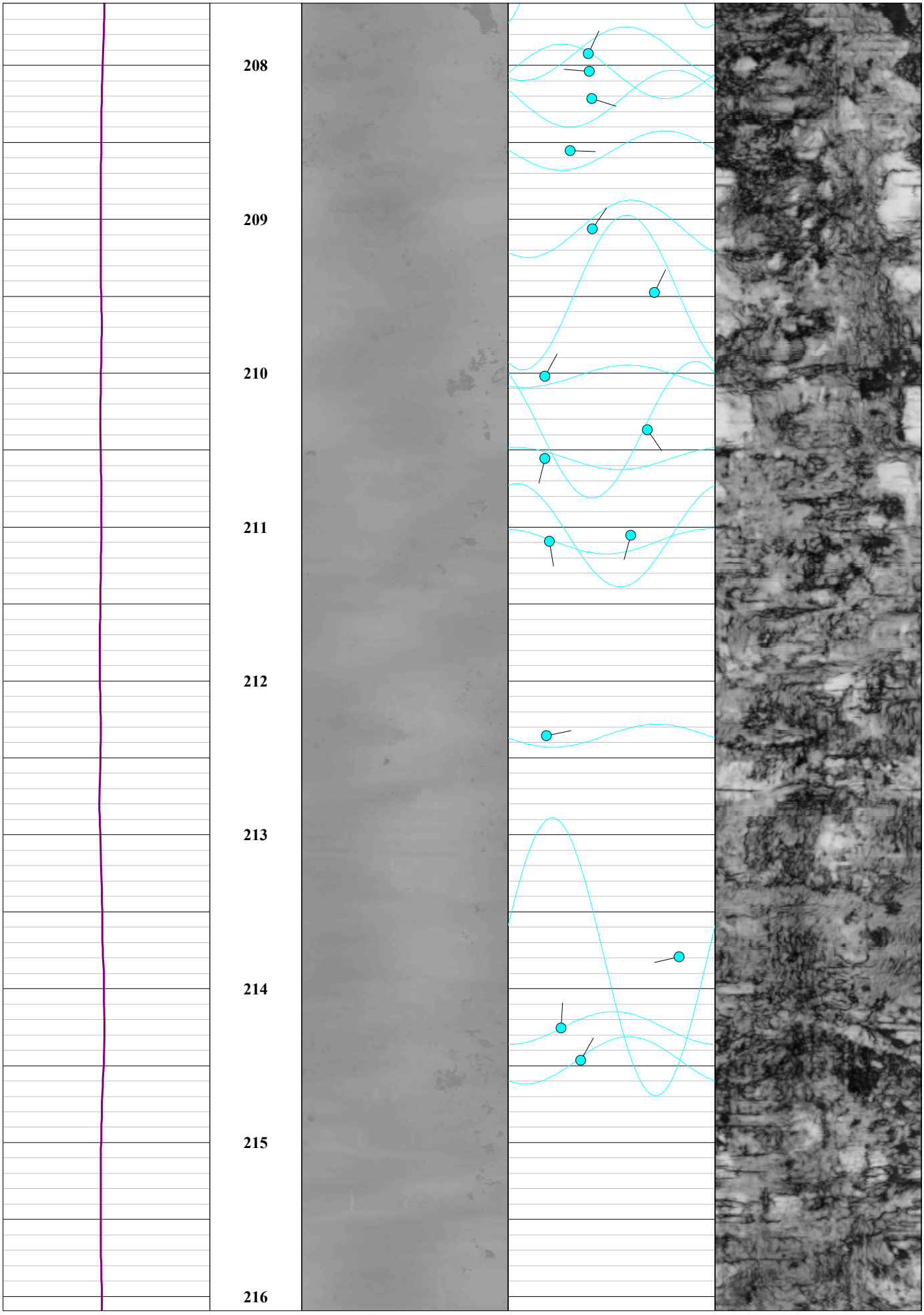

166
167
168
169
170
171
172
173

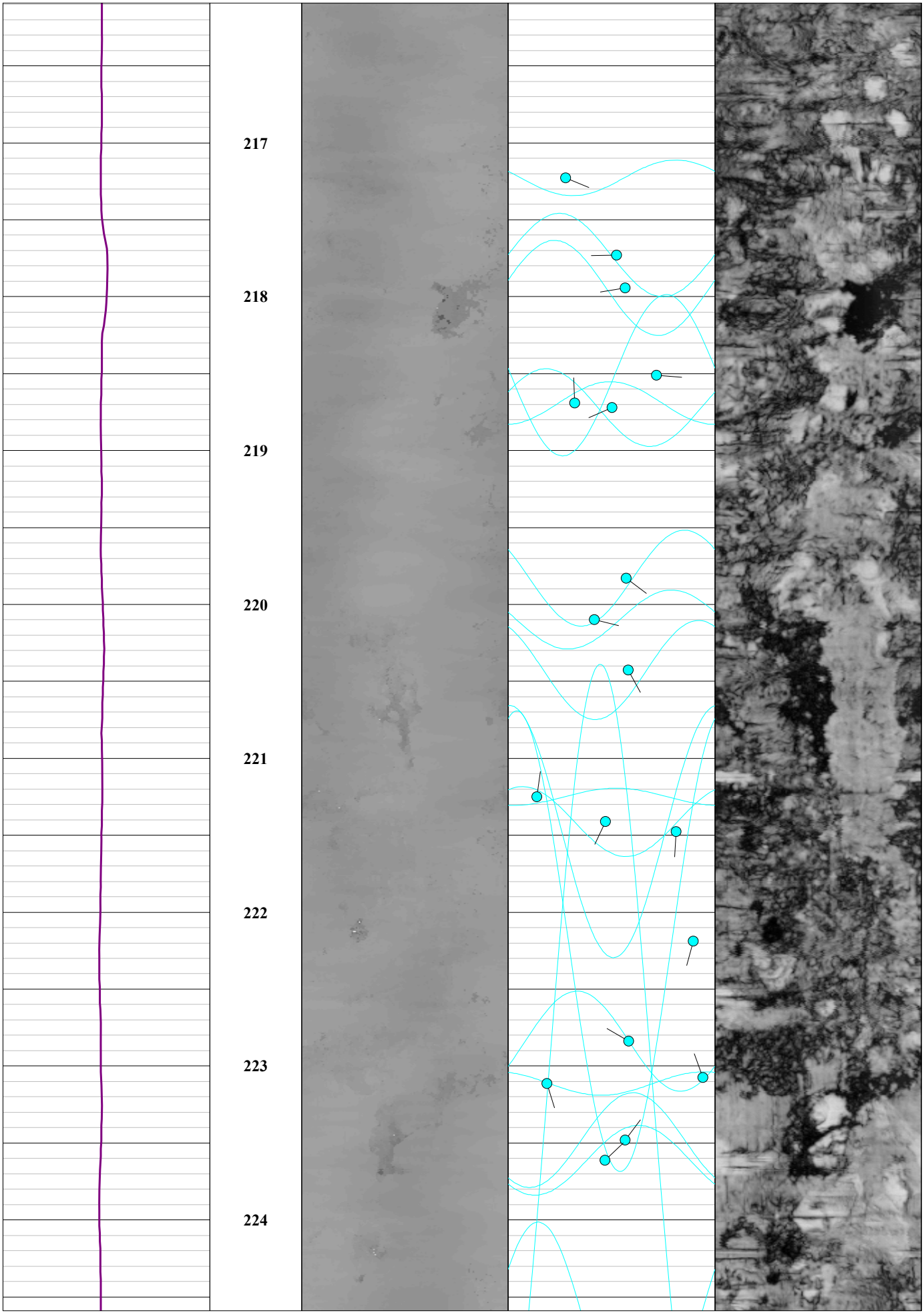

174
175
176
177
178
179
180
181
182

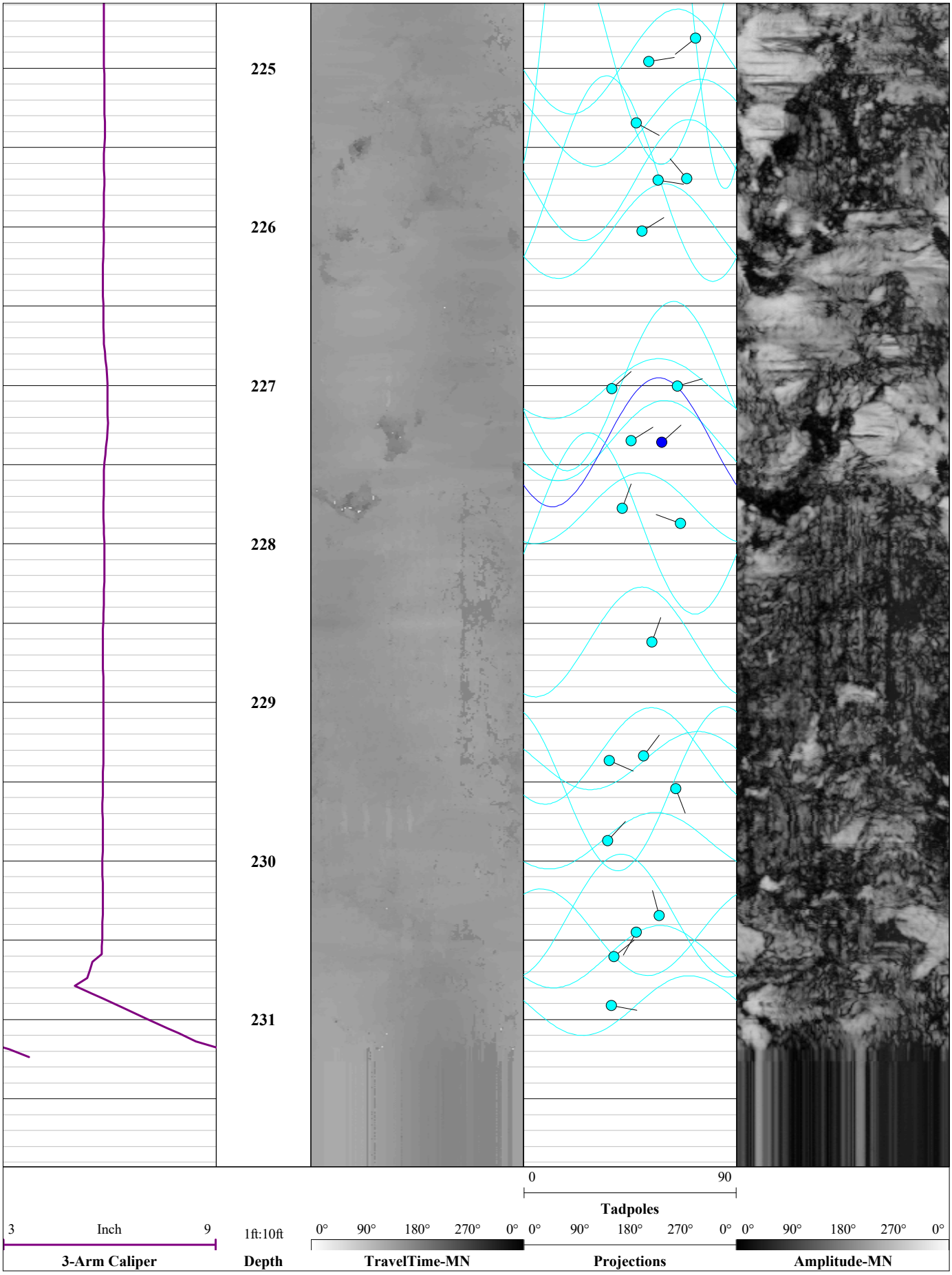

183
184
185
186
187
188
189
190


191
192
193
194
195
196
197
198
199

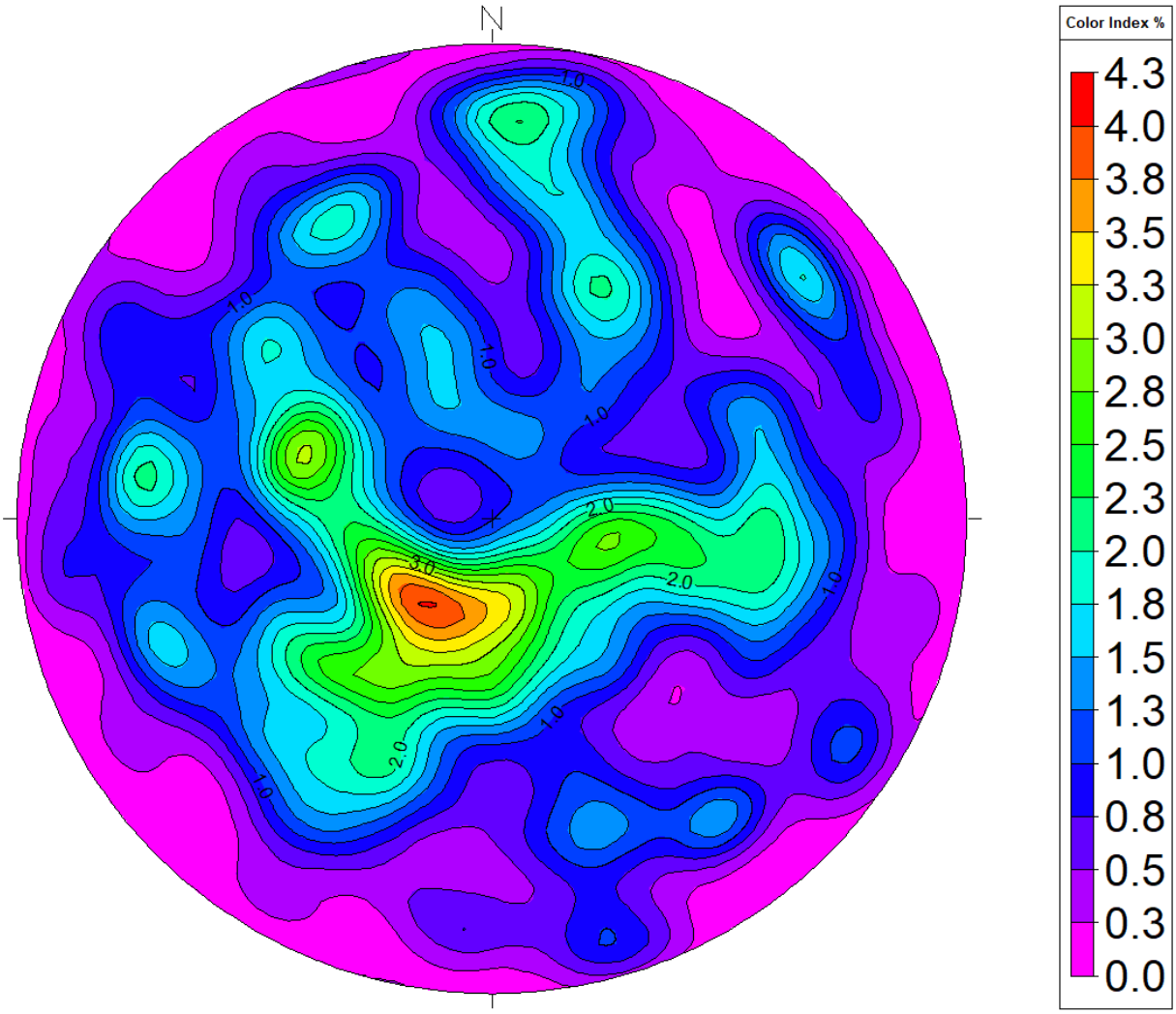

200
201
202
203
204
205
206
207


208
209
210
211
212
213
214
215
216


217
218
219
220
221
222
223
224

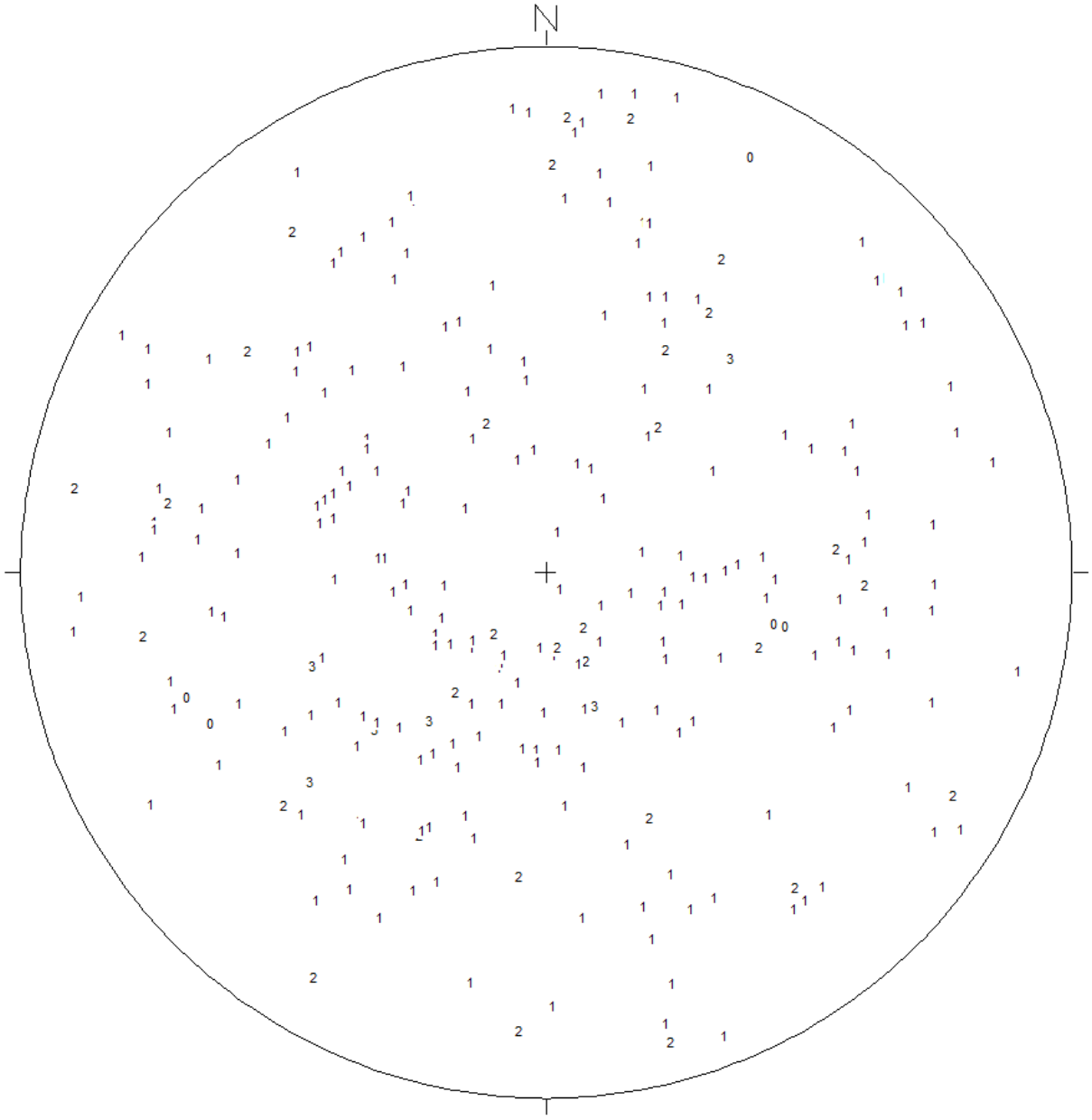

225
226
227
228
229
230
231
0
90
Tadpoles
3
Inch
9
1ft:10ft
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-35
27 July 2019



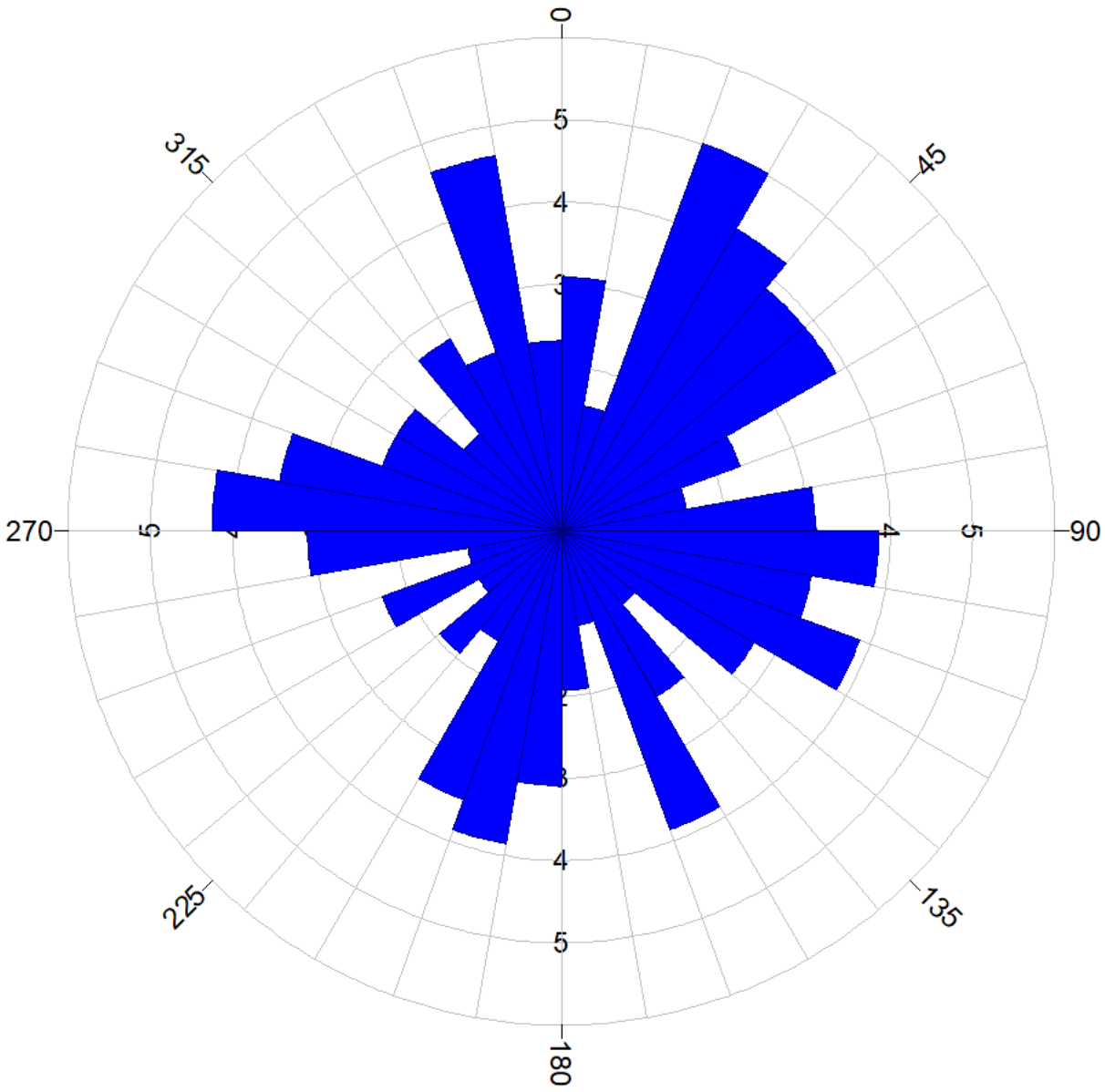
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-35
27 July 2019



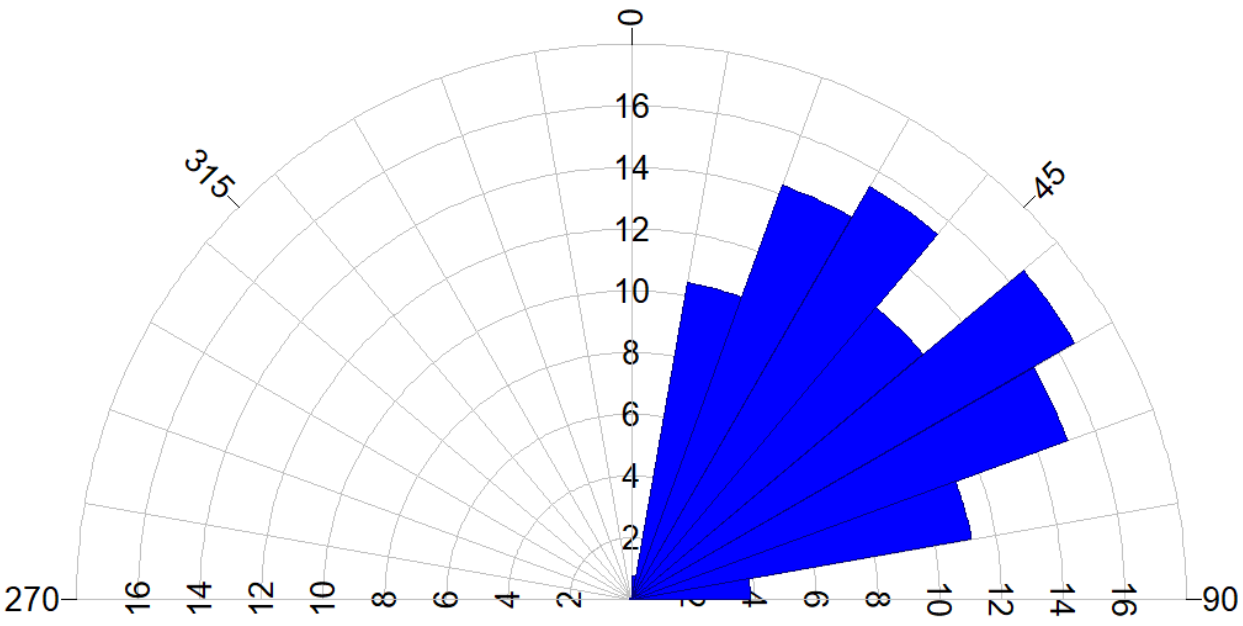
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-35
27 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-35
27 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-35

27 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	48.24	158.3	187	64	1
2	48.39	158.8	209	56	2
3	48.40	158.8	180	65	2
4	48.48	159.1	278	54	1
5	48.48	159.1	27	18	1
6	48.50	159.1	32	62	1
7	48.55	159.3	32	35	1
8	48.58	159.4	183	71	1
9	48.61	159.5	346	79	1
10	48.71	159.8	194	67	1
11	48.77	160.0	310	10	1
12	48.87	160.4	266	50	1
13	49.04	160.9	272	27	1
14	49.10	161.1	25	46	1
15	49.20	161.4	246	72	1
16	49.40	162.1	70	63	0
17	49.56	162.6	82	81	1
18	49.61	162.8	206	75	0
19	49.62	162.8	285	36	0
20	49.69	163.0	346	83	2
21	49.69	163.0	359	14	1
22	49.76	163.3	262	14	1
23	49.78	163.3	16	19	1
24	49.99	164.0	172	32	1
25	50.13	164.5	186	79	1
26	50.18	164.6	0	73	1
27	50.29	165.0	65	61	0
28	50.35	165.2	285	38	0
29	50.48	165.6	275	22	1
30	50.51	165.7	124	35	1
31	50.53	165.8	27	17	1
32	50.82	166.7	323	33	1
33	50.85	166.8	237	73	1
34	51.02	167.4	159	63	1
35	51.05	167.5	203	46	1
36	51.08	167.6	86	79	1
37	51.21	168.0	351	32	1
38	51.30	168.3	192	40	1
39	51.36	168.5	155	61	1
40	51.39	168.6	23	29	1
41	51.43	168.7	5	29	1
42	51.44	168.8	334	60	1
43	51.61	169.3	38	31	3
44	51.73	169.7	67	41	3
45	51.73	169.7	221	43	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-35

27 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	51.85	170.1	47	38	3
47	51.88	170.2	48	52	3
48	51.96	170.5	343	23	3
49	52.01	170.7	30	80	2
50	52.18	171.2	341	16	2
51	52.22	171.3	20	23	1
52	52.30	171.6	270	29	1
53	52.33	171.7	130	53	1
54	52.44	172.1	82	55	1
55	52.51	172.3	182	74	2
56	52.56	172.5	4	78	2
57	52.64	172.7	286	50	1
58	52.72	173.0	118	82	1
59	52.74	173.0	45	57	1
60	52.81	173.3	6	50	2
61	52.84	173.4	16	45	1
62	52.94	173.7	99	81	2
63	53.04	174.0	240	29	1
64	53.08	174.1	229	72	1
65	53.24	174.7	118	76	1
66	53.33	175.0	302	69	1
67	53.35	175.0	106	37	1
68	53.40	175.2	23	57	1
69	53.42	175.3	114	73	1
70	53.48	175.5	285	47	1
71	53.55	175.7	291	18	1
72	53.57	175.8	125	60	2
73	53.72	176.3	148	23	1
74	53.74	176.3	56	22	1
75	53.75	176.4	111	34	1
76	53.95	177.0	283	80	1
77	54.16	177.7	59	63	1
78	54.20	177.8	355	57	1
79	54.22	177.9	147	78	1
80	54.31	178.2	190	80	1
81	54.32	178.2	57	40	1
82	54.36	178.4	264	62	1
83	54.38	178.4	252	70	1
84	54.39	178.5	303	82	1
85	54.61	179.2	341	4	1
86	54.66	179.3	190	5	1
87	54.71	179.5	109	66	1
88	54.75	179.6	241	42	1
89	54.85	180.0	96	65	1
90	55.02	180.5	290	13	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-35

27 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	55.08	180.7	156	41	1
92	55.16	181.0	334	11	2
93	55.23	181.2	338	60	1
94	55.24	181.2	144	60	1
95	55.28	181.4	224	74	1
96	55.35	181.6	296	53	1
97	55.45	181.9	328	14	1
98	55.57	182.3	324	28	1
99	55.57	182.3	92	26	1
100	55.79	183.0	127	45	1
101	55.84	183.2	284	18	1
102	55.86	183.3	277	62	1
103	55.93	183.5	82	23	1
104	56.09	184.0	101	65	1
105	56.16	184.3	236	70	1
106	56.17	184.3	175	76	1
107	56.21	184.4	285	56	1
108	56.28	184.6	325	69	1
109	56.28	184.7	305	21	1
110	56.43	185.2	200	45	1
111	56.47	185.3	357	38	1
112	56.60	185.7	339	43	2
113	56.61	185.7	274	50	2
114	56.74	186.2	40	14	2
115	56.74	186.2	212	47	2
116	56.75	186.2	267	45	2
117	56.86	186.5	356	13	2
118	56.86	186.5	323	66	2
119	56.92	186.7	155	24	2
120	56.94	186.8	99	63	2
121	56.97	186.9	208	38	2
122	57.08	187.3	249	50	1
123	57.13	187.4	123	16	1
124	57.13	187.5	66	55	1
125	57.21	187.7	59	78	1
126	57.26	187.9	142	69	2
127	57.27	187.9	26	48	2
128	57.44	188.5	102	35	1
129	57.49	188.6	80	68	2
130	57.52	188.7	300	77	2
131	57.54	188.8	190	75	2
132	57.56	188.9	218	27	2
133	57.58	188.9	68	39	1
134	57.61	189.0	273	62	1
135	57.64	189.1	292	35	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-35

27 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	57.72	189.4	159	41	1
137	57.84	189.8	345	46	1
138	57.88	189.9	347	23	1
139	57.91	190.0	11	70	1
140	57.92	190.0	336	27	1
141	57.99	190.3	305	78	1
142	58.01	190.3	121	65	1
143	58.09	190.6	345	63	1
144	58.21	191.0	26	47	1
145	58.29	191.3	319	53	1
146	58.35	191.4	287	21	1
147	58.38	191.5	168	45	1
148	58.44	191.7	155	55	1
149	58.54	192.1	268	33	1
150	58.67	192.5	118	31	1
151	58.81	192.9	339	53	1
152	58.82	193.0	37	25	2
153	58.95	193.4	122	34	1
154	58.95	193.4	30	25	1
155	59.13	194.0	202	16	1
156	59.15	194.1	64	19	1
157	59.41	194.9	266	20	1
158	59.41	194.9	72	23	1
159	59.75	196.0	105	52	1
160	59.80	196.2	289	44	1
161	59.83	196.3	59	21	1
162	59.86	196.4	55	22	1
163	59.94	196.7	9	29	1
164	59.97	196.8	150	61	1
165	59.97	196.8	217	25	1
166	60.06	197.1	44	18	1
167	60.07	197.1	195	57	1
168	60.09	197.2	35	67	1
169	60.15	197.3	86	34	1
170	60.30	197.8	52	20	1
171	60.32	197.9	143	39	1
172	60.37	198.1	229	71	1
173	60.37	198.1	323	69	1
174	60.43	198.3	80	25	1
175	60.49	198.5	189	59	1
176	60.59	198.8	134	44	1
177	60.71	199.2	310	23	1
178	60.71	199.2	245	53	1
179	60.90	199.8	222	37	1
180	60.95	200.0	4	31	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-35

27 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	61.25	200.9	318	33	1
182	61.29	201.1	113	49	1
183	61.38	201.4	279	34	1
184	61.44	201.6	69	66	1
185	61.48	201.7	345	16	1
186	61.62	202.2	46	17	1
187	61.63	202.2	35	58	1
188	61.64	202.2	208	31	1
189	61.81	202.8	117	25	1
190	61.82	202.8	91	67	1
191	61.85	202.9	177	75	1
192	61.97	203.3	94	57	1
193	62.06	203.6	182	59	1
194	62.12	203.8	154	30	1
195	62.12	203.8	196	57	1
196	62.36	204.6	253	51	1
197	62.43	204.8	218	13	1
198	62.50	205.1	275	24	1
199	62.59	205.3	132	52	1
200	62.64	205.5	172	29	1
201	62.80	206.1	92	50	1
202	62.82	206.1	299	30	1
203	62.85	206.2	164	35	1
204	63.09	207.0	344	72	1
205	63.13	207.1	277	46	1
206	63.37	207.9	25	35	1
207	63.41	208.0	274	35	1
208	63.46	208.2	108	36	1
209	63.57	208.6	92	27	1
210	63.72	209.1	34	37	1
211	63.85	209.5	26	64	1
212	64.01	210.0	28	16	1
213	64.12	210.4	146	61	1
214	64.18	210.6	194	16	1
215	64.33	211.1	195	53	1
216	64.34	211.1	171	18	1
217	64.72	212.4	79	17	1
218	65.16	213.8	257	75	1
219	65.30	214.3	3	23	1
220	65.37	214.5	29	32	1
221	66.21	217.2	112	25	1
222	66.36	217.7	269	47	1
223	66.43	217.9	261	51	1
224	66.60	218.5	95	65	1
225	66.66	218.7	358	29	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-35

27 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	66.67	218.7	246	45	1
227	67.00	219.8	127	51	1
228	67.09	220.1	104	38	1
229	67.19	220.4	151	52	1
230	67.44	221.3	8	13	1
231	67.49	221.4	205	42	1
232	67.51	221.5	184	73	1
233	67.72	222.2	195	81	1
234	67.92	222.8	300	52	1
235	67.99	223.1	340	85	1
236	68.01	223.1	162	17	1
237	68.12	223.5	37	51	1
238	68.16	223.6	47	42	1
239	68.52	224.8	232	73	1
240	68.57	225.0	81	53	1
241	68.69	225.4	119	48	1
242	68.79	225.7	320	69	1
243	68.80	225.7	99	57	1
244	68.89	226.0	58	50	1
245	69.19	227.0	73	65	1
246	69.20	227.0	48	37	1
247	69.30	227.4	58	45	1
248	69.30	227.4	48	58	2
249	69.43	227.8	19	42	1
250	69.45	227.9	290	66	1
251	69.68	228.6	20	54	1
252	69.90	229.3	36	51	1
253	69.91	229.4	114	36	1
254	69.97	229.6	159	64	1
255	70.06	229.9	43	35	1
256	70.21	230.4	345	57	1
257	70.24	230.5	209	48	1
258	70.29	230.6	51	38	1
259	70.38	230.9	100	37	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-35
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-35
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79960 N
Longitude: 84.77182 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 499.2'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	27 July 2019	27 July 2019	27 July 2019	
RUN NUMBER	1	1	1	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	231.24'	231.24'	231.24'	
DEPTH-LOGGER	231'	231'	231'	
BTM LOG INTERVAL	230.9'	231.3'	229.5'	
TOP LOG INTERVAL	155.5'	0.0'	0.0'	
RECORDED BY	JBG	JBG	JBG	
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP	Conrad Fischer-WSP	
PROBE TYPE, S/N	TDCS #3463	3ACS #3596	ELXG #4314	
LOGGING SPEED	15 fpm	10 fpm	15fpm	
A.S.D.E. / Sample Interval	0.2' / 0.10'	0.31' / 0.10'	0.11' / 0.25'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

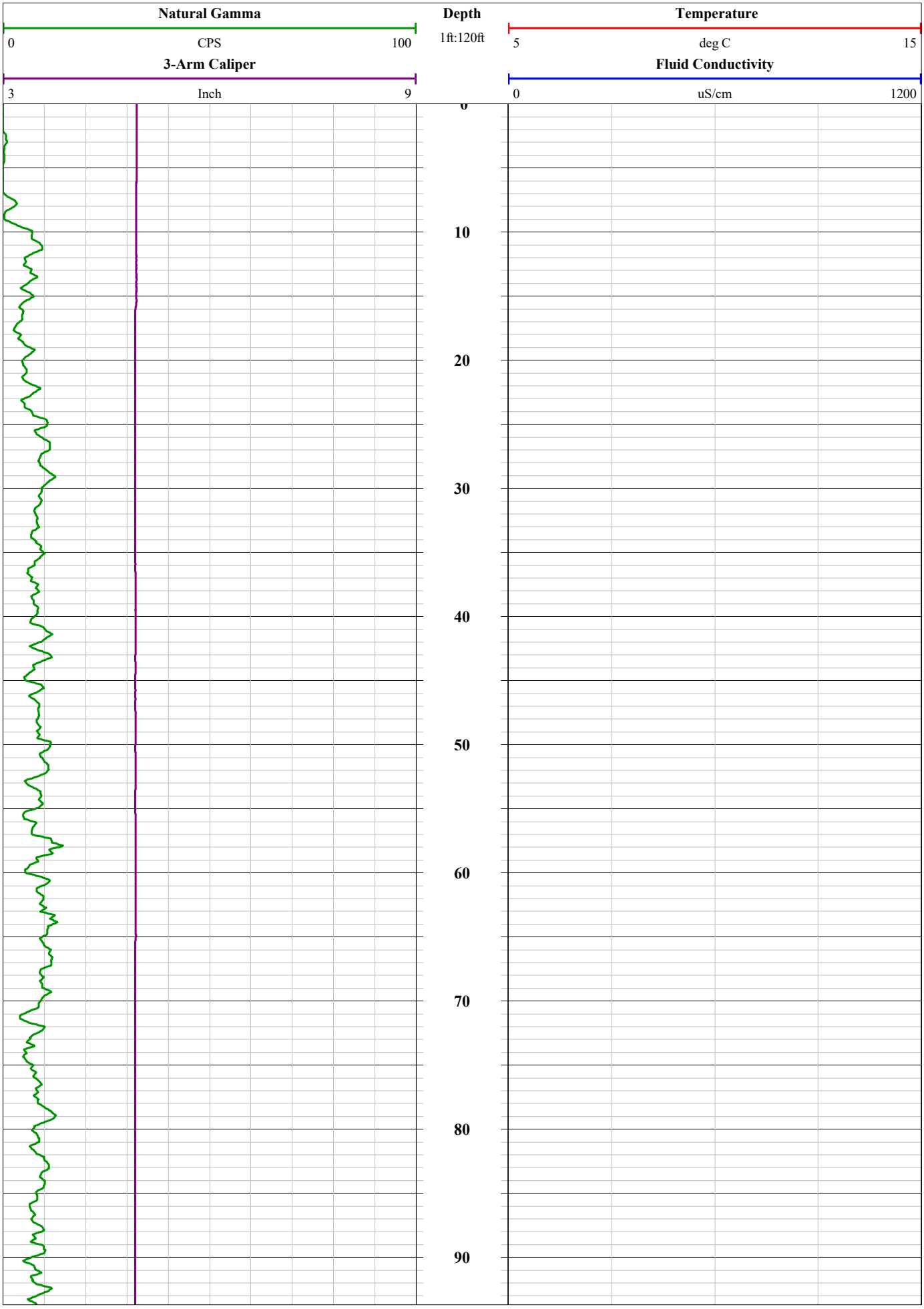
RUN No.	BIT	FROM	TO
1	7"	Mudline	13.45'
2	6"	13.45'	TD

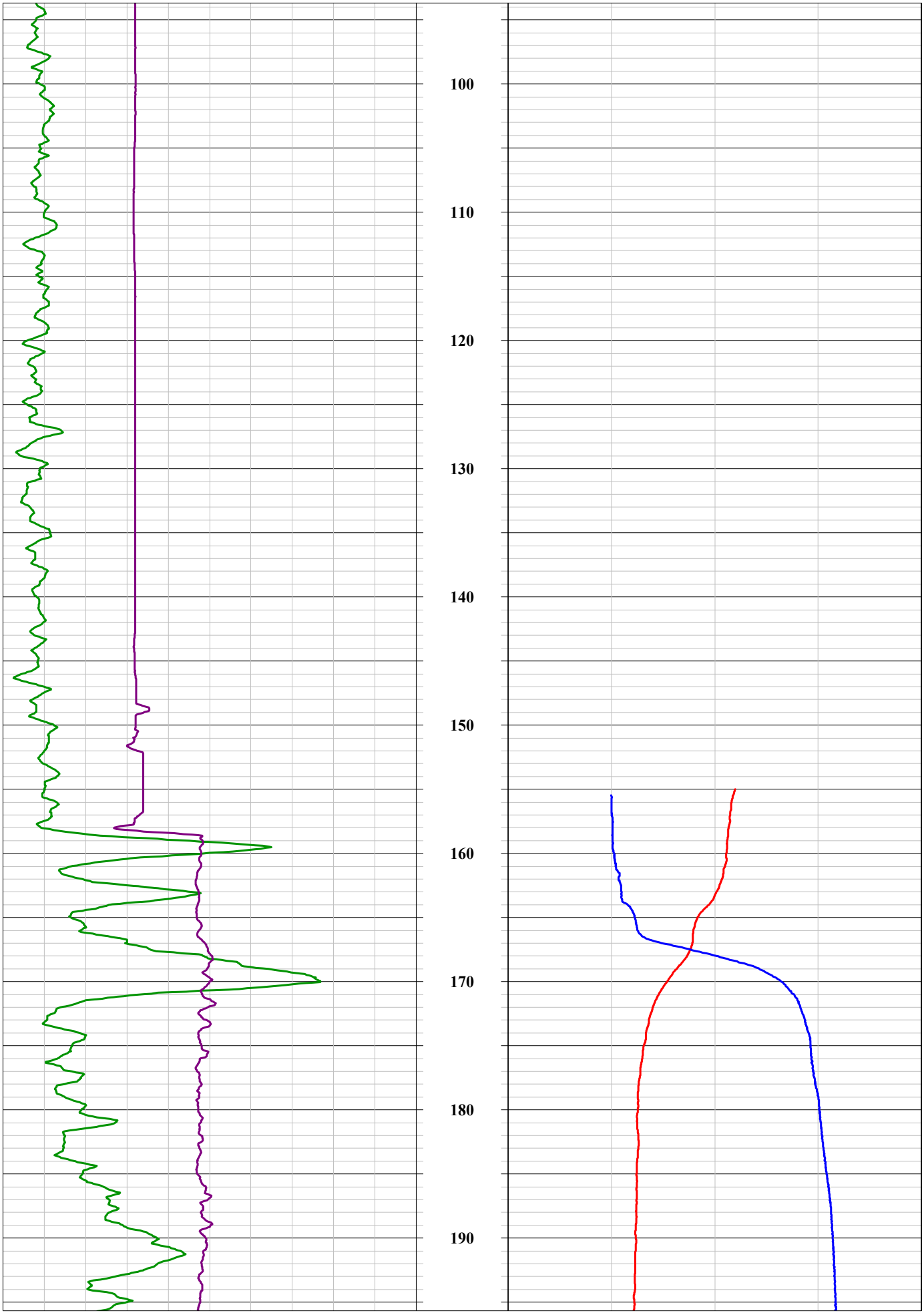
CASING RECORD

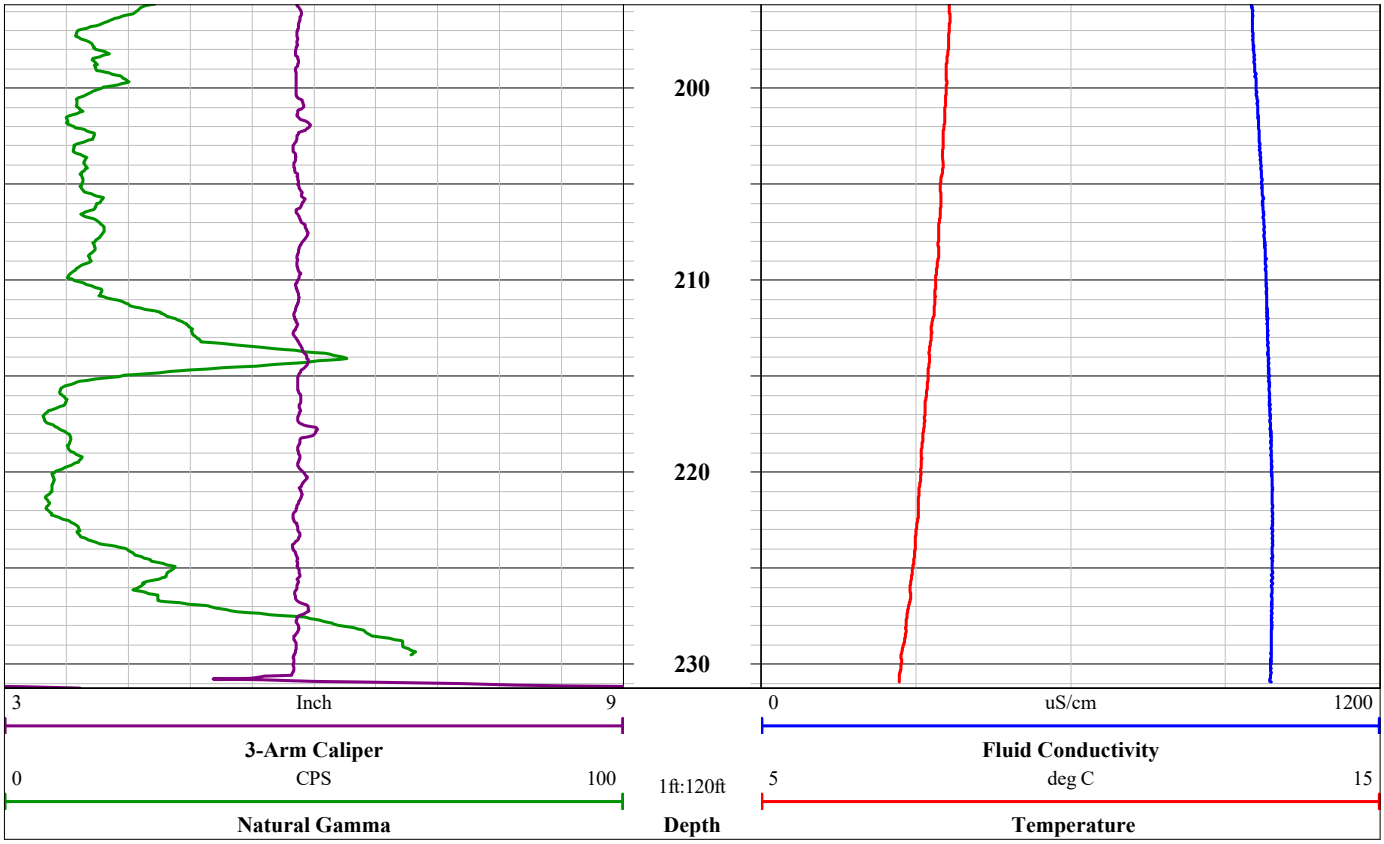
SIZE	WGT.	FROM	TO
7"	Steel	SU	13.45'
6"	Steel	SU	158.8'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
3
Inch
9
Depth
1ft:120ft
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
1200
0
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
3
Inch
9
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1200
Fluid Conductivity
5
deg C
15
Temperature

Borehole Deviation

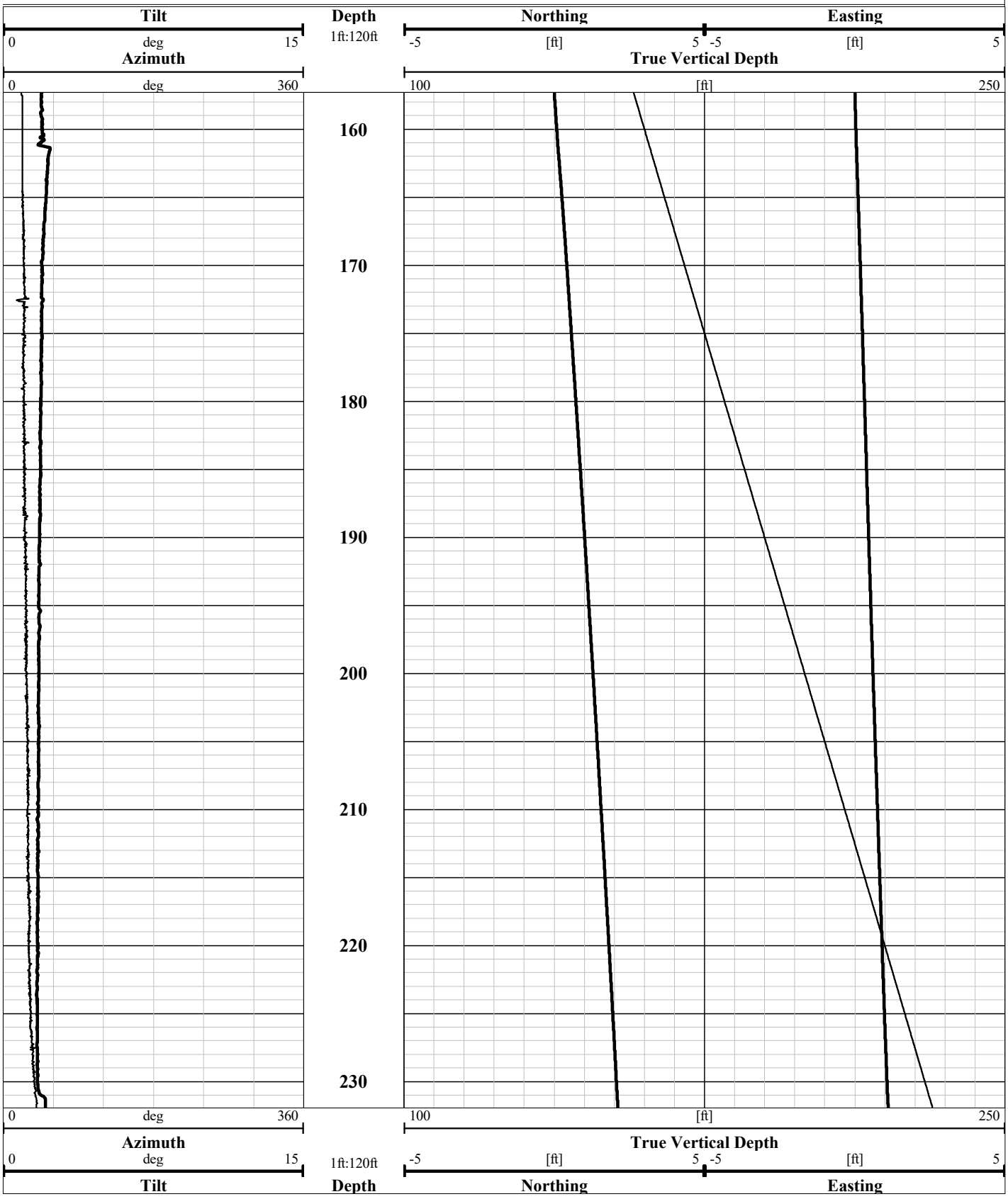
COLOG
borehole geophysics / hydrophysics

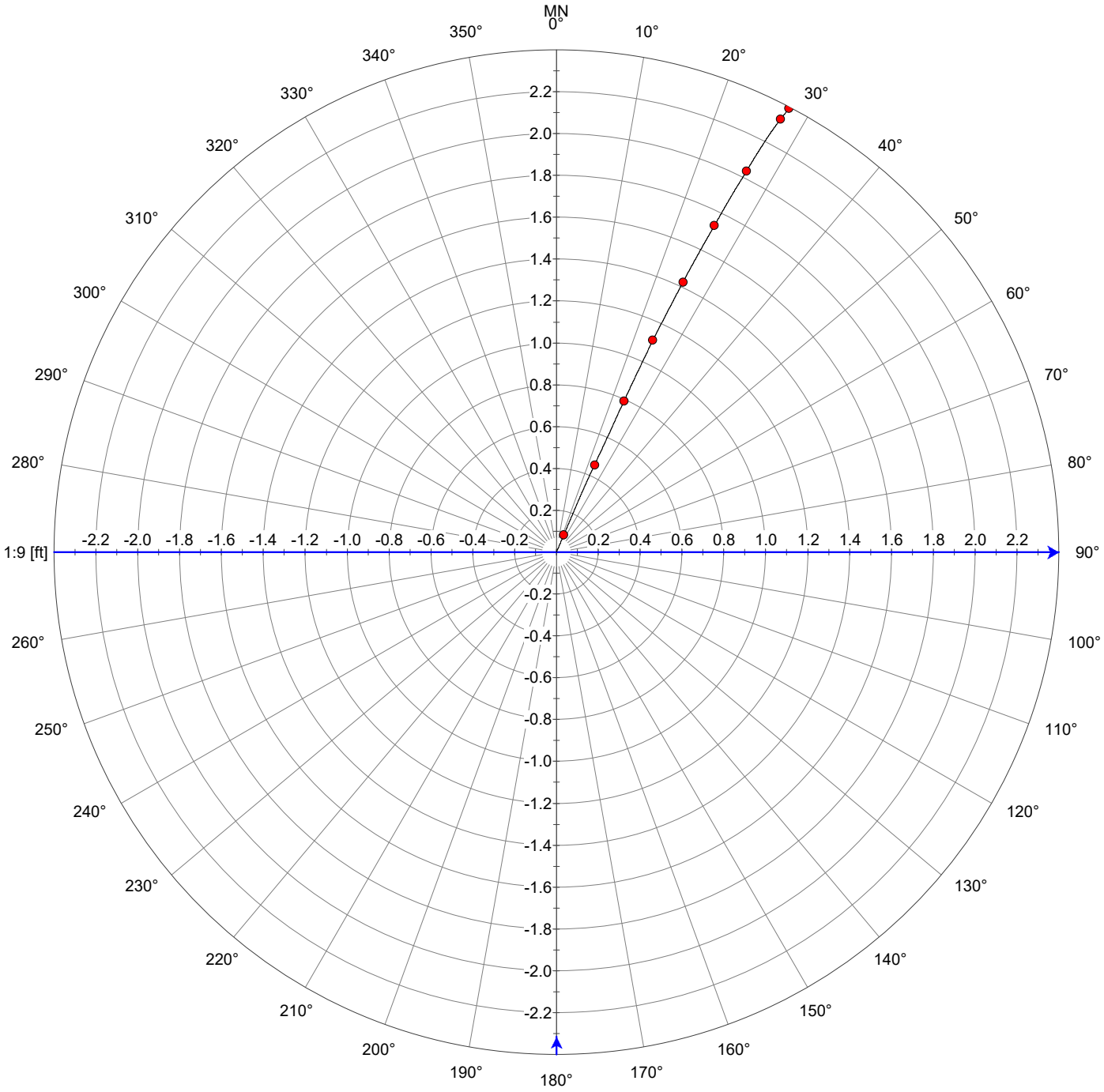
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 27 July 2019	WELL: BH19-35 - Mid Strait

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 499.2'** **Latitude: 45.79960 N** **Longitude: 84.77182 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1:9 [ft]
-2.2 -2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
-2.2 -2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-35
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-35
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79960 N
Longitude: 84.77182 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
3-Arm Caliper

PERMANENT DATUM Mudline **ELEVATION** 499.2'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	27 July 2019	27 July 2019		
RUN NUMBER	2	2		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	232.24'	232.24'		
DEPTH-LOGGER	231'	231'		
BTM LOG INTERVAL	229.5'	230.8'		
TOP LOG INTERVAL	0.0	150'		
RECORDED BY	JBG	JBG		
WITNESSED BY	Conrad Fischer-WSP	Conrad Fischer-WSP		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	15 fpm	15 fpm		
A.S.D.E. / Sample Interval	0.11' / 0.25'	0.11' / 0.25'		
Fluid Level / Fluid Type	NA/water	NA/water		

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	7"	Mudline	13.45'
2	6"	13.45'	TD

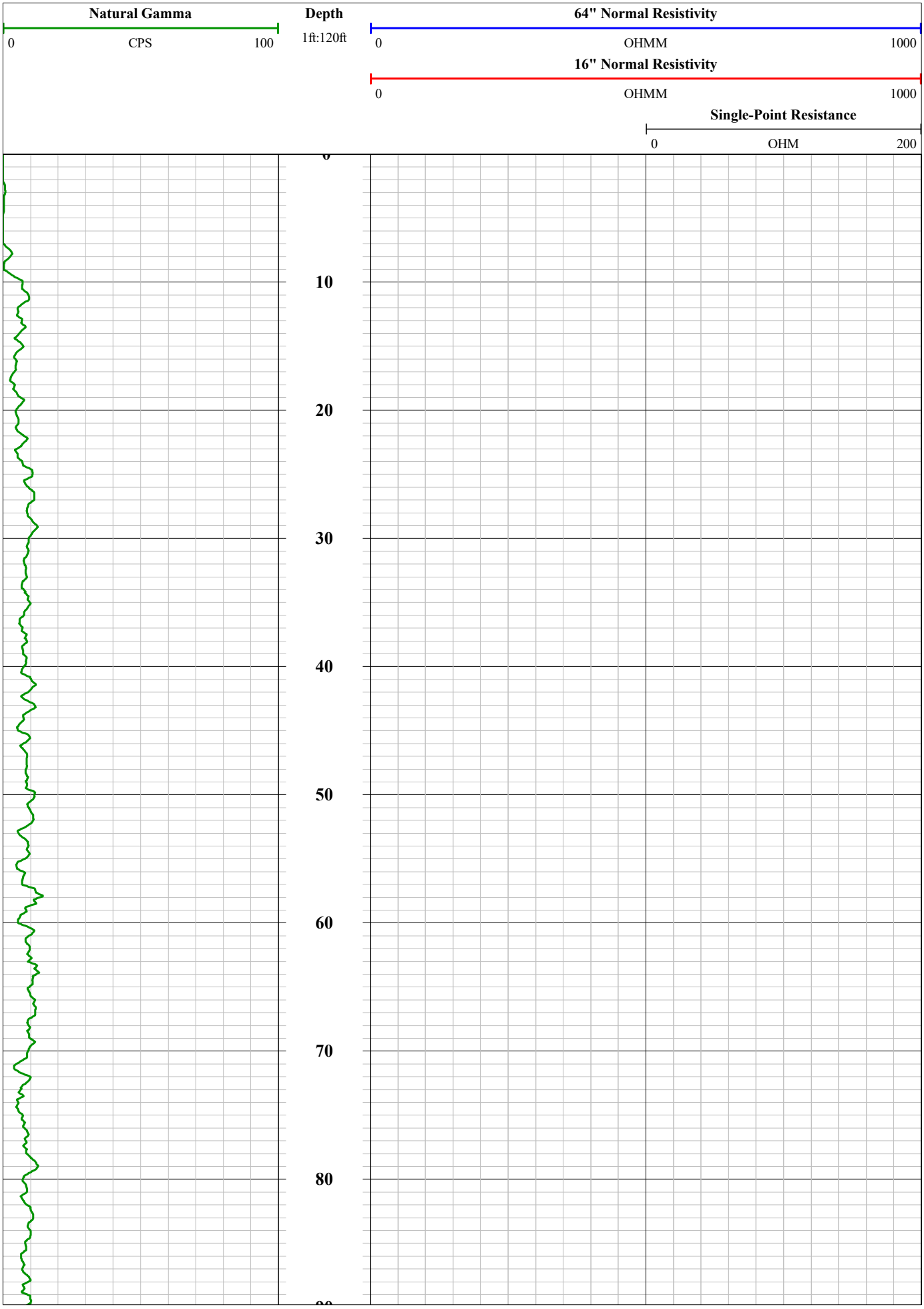
CASING RECORD

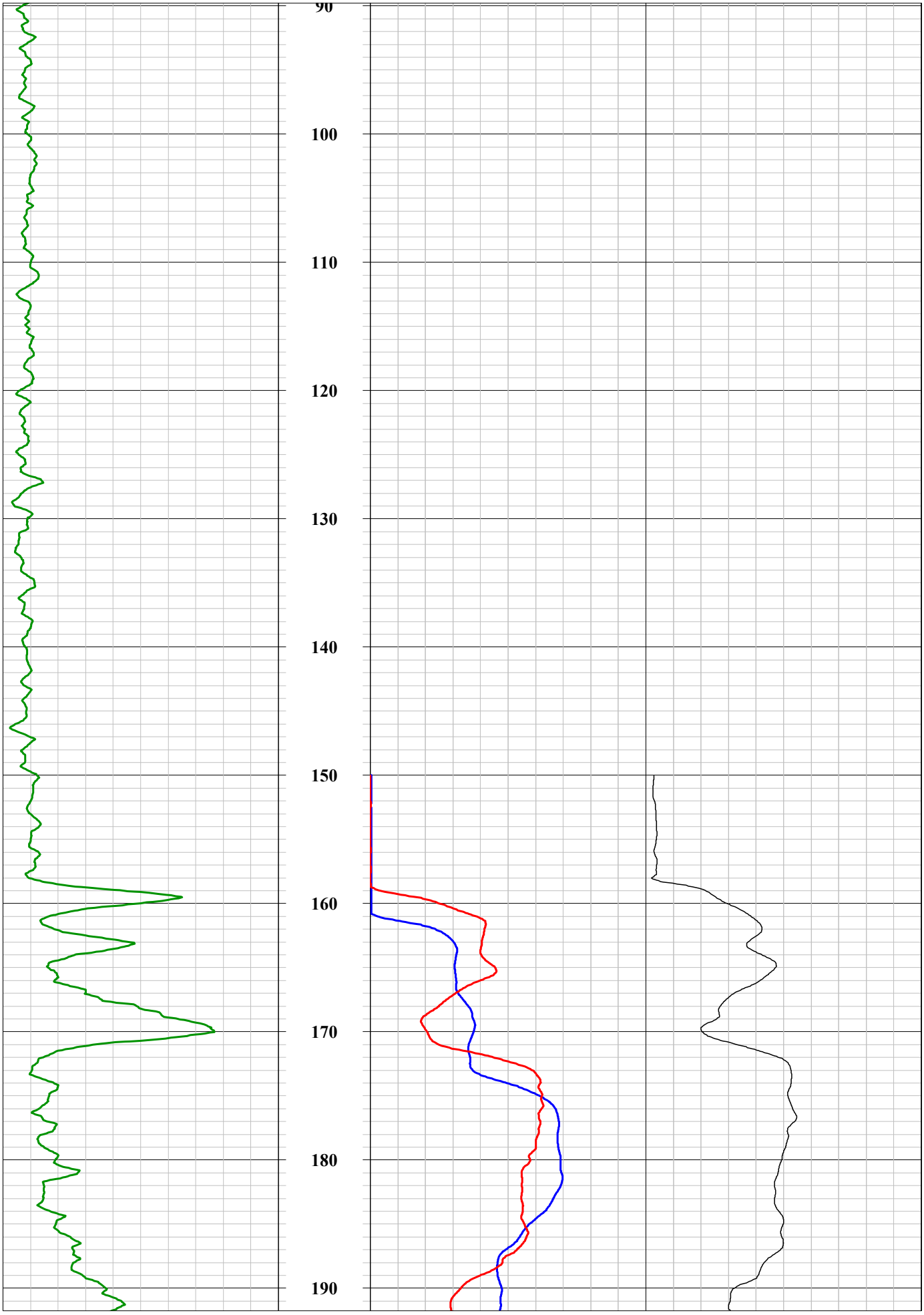
SIZE	WGT.	FROM	TO
7"	Steel	SU	13.45'
6"	Steel	SU	158.8'

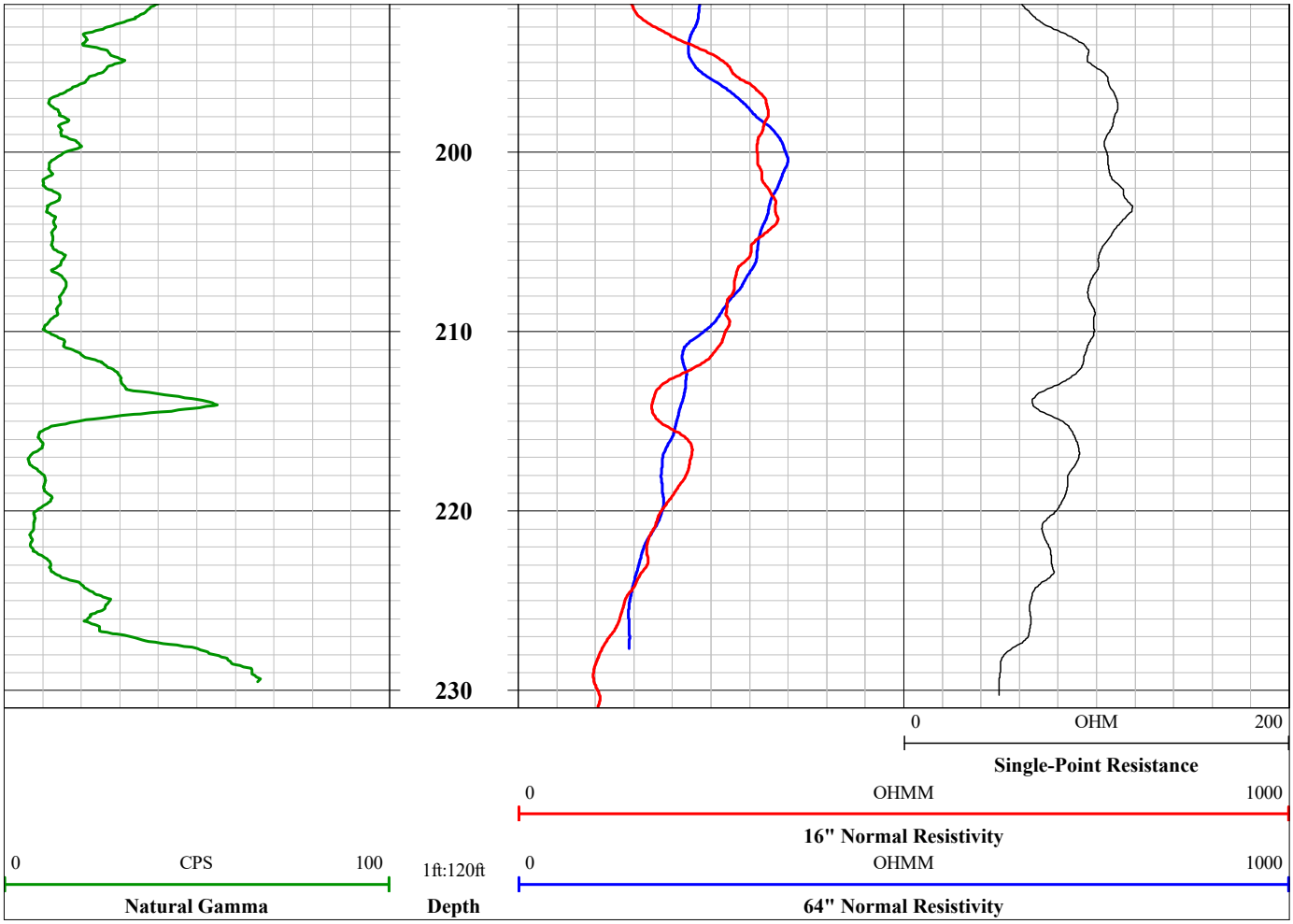
NA - Not Available, N/A - Not Applicable

COMMENTS

Spontaneous Potential omitted due to configuration error.


Natural Gamma
0
CPS
100
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
1000
16" Normal Resistivity
0
OHMM
1000
Single-Point Resistance
0
OHM
200
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
220
230
0
OHM
200
Single-Point Resistance
0
OHMM
1000
16" Normal Resistivity
0
CPS
100
1ft:120ft
0
OHMM
1000
Natural Gamma
Depth
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-35
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-35
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79960 N
Longitude: 84.77182 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
Acoustic Televiewer

PERMANENT DATUM Mudline **ELEVATION** 499.2'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	27 July 2019			
RUN NUMBER	4			
LOG TYPE	PSLog			
DEPTH-DRILLER	231.24'			
DEPTH-LOGGER	220'			
BTM LOG INTERVAL	220'			
TOP LOG INTERVAL	156'			
RECORDED BY	JBG			
WITNESSED BY	Conrad Fischer-WSP			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	0.03'/2.0'			
Fluid Level / Fluid Type	NA'/Water			

BOREHOLE RECORD

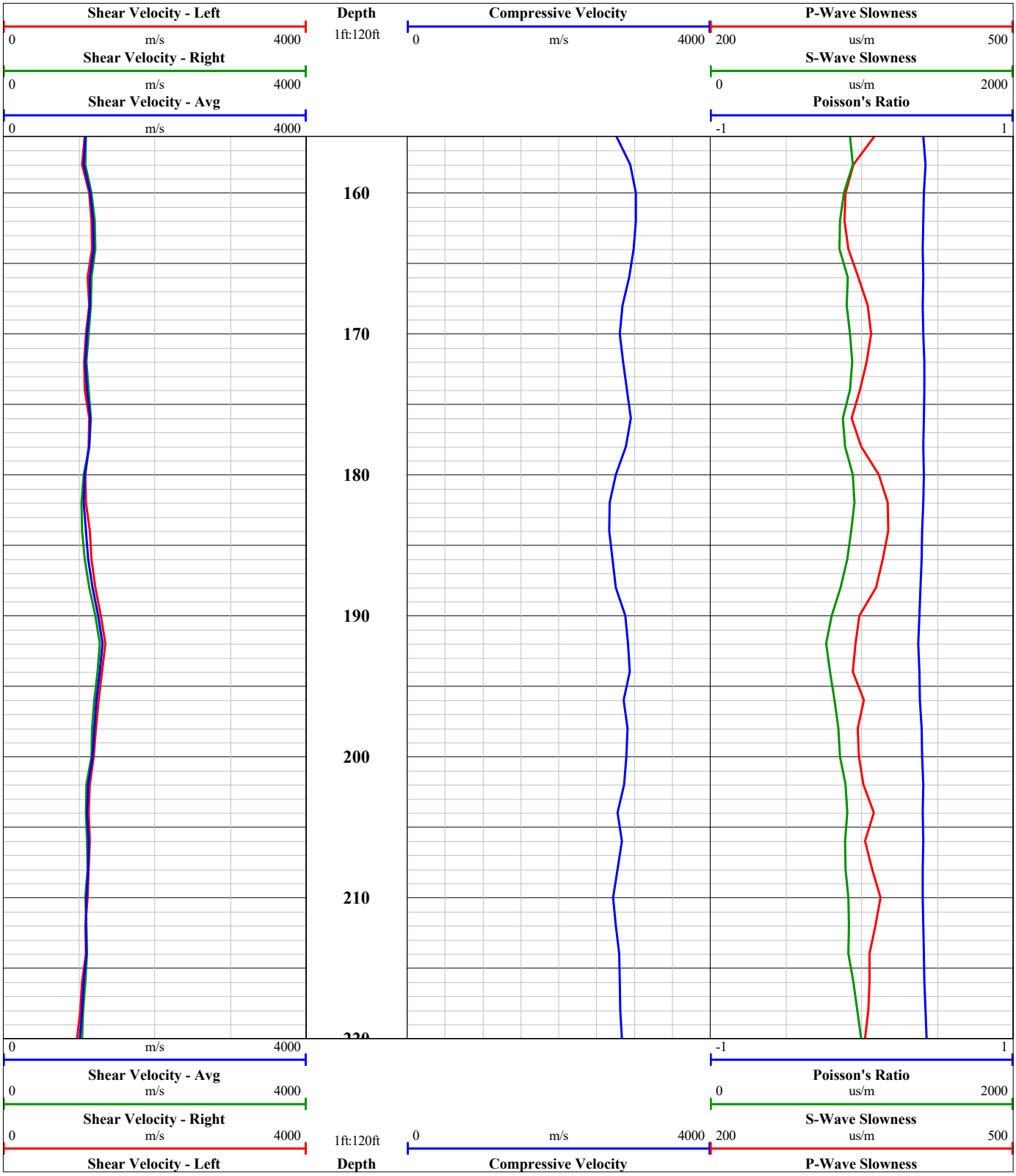
RUN No.	BIT	FROM	TO
1	7"	Mudline	13.45'
2	6"	13.45'	TD

CASING RECORD

SIZE	WGT.	FROM	TO
7"	Steel	SU	13.45'
6"	Steel	SU	158.8'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
160
170
180
190
200
210
220
Compressive Velocity
0
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
Depth
1ft:120ft
0
m/s
4000
Compressive Velocity
-1
1
Poisson's Ratio
0
us/m
2000
S-Wave Slowness
200
us/m
500
P-Wave Slowness

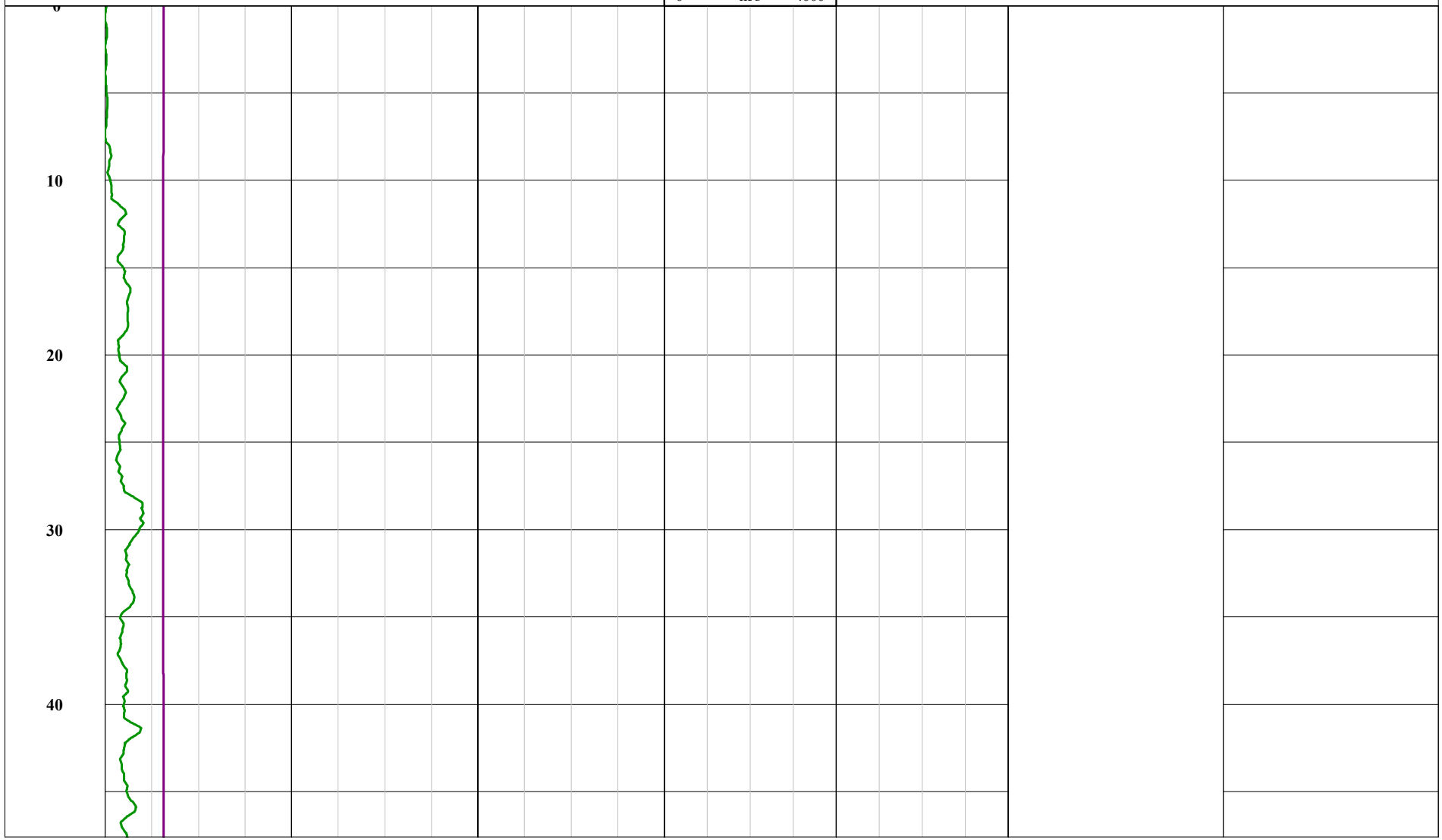
Geophysical Summary Plot

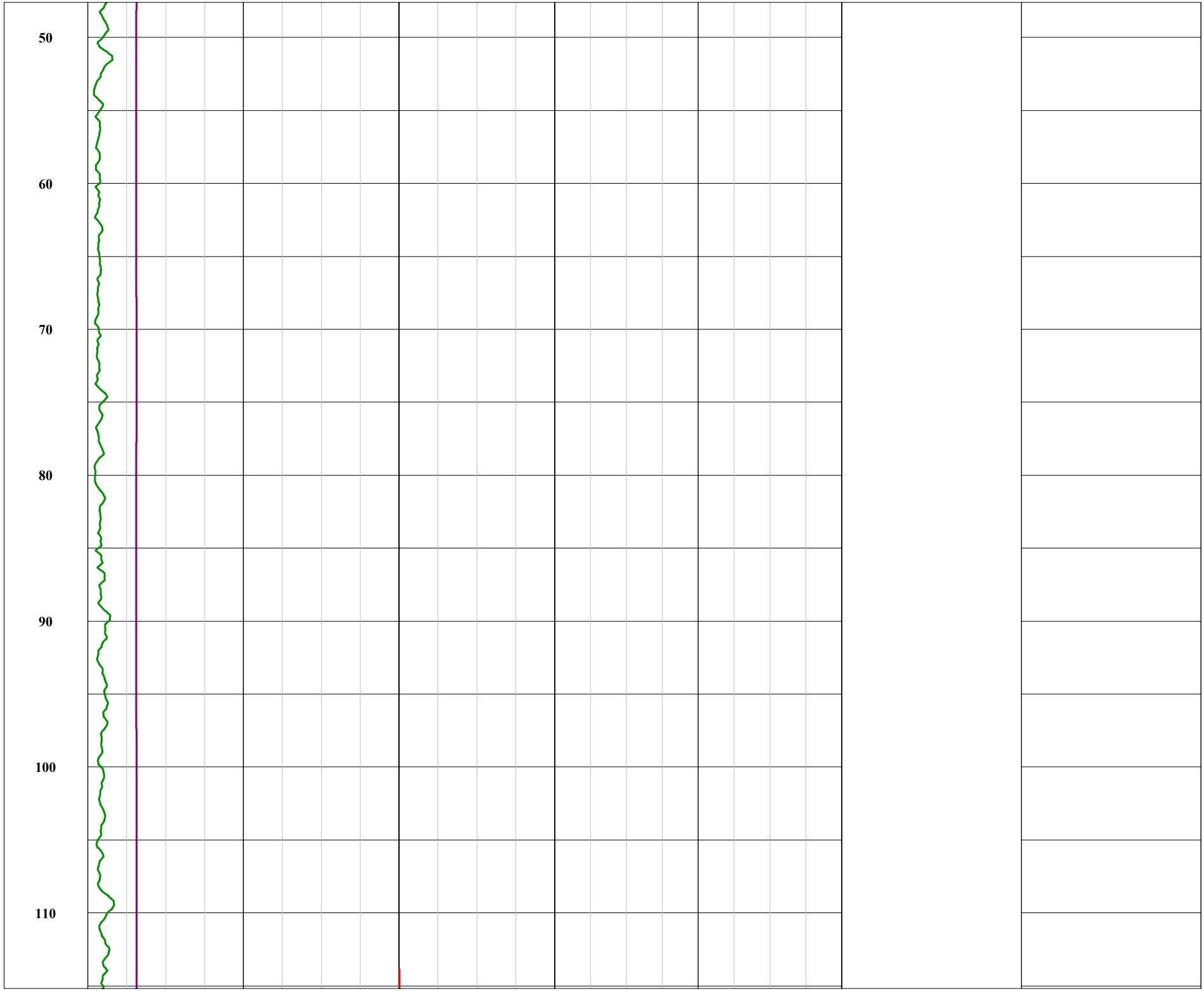
COLOG
borehole geophysics / hydrophysics

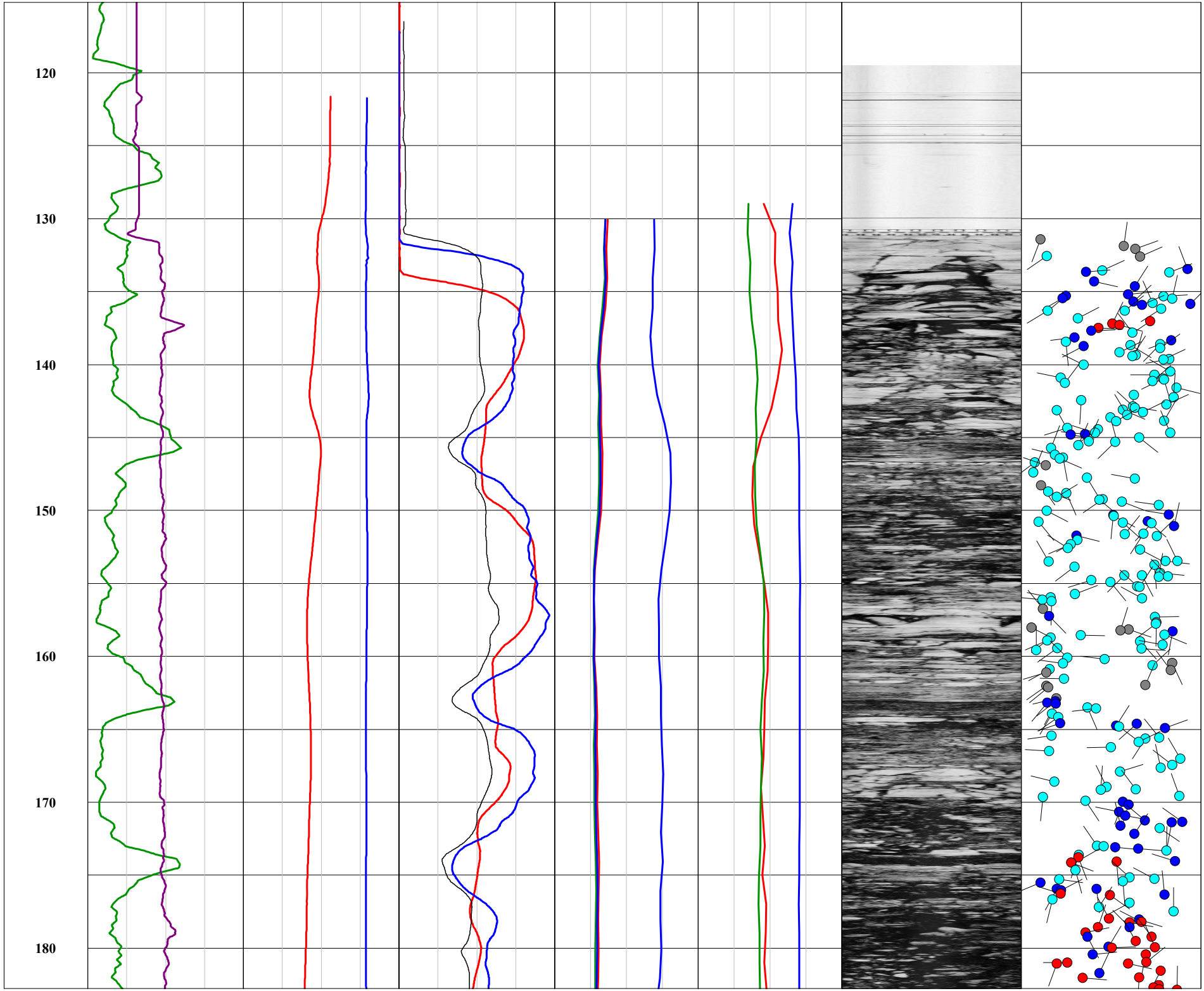
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 16 September 2019
WELL: BH19-36 - Mid Strait

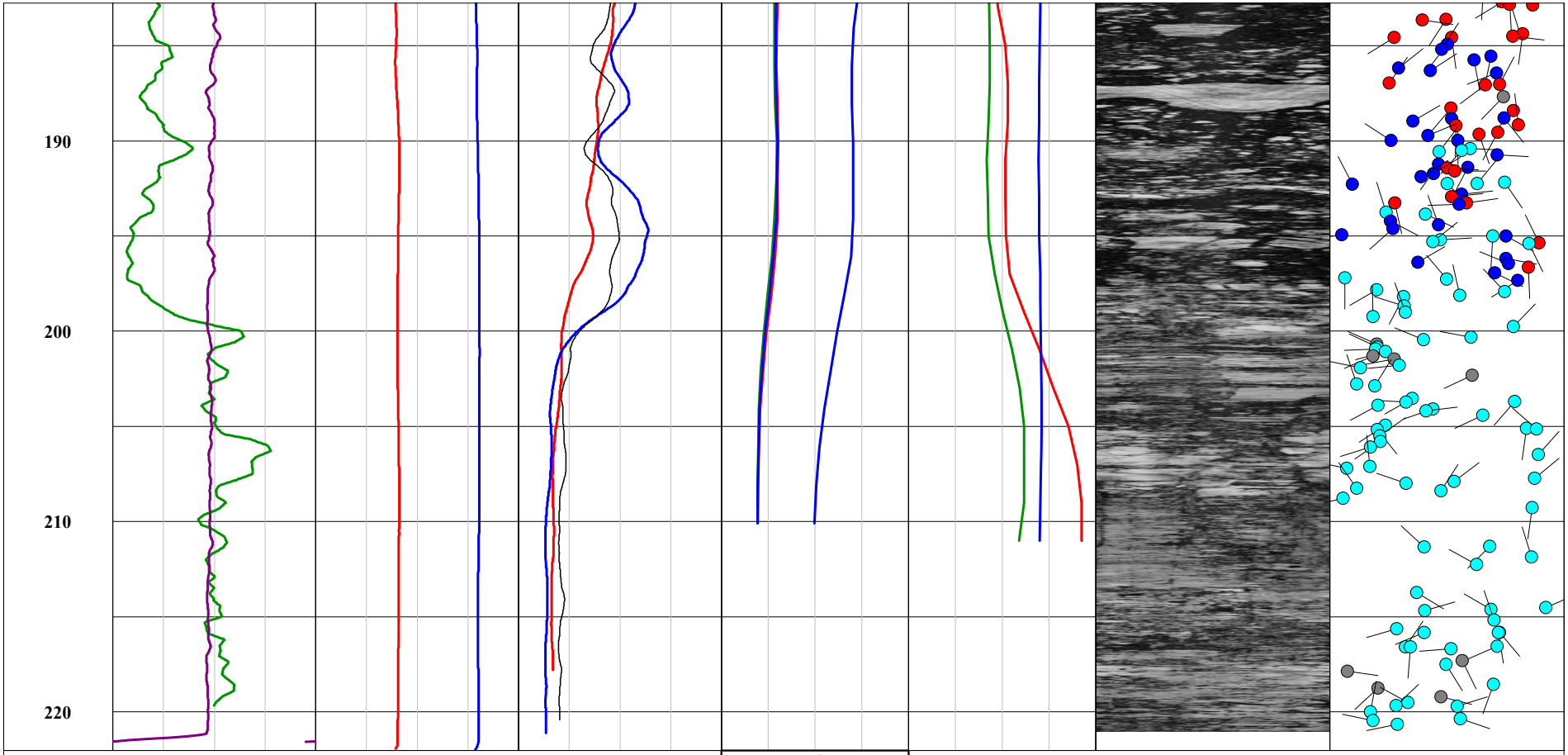
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	Temperature	64" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Amplitude-MN	Tadpoles
1ft:100ft	0 CPS 100	5 deg C 15	0 Ohm-m 500	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	**Fluid Conductivity**	**16" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**		
	3 Inch 9	0 uS/cm 1200	0 Ohm-m 500	0 m/s 4000	0 us/m 2000		
			Single-Point Resistance	**Shear Velocity - Avg**	**Poisson's Ratio**		
			0 OHM 250	0 m/s 4000	-1 1		
				Compressive Velocity			
				0 m/s 4000			




50
60
70
80
90
100
110


120
130
140
150
160
170
180



				0 m/s 4000 **Compressive Velocity**			
			0 OHM 250 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-1 1 **Poisson's Ratio**		
	3 Inch 9 **3-Arm Caliper**	0 uS/cm 1200 **Fluid Conductivity**	0 Ohm-m 500 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**		
1ft:100ft	0 CPS 100	5 deg C 15	0 Ohm-m 500	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0 90
Depth	**Natural Gamma**	**Temperature**	**64" Normal Resistivity**	**Shear Velocity - Left**	**P-Wave Slowness**	**Amplitude-MN**	**Tadpoles**

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-36
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-36
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79716 N
Longitude: 84.77391 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Mudline **ELEVATION** 502.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 September 2019			
RUN NUMBER	5			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	221.4'			
DEPTH-LOGGER	221.71'			
BTM LOG INTERVAL	221.71			
TOP LOG INTERVAL	120.04'			
RECORDED BY	JBG/DRE			
WITNESSED BY	Duncan			
PROBE TYPE, S/N	ALT ABI/#111018			
LOGGING SPEED	5 fpm			
A.S.D.E. / Sample Interval	.008			
Fluid Level / Fluid Type	NA/water			

BOREHOLE RECORD

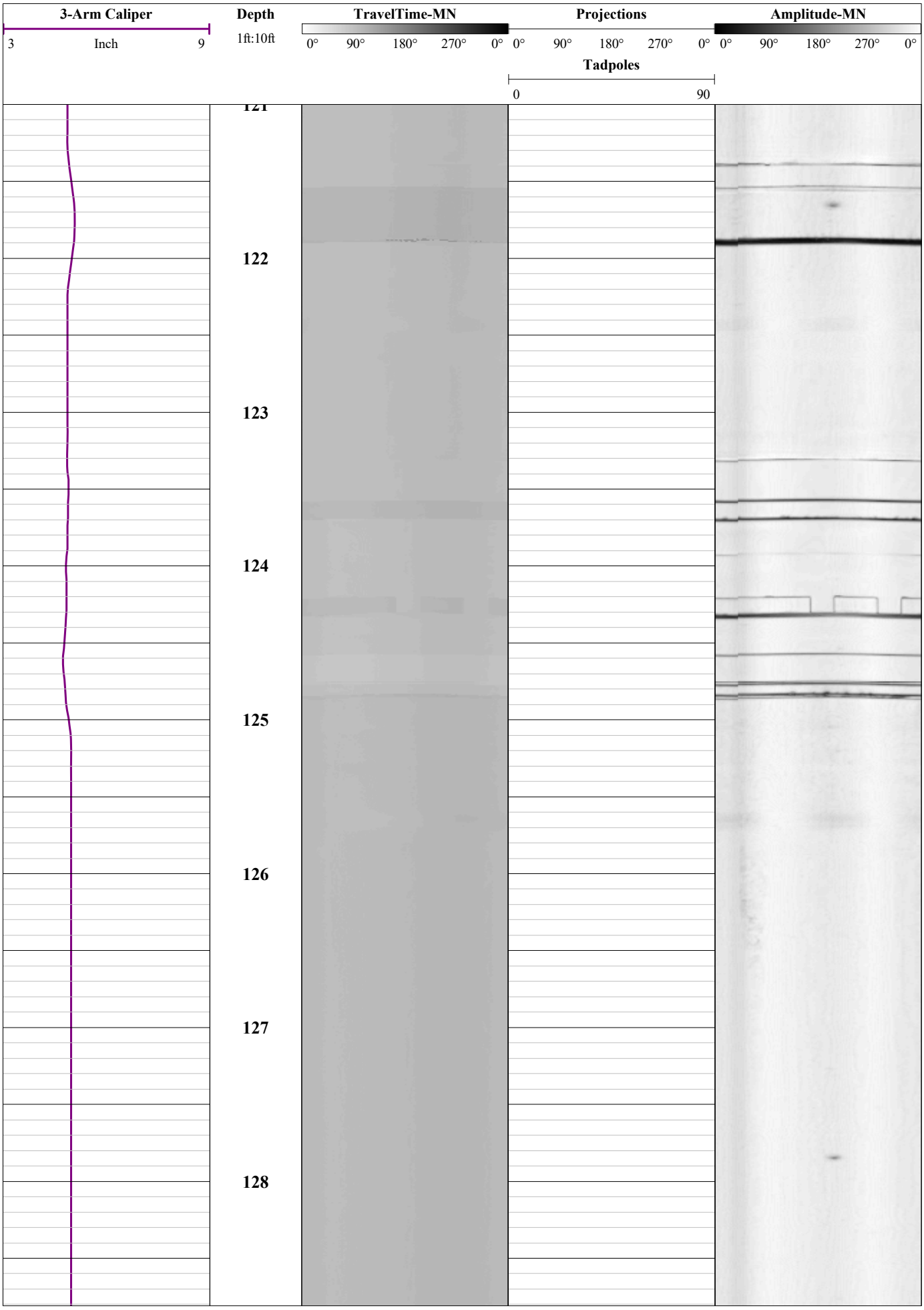
RUN No.	BIT	FROM	TO
1	5.5"	Mudline	TD

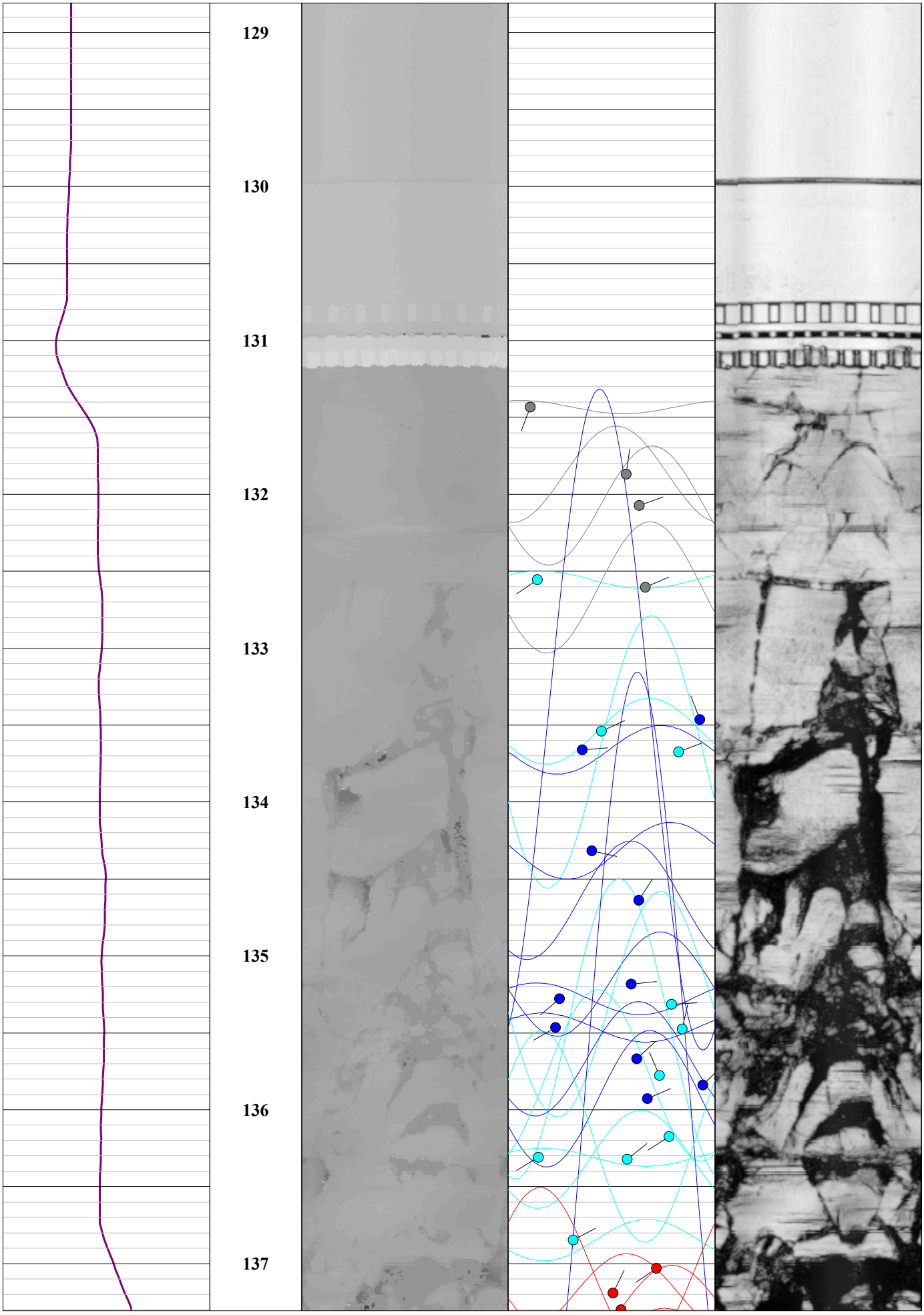
CASING RECORD

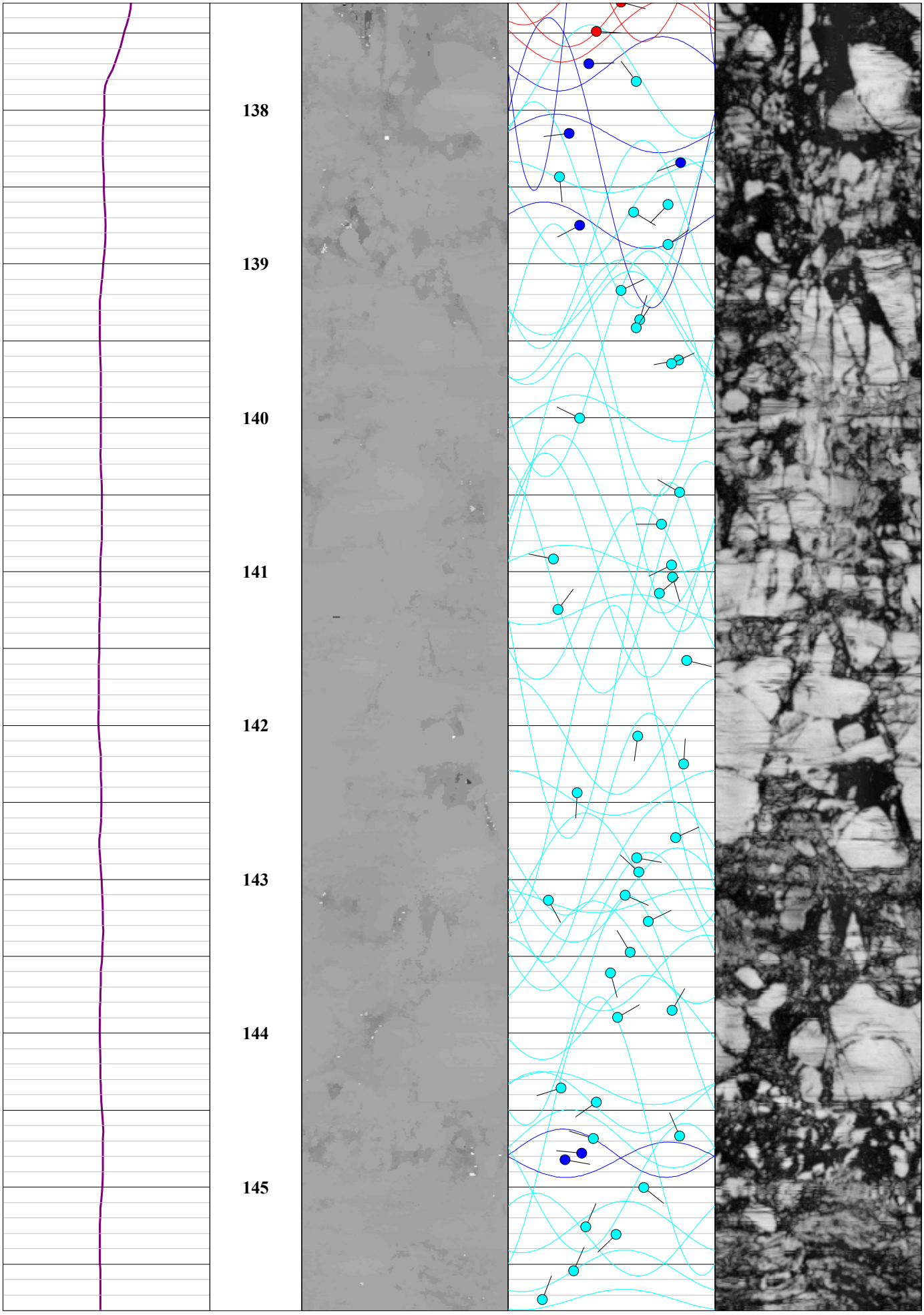
SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	130.9'
7"	Steel	Mudline	27.88'

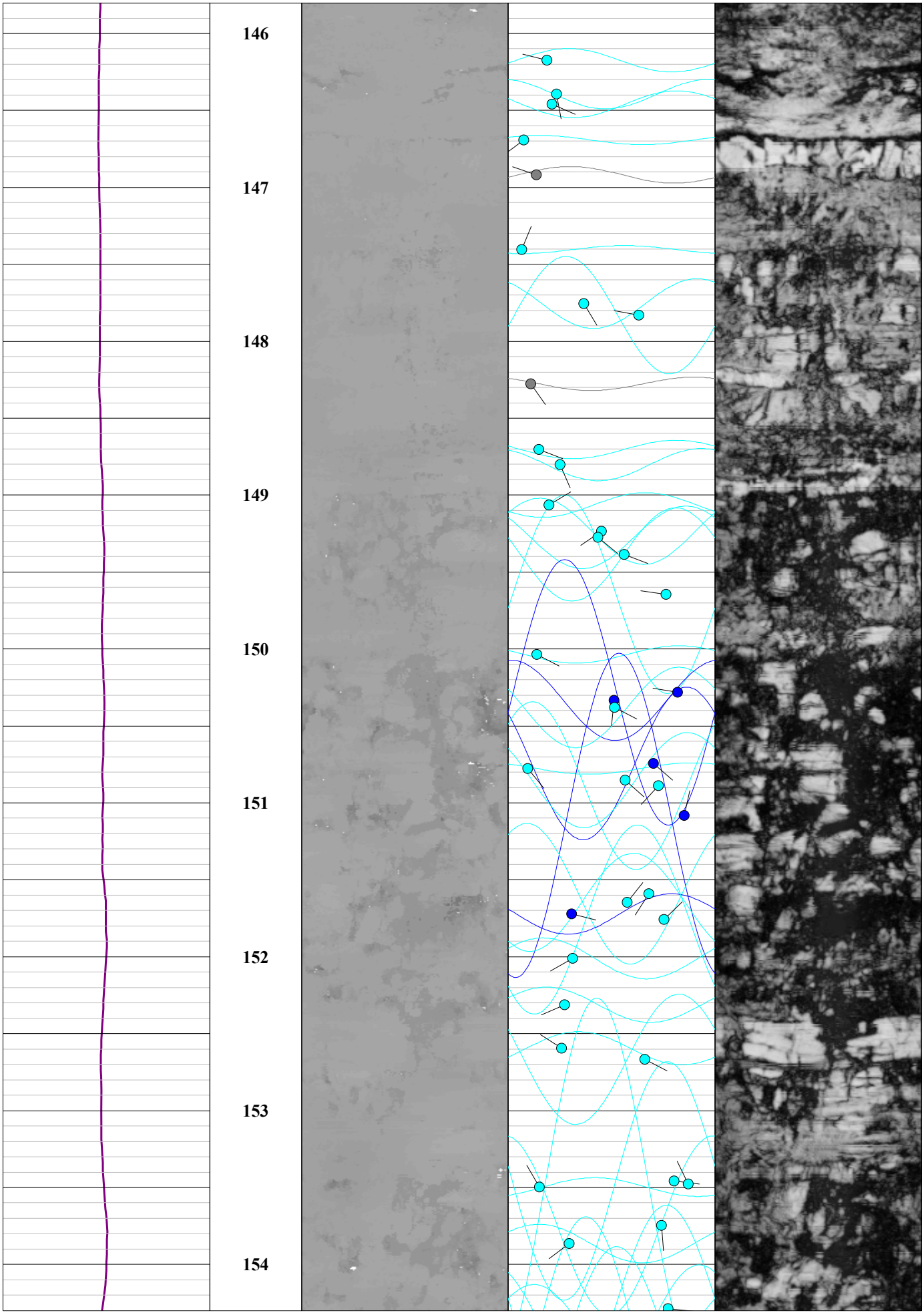
NA - Not Available, N/A - Not Applicable

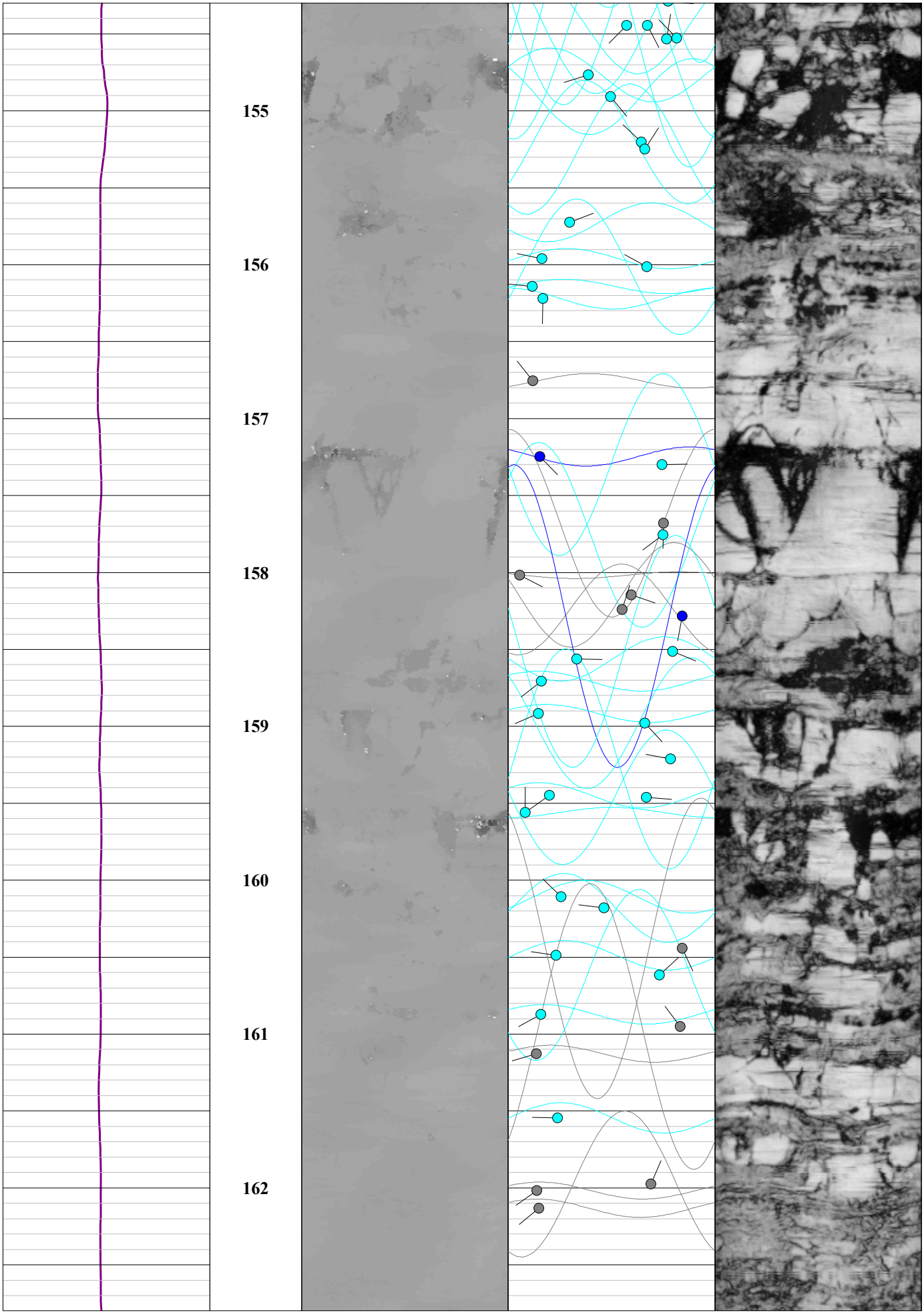
COMMENTS

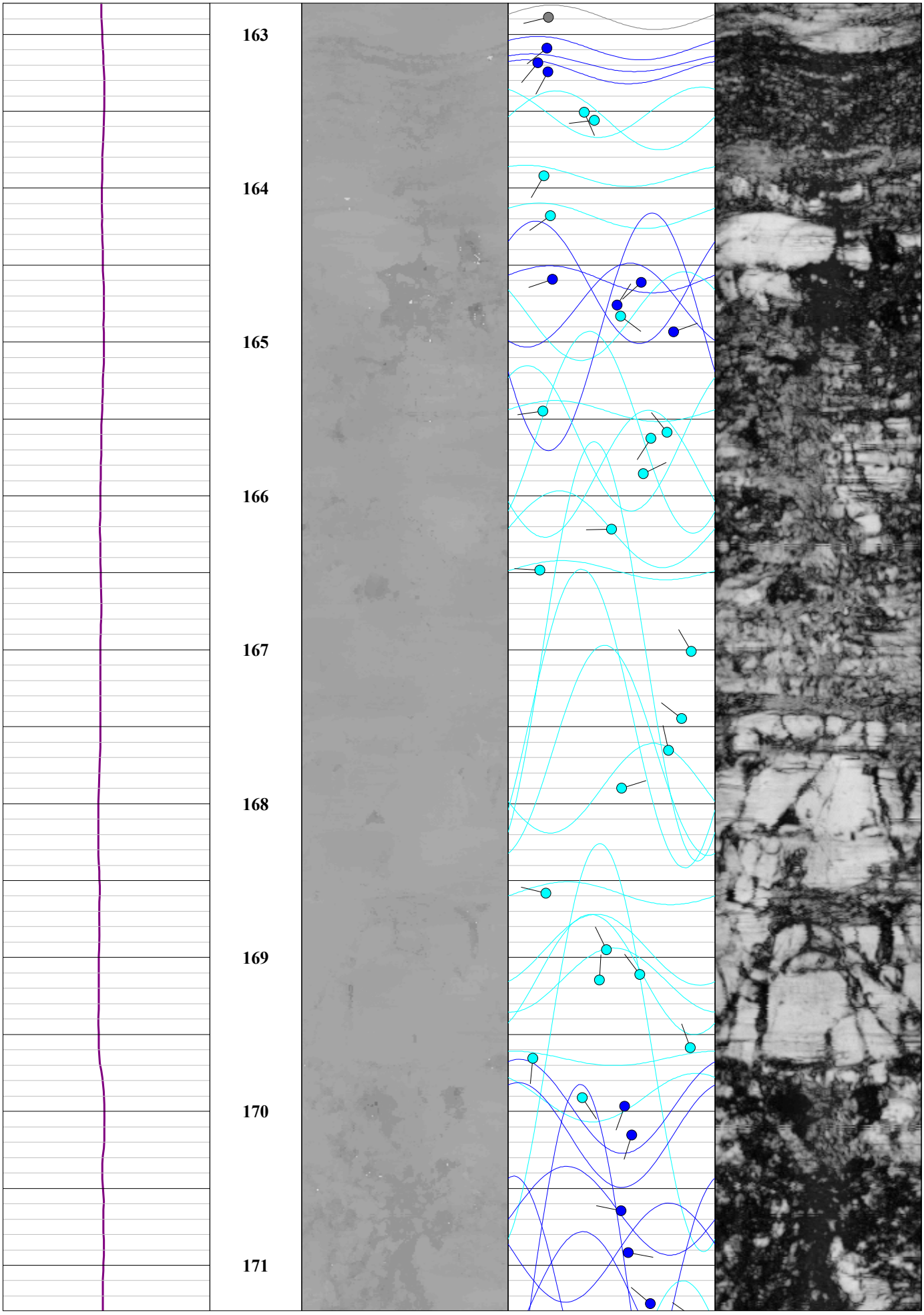

3-Arm Caliper
3
Inch
9
Depth
1ft:10ft
TravelTime-MN
0°
90°
180°
270°
0°
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
Amplitude-MN
0°
90°
180°
270°
0°
121
122
123
124
125
126
127
128

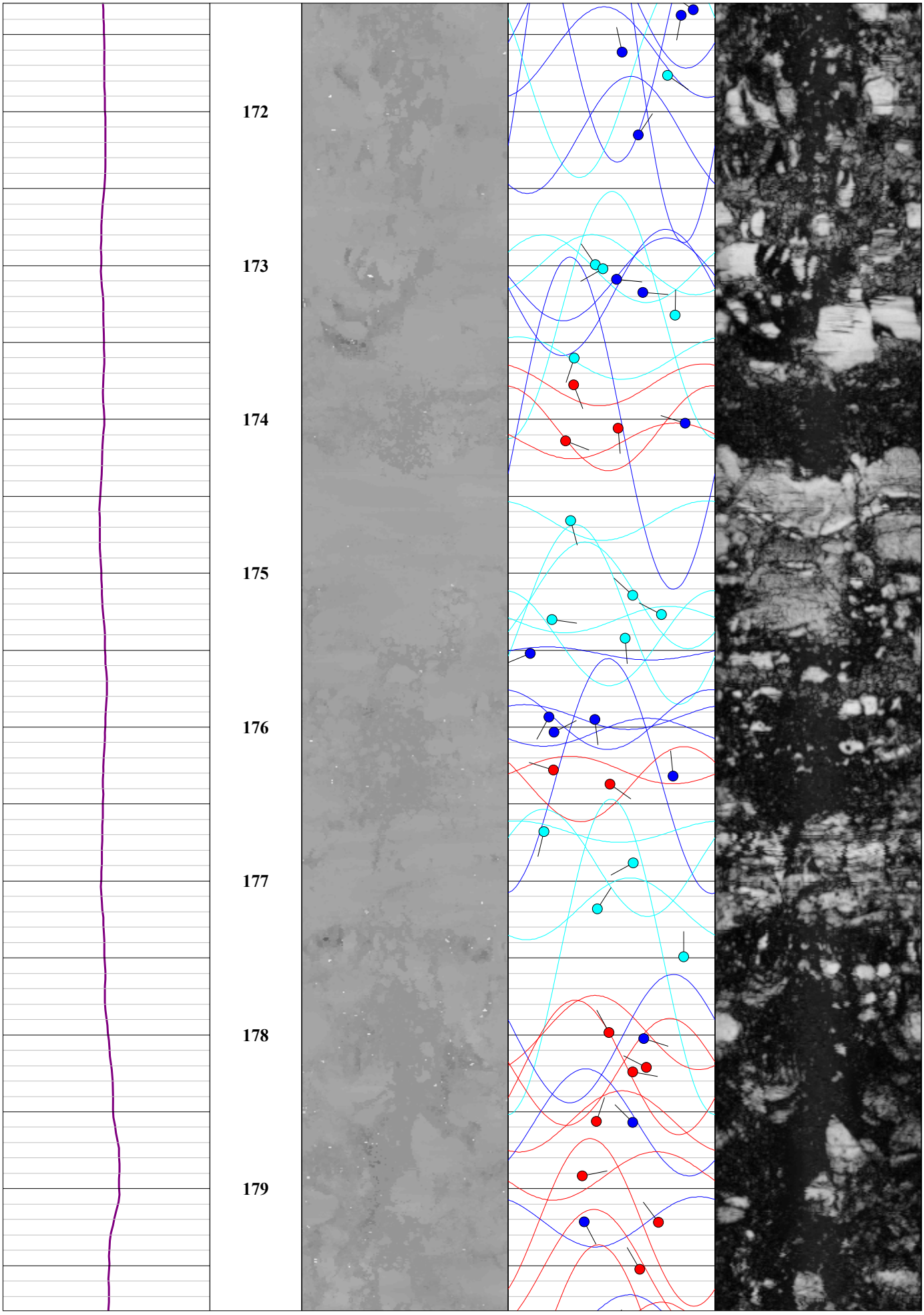

129
130
131
132
133
134
135
136
137

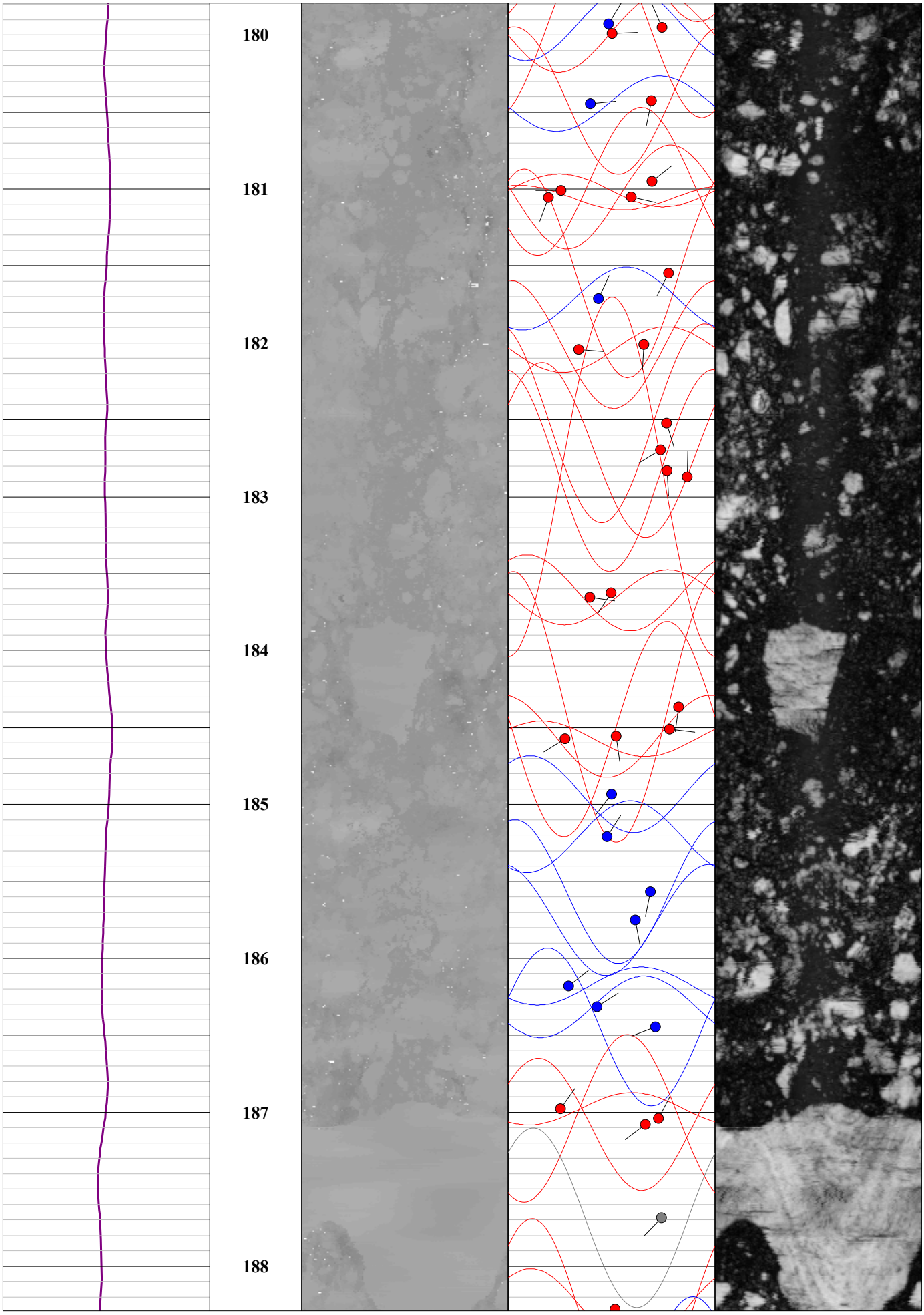

138
139
140
141
142
143
144
145

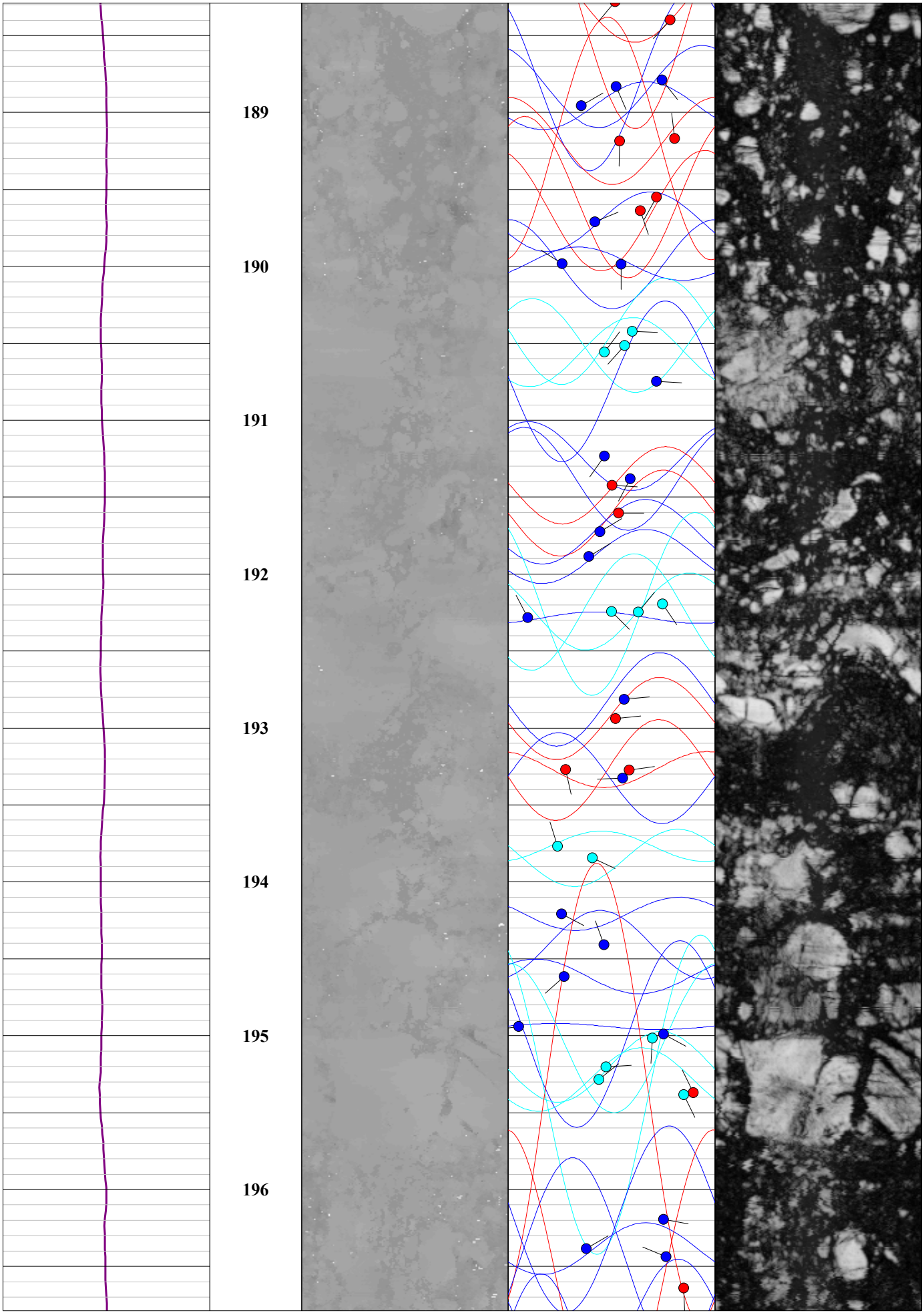

146
147
148
149
150
151
152
153
154

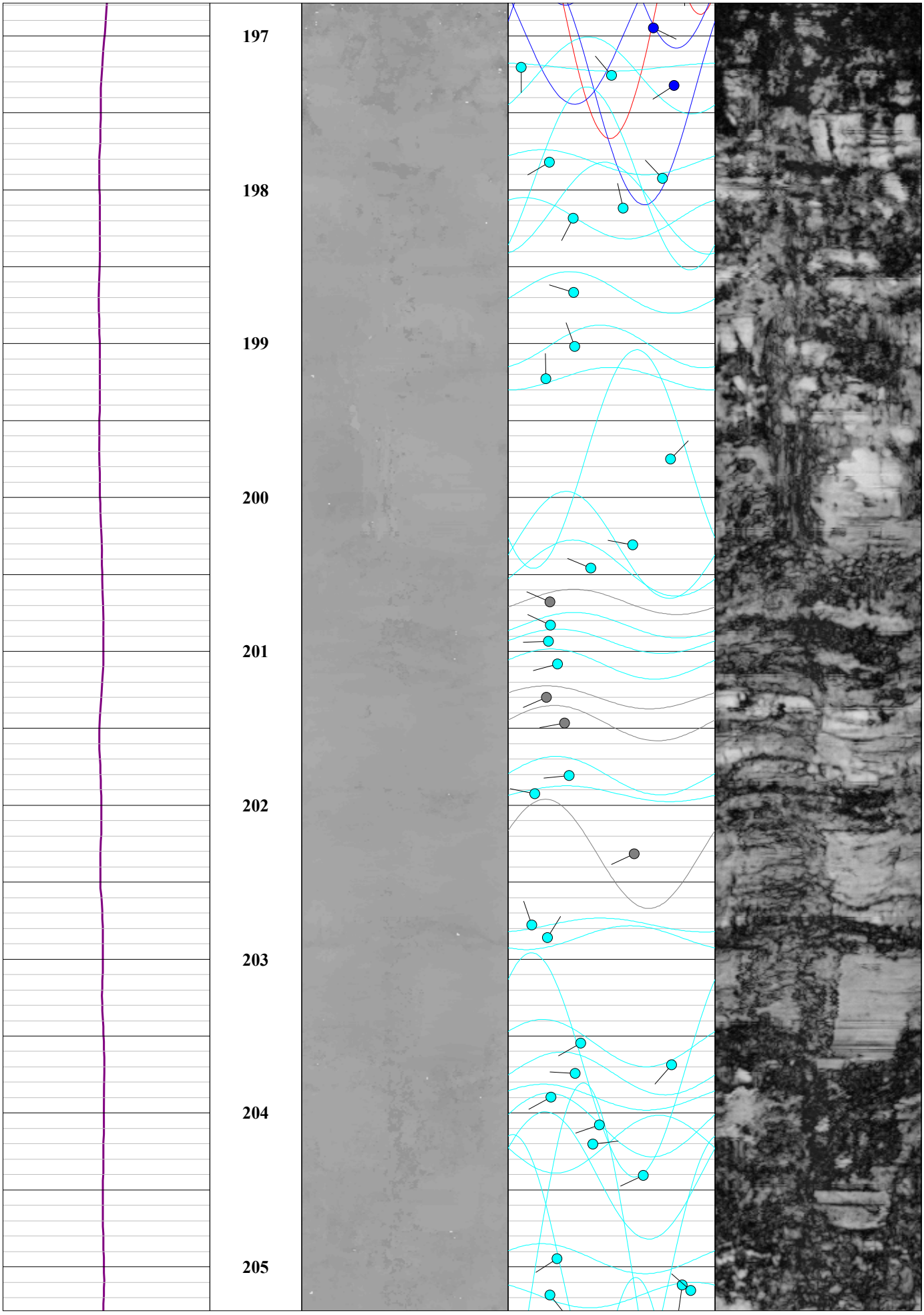

155
156
157
158
159
160
161
162

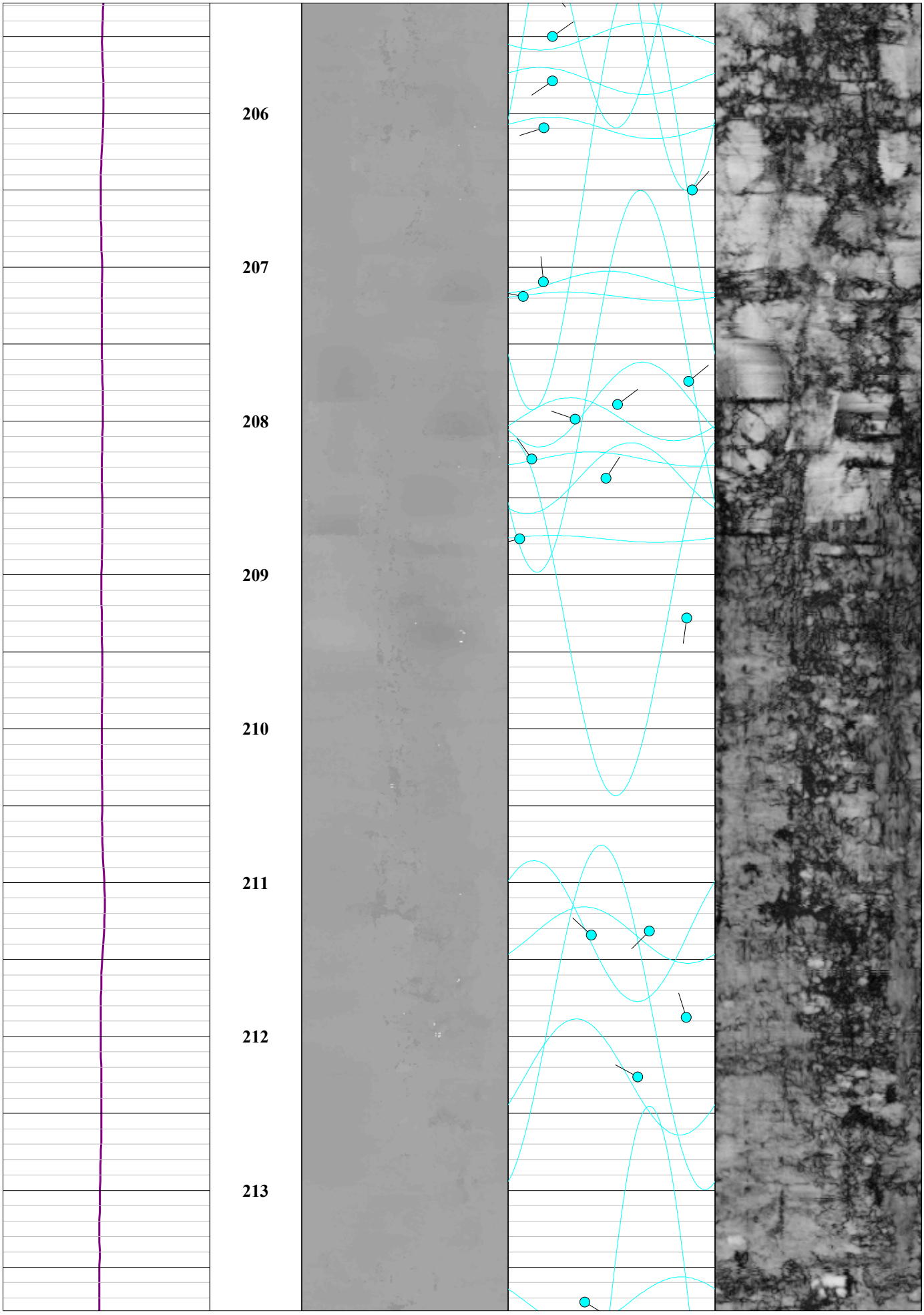

163
164
165
166
167
168
169
170
171

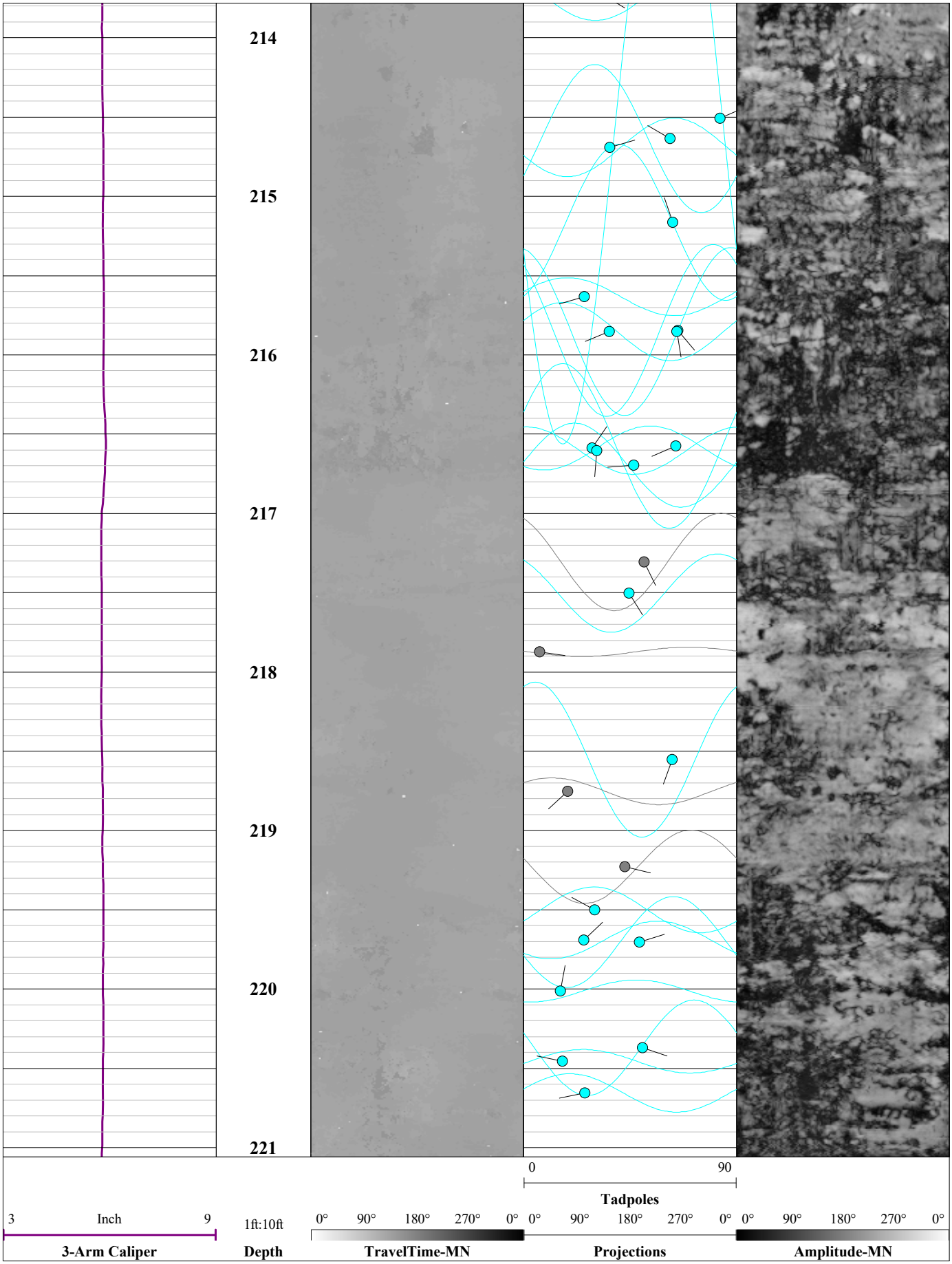

172
173
174
175
176
177
178
179


180
181
182
183
184
185
186
187
188

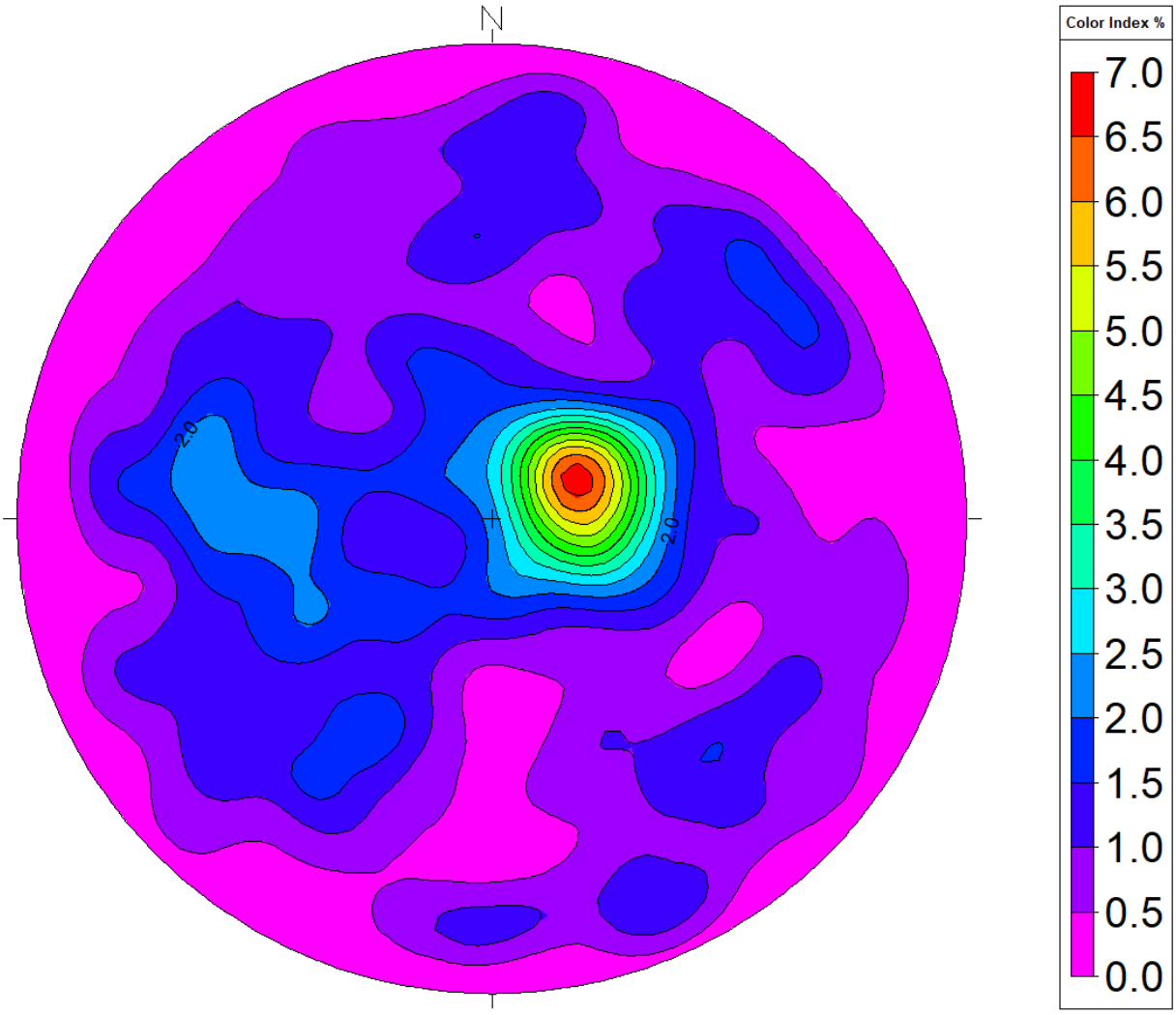

189
190
191
192
193
194
195
196


197
198
199
200
201
202
203
204
205


206
207
208
209
210
211
212
213

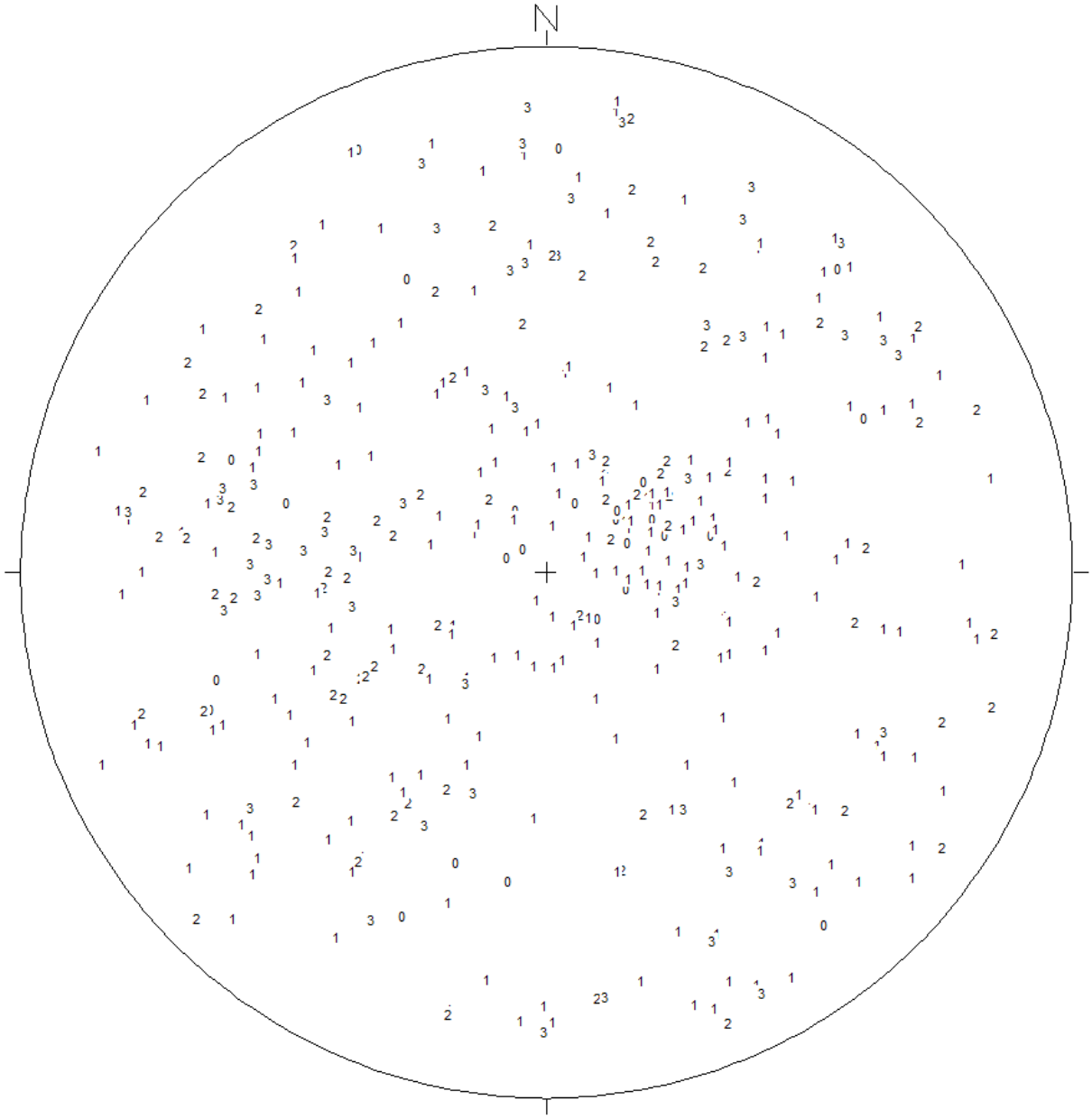

214
215
216
217
218
219
220
221
0
90
Tadpoles
3
Inch
9
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
3-Arm Caliper
Depth
TravelTime-MN
Projections
Amplitude-MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-36
16 September 2019



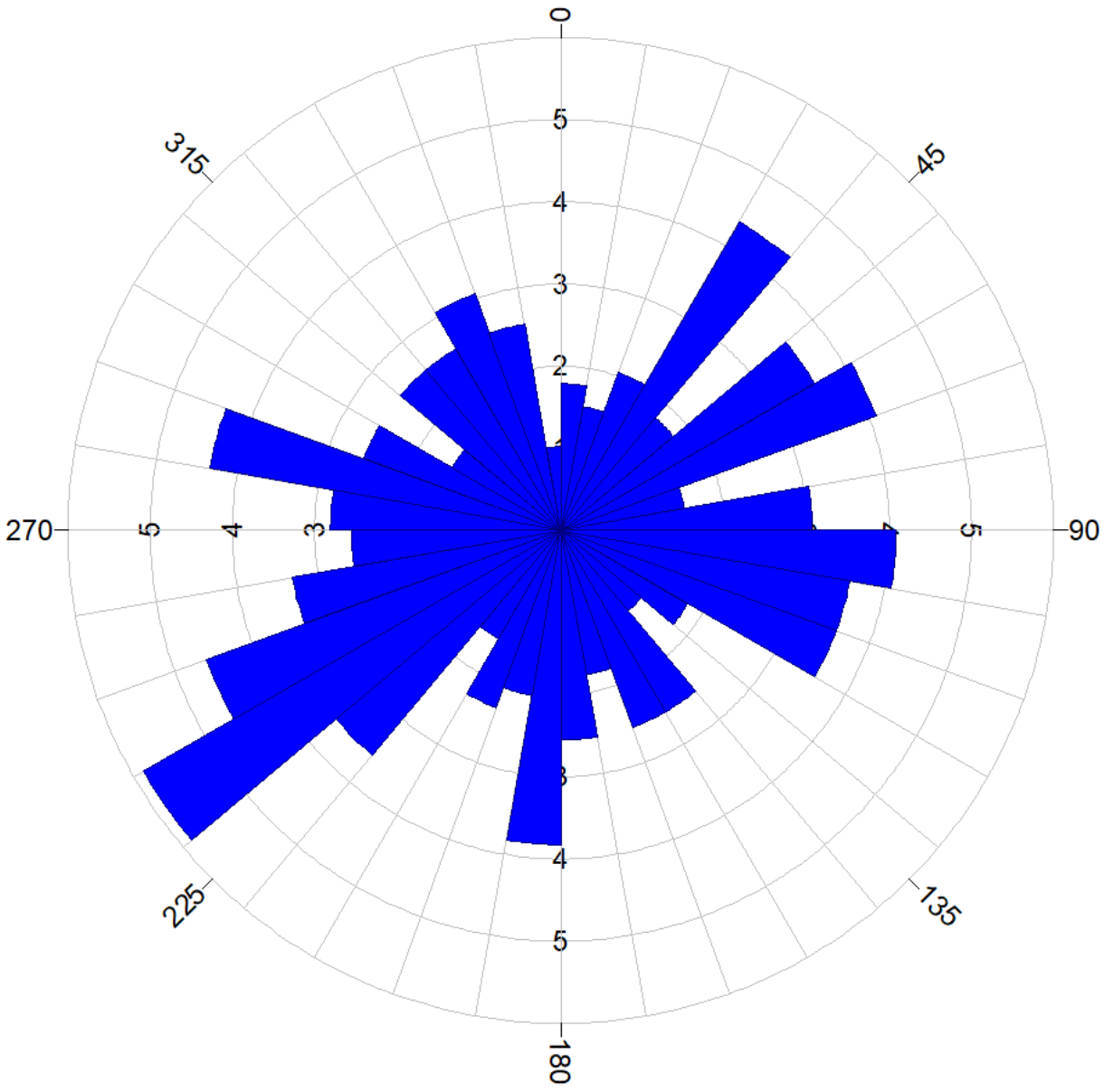
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-36
16 September 2019



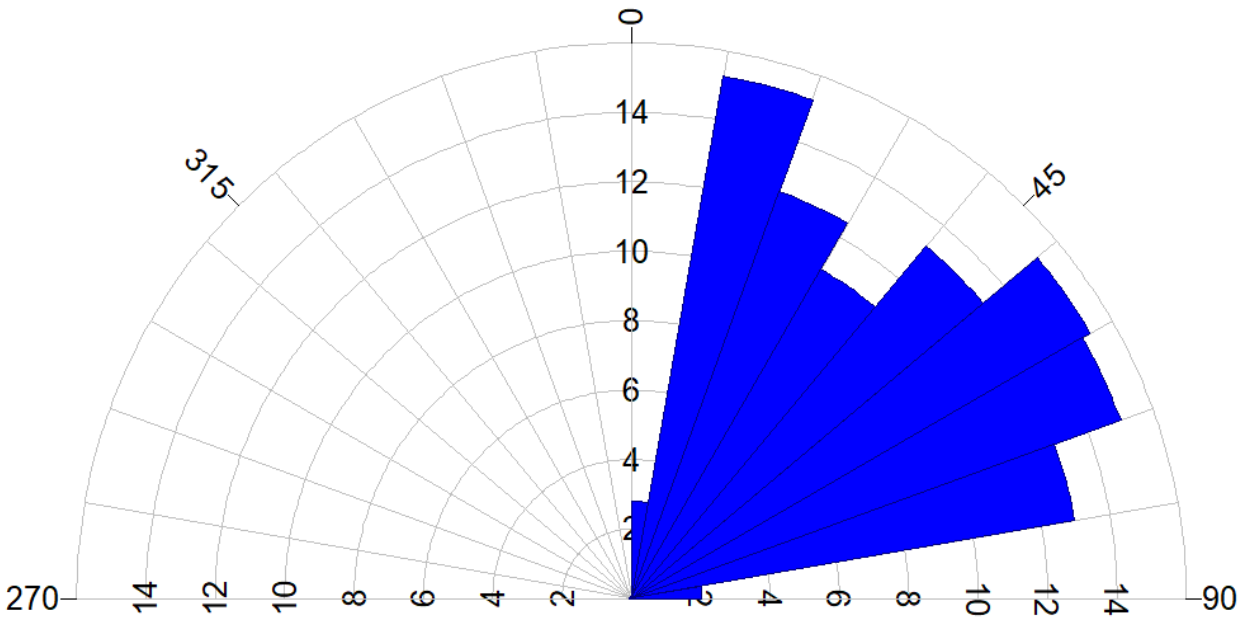
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-36
16 September 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-36
16 September 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	40.06	131.4	201	10	0
2	40.19	131.9	8	51	0
3	40.25	132.1	71	57	0
4	40.40	132.6	236	13	1
5	40.42	132.6	67	60	0
6	40.68	133.5	339	83	2
7	40.70	133.5	66	41	1
8	40.74	133.7	86	32	2
9	40.74	133.7	69	74	1
10	40.94	134.3	102	36	2
11	41.04	134.6	33	57	2
12	41.20	135.2	85	54	2
13	41.23	135.3	230	22	2
14	41.24	135.3	86	71	1
15	41.29	135.5	240	21	2
16	41.29	135.5	13	76	1
17	41.35	135.7	47	56	2
18	41.39	135.8	336	66	1
19	41.40	135.8	45	85	2
20	41.43	135.9	67	61	2
21	41.50	136.2	238	70	1
22	41.55	136.3	239	13	1
23	41.55	136.3	52	52	1
24	41.71	136.9	62	28	1
25	41.77	137.0	236	65	3
26	41.82	137.2	26	46	3
27	41.85	137.3	105	49	3
28	41.91	137.5	93	39	3
29	41.97	137.7	88	35	2
30	42.00	137.8	323	56	1
31	42.11	138.2	263	27	2
32	42.17	138.3	250	75	2
33	42.19	138.4	174	22	1
34	42.25	138.6	225	69	1
35	42.26	138.7	121	55	1
36	42.29	138.8	242	31	2
37	42.33	138.9	54	70	1
38	42.42	139.2	64	49	1
39	42.48	139.4	17	57	1
40	42.50	139.4	33	56	1
41	42.56	139.6	259	74	1
42	42.57	139.7	65	71	1
43	42.67	140.0	297	31	1
44	42.82	140.5	300	75	1
45	42.88	140.7	270	67	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	42.95	140.9	281	20	1
47	42.96	141.0	244	71	1
48	42.99	141.0	164	72	1
49	43.02	141.1	50	66	1
50	43.05	141.3	37	22	1
51	43.15	141.6	104	78	1
52	43.30	142.1	189	57	1
53	43.36	142.3	4	76	1
54	43.42	142.4	184	30	1
55	43.50	142.7	66	73	1
56	43.54	142.9	100	56	1
57	43.57	143.0	313	57	1
58	43.62	143.1	114	51	1
59	43.63	143.1	151	18	1
60	43.67	143.3	64	61	1
61	43.73	143.5	329	53	1
62	43.77	143.6	164	45	1
63	43.85	143.9	30	71	1
64	43.86	143.9	60	48	1
65	44.00	144.4	253	23	1
66	44.03	144.5	234	38	1
67	44.10	144.7	337	75	1
68	44.10	144.7	287	37	1
69	44.13	144.8	275	32	2
70	44.14	144.8	100	25	2
71	44.20	145.0	128	59	1
72	44.28	145.3	23	34	1
73	44.29	145.3	226	47	1
74	44.36	145.5	23	29	1
75	44.42	145.7	21	15	1
76	44.55	146.2	284	17	1
77	44.62	146.4	169	21	1
78	44.64	146.5	113	19	1
79	44.71	146.7	234	7	1
80	44.78	146.9	289	12	0
81	44.93	147.4	23	6	1
82	45.03	147.8	149	33	1
83	45.06	147.8	281	57	1
84	45.20	148.3	145	10	0
85	45.32	148.7	112	13	1
86	45.35	148.8	156	23	1
87	45.43	149.1	58	18	1
88	45.49	149.2	236	41	1
89	45.50	149.3	129	39	1
90	45.53	149.4	111	50	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	45.61	149.6	278	69	1
92	45.73	150.0	118	13	1
93	45.81	150.3	279	74	2
94	45.82	150.3	186	46	2
95	45.84	150.4	117	46	1
96	45.95	150.7	131	63	2
97	45.96	150.8	140	9	1
98	45.98	150.9	132	51	1
99	45.99	150.9	223	65	1
100	46.05	151.1	13	77	2
101	46.20	151.6	213	61	1
102	46.22	151.7	38	52	1
103	46.24	151.7	104	28	2
104	46.26	151.8	45	68	1
105	46.33	152.0	241	28	1
106	46.42	152.3	247	25	1
107	46.51	152.6	302	23	1
108	46.53	152.7	117	59	1
109	46.77	153.5	97	72	1
110	46.78	153.5	334	78	1
111	46.79	153.5	330	14	1
112	46.86	153.7	176	67	1
113	46.90	153.9	233	27	1
114	47.03	154.3	96	70	1
115	47.07	154.4	153	61	1
116	47.08	154.5	225	52	1
117	47.10	154.5	316	73	1
118	47.10	154.5	9	69	1
119	47.17	154.8	253	35	1
120	47.22	154.9	141	45	1
121	47.30	155.2	313	58	1
122	47.32	155.3	33	59	1
123	47.46	155.7	68	27	1
124	47.54	156.0	282	15	1
125	47.55	156.0	299	60	1
126	47.59	156.1	276	10	1
127	47.62	156.2	181	15	1
128	47.78	156.8	321	11	0
129	47.93	157.3	136	14	2
130	47.95	157.3	89	67	1
131	48.06	157.7	181	68	0
132	48.09	157.8	233	67	1
133	48.16	158.0	117	5	0
134	48.20	158.2	108	54	0
135	48.23	158.2	18	50	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	48.24	158.3	190	76	2
137	48.31	158.5	112	72	1
138	48.33	158.6	92	30	1
139	48.37	158.7	232	15	1
140	48.44	158.9	246	13	1
141	48.46	159.0	137	60	1
142	48.53	159.2	280	71	1
143	48.60	159.5	234	18	1
144	48.60	159.5	95	60	1
145	48.63	159.6	0	8	1
146	48.80	160.1	315	23	1
147	48.82	160.2	277	42	1
148	48.90	160.4	155	76	0
149	48.92	160.5	278	21	1
150	48.96	160.6	48	66	1
151	49.03	160.9	241	14	1
152	49.06	161.0	323	75	0
153	49.11	161.1	254	12	0
154	49.24	161.5	271	21	1
155	49.37	162.0	23	62	0
156	49.38	162.0	235	12	0
157	49.42	162.1	231	13	0
158	49.65	162.9	256	18	0
159	49.71	163.1	231	17	2
160	49.74	163.2	220	13	2
161	49.76	163.2	209	17	2
162	49.84	163.5	156	33	1
163	49.85	163.6	263	37	1
164	49.96	163.9	211	15	1
165	50.04	164.2	235	18	1
166	50.17	164.6	252	19	2
167	50.17	164.6	228	58	2
168	50.22	164.8	32	47	2
169	50.24	164.8	126	49	1
170	50.27	164.9	70	72	2
171	50.43	165.5	262	15	1
172	50.47	165.6	321	69	1
173	50.48	165.6	213	62	1
174	50.55	165.9	64	59	1
175	50.66	166.2	269	45	1
176	50.74	166.5	274	14	1
177	50.90	167.0	330	80	1
178	51.04	167.5	308	76	1
179	51.10	167.7	348	70	1
180	51.18	167.9	73	49	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	51.38	168.6	284	17	1
182	51.50	169.0	334	43	1
183	51.54	169.1	324	57	1
184	51.56	169.2	4	40	1
185	51.69	169.6	340	79	1
186	51.71	169.7	185	11	1
187	51.79	169.9	146	32	1
188	51.81	170.0	199	51	2
189	51.86	170.2	197	54	2
190	52.01	170.7	281	49	2
191	52.10	170.9	100	52	2
192	52.20	171.3	310	62	2
193	52.22	171.3	306	81	2
194	52.23	171.4	190	75	2
195	52.31	171.6	347	50	2
196	52.35	171.8	124	69	1
197	52.47	172.2	33	57	2
198	52.73	173.0	326	38	1
199	52.74	173.0	240	41	1
200	52.76	173.1	95	47	2
201	52.79	173.2	94	59	2
202	52.83	173.3	1	73	1
203	52.91	173.6	198	29	1
204	52.97	173.8	159	29	3
205	53.04	174.0	288	77	2
206	53.05	174.1	175	48	3
207	53.08	174.1	112	25	3
208	53.24	174.7	165	27	1
209	53.38	175.1	313	54	1
210	53.42	175.3	298	67	1
211	53.43	175.3	99	19	1
212	53.47	175.4	176	51	1
213	53.50	175.5	247	10	2
214	53.62	175.9	208	18	2
215	53.63	176.0	173	38	2
216	53.65	176.0	62	20	2
217	53.73	176.3	287	20	3
218	53.74	176.3	354	72	2
219	53.76	176.4	126	44	3
220	53.85	176.7	194	16	1
221	53.91	176.9	242	54	1
222	54.00	177.2	32	39	1
223	54.10	177.5	360	76	1
224	54.25	178.0	332	44	3
225	54.26	178.0	107	59	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	54.32	178.2	297	60	3
227	54.33	178.2	101	54	3
228	54.43	178.6	19	38	3
229	54.43	178.6	315	54	2
230	54.53	178.9	78	32	3
231	54.63	179.2	152	33	2
232	54.63	179.2	323	65	3
233	54.72	179.5	330	57	3
234	54.84	179.9	31	44	2
235	54.85	180.0	337	67	3
236	54.86	180.0	87	45	3
237	55.00	180.4	192	62	3
238	55.00	180.4	84	36	2
239	55.15	181.0	51	63	3
240	55.17	181.0	270	23	3
241	55.18	181.1	103	54	3
242	55.18	181.1	200	18	3
243	55.34	181.6	208	70	3
244	55.39	181.7	25	39	2
245	55.48	182.0	183	59	3
246	55.49	182.0	94	31	3
247	55.63	182.5	162	69	3
248	55.69	182.7	239	66	3
249	55.73	182.8	176	69	3
250	55.74	182.9	1	78	3
251	55.97	183.6	213	45	3
252	55.98	183.7	98	36	3
253	56.20	184.4	189	74	3
254	56.24	184.5	97	70	3
255	56.25	184.6	172	47	3
256	56.26	184.6	238	25	3
257	56.37	184.9	218	45	2
258	56.45	185.2	33	43	2
259	56.56	185.6	192	62	2
260	56.62	185.8	170	55	2
261	56.75	186.2	51	26	2
262	56.79	186.3	57	39	2
263	56.83	186.5	249	64	2
264	56.99	187.0	36	23	3
265	57.01	187.0	27	65	3
266	57.02	187.1	232	60	3
267	57.21	187.7	224	67	0
268	57.39	188.3	220	47	3
269	57.42	188.4	222	71	3
270	57.54	188.8	141	67	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	57.56	188.8	157	47	2
272	57.60	189.0	60	32	2
273	57.66	189.2	353	72	3
274	57.66	189.2	181	49	3
275	57.77	189.6	209	64	3
276	57.80	189.6	161	57	3
277	57.82	189.7	68	38	2
278	57.91	190.0	303	23	2
279	57.91	190.0	180	49	2
280	58.04	190.4	92	54	1
281	58.07	190.5	222	51	1
282	58.08	190.6	37	42	1
283	58.14	190.8	94	64	2
284	58.29	191.2	215	42	2
285	58.33	191.4	207	53	2
286	58.34	191.4	94	45	3
287	58.40	191.6	90	48	3
288	58.44	191.7	59	40	2
289	58.49	191.9	59	35	2
290	58.58	192.2	146	67	1
291	58.59	192.2	135	45	1
292	58.60	192.3	39	57	1
293	58.61	192.3	332	9	2
294	58.77	192.8	84	51	2
295	58.81	192.9	84	47	3
296	58.91	193.3	167	25	3
297	58.91	193.3	82	53	3
298	58.93	193.3	267	50	2
299	59.06	193.8	342	22	1
300	59.08	193.8	115	37	1
301	59.20	194.2	118	23	2
302	59.26	194.4	340	42	2
303	59.32	194.6	228	24	2
304	59.42	194.9	262	5	2
305	59.43	195.0	119	68	2
306	59.44	195.0	184	63	1
307	59.50	195.2	86	43	1
308	59.52	195.3	52	40	1
309	59.55	195.4	334	80	3
310	59.55	195.4	154	76	1
311	59.80	196.2	100	68	2
312	59.86	196.4	59	34	2
313	59.87	196.4	292	69	2
314	59.94	196.6	177	76	3
315	60.03	197.0	116	63	2

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
316	60.11	197.2	180	6	1
317	60.12	197.3	320	45	1
318	60.14	197.3	237	72	2
319	60.30	197.8	239	18	1
320	60.33	197.9	317	67	1
321	60.39	198.1	348	50	1
322	60.41	198.2	208	28	1
323	60.55	198.7	287	28	1
324	60.66	199.0	340	29	1
325	60.73	199.2	359	16	1
326	60.88	199.8	44	71	1
327	61.05	200.3	281	54	1
328	61.10	200.5	292	36	1
329	61.17	200.7	294	18	0
330	61.21	200.8	295	18	1
331	61.24	200.9	268	18	1
332	61.29	201.1	255	21	1
333	61.36	201.3	246	17	0
334	61.41	201.5	260	25	0
335	61.51	201.8	264	27	1
336	61.55	201.9	281	12	1
337	61.67	202.3	245	55	0
338	61.81	202.8	341	10	1
339	61.83	202.9	32	17	1
340	62.04	203.5	240	32	1
341	62.08	203.7	221	71	1
342	62.10	203.7	274	29	1
343	62.15	203.9	241	19	1
344	62.20	204.1	251	40	1
345	62.24	204.2	83	37	1
346	62.30	204.4	245	59	1
347	62.47	205.0	238	21	1
348	62.52	205.1	188	76	1
349	62.53	205.2	311	80	1
350	62.54	205.2	142	18	1
351	62.64	205.5	55	19	1
352	62.72	205.8	235	19	1
353	62.82	206.1	252	16	1
354	62.94	206.5	42	80	1
355	63.12	207.1	354	15	1
356	63.15	207.2	281	7	1
357	63.32	207.7	50	79	1
358	63.36	207.9	54	48	1
359	63.40	208.0	288	29	1
360	63.47	208.3	325	10	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-36

16 September 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
361	63.51	208.4	33	43	1
362	63.63	208.8	257	5	1
363	63.79	209.3	188	78	1
364	64.41	211.3	225	61	1
365	64.42	211.3	312	36	1
366	64.58	211.9	342	77	1
367	64.70	212.3	299	56	1
368	65.14	213.7	121	33	1
369	65.38	214.5	66	83	1
370	65.42	214.6	300	62	1
371	65.44	214.7	74	36	1
372	65.58	215.2	341	63	1
373	65.72	215.6	254	26	1
374	65.79	215.9	140	65	1
375	65.79	215.9	248	36	1
376	65.79	215.9	170	65	1
377	66.01	216.6	246	64	1
378	66.02	216.6	34	29	1
379	66.02	216.6	185	31	1
380	66.05	216.7	266	47	1
381	66.23	217.3	153	51	0
382	66.29	217.5	148	45	1
383	66.41	217.9	98	7	0
384	66.61	218.6	200	63	1
385	66.68	218.8	228	19	0
386	66.82	219.2	103	43	0
387	66.90	219.5	299	30	1
388	66.96	219.7	47	26	1
389	66.96	219.7	73	49	1
390	67.06	220.0	10	16	1
391	67.17	220.4	108	50	1
392	67.20	220.5	281	17	1
393	67.26	220.7	258	26	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Armed Caliper

Company WSP
Well BH19-36
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-36
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79716 N
Longitude: 84.77391 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Electrical Log

PERMANENT DATUM Mudline **ELEVATION** 502.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 September 2019	16 September 2019	16 September 2019	
RUN NUMBER	4	2	1	
LOG TYPE	FTC	Natural Gamma	Caliper	
DEPTH-DRILLER	221.4'	221.4'	221.4'	
DEPTH-LOGGER	221.7'	221.2'	221.1'	
BTM LOG INTERVAL	221.7'	219.6'	221.1'	
TOP LOG INTERVAL	121.6'	0.0'	0.0'	
RECORDED BY	DRC/JBG	DRC/JBG	DRC/JBG	
WITNESSED BY	Duncan	Duncan	Duncan	
PROBE TYPE, S/N	2PFA #3656	ELXG #4314	3ACS#5596	
LOGGING SPEED	20 fpm	20 fpm	20 fpm	
A.S.D.E. / Sample Interval	0.15' / 0.10'	0.05' / 0.25'	0.11' / 0.10'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

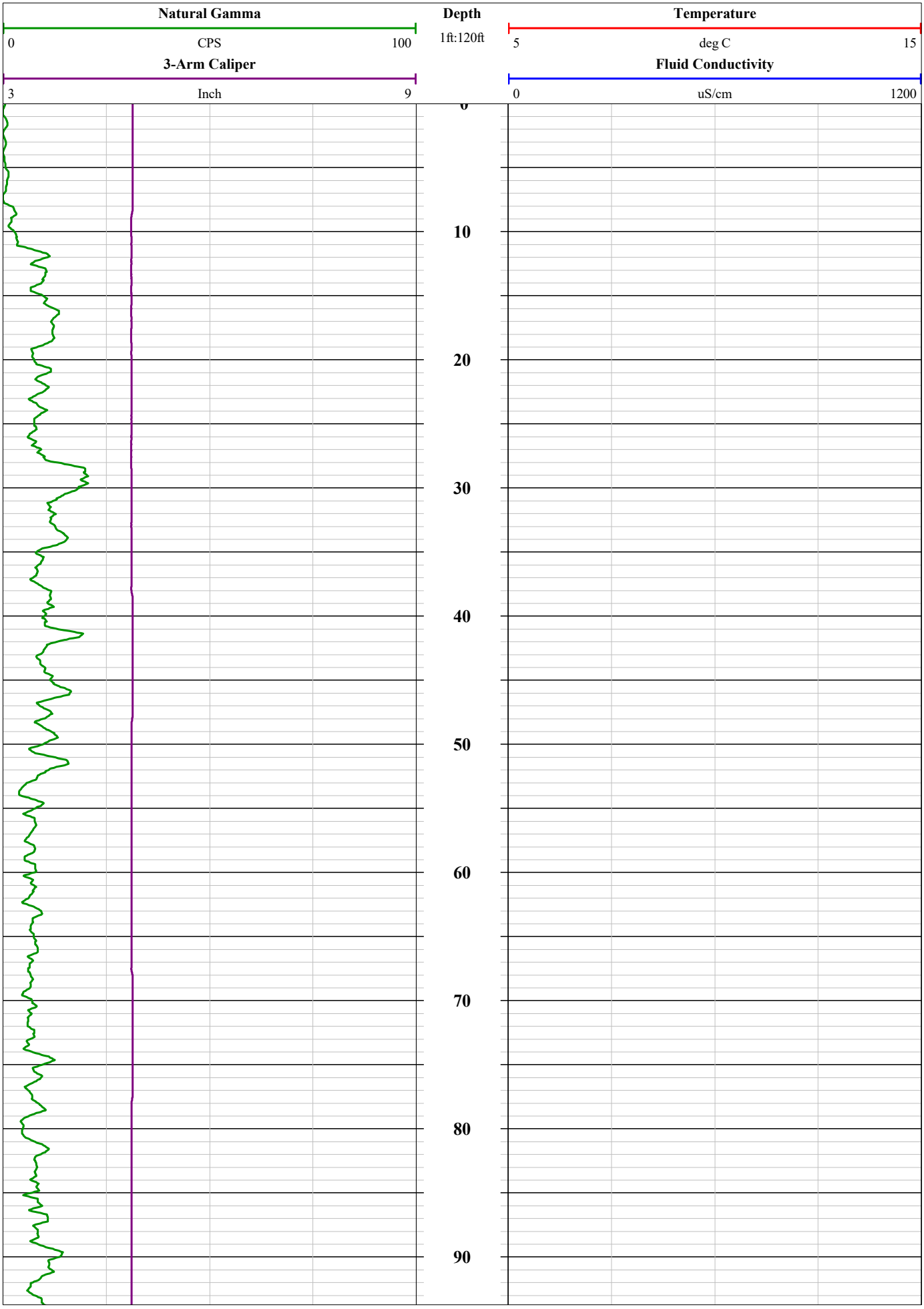
RUN No.	BIT	FROM	TO
1	5.5"	Mudline	TD

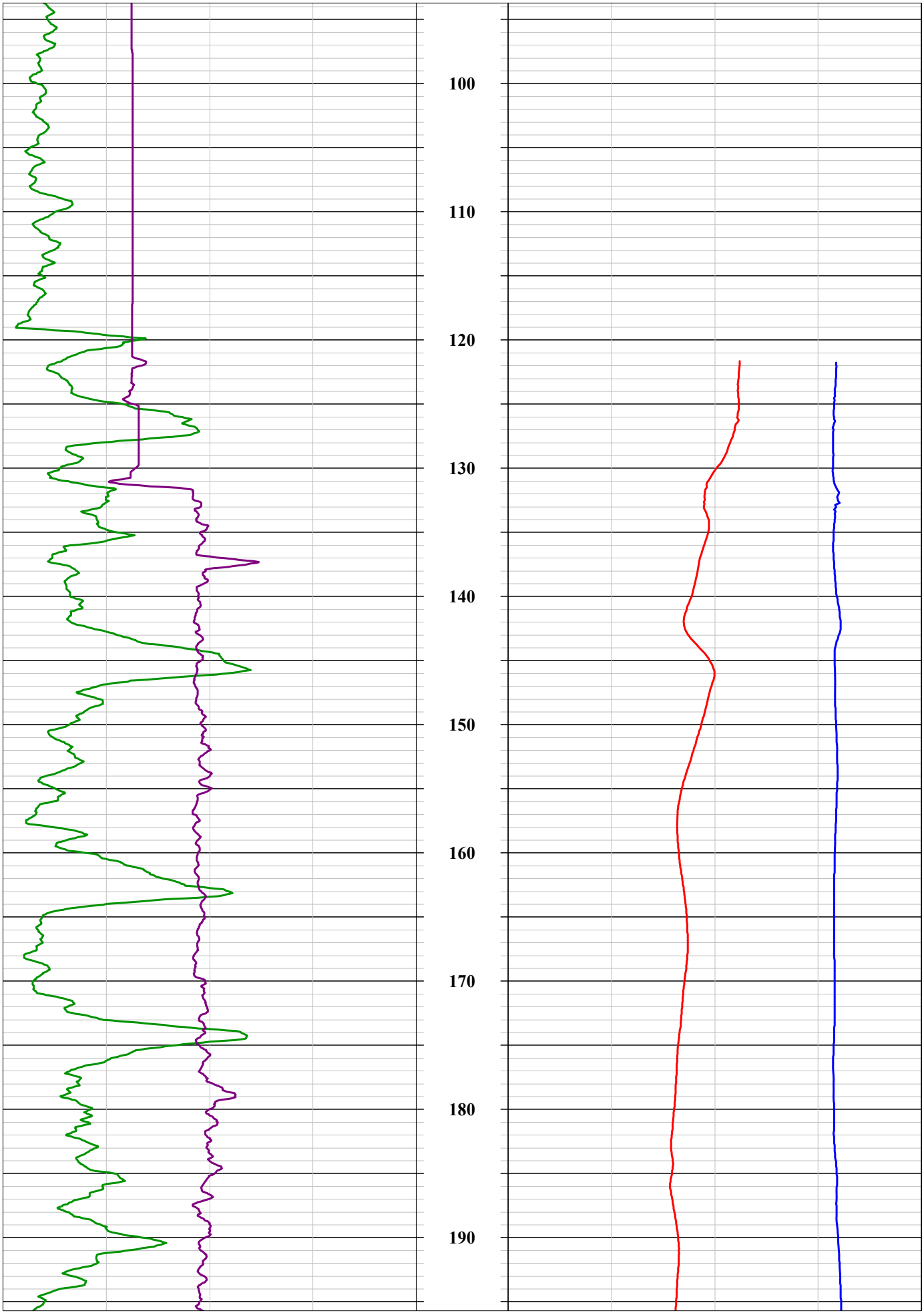
CASING RECORD

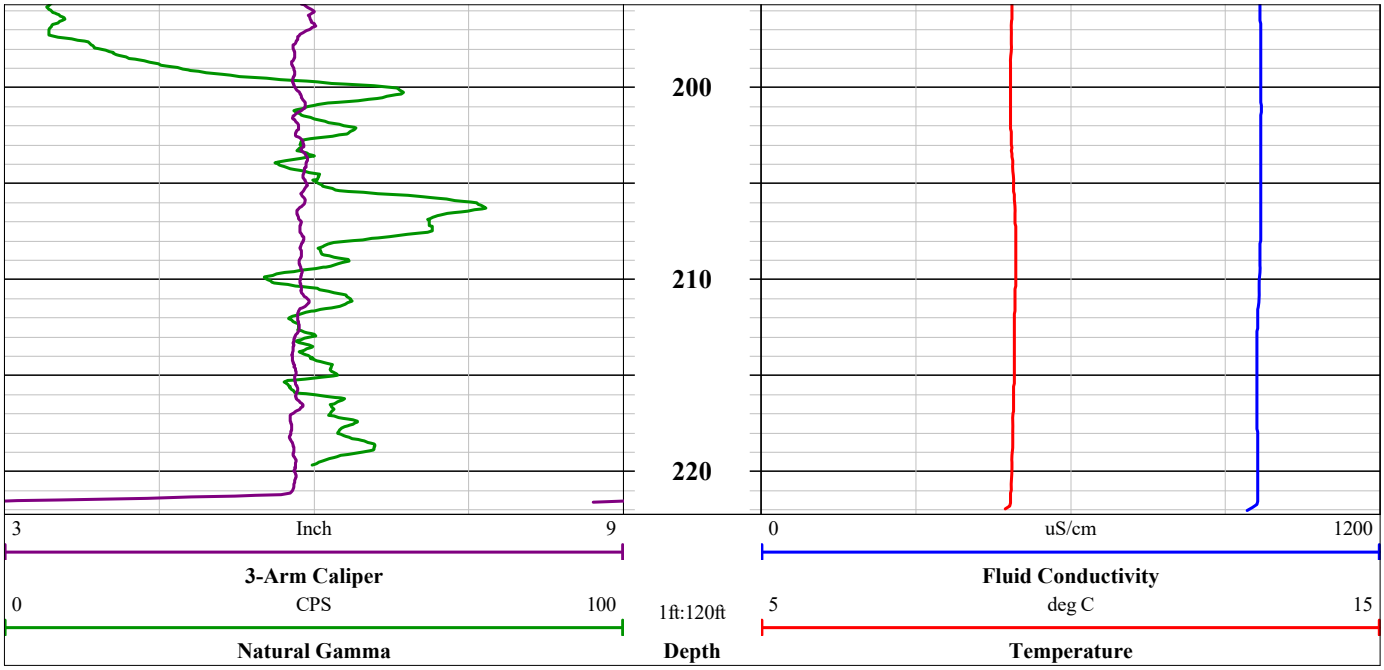
SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	130.9'
7 "	Steel	Mudline	27.88'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
3-Arm Caliper
3
Inch
9
Depth
1ft:120ft
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
1200
0
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
3
Inch
9
3-Arm Caliper
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1200
Fluid Conductivity
5
deg C
15
Temperature

Borehole Deviation

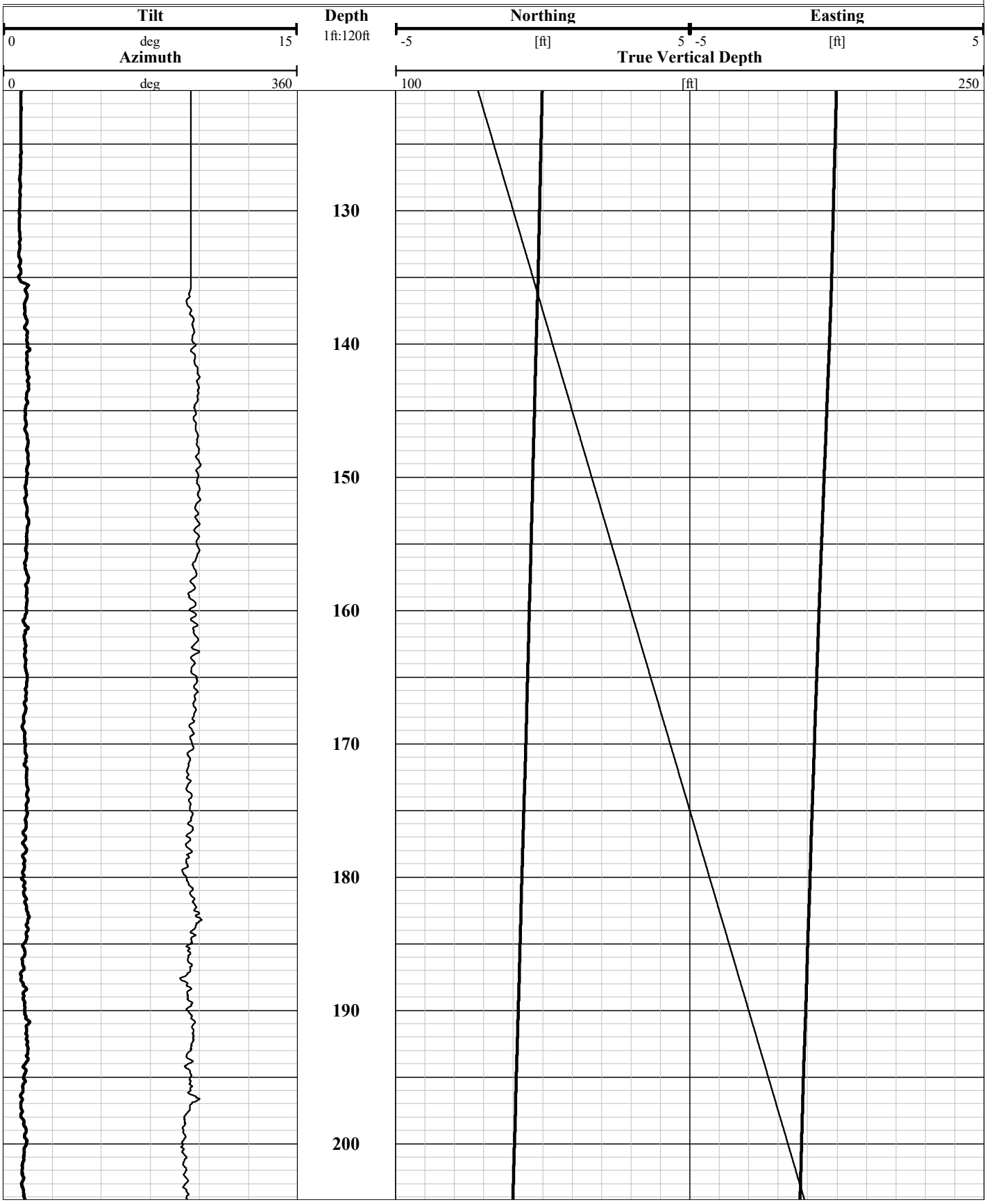
COLOG
borehole geophysics / hydrophysics

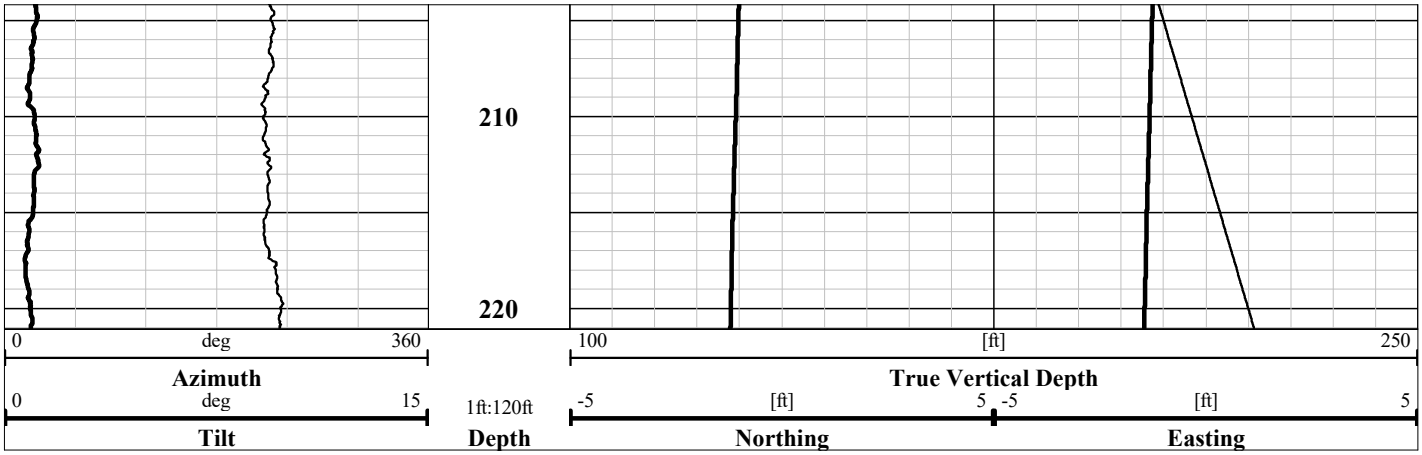
COMPANY: WSP	PROJECT: LR5T Project
DATE LOGGED: 16 Sept. 2019	WELL: BH19-36 - Mid Strait

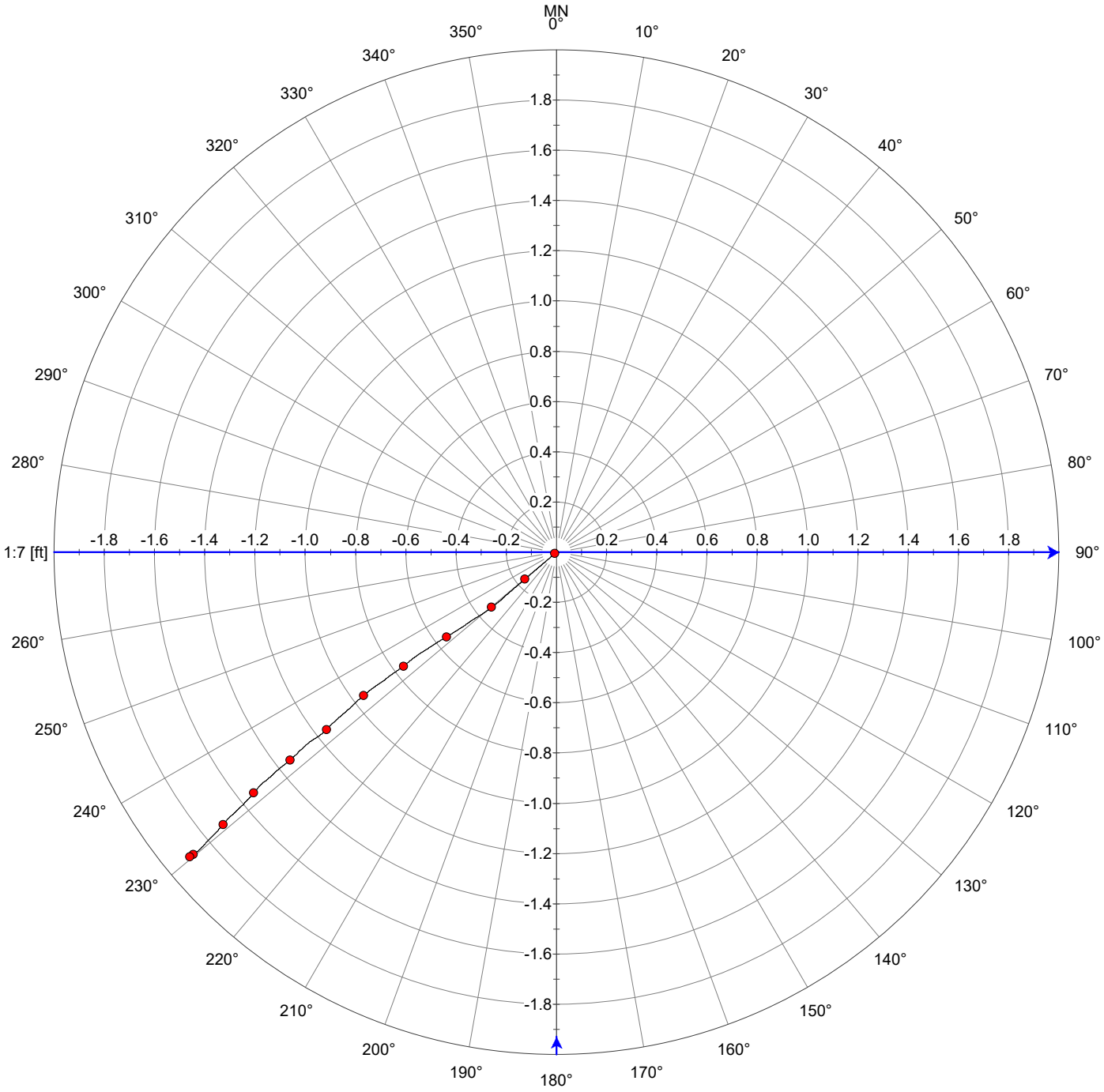
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 502.4'** **Latitude: 45.79716 N** **Longitude: 84.77391 W**




210
220
0
deg
360
Azimuth
0
deg
15
Tilt
1ft:120ft
Depth
100
[ft]
250
True Vertical Depth
-5
[ft]
5
Northing
-5
[ft]
5
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1:7 [ft]
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-36
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-36
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79716 N
Longitude: 84.77391 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
P&S Suspension Log
Fluid Temp. & Cond.

PERMANENT DATUM Mudline **ELEVATION** 502.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 September 2019	16 September 2019		
RUN NUMBER	2	2		
LOG TYPE	Natural Gamma	Electric log		
DEPTH-DRILLER	221.4'	221.4'		
DEPTH-LOGGER	221.2'	221.2'		
BTM LOG INTERVAL	221.2'	221.2'		
TOP LOG INTERVAL	0.0'	113.9'		
RECORDED BY	DRE/JBG	DRE/JBG		
WITNESSED BY	Duncan	Duncan		
PROBE TYPE, S/N	ELXG #4314	ELXG #4314		
LOGGING SPEED	20 fpm	20 fpm		
A.S.D.E. / Sample Interval	0.05' / 0.25'	0.05' / 0.25'		
Fluid Level / Fluid Type	NA/Water	NA/Water		

BOREHOLE RECORD

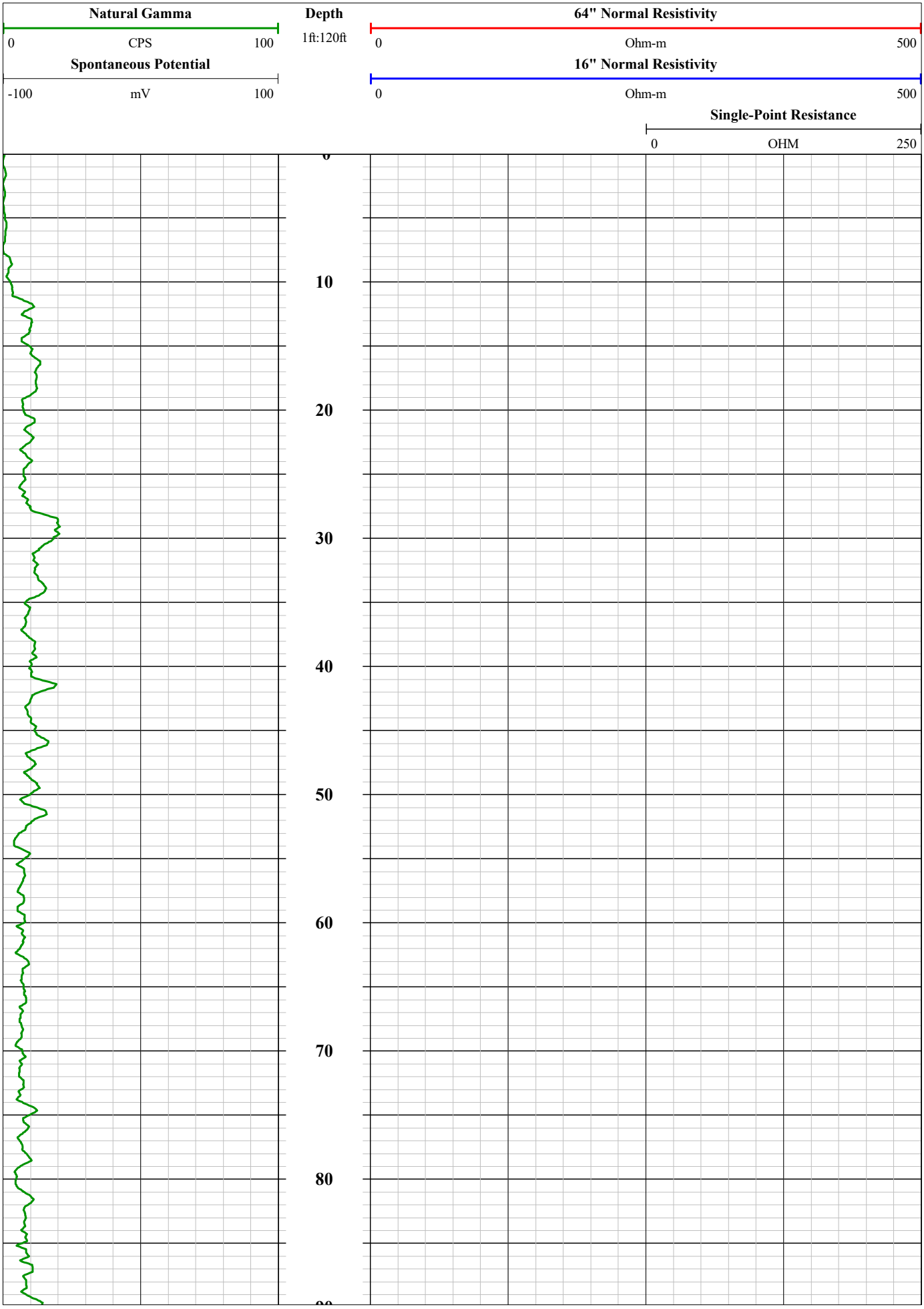
RUN No.	BIT	FROM	TO
1	5.5"	Mudline	TD

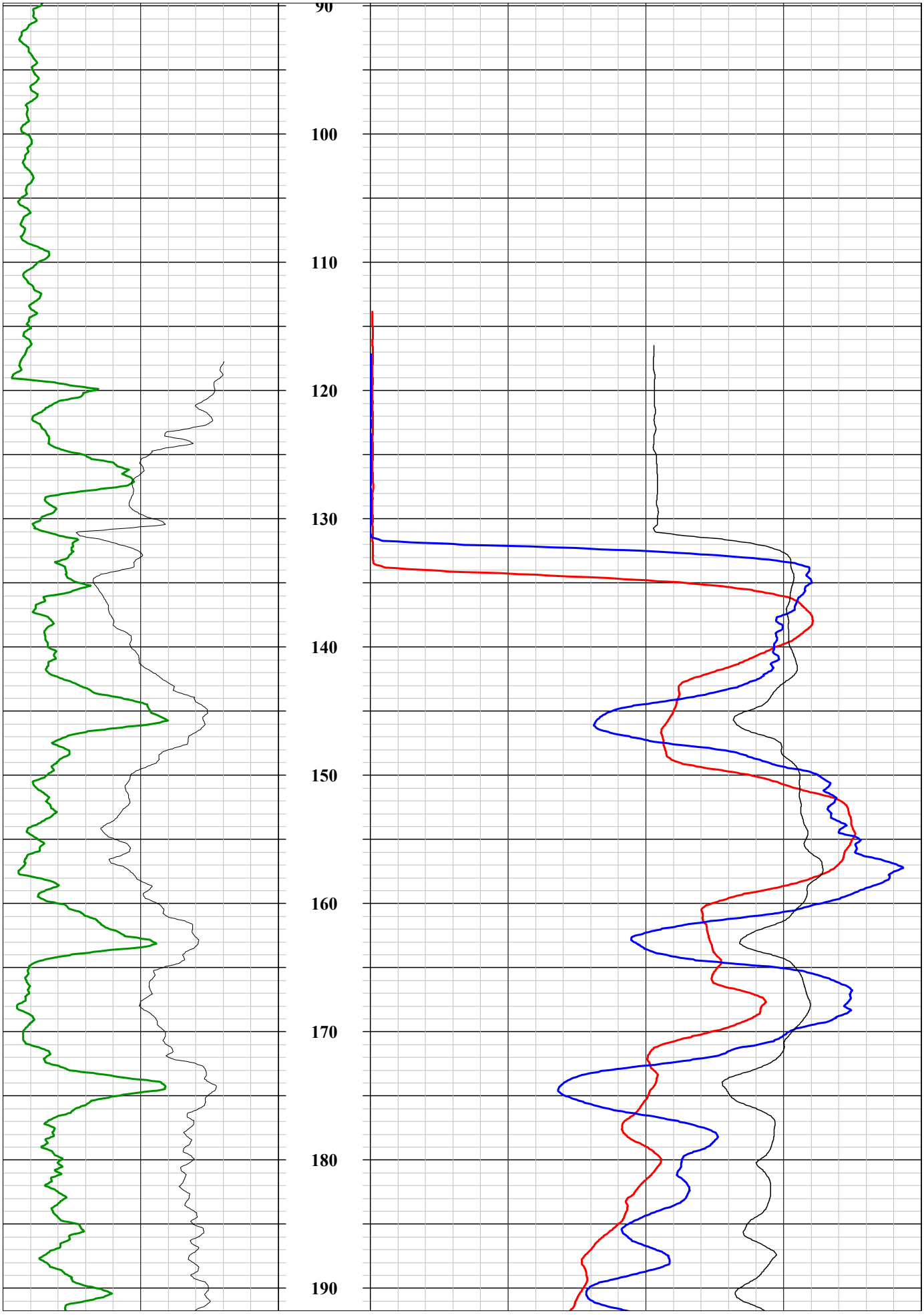
CASING RECORD

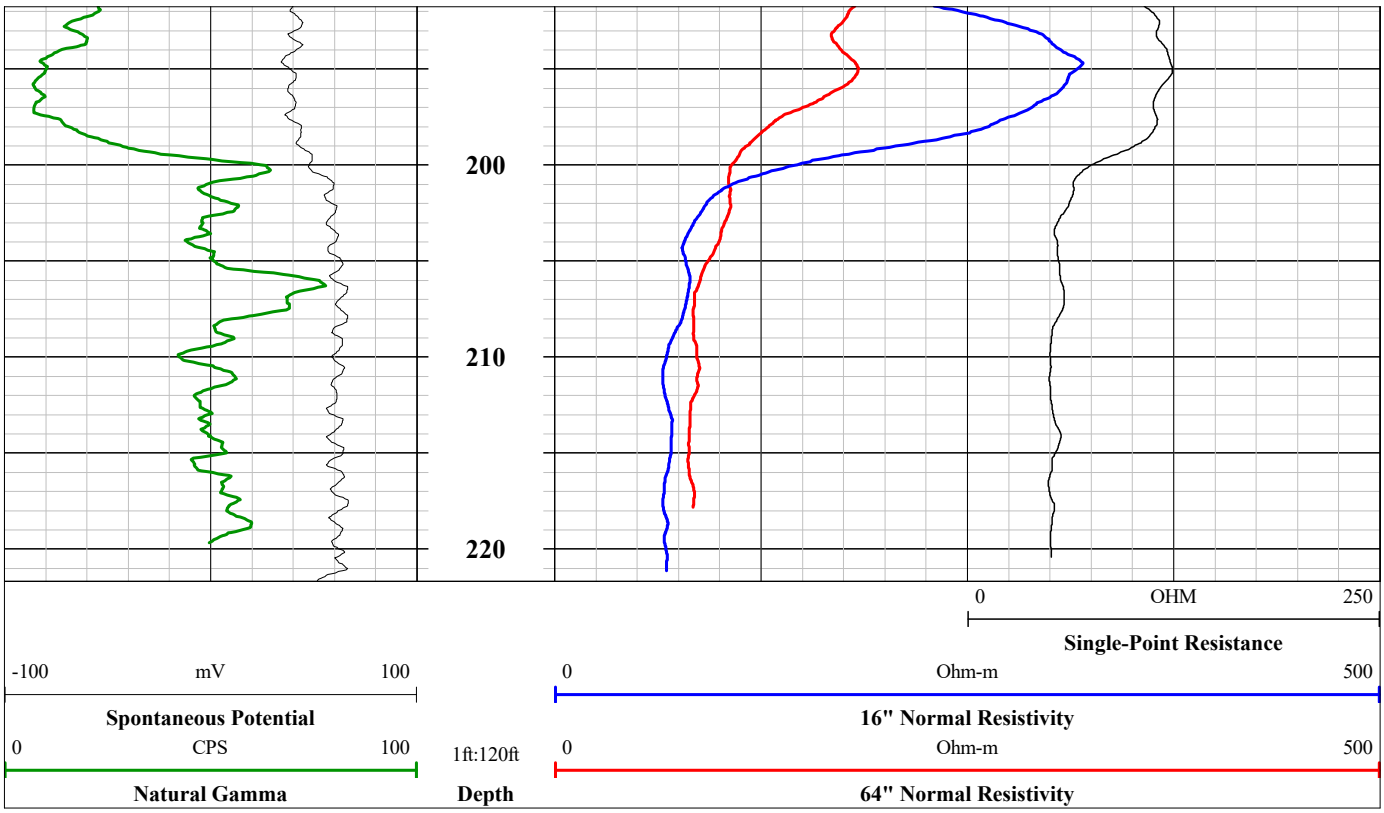
SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	130.9'
7"	Steel	Mudline	27.88'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-100
mV
100
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
500
16" Normal Resistivity
0
Ohm-m
500
Single-Point Resistance
0
OHM
250
10
20
30
40
50
60
70
80


90
100
110
120
130
140
150
160
170
180
190


200
210
220
0
OHM
250
Single-Point Resistance
-100
mV
100
Spontaneous Potential
0
Ohm-m
500
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
500
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-36
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-36
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - Mid Strait
Latitude: 45.79716 N
Longitude: 84.77391 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Electric log
Natural Gamma
3-Armed caliper
Fluid Temp. & Cond.
Acoustic Televiewer

PERMANENT DATUM Mudline **ELEVATION** 502.4'

LOG MEAS. FROM Mudline 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Mudline

DATE ACQUIRED	16 September 2019			
RUN NUMBER	7			
LOG TYPE	PSLog			
DEPTH-DRILLER	221.4'			
DEPTH-LOGGER	210'			
BTM LOG INTERVAL	210'			
TOP LOG INTERVAL	130'			
RECORDED BY	JBG/DRE			
WITNESSED BY	Duncan			
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	0.4'/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

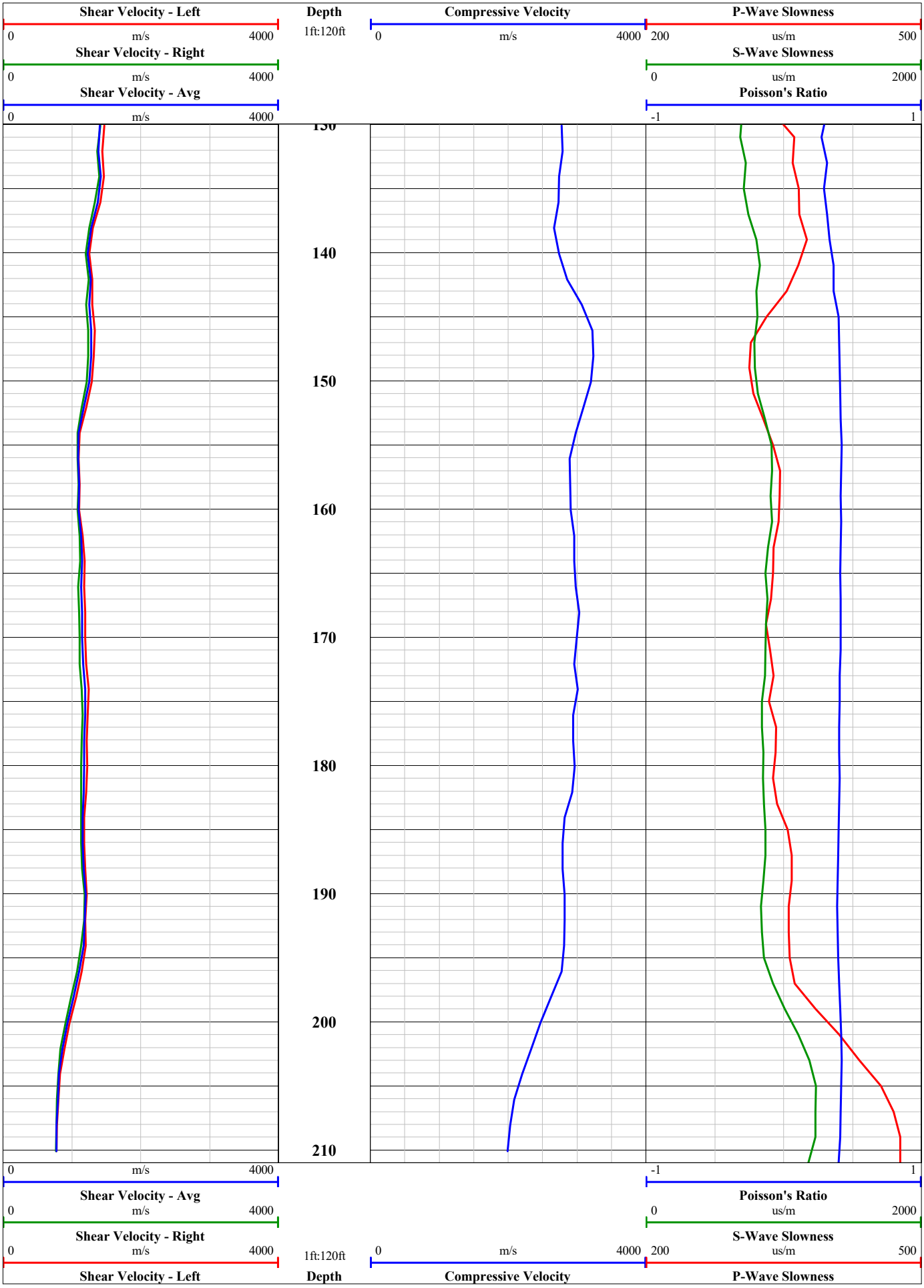
RUN No.	BIT	FROM	TO
1	5.5"	Mudline	221.4'

CASING RECORD

SIZE	WGT.	FROM	TO
5.5"	Steel	Mudline	130.9'
7"	Steel	Mudline	27.88'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
0
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1
130
140
150
160
170
180
190
200
210
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Left
Depth
1ft:120ft
Compressive Velocity
0
m/s
4000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-1
1

Geophysical Summary Plot

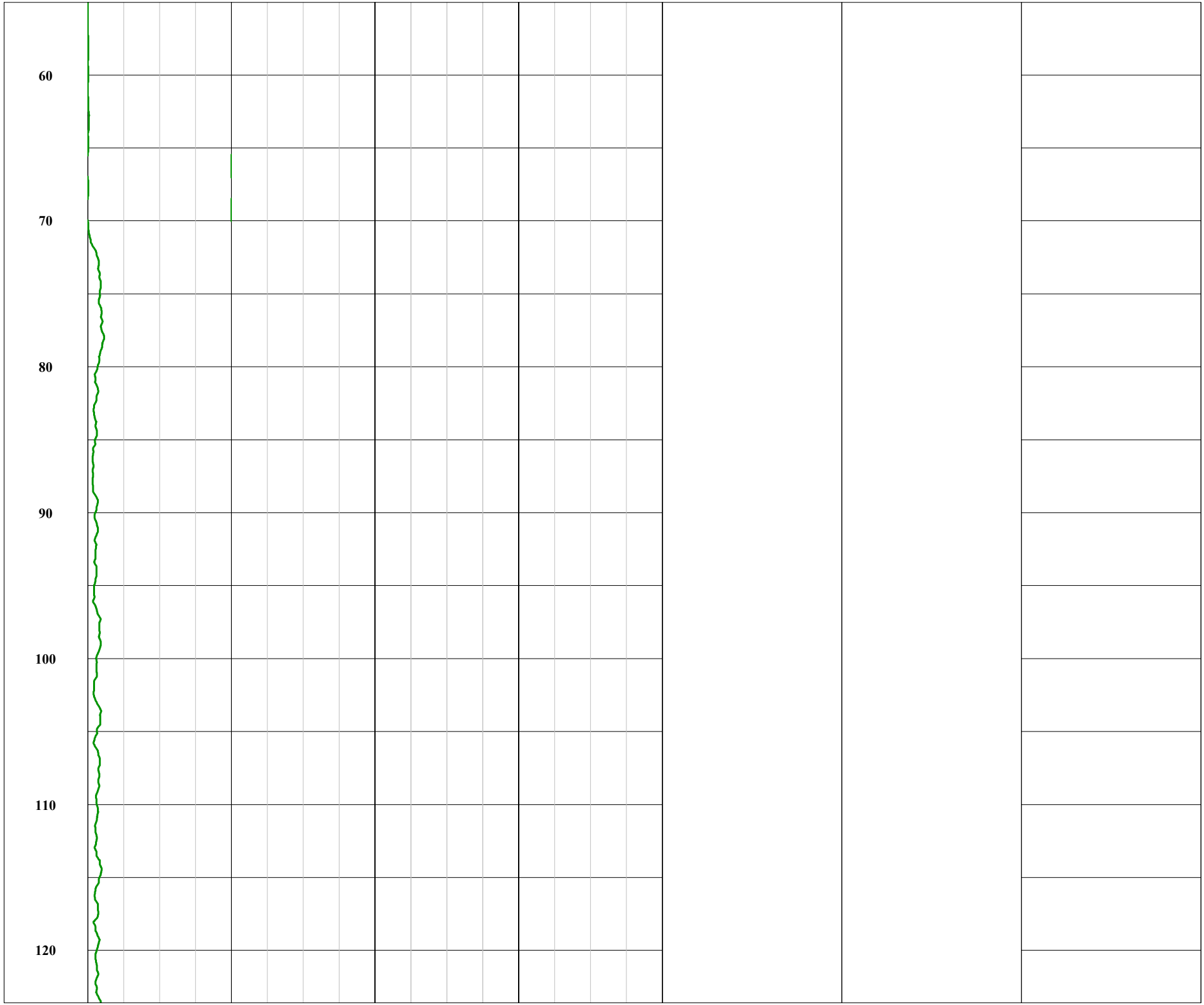
COLOG
borehole geophysics / hydrophysics

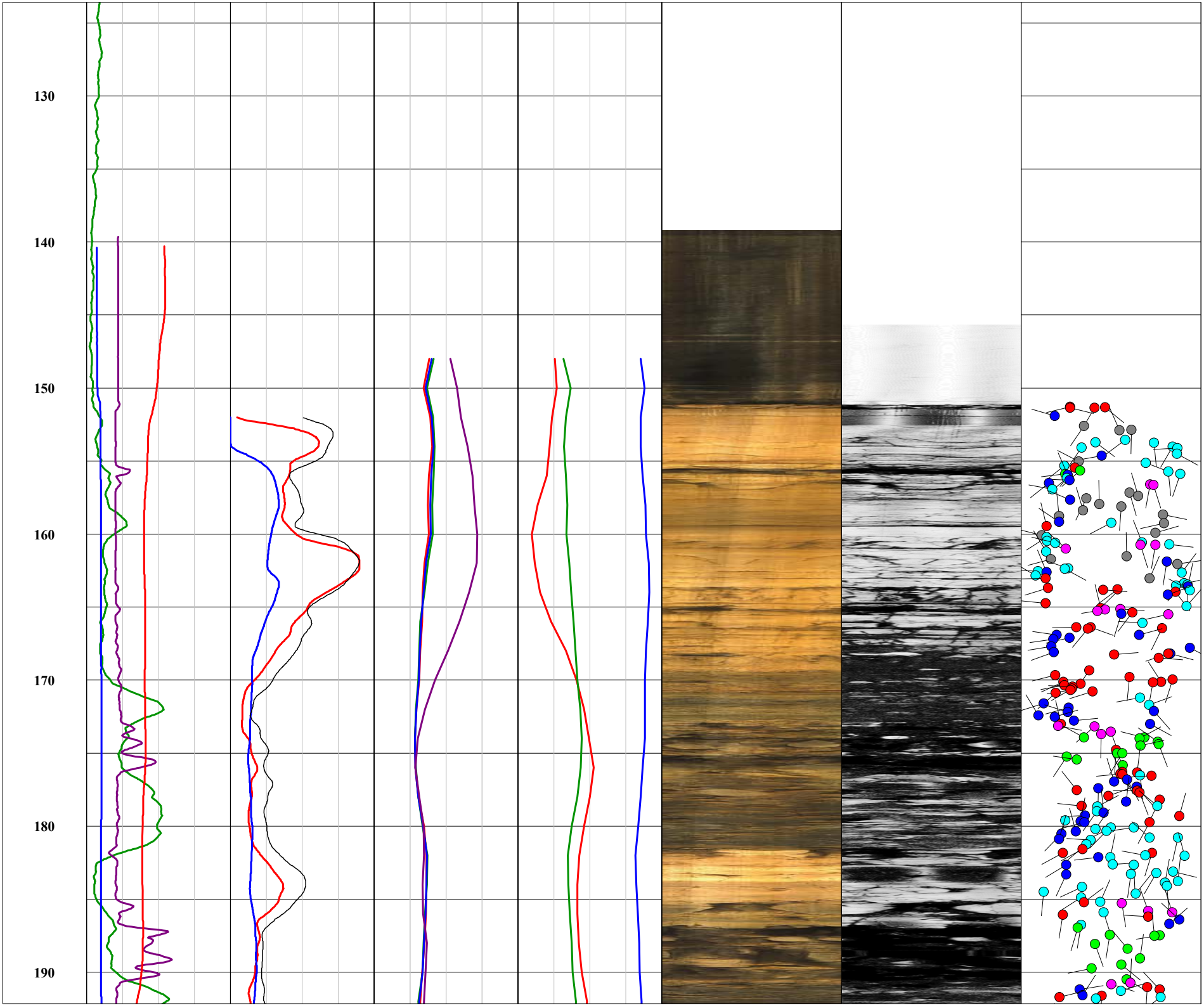
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 16 July 2019
WELL: BH19-37 - South Side

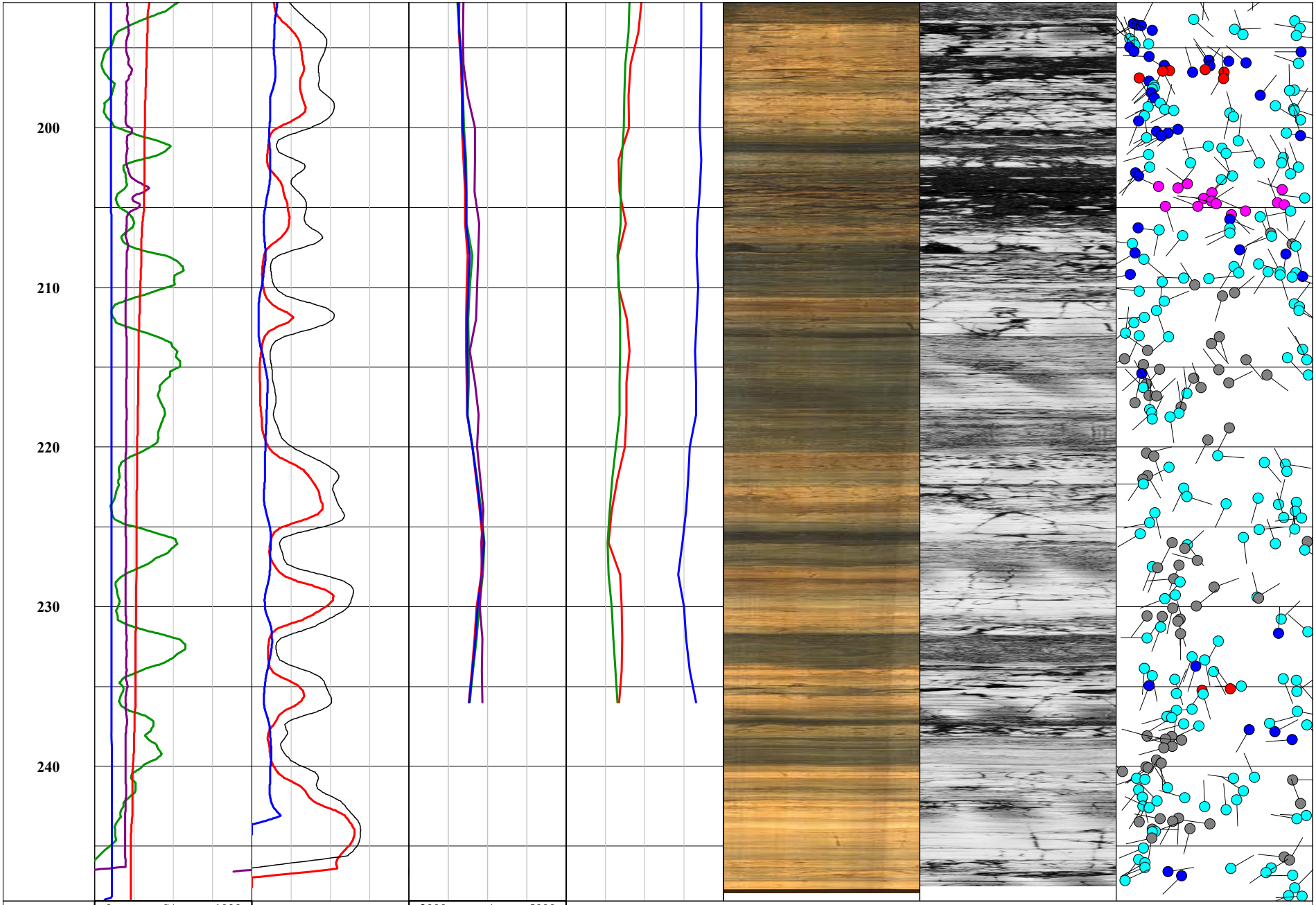
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN	Tadpoles - MN
1ft:100ft	0 CPS 200	0 Ohm-m 3000	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	**64" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**			
	2 Inch 12	0 Ohm-m 3000	0 m/s 4000	0 us/m 2000			
	Temperature	**Single-Point Resistance**	**Shear Velocity - Avg**	**Poisson's Ratio**			
	5 deg C 15	0 Ohm 1000	0 m/s 4000	-0.3 0.5			
	Fluid Conductivity		**Compressive Velocity**				
	0 uS/cm 1000		2000 m/s 5000				

10
20
30
40
50


60
70
80
90
100
110
120


130
140
150
160
170
180
190



	0 uS/cm 1000 **Fluid Conductivity**		2000 m/s 5000 **Compressive Velocity**				
	5 deg C 15 **Temperature**	0 Ohm 1000 **Single-Point Resistance**	0 m/s 4000 **Shear Velocity - Avg**	-0.3 0.5 **Poisson's Ratio**			
	2 Inch 12 **3-Arm Caliper**	0 Ohm-m 3000 **64" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Right**	0 us/m 2000 **S-Wave Slowness**			
1ft:100ft **Depth**	0 CPS 200 **Natural Gamma**	0 Ohm-m 3000 **16" Normal Resistivity**	0 m/s 4000 **Shear Velocity - Left**	200 us/m 500 **P-Wave Slowness**	0° 90° 180° 270° 0° **Optical Image - MN**	0° 90° 180° 270° 0° **Amplitude - MN**	0 90 **Tadpoles - MN**

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-37
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-37
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79428 N
Longitude: 84.77377 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Top of Casing **ELEVATION** 600.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	16 July 2019			
RUN NUMBER	1			
LOG TYPE	Acoustic Televiewer			
DEPTH-DRILLER	248.4'			
DEPTH-LOGGER	248'			
BTM LOG INTERVAL	247.5'			
TOP LOG INTERVAL	145.7'			
RECORDED BY	CKL			
WITNESSED BY				
PROBE TYPE, S/N	BHTV #1730			
LOGGING SPEED	4.5fpm			
A.S.D.E. / Sample Interval	0.45'/0.00038			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

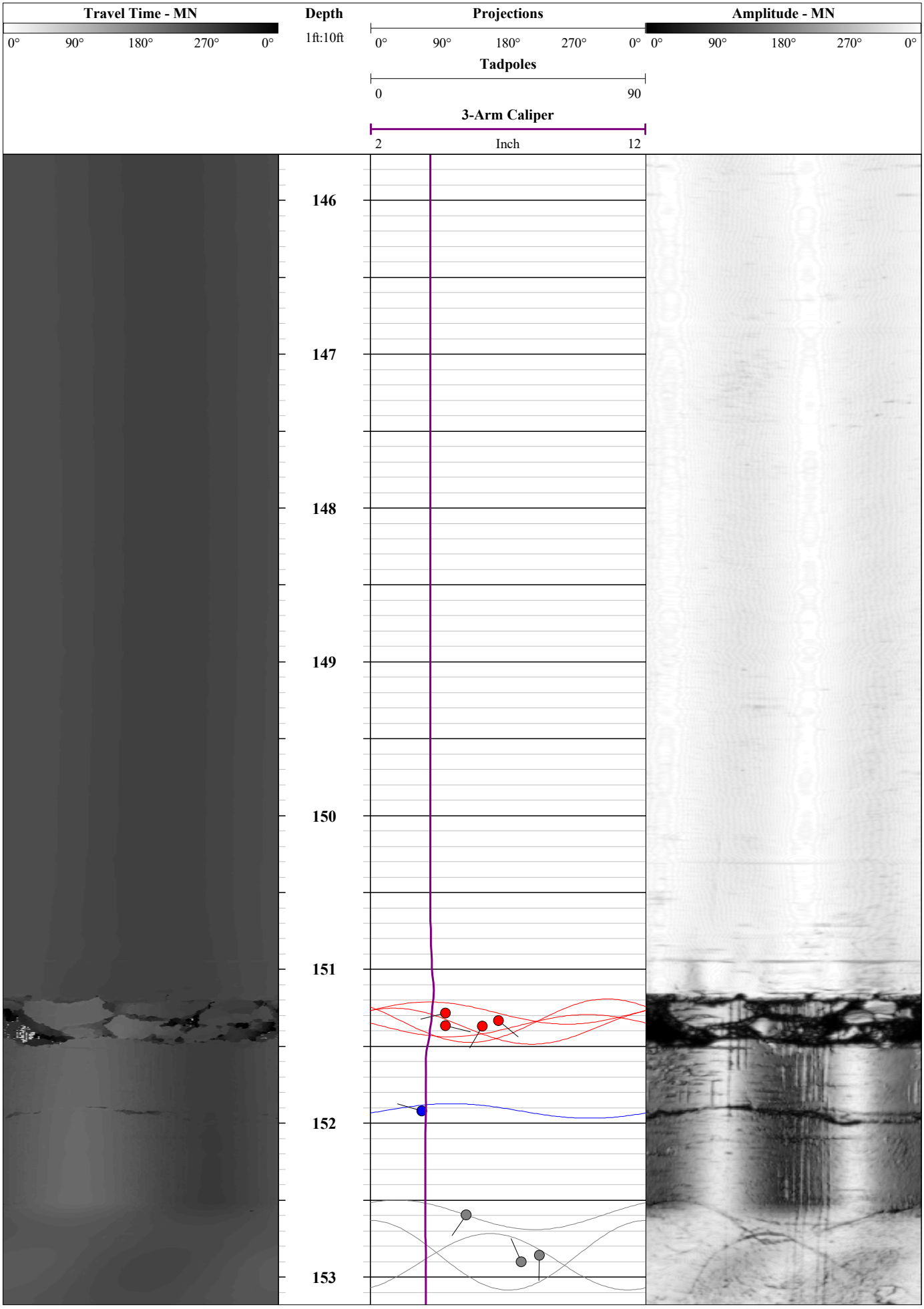
RUN No.	BIT	FROM	TO
1	HQ	0'	248.4'

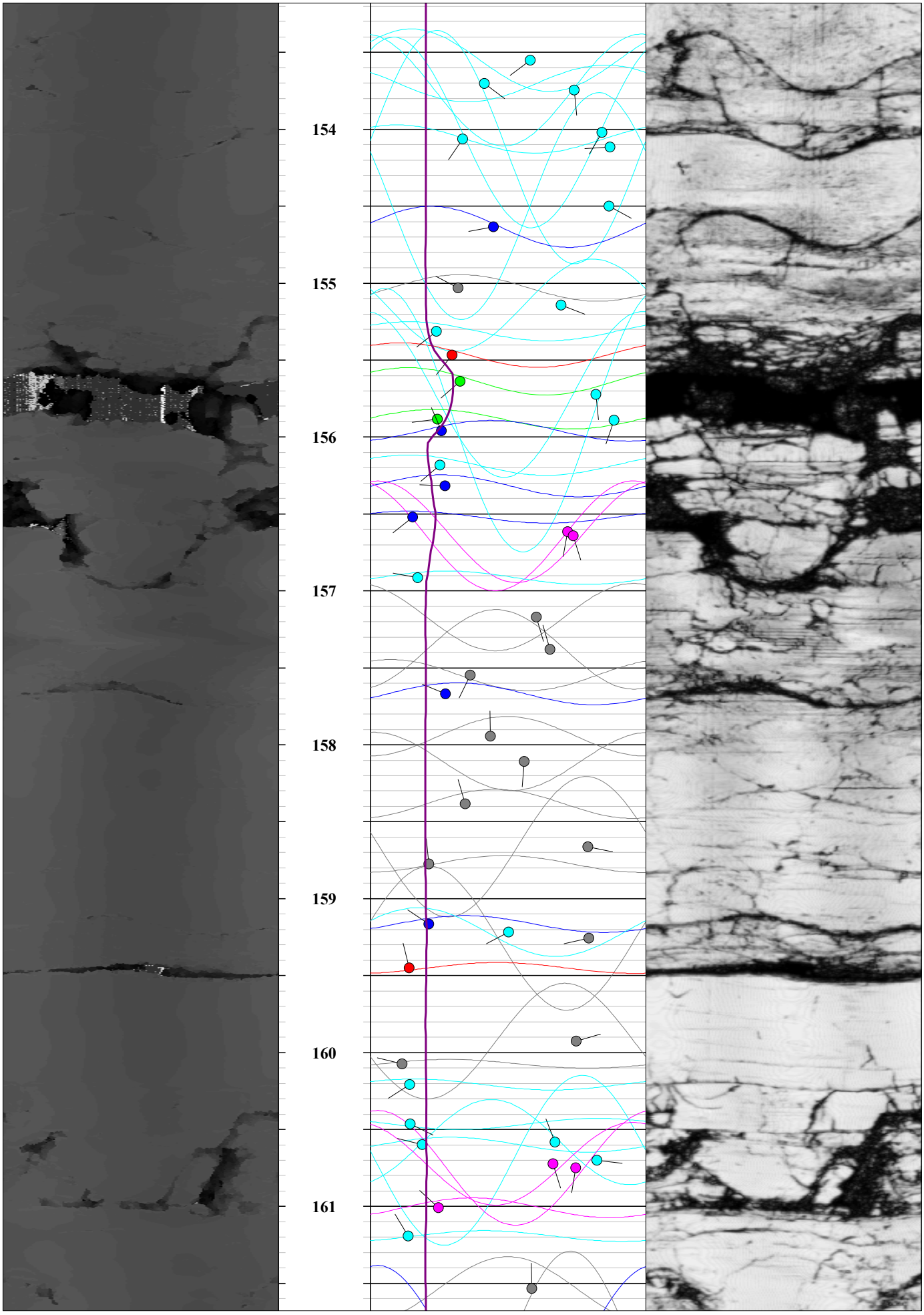
CASING RECORD

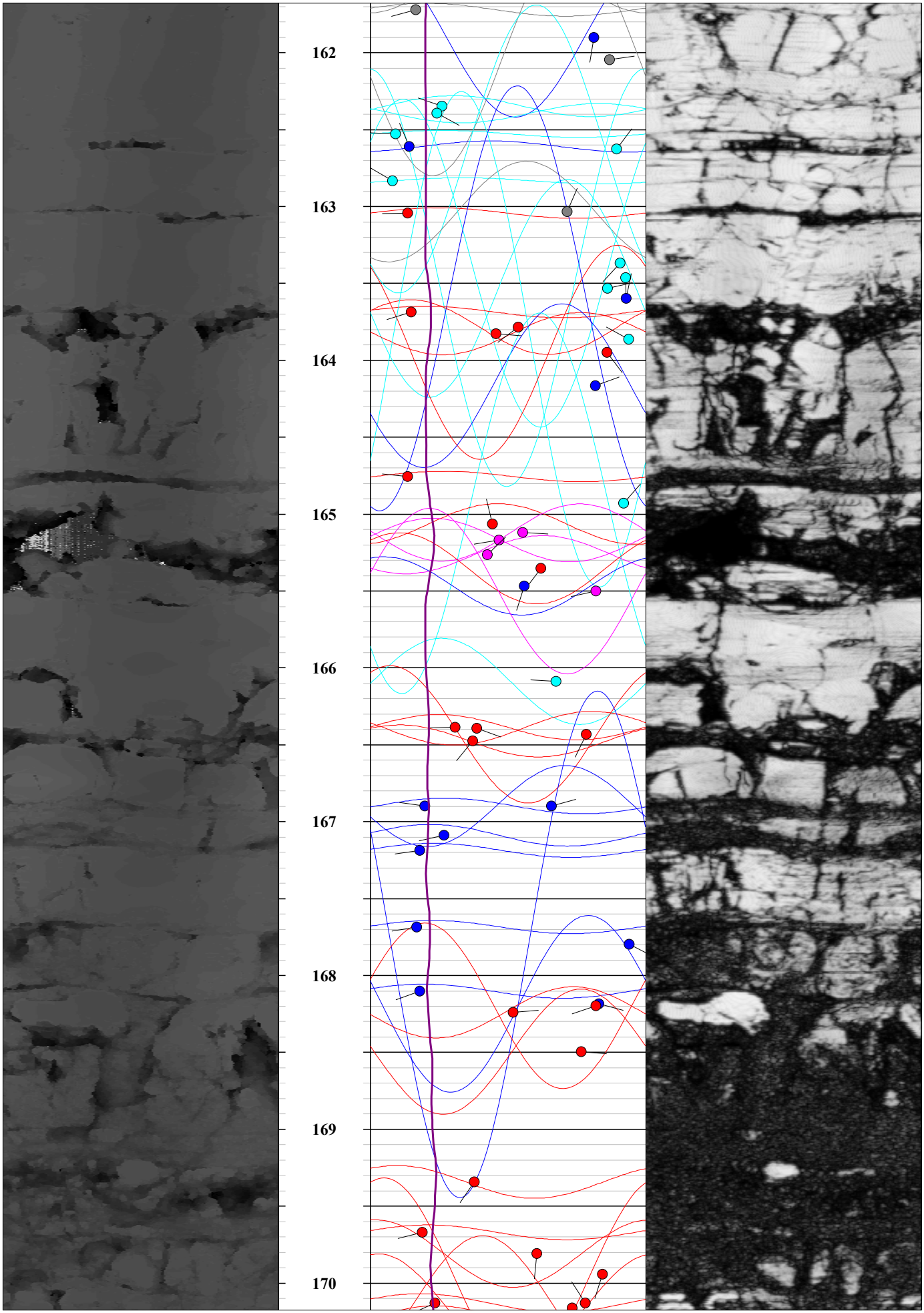
SIZE	WGT.	FROM	TO
HQ	Steel	0'	150'

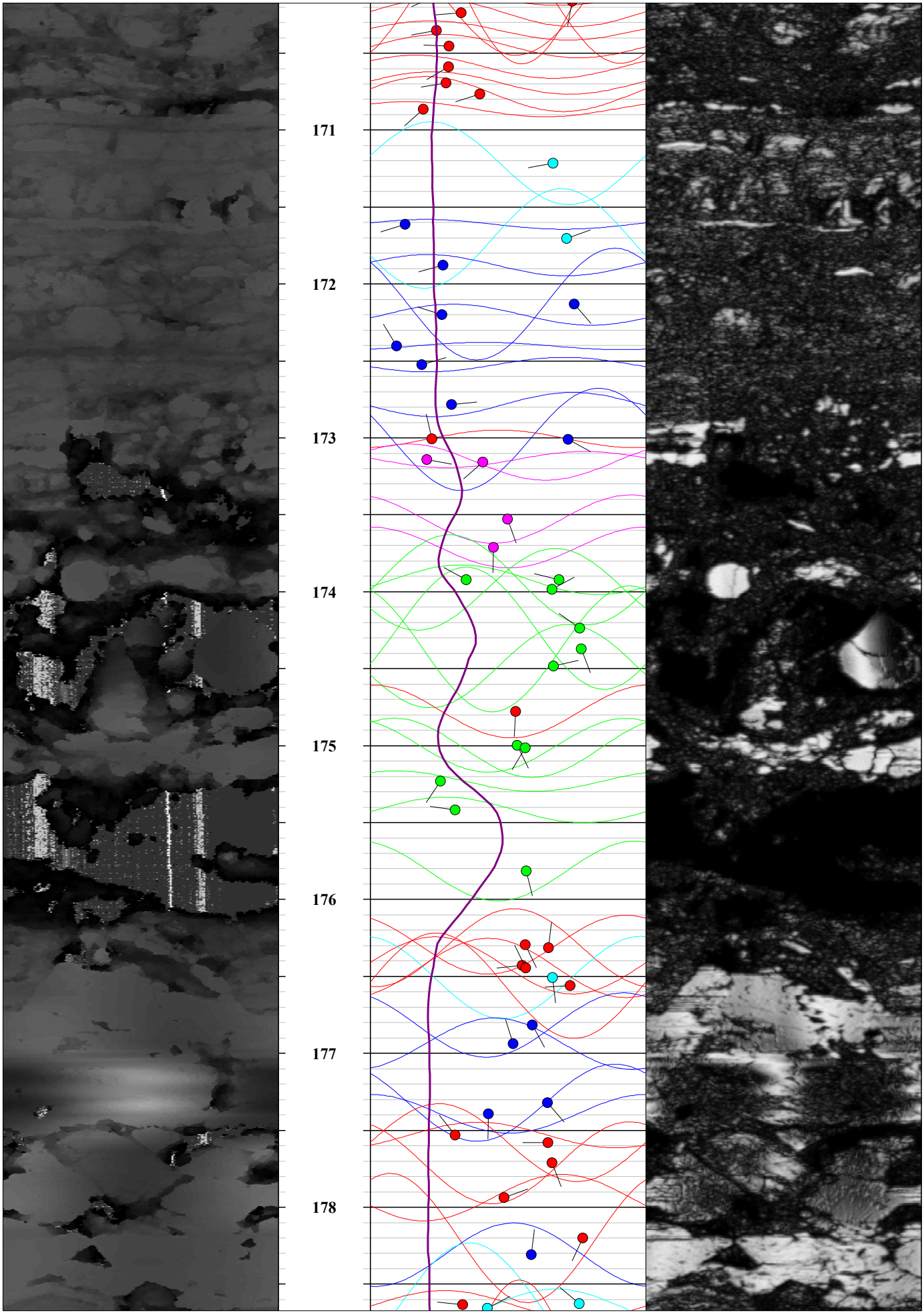
NA - Not Available, N/A - Not Applicable

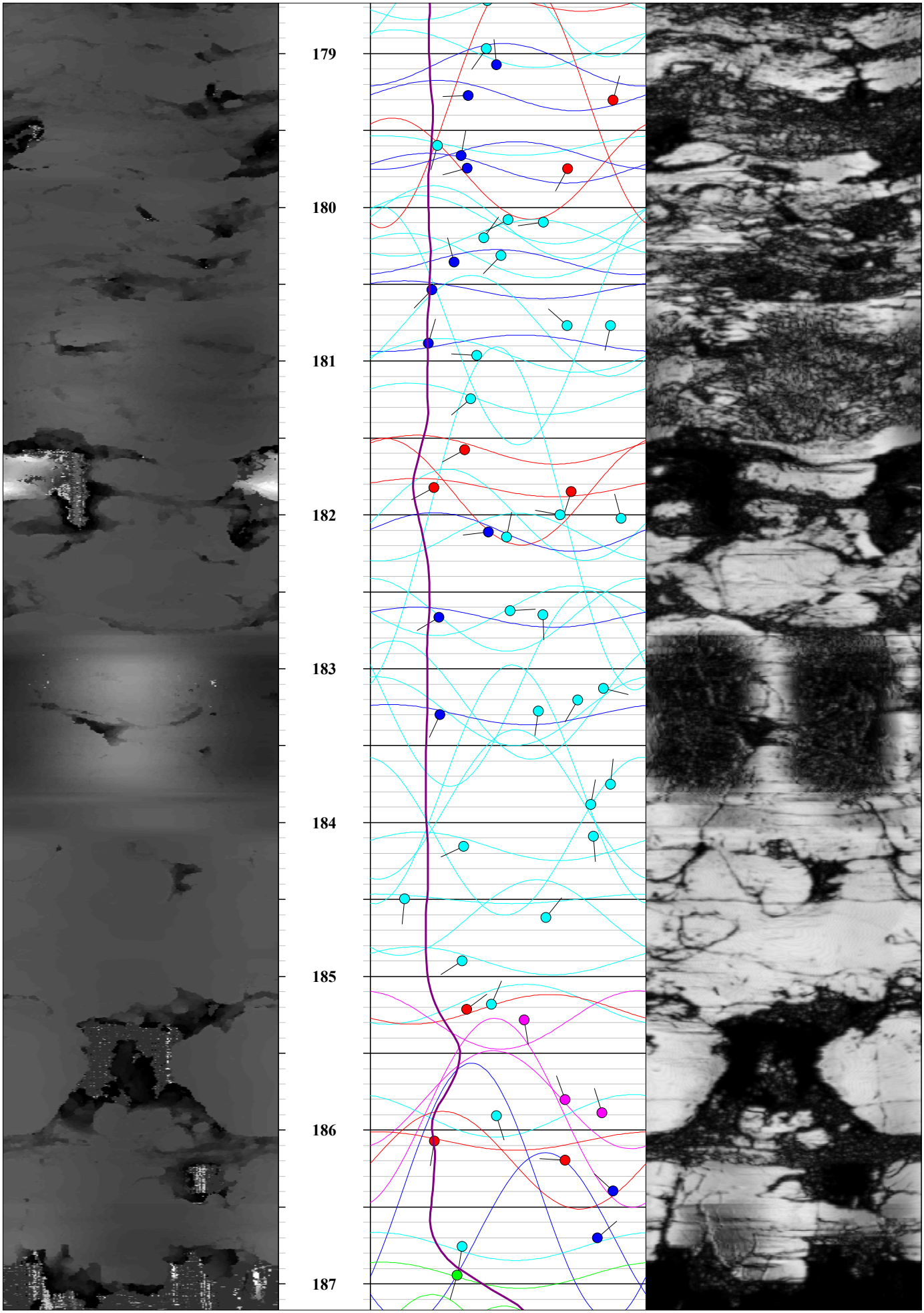
COMMENTS

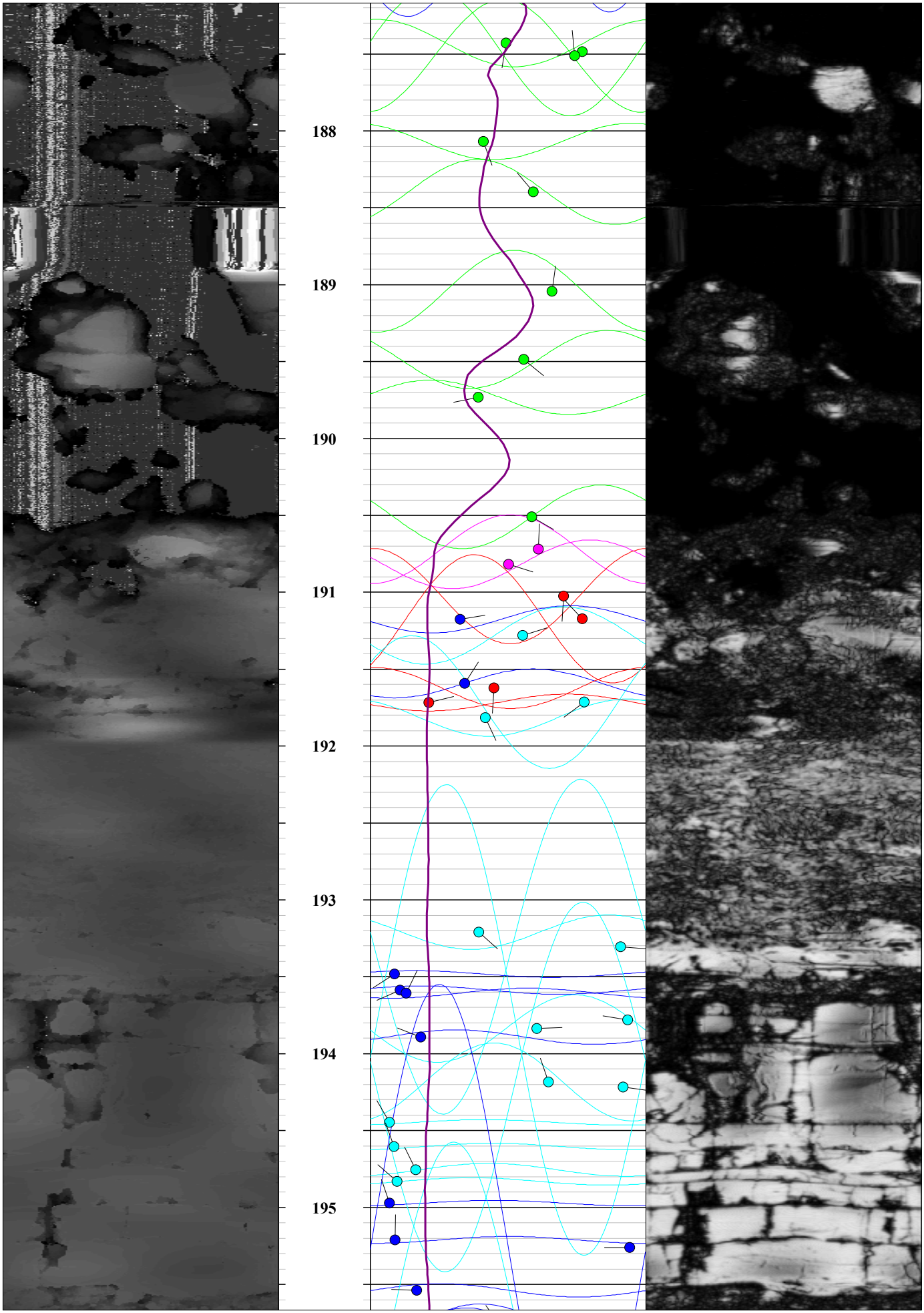

Travel Time - MN
0°
90°
180°
270°
0°
Depth
1ft:10ft
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
3-Arm Caliper
2
Inch
12
Amplitude - MN
0°
90°
180°
270°
0°
146
147
148
149
150
151
152
153

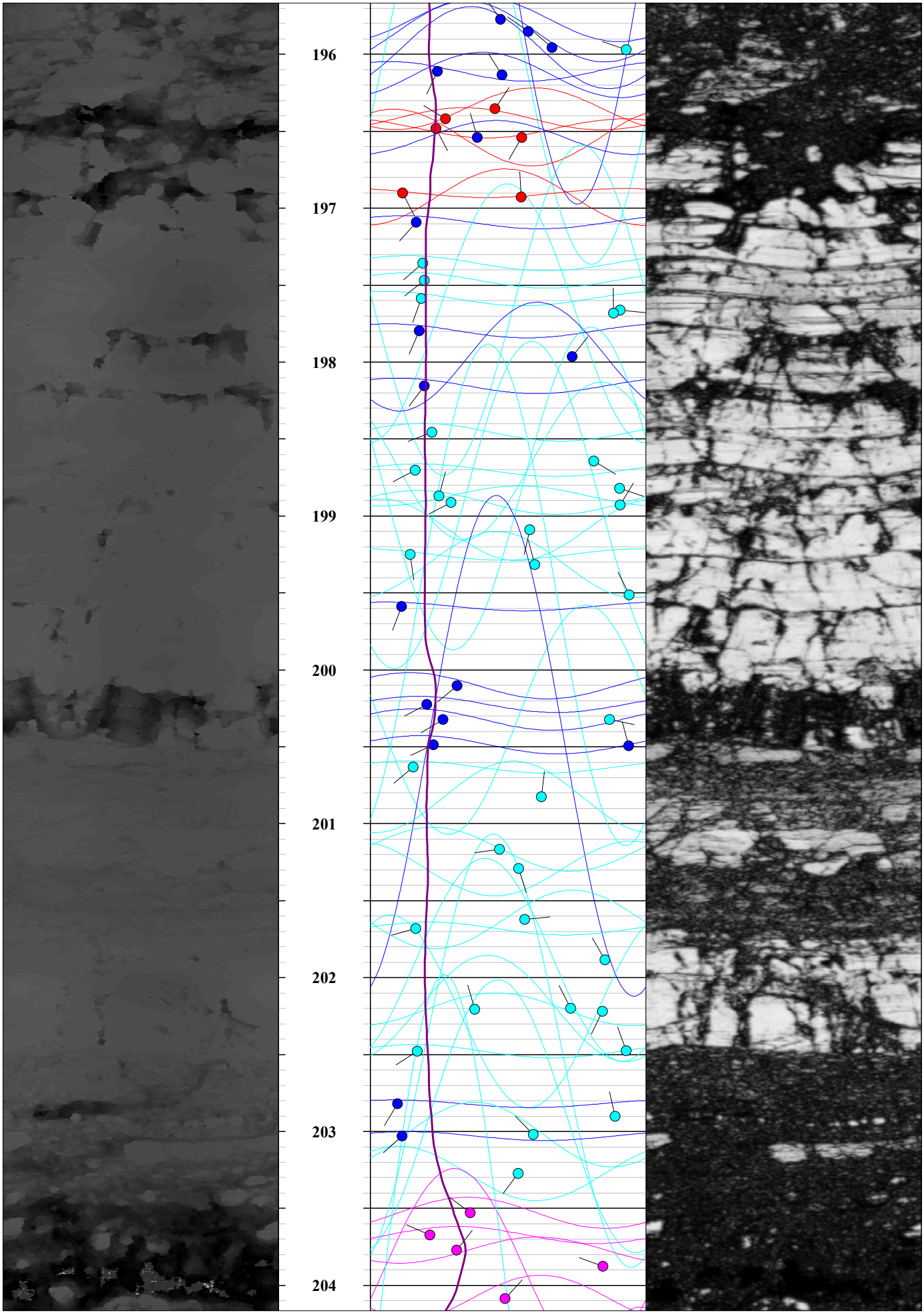

154
155
156
157
158
159
160
161

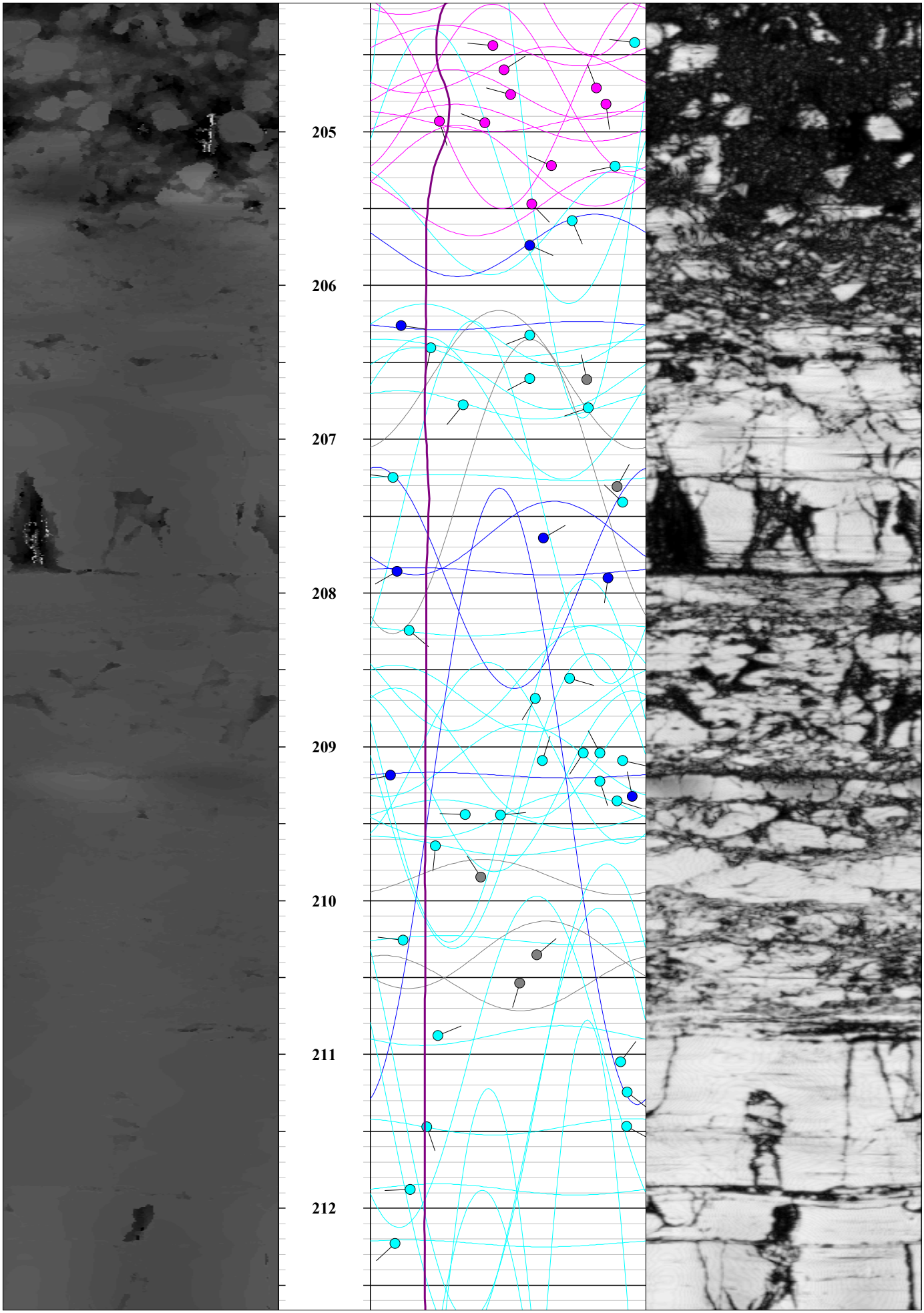

162
163
164
165
166
167
168
169
170

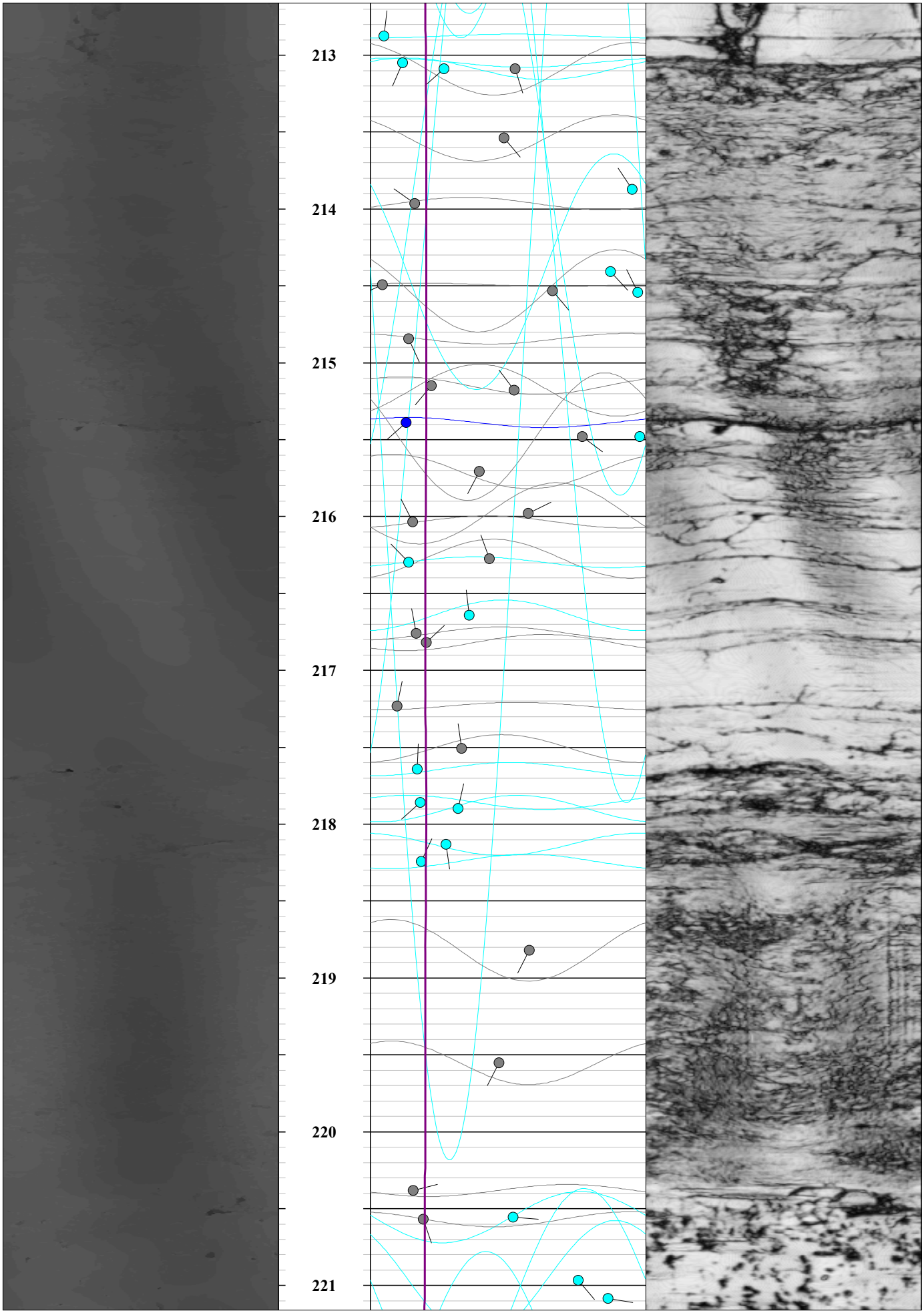

171
172
173
174
175
176
177
178

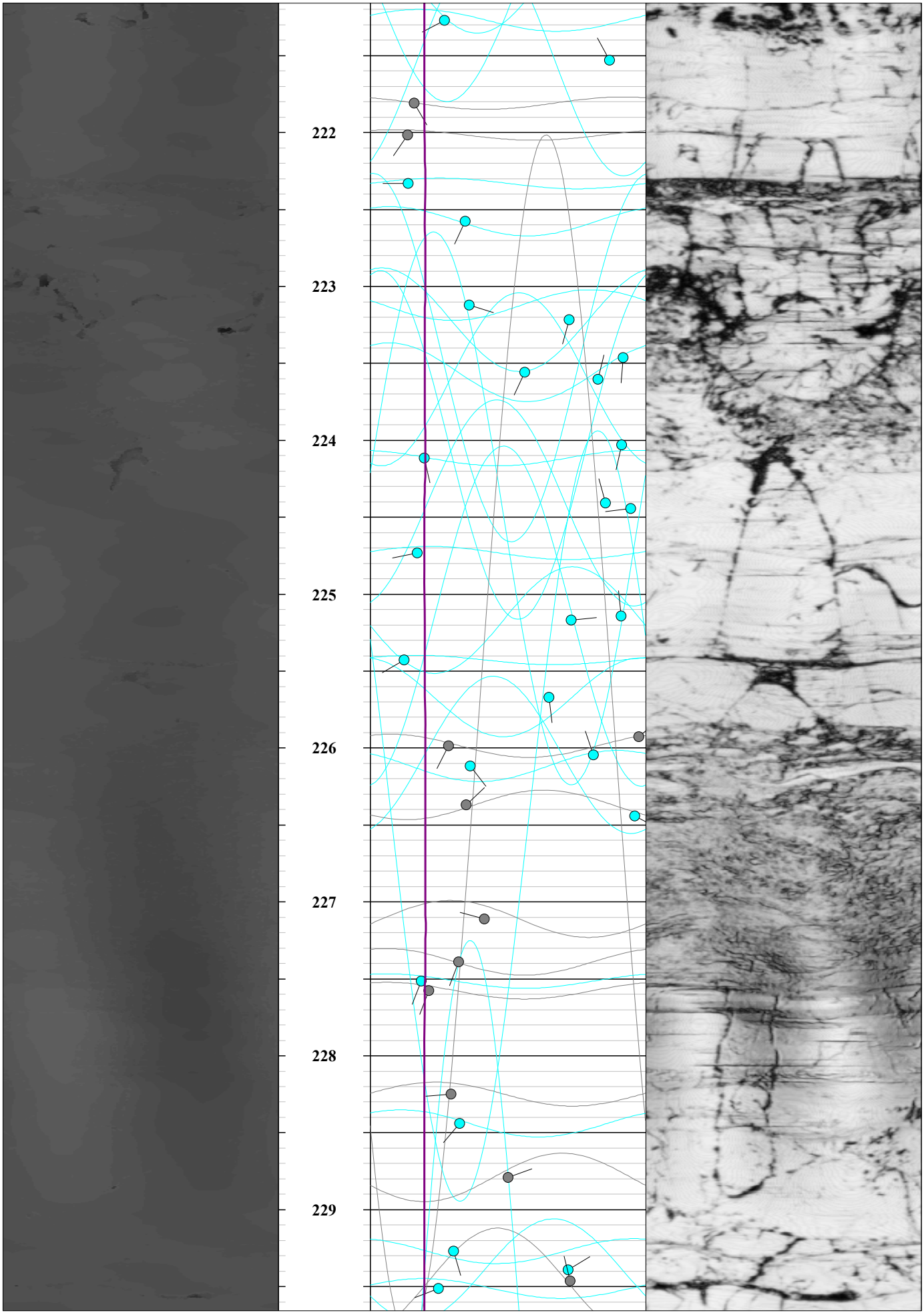

179
180
181
182
183
184
185
186
187

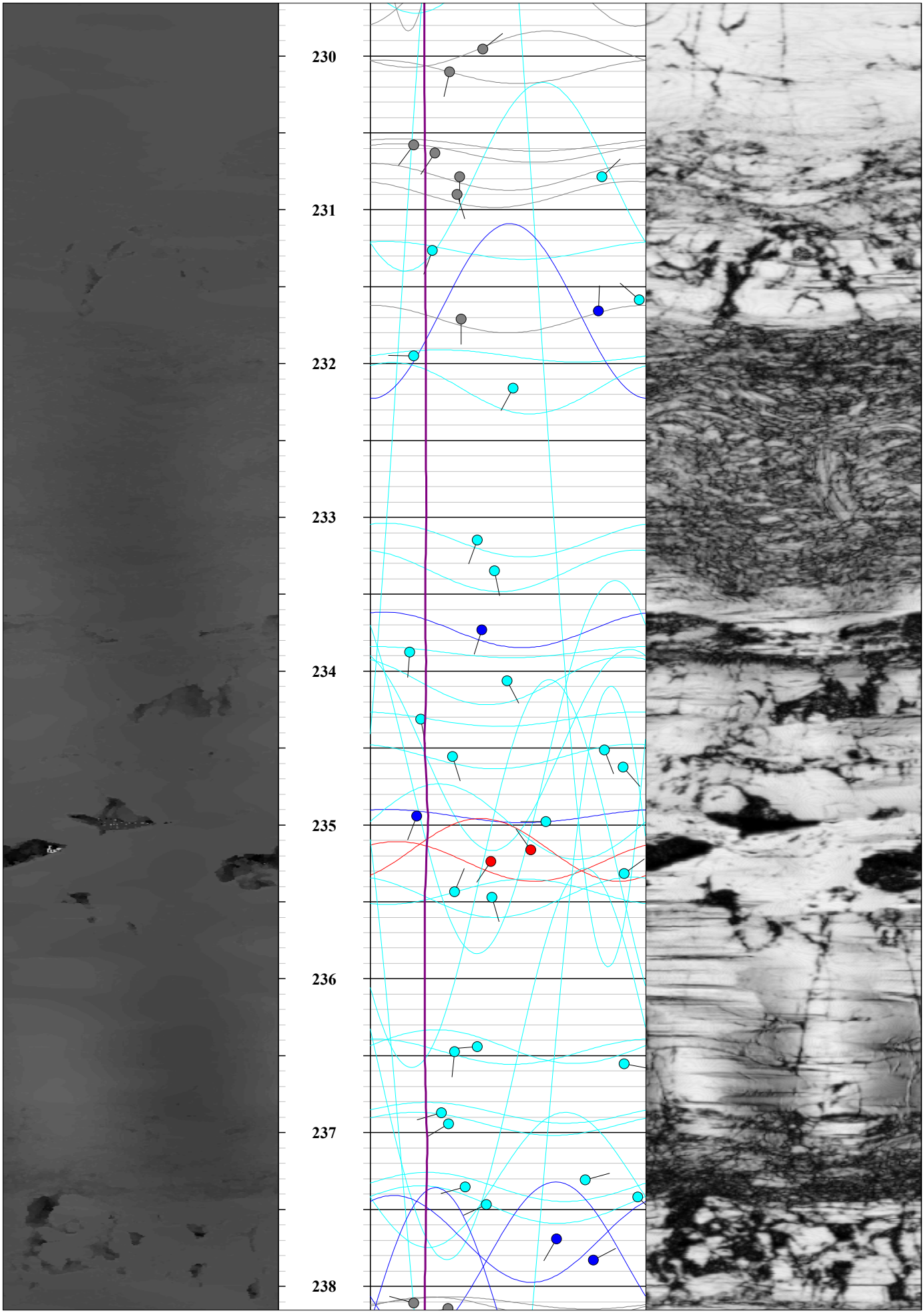

188
189
190
191
192
193
194
195

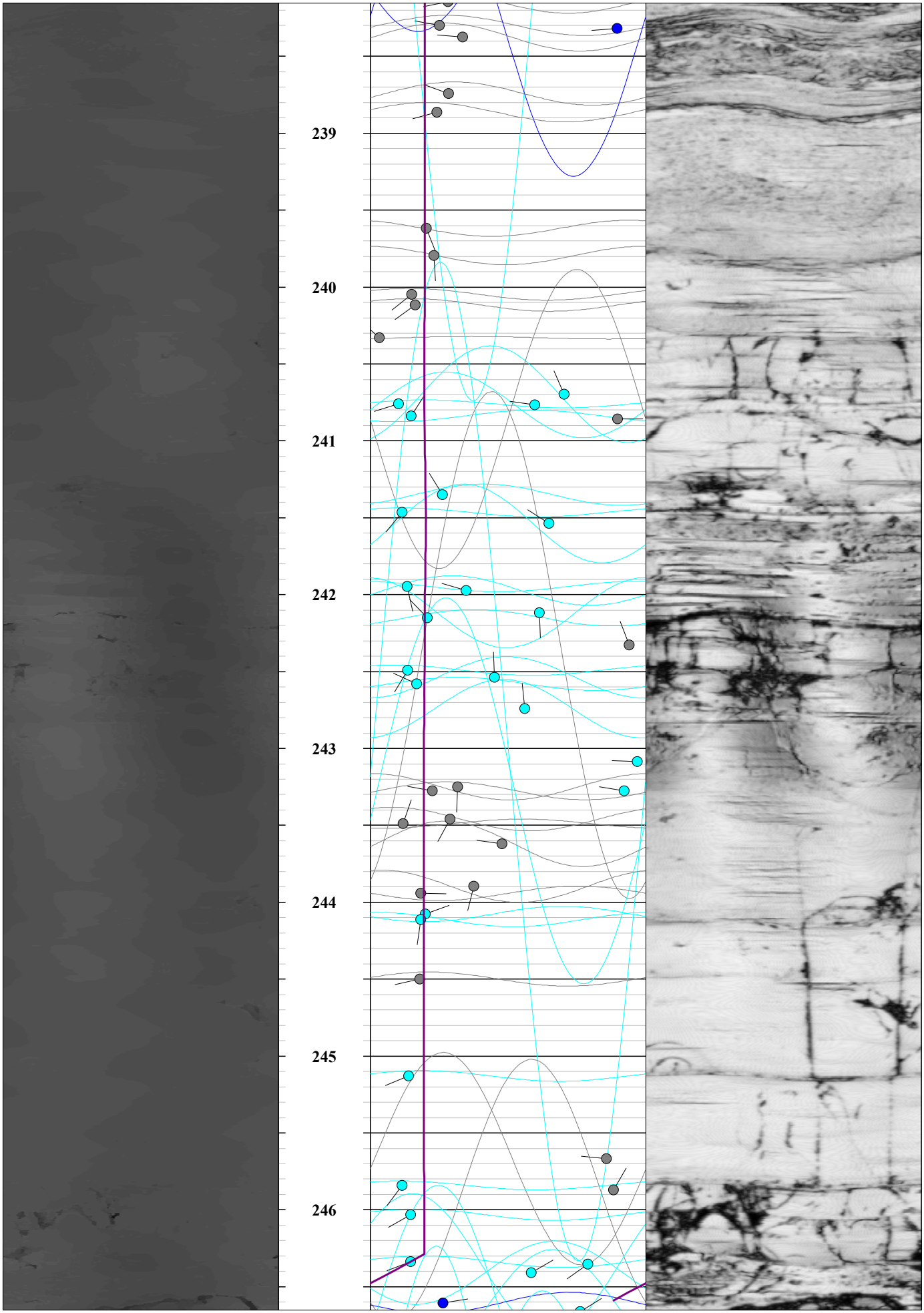

196
197
198
199
200
201
202
203
204

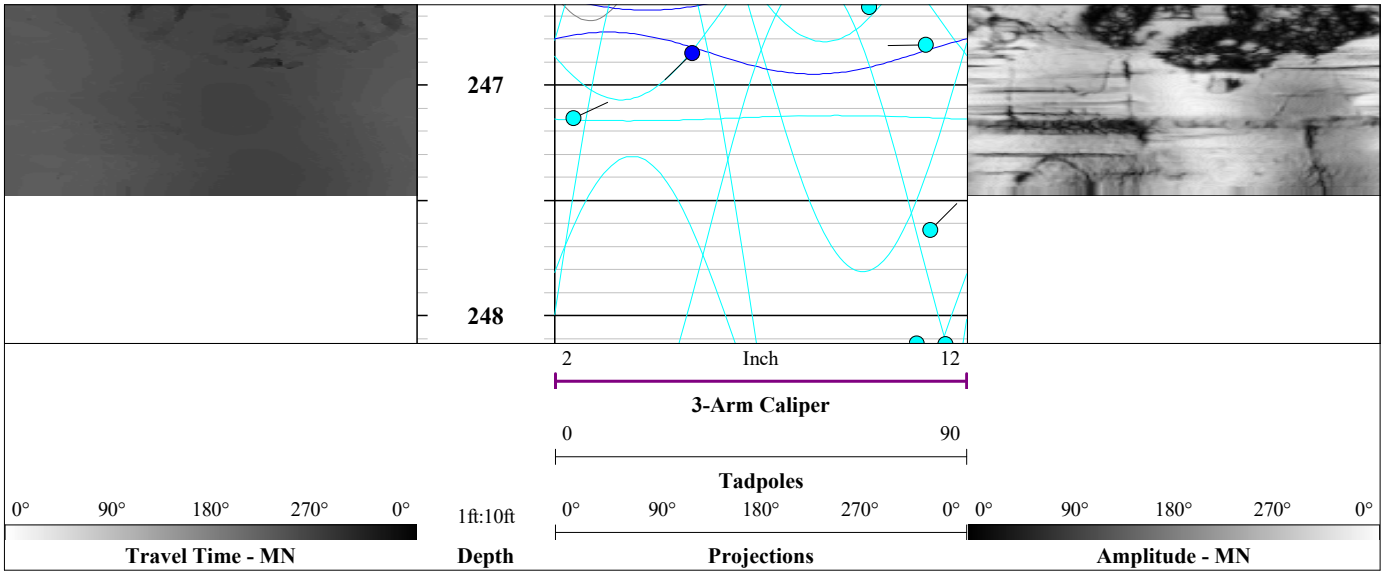

205
206
207
208
209
210
211
212


213
214
215
216
217
218
219
220
221


222
223
224
225
226
227
228
229


230
231
232
233
234
235
236
237
238


239
240
241
242
243
244
245
246


247
248
2
Inch
12
3-Arm Caliper
0
90
Tadpoles
0° 90° 180° 270° 0°
1ft:10ft
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
Travel Time - MN
Depth
Projections
Amplitude - MN

borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Optical Televiewer

Company WSP
Well BH19-37
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-37
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79428 N
Longitude: 84.77377 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Electric log
Natural Gamma
3-armed caliper
Fluid Temp. & Cond.
P&S Suspension Log

PERMANENT DATUM Top of Casing **ELEVATION** 600.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	16 July 2019			
RUN NUMBER	1			
LOG TYPE	Optical Televiewer			
DEPTH-DRILLER	248.4'			
DEPTH-LOGGER	248'			
BTM LOG INTERVAL	247.9'			
TOP LOG INTERVAL	139.2'			
RECORDED BY	CKL			
WITNESSED BY				
PROBE TYPE, S/N	OPTV #1729			
LOGGING SPEED	4.5 fpm			
A.S.D.E. / Sample Interval	0.5'/0.00038			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	248.4'

CASING RECORD

SIZE	WGT.	FROM	TO
HQ	Steel	0'	150'

NA - Not Available, N/A - Not Applicable

COMMENTS

3-Arm Caliper			Depth	Projections					Optical Image - MN					
2	Inch	12	1ft:10ft	0°	90°	180°	270°	0°	0°	90°	180°	270°	0°
				Tadpoles									
				0				90					

140

141

142

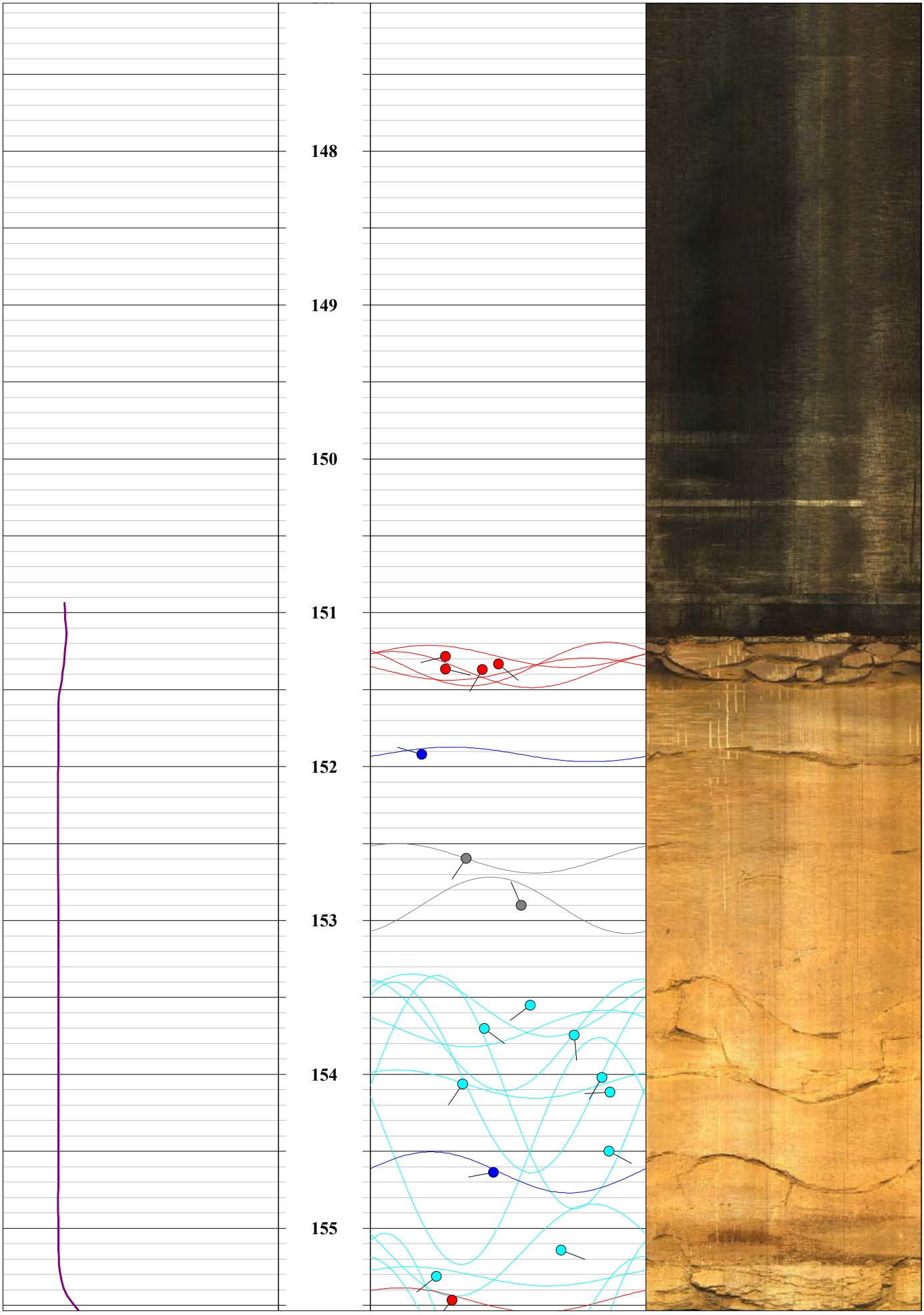
143

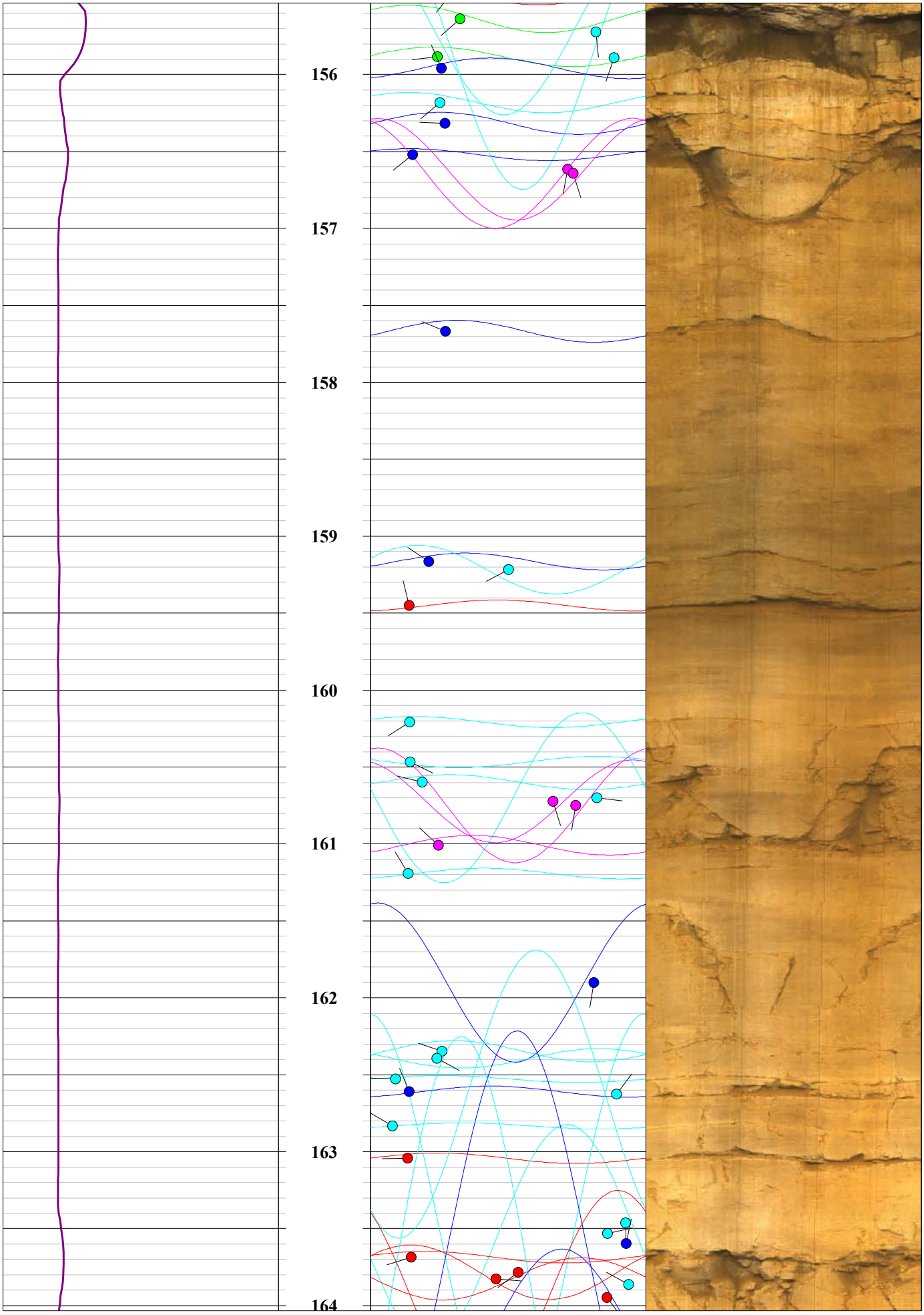
144

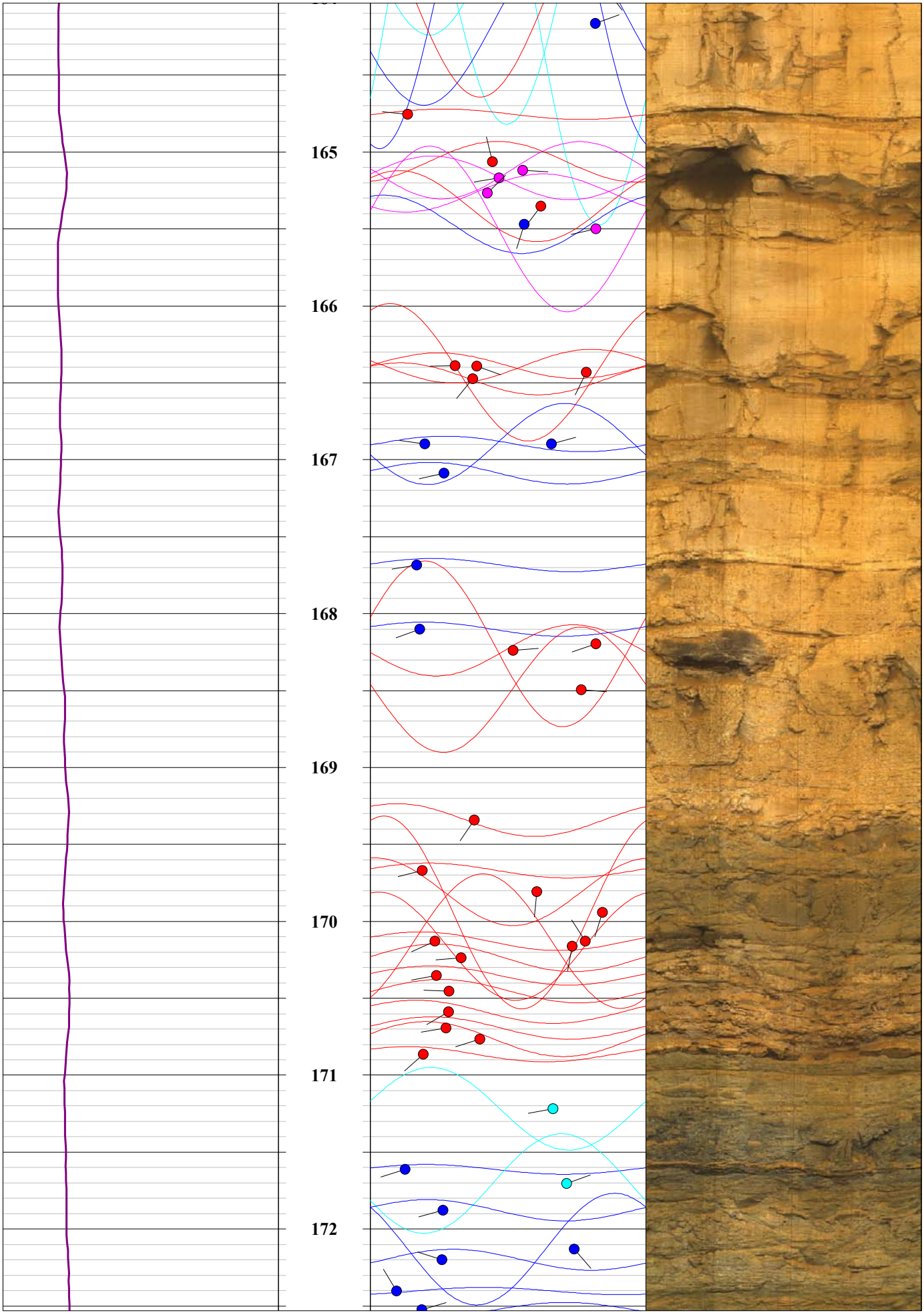
145

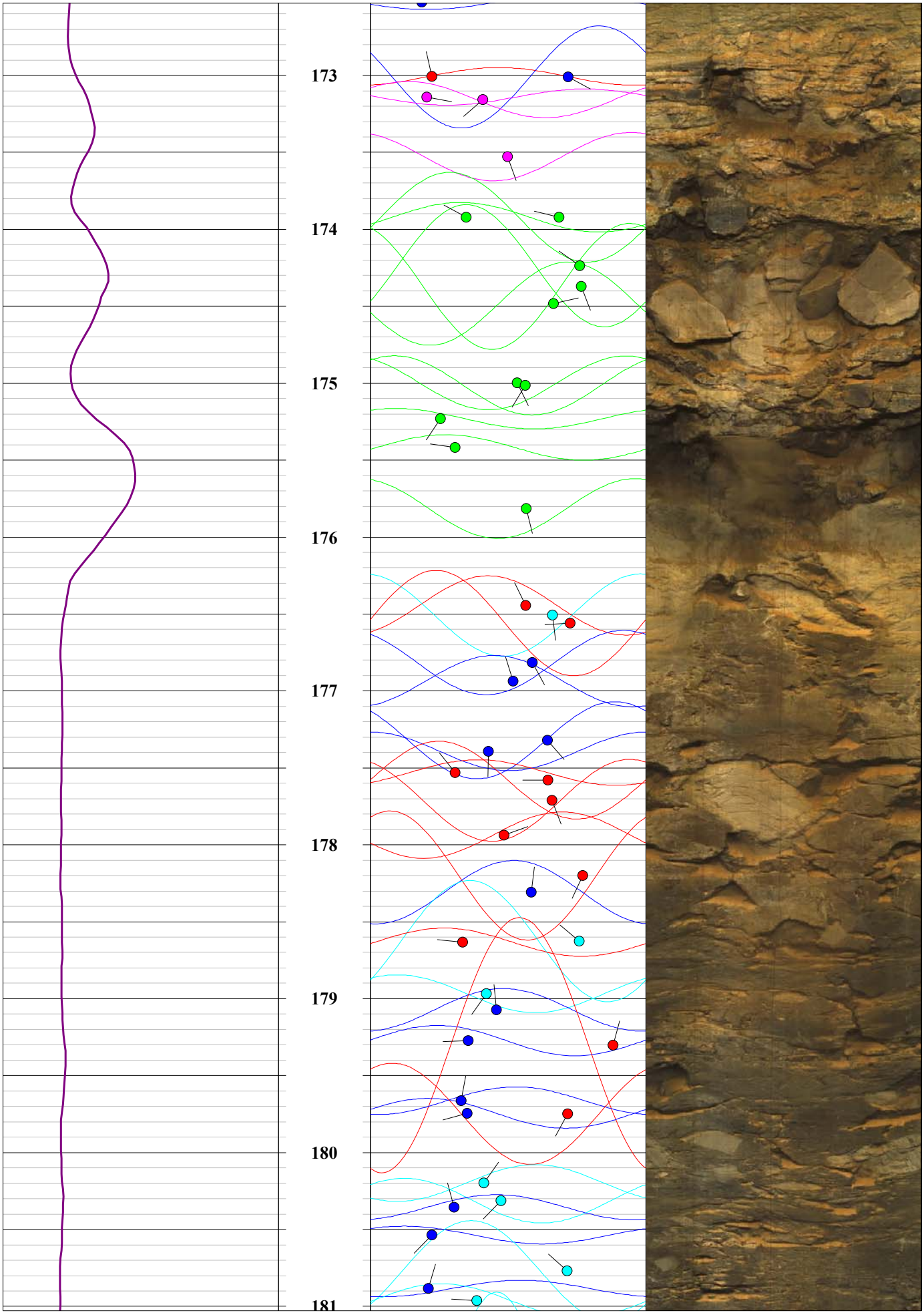
146

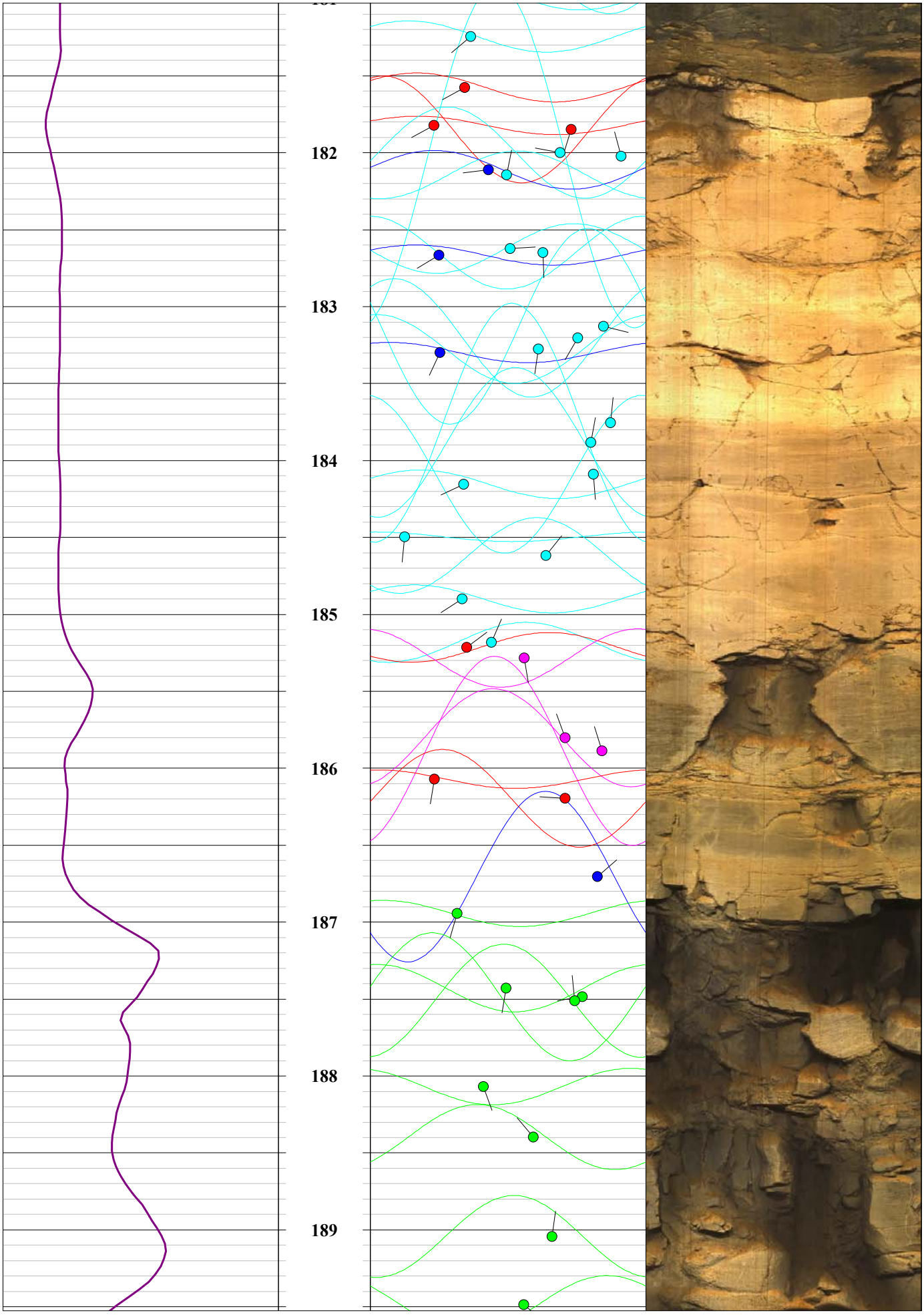
147

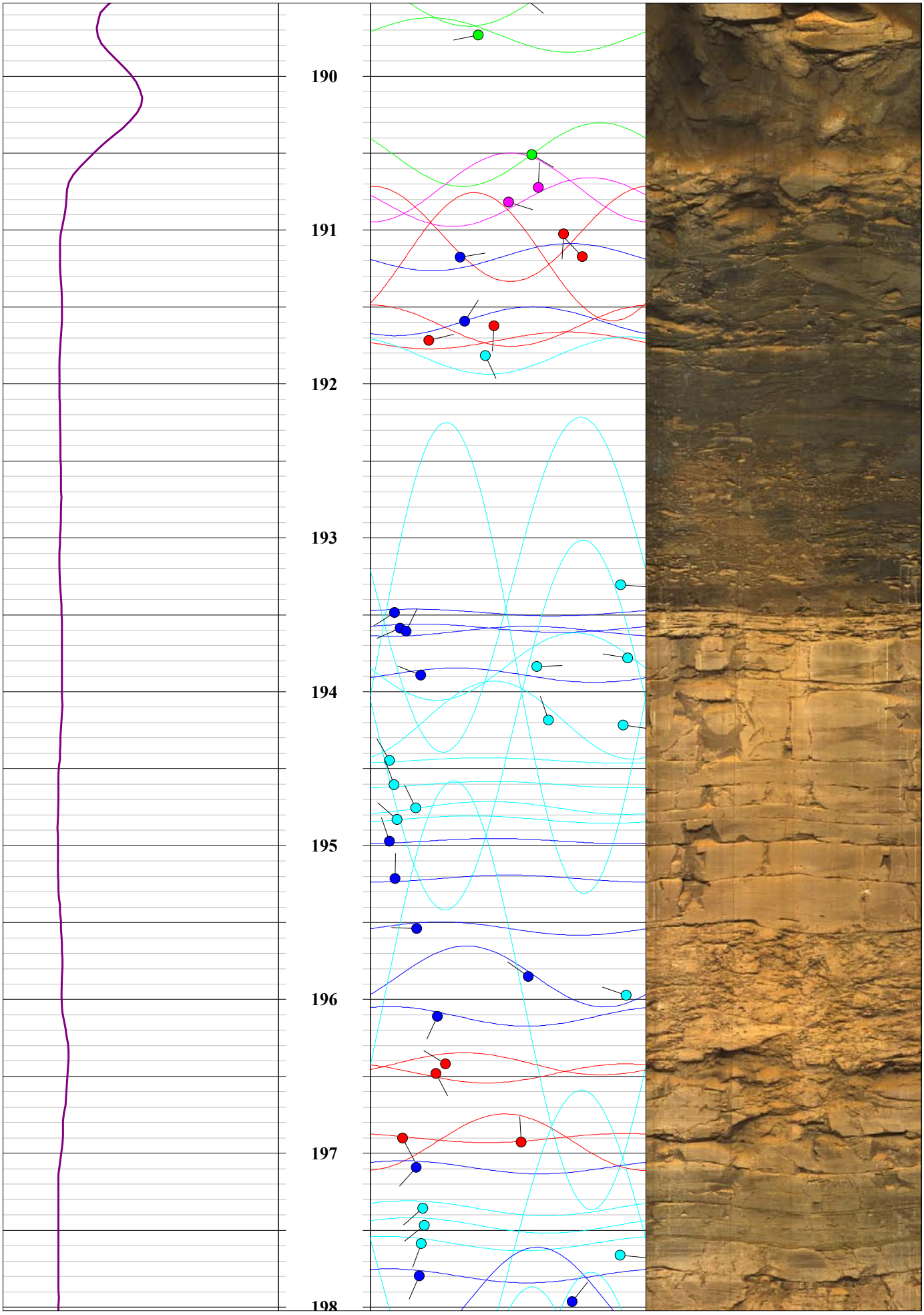

148
149
150
151
152
153
154
155

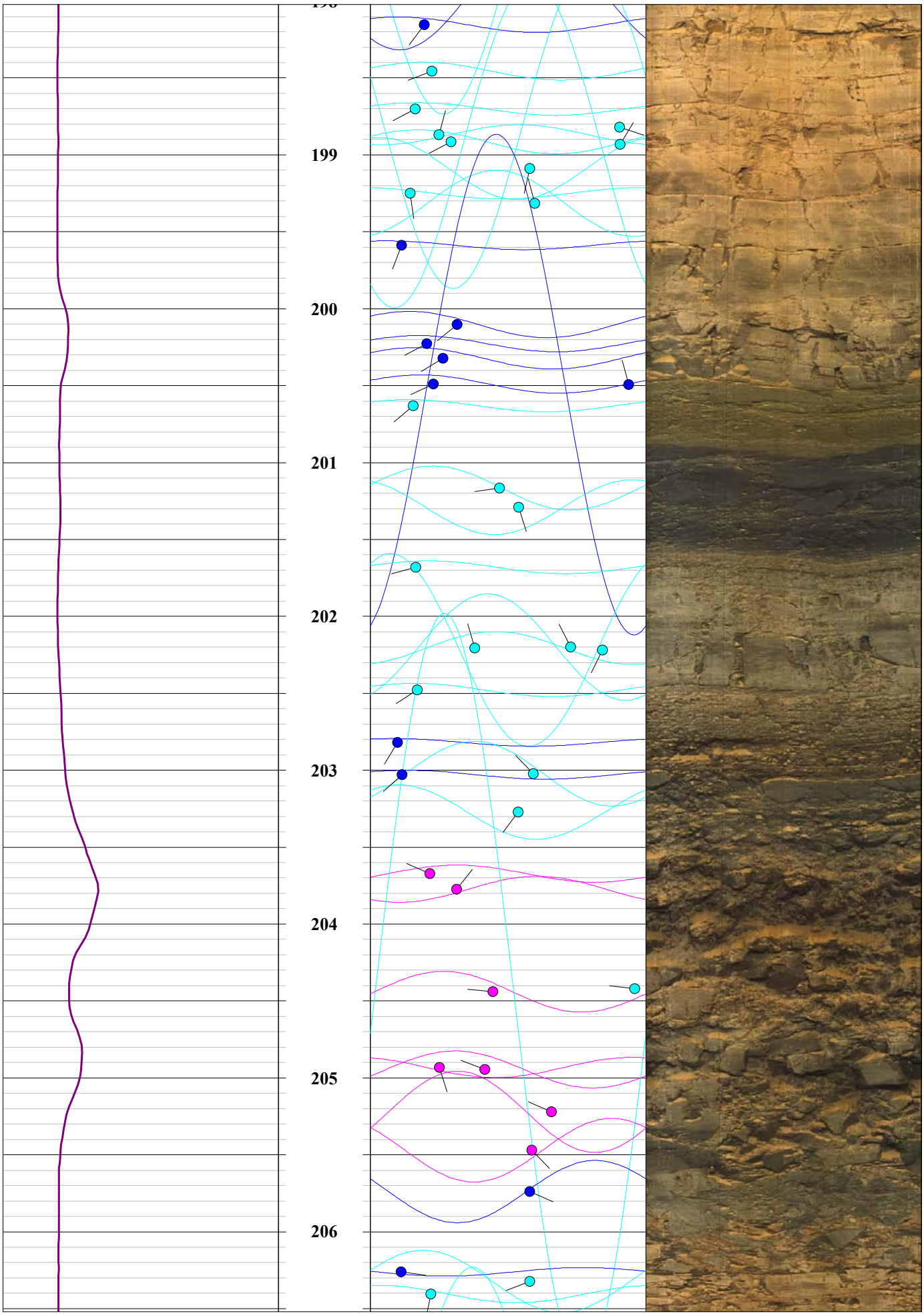

156
157
158
159
160
161
162
163
164

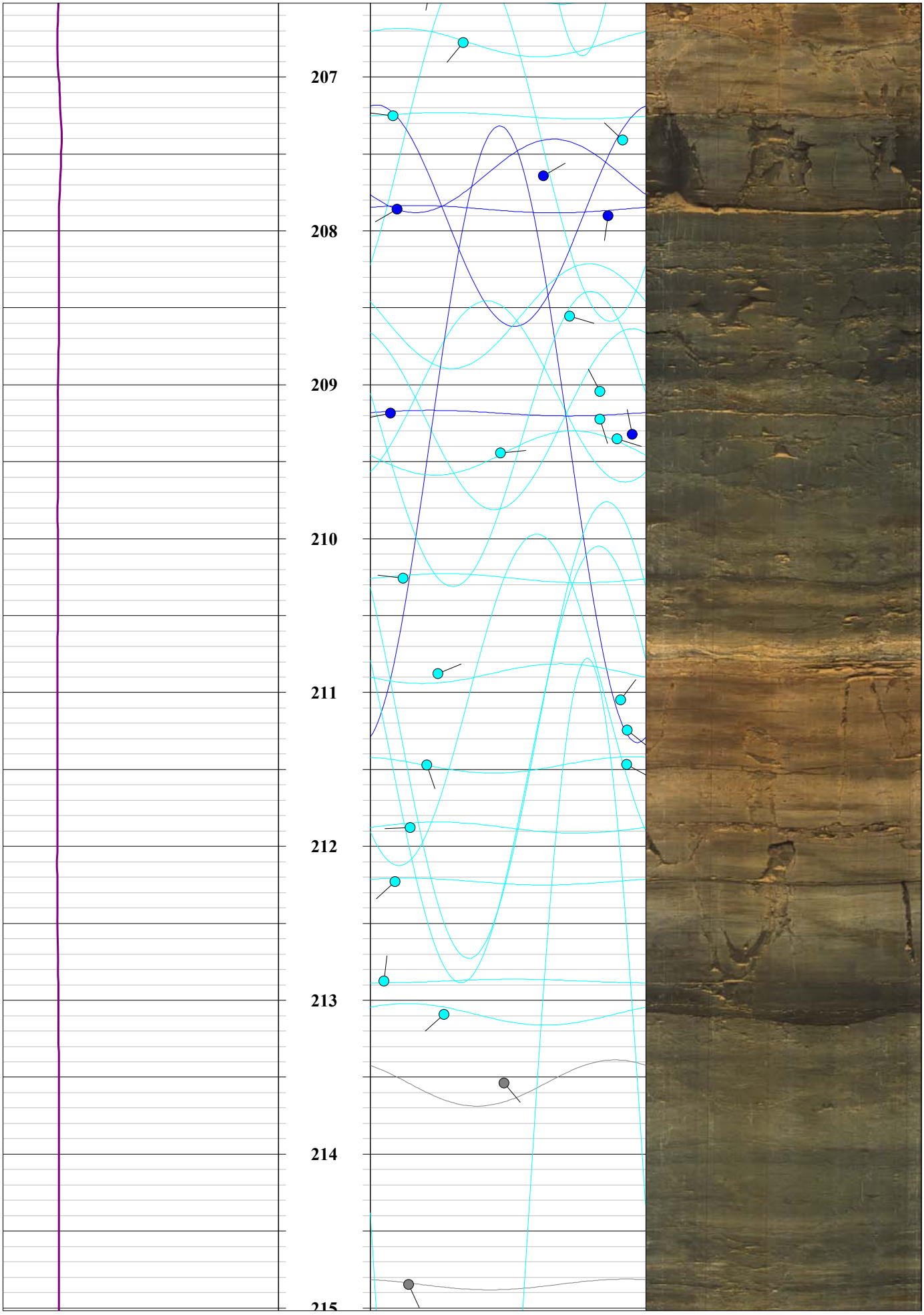

165
166
167
168
169
170
171
172

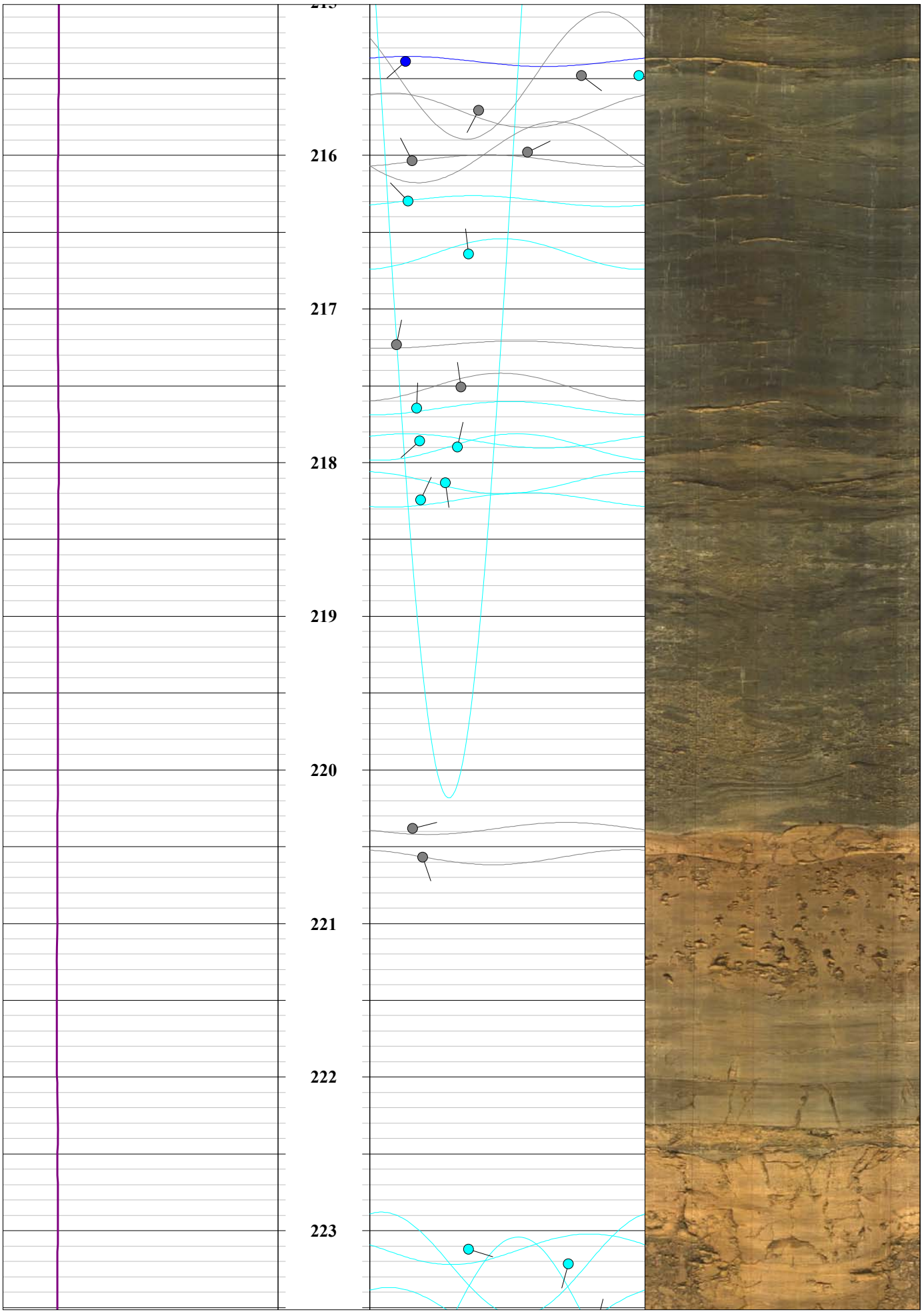

173
174
175
176
177
178
179
180
181

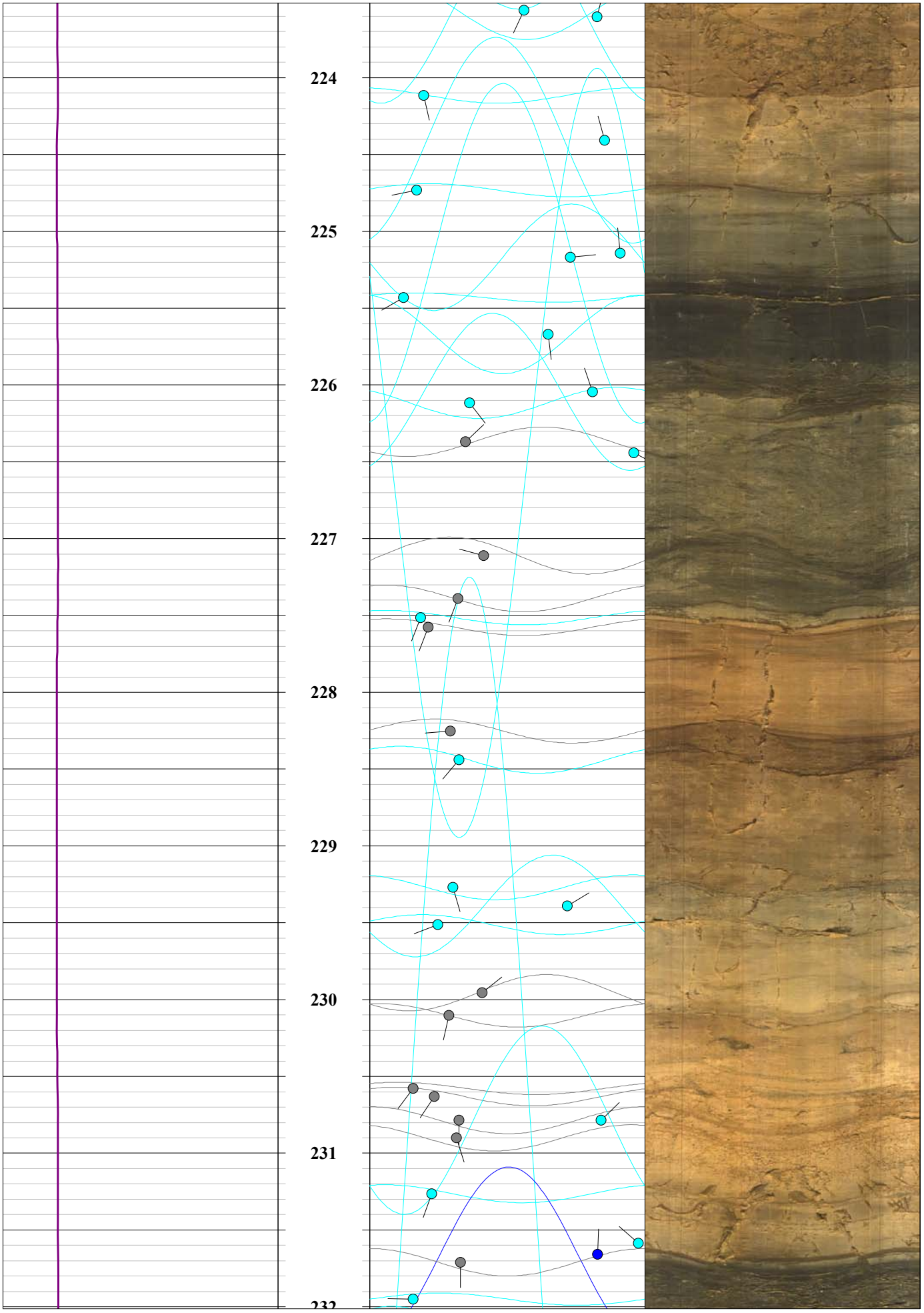

182
183
184
185
186
187
188
189

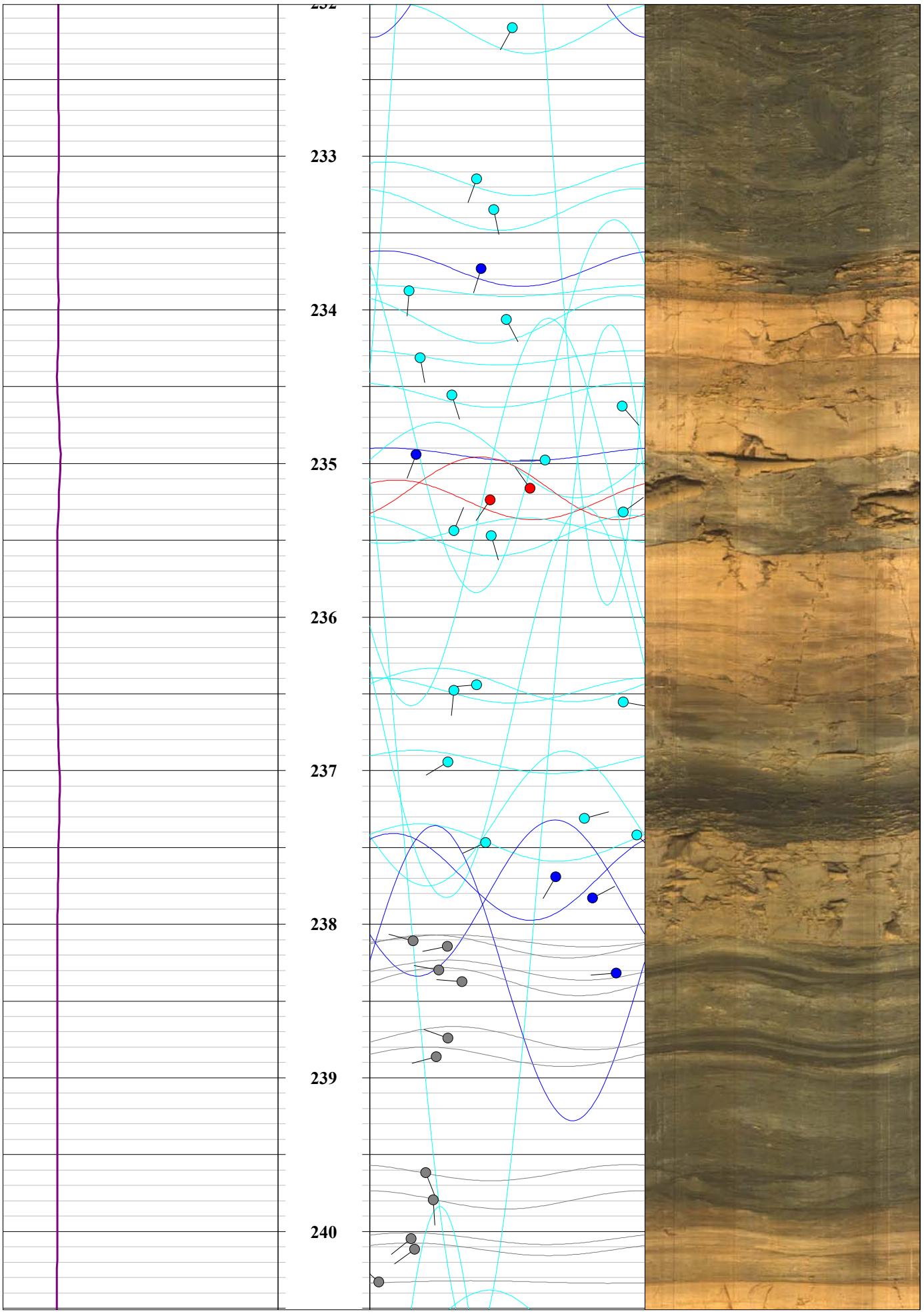

190
191
192
193
194
195
196
197
198

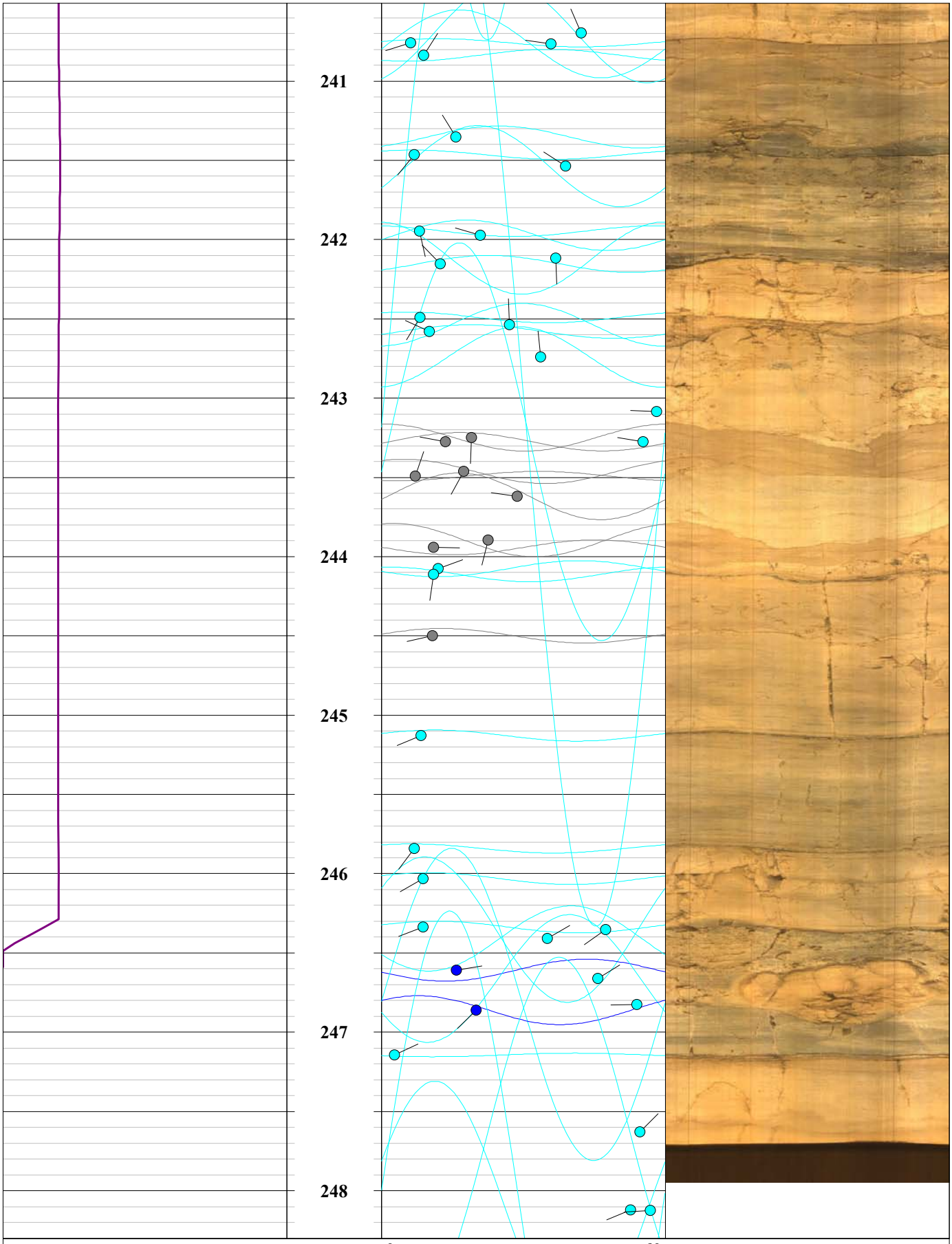

199
200
201
202
203
204
205
206


207
208
209
210
211
212
213
214
215

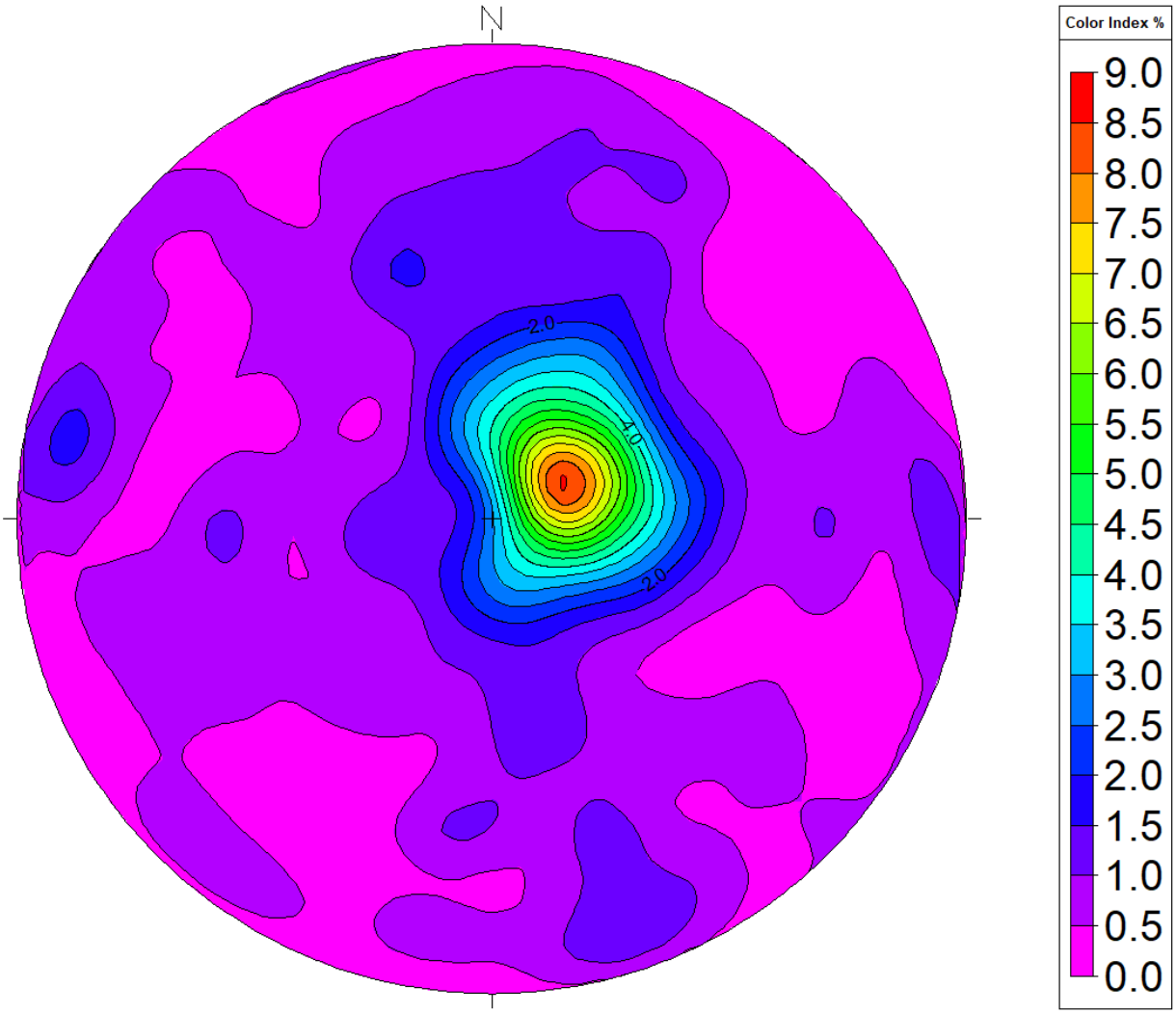

216
217
218
219
220
221
222
223


224
225
226
227
228
229
230
231
232


233
234
235
236
237
238
239
240

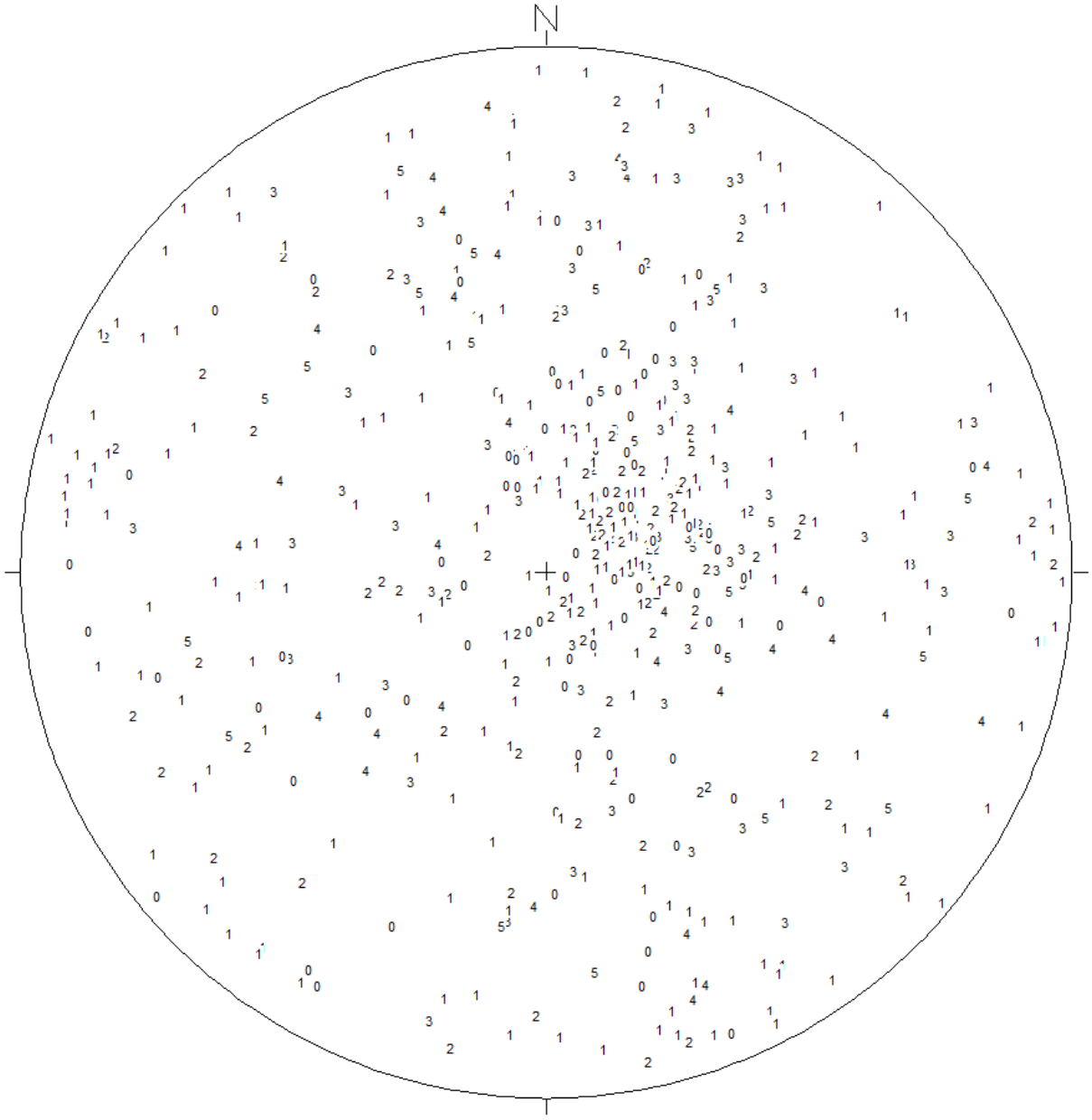

241
242
243
244
245
246
247
248
0
90
Tadpoles
2
Inch
12
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
3-Arm Caliper
Depth
Projections
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-37
16 July 2019



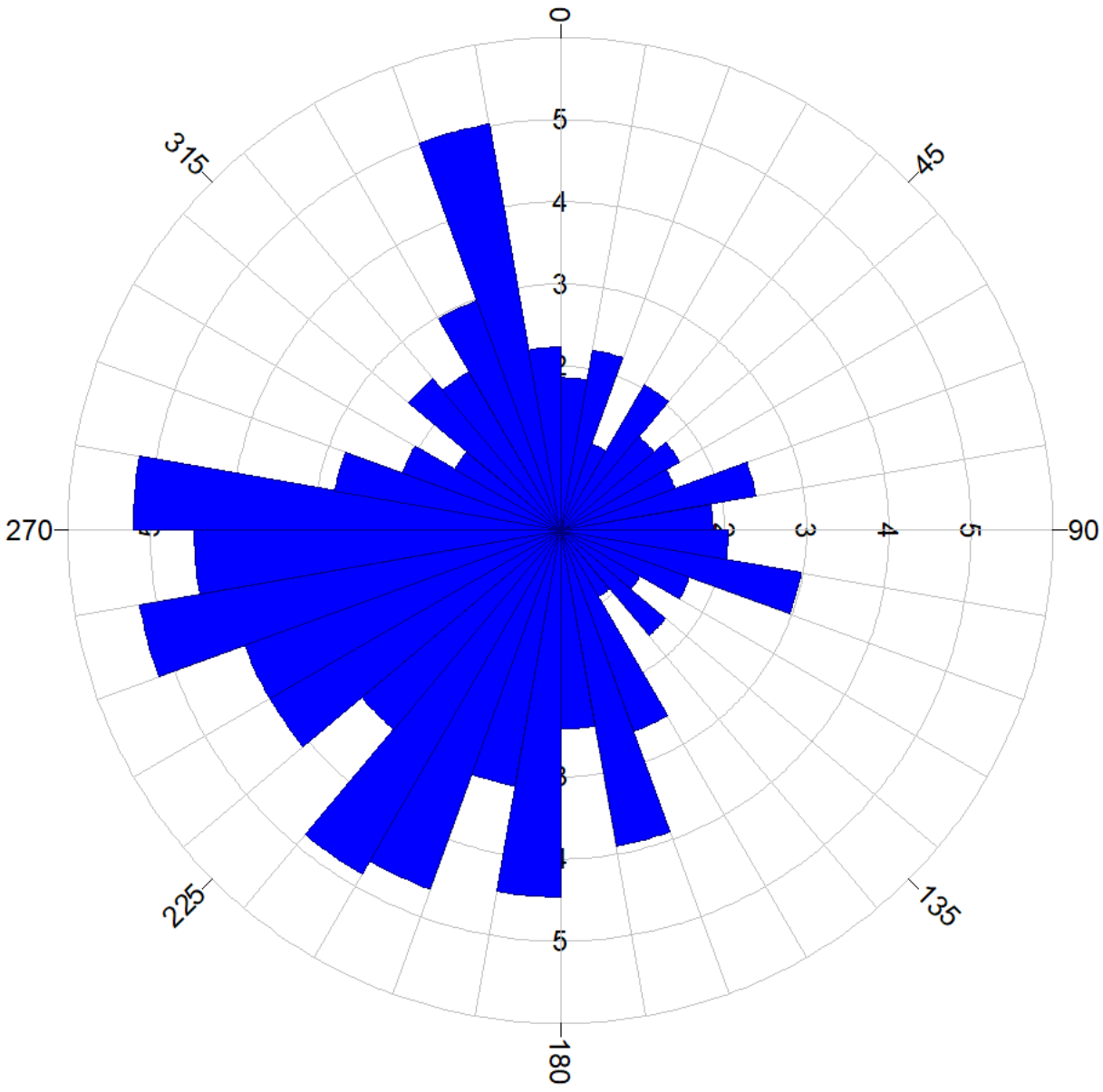
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-37
16 July 2019



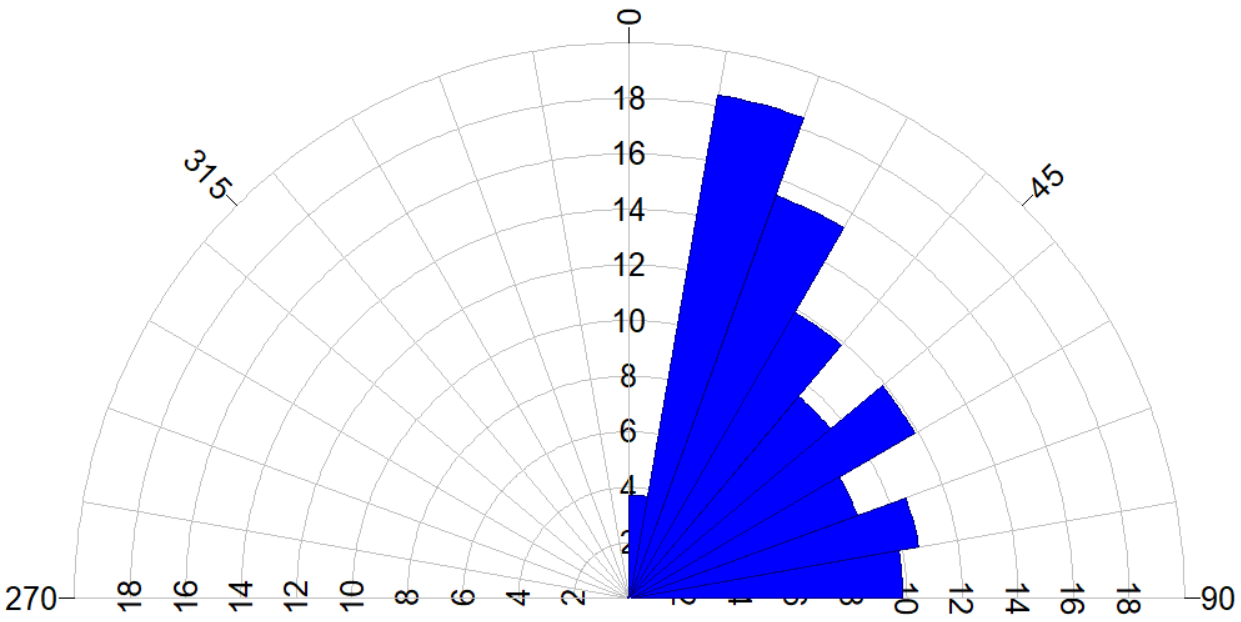
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-37
16 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-37
16 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	46.11	151.3	257	25	3
2	46.13	151.3	130	42	3
3	46.13	151.4	104	25	3
4	46.14	151.4	211	37	3
5	46.31	151.9	286	17	2
6	46.51	152.6	214	31	0
7	46.59	152.9	181	55	0
8	46.60	152.9	336	49	0
9	46.80	153.6	234	52	1
10	46.85	153.7	127	37	1
11	46.86	153.7	174	67	1
12	46.95	154.0	210	76	1
13	46.96	154.1	214	30	1
14	46.98	154.1	267	78	1
15	47.09	154.5	119	78	1
16	47.13	154.6	260	40	2
17	47.25	155.0	297	29	0
18	47.29	155.1	111	62	1
19	47.34	155.3	231	22	1
20	47.39	155.5	219	27	3
21	47.44	155.6	229	29	5
22	47.46	155.7	175	74	1
23	47.51	155.9	263	22	5
24	47.52	155.9	199	80	1
25	47.54	156.0	337	23	2
26	47.60	156.2	230	23	1
27	47.65	156.3	272	24	2
28	47.71	156.5	231	14	2
29	47.73	156.6	191	64	4
30	47.74	156.6	163	66	4
31	47.83	156.9	280	16	1
32	47.91	157.2	164	54	0
33	47.97	157.4	344	59	0
34	48.02	157.6	206	33	0
35	48.06	157.7	293	24	2
36	48.14	158.0	359	39	0
37	48.19	158.1	185	50	0
38	48.27	158.4	343	31	0
39	48.36	158.7	102	71	0
40	48.39	158.8	354	19	0
41	48.52	159.2	304	19	2
42	48.53	159.2	242	45	1
43	48.54	159.3	257	71	0
44	48.60	159.5	346	13	3
45	48.74	159.9	74	67	0

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	48.79	160.1	283	10	0
47	48.83	160.2	237	13	1
48	48.91	160.5	116	13	1
49	48.94	160.6	338.4	60.4	1
50	48.95	160.6	283.5	17.1	1
51	48.98	160.7	96.4	74.1	1
52	48.99	160.7	162.8	59.7	4
53	49.00	160.8	189.4	67.1	4
54	49.08	161.0	312.8	22.2	4
55	49.13	161.2	328.4	12.4	1
56	49.23	161.5	359.4	52.7	0
57	49.29	161.7	254.4	14.8	0
58	49.35	161.9	189.6	73.1	2
59	49.39	162.1	81.7	78.2	0
60	49.48	162.4	289.1	23.5	1
61	49.50	162.4	118.6	21.8	1
62	49.54	162.5	272.3	8.3	1
63	49.56	162.6	337.2	12.8	2
64	49.57	162.6	37.0	80.5	1
65	49.63	162.8	300.2	7.2	1
66	49.69	163.0	23.8	64.3	0
67	49.69	163.0	268.7	12.3	3
68	49.80	163.4	222.5	81.6	1
69	49.82	163.5	178.5	83.4	1
70	49.84	163.5	77.3	77.5	1
71	49.87	163.6	11.9	83.5	2
72	49.89	163.7	252.1	13.4	3
73	49.92	163.8	232.6	48.4	3
74	49.94	163.8	94.7	41.1	3
75	49.94	163.9	299.2	84.4	1
76	49.97	164.0	143.2	77.3	3
77	50.04	164.2	70.1	73.5	2
78	50.22	164.8	275.7	12.2	3
79	50.27	164.9	41.1	82.7	1
80	50.31	165.1	346.2	39.9	3
81	50.33	165.1	93.4	49.8	4
82	50.34	165.2	260.4	42.1	4
83	50.37	165.3	45.9	38.2	4
84	50.40	165.4	217.6	55.8	3
85	50.44	165.5	197.6	50.3	2
86	50.44	165.5	257.3	73.7	4
87	50.62	166.1	273.0	60.7	1
88	50.72	166.4	269.2	27.7	3
89	50.72	166.4	109.4	34.8	3
90	50.73	166.4	206.0	70.6	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	50.74	166.5	219.2	33.4	3
92	50.87	166.9	277.9	17.9	2
93	50.87	166.9	74.5	59.1	2
94	50.93	167.1	257.8	24.1	2
95	50.96	167.2	261.7	16.2	2
96	51.11	167.7	261.1	15.2	2
97	51.15	167.8	116.9	84.5	2
98	51.24	168.1	250.0	16.2	2
99	51.26	168.2	104.9	74.7	2
100	51.27	168.2	251.4	73.7	3
101	51.28	168.2	85.8	46.6	3
102	51.36	168.5	94.9	68.9	3
103	51.61	169.3	214.7	34.0	3
104	51.72	169.7	255.9	17.0	3
105	51.76	169.8	186.1	54.4	3
106	51.80	169.9	197.8	75.9	3
107	51.86	170.1	327.0	70.2	3
108	51.86	170.1	245.6	21.1	3
109	51.86	170.2	190.4	65.9	3
110	51.89	170.2	265.4	29.7	3
111	51.92	170.4	259.1	21.6	3
112	51.95	170.5	272.3	25.7	3
113	52.00	170.6	239.4	25.5	3
114	52.03	170.7	260.7	24.8	3
115	52.05	170.8	252.2	35.8	3
116	52.08	170.9	228.1	17.4	3
117	52.19	171.2	259.3	59.6	1
118	52.31	171.6	252.4	11.4	2
119	52.33	171.7	69.8	64.1	1
120	52.39	171.9	254.7	23.7	2
121	52.47	172.1	138.9	66.5	2
122	52.49	172.2	288.0	23.4	2
123	52.55	172.4	328.3	8.6	2
124	52.59	172.5	73.7	16.8	2
125	52.66	172.8	84.1	26.5	2
126	52.73	173.0	347.1	20.0	3
127	52.73	173.0	118.5	64.7	2
128	52.77	173.1	100	18	4
129	52.78	173.2	229	37	4
130	52.89	173.5	160	45	4
131	52.95	173.7	181	40	4
132	53.01	173.9	298	31	5
133	53.01	173.9	284	62	5
134	53.03	174.0	62	59	5
135	53.11	174.2	306	68	5

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	53.15	174.4	159	69	5
137	53.18	174.5	78	60	5
138	53.27	174.8	184	47	3
139	53.34	175.0	154	48	5
140	53.34	175.0	211	51	5
141	53.41	175.2	214	23	5
142	53.47	175.4	279	28	5
143	53.59	175.8	166	51	5
144	53.73	176.3	153	51	3
145	53.74	176.3	7	58	3
146	53.78	176.4	265	50	3
147	53.78	176.4	334	51	3
148	53.80	176.5	174	60	1
149	53.82	176.6	266	65	3
150	53.89	176.8	151	53	2
151	53.93	176.9	342	47	2
152	54.05	177.3	139	58	2
153	54.07	177.4	181	39	2
154	54.11	177.5	321	28	3
155	54.13	177.6	270	58	3
156	54.17	177.7	159	59	3
157	54.24	177.9	70	44	3
158	54.32	178.2	205	69	3
159	54.35	178.3	7	53	2
160	54.45	178.6	310	68	1
161	54.45	178.6	276	30	3
162	54.46	178.7	62	38	1
163	54.55	179.0	216	38	1
164	54.58	179.1	354	41	2
165	54.64	179.3	268	32	2
166	54.65	179.3	15	79	3
167	54.74	179.6	195	22	1
168	54.76	179.7	10	30	2
169	54.79	179.8	255	32	2
170	54.79	179.8	209	64	3
171	54.89	180.1	243	45	1
172	54.89	180.1	262	57	1
173	54.92	180.2	35	37	1
174	54.96	180.3	224	43	1
175	54.97	180.4	345	27	2
176	55.03	180.5	224	20	2
177	55.10	180.8	193	79	1
178	55.10	180.8	312	64	1
179	55.13	180.9	17	19	2
180	55.16	181.0	274	35	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	55.25	181.3	230	33	1
182	55.35	181.6	241	31	3
183	55.42	181.8	241	21	3
184	55.43	181.9	198	66	3
185	55.47	182.0	280	62	1
186	55.48	182.0	345	82	1
187	55.51	182.1	263	39	2
188	55.52	182.1	12	45	1
189	55.66	182.6	86	46	1
190	55.67	182.7	178	56	1
191	55.67	182.7	239	23	2
192	55.82	183.1	104	76	1
193	55.84	183.2	211	68	1
194	55.86	183.3	188	55	1
195	55.87	183.3	205	23	2
196	56.01	183.8	5	79	1
197	56.05	183.9	10	72	1
198	56.11	184.1	175	73	1
199	56.13	184.2	245	30	1
200	56.24	184.5	186	11	1
201	56.27	184.6	38	57	1
202	56.36	184.9	237	30	1
203	56.44	185.2	23	40	1
204	56.46	185.2	54	32	3
205	56.47	185.3	170	50	4
206	56.63	185.8	340	64	4
207	56.66	185.9	342	76	4
208	56.67	185.9	163	41	1
209	56.71	186.1	189	21	3
210	56.75	186.2	274	64	3
211	56.81	186.4	312	79	2
212	56.91	186.7	49	74	2
213	56.92	186.8	189	30	1
214	56.98	186.9	196	28	5
215	57.13	187.4	189	44	5
216	57.15	187.5	261	69	5
217	57.15	187.5	354	67	5
218	57.32	188.1	160	37	5
219	57.42	188.4	320	53	5
220	57.62	189.0	8	59	5
221	57.76	189.5	129	50	5
222	57.83	189.7	259	35	5
223	58.07	190.5	120	53	5
224	58.13	190.7	3	55	4
225	58.16	190.8	107	45	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	58.22	191.0	183	63	3
227	58.27	191.2	316	69	3
228	58.27	191.2	81	29	2
229	58.30	191.3	72	50	1
230	58.40	191.6	33	31	2
231	58.41	191.6	183	40	3
232	58.43	191.7	234	70	1
233	58.44	191.7	77	19	3
234	58.46	191.8	155	38	1
235	58.89	193.2	131	35	1
236	58.92	193.3	95	82	1
237	58.97	193.5	237	8	2
238	59.01	193.6	246	10	2
239	59.01	193.6	26	12	2
240	59.06	193.8	279	84	1
241	59.08	193.8	87	54	1
242	59.10	193.9	292	16	2
243	59.19	194.2	341	58	1
244	59.20	194.2	98	83	1
245	59.27	194.5	330	6	1
246	59.31	194.6	340	8	1
247	59.36	194.8	334	15	1
248	59.38	194.8	311	9	1
249	59.43	195.0	342	6	2
250	59.50	195.2	1	8	2
251	59.52	195.3	270	85	2
252	59.60	195.5	272	15	2
253	59.67	195.8	325	43	2
254	59.70	195.9	306	52	2
255	59.73	196.0	311	59	2
256	59.73	196.0	289	84	1
257	59.77	196.1	205	22	2
258	59.78	196.1	327	43	2
259	59.85	196.4	33	41	3
260	59.87	196.4	302	25	3
261	59.89	196.5	152	21	3
262	59.91	196.5	211	49	3
263	59.91	196.5	344	35	2
264	60.02	196.9	152	11	3
265	60.02	196.9	356	49	3
266	60.07	197.1	222	15	2
267	60.16	197.4	229	17	1
268	60.19	197.5	232	18	1
269	60.23	197.6	200	17	1
270	60.25	197.7	96	82	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	60.25	197.7	359	79	1
272	60.29	197.8	204	16	2
273	60.34	198.0	38	66	2
274	60.40	198.2	217	18	2
275	60.49	198.5	249	20	1
276	60.55	198.6	122	73	1
277	60.56	198.7	242	15	1
278	60.60	198.8	108	81	1
279	60.62	198.9	15	22	1
280	60.63	198.9	242	26	1
281	60.63	198.9	31	82	1
282	60.68	199.1	192	52	1
283	60.73	199.3	172	13	1
284	60.75	199.3	344	54	1
285	60.81	199.5	334	84	1
286	60.84	199.6	201	10	2
287	60.99	200.1	231	28	2
288	61.03	200.2	243	18	2
289	61.06	200.3	238	24	2
290	61.06	200.3	102	78	1
291	61.11	200.5	245	21	2
292	61.11	200.5	344	84	2
293	61.15	200.6	230	14	1
294	61.21	200.8	7	56	1
295	61.32	201.2	261	42	1
296	61.35	201.3	162	49	1
297	61.45	201.6	84	50	1
298	61.47	201.7	255	15	1
299	61.53	201.9	330	77	1
300	61.63	202.2	333	65	1
301	61.63	202.2	343	34	1
302	61.64	202.2	207	76	1
303	61.71	202.5	341	84	1
304	61.72	202.5	238	15	1
305	61.82	202.8	211	9	2
306	61.84	202.9	347	80	1
307	61.88	203.0	316	53	1
308	61.88	203.0	228	10	2
309	61.96	203.3	217	48	1
310	62.04	203.5	307	33	4
311	62.08	203.7	293	19	4
312	62.11	203.8	38	28	4
313	62.14	203.9	290	76	4
314	62.20	204.1	42	44	4
315	62.31	204.4	277	86	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
316	62.31	204.4	276	40	4
317	62.36	204.6	57	44	4
318	62.40	204.7	340	74	4
319	62.41	204.8	285	46	4
320	62.43	204.8	172	77	4
321	62.46	204.9	163	23	4
322	62.47	204.9	291	37	4
323	62.55	205.2	294	59	4
324	62.55	205.2	259	80	1
325	62.63	205.5	135	53	4
326	62.66	205.6	156	66	1
327	62.71	205.7	114	52	2
328	62.87	206.3	98	10	2
329	62.89	206.3	249	52	1
330	62.91	206.4	191	20	1
331	62.97	206.6	243	52	1
332	62.97	206.6	348	71	0
333	63.03	206.8	220	30	1
334	63.03	206.8	251	71	1
335	63.17	207.3	277	7	1
336	63.19	207.3	29	81	0
337	63.22	207.4	313	82	1
338	63.29	207.6	59	57	2
339	63.36	207.9	240	9	2
340	63.37	207.9	188	78	2
341	63.47	208.2	130	13	1
342	63.57	208.6	106	65	1
343	63.61	208.7	212	54	1
344	63.72	209.0	213	70	1
345	63.72	209.0	332	75	1
346	63.73	209.1	17	56	1
347	63.73	209.1	103	82	1
348	63.76	209.2	258	7	2
349	63.77	209.2	162	75	1
350	63.80	209.3	349	86	2
351	63.81	209.4	108	81	1
352	63.84	209.4	273	31	1
353	63.84	209.4	85	42	1
354	63.90	209.6	185	21	1
355	63.96	209.9	328	36	0
356	64.09	210.3	276	11	1
357	64.11	210.4	50	54	0
358	64.17	210.5	197	49	0
359	64.28	210.9	68	22	1
360	64.33	211.1	37	82	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
361	64.39	211.3	129	84	1
362	64.46	211.5	119	84	1
363	64.46	211.5	161	18	1
364	64.58	211.9	268	13	1
365	64.69	212.2	227	8	1
366	64.88	212.9	7	4	1
367	64.94	213.1	203	10	1
368	64.95	213.1	162	47	0
369	64.95	213.1	228	24	1
370	65.09	213.5	140	44	0
371	65.19	213.9	326	85	1
372	65.22	214.0	306	14	0
373	65.35	214.4	138	78	1
374	65.38	214.5	246	4	0
375	65.39	214.5	140	60	0
376	65.39	214.5	334	87	1
377	65.49	214.9	156	13	0
378	65.58	215.2	220	20	0
379	65.59	215.2	322	47	0
380	65.65	215.4	228	12	2
381	65.68	215.5	127	69	0
382	65.68	215.5	104	88	1
383	65.75	215.7	207	36	0
384	65.83	216.0	64	52	0
385	65.85	216.0	333	14	0
386	65.92	216.3	341	39	0
387	65.93	216.3	316	13	1
388	66.03	216.6	353	32	1
389	66.07	216.8	349	15	0
390	66.09	216.8	46	18	0
391	66.21	217.2	12	9	0
392	66.30	217.5	352	30	0
393	66.34	217.6	2	15	1
394	66.40	217.9	228	16	1
395	66.42	217.9	13	29	1
396	66.49	218.1	172	25	1
397	66.52	218.2	25	17	1
398	66.70	218.8	207	52	0
399	66.92	219.6	207	42	0
400	67.17	220.4	76	14	0
401	67.22	220.6	94	47	1
402	67.23	220.6	161	17	0
403	67.35	221.0	140	68	1
404	67.39	221.1	100	78	1
405	67.44	221.3	243	24	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
406	67.52	221.5	331	78	1
407	67.61	221.8	150	14	0
408	67.67	222.0	214	12	0
409	67.77	222.3	270	12	1
410	67.84	222.6	205	31	1
411	68.01	223.1	107	32	1
412	68.04	223.2	195	65	1
413	68.11	223.5	184	83	1
414	68.14	223.6	205	50	1
415	68.15	223.6	14	74	1
416	68.28	224.0	193	82	1
417	68.31	224.1	167	18	1
418	68.40	224.4	345	77	1
419	68.41	224.4	263	85	1
420	68.50	224.7	258	15	1
421	68.62	225.1	354	82	1
422	68.63	225.2	84	66	1
423	68.71	225.4	239	11	1
424	68.78	225.7	173	58	1
425	68.86	225.9	50	88	0
426	68.88	226.0	207	26	0
427	68.90	226.1	341	73	1
428	68.92	226.1	142	33	1
429	69.00	226.4	47	31	0
430	69.02	226.4	117	86	1
431	69.22	227.1	285	37	0
432	69.31	227.4	201	29	0
433	69.35	227.5	202	17	1
434	69.37	227.6	201	19	0
435	69.57	228.3	265	26	0
436	69.63	228.4	220	29	1
437	69.74	228.8	71	45	0
438	69.88	229.3	164	27	1
439	69.92	229.4	59	65	1
440	69.94	229.5	346	65	0
441	69.95	229.5	249	22	1
442	70.09	230.0	51	37	0
443	70.13	230.1	193	26	0
444	70.28	230.6	217	14	0
445	70.30	230.6	214	21	0
446	70.34	230.8	46	76	1
447	70.34	230.8	181	29	0
448	70.38	230.9	162	28	0
449	70.49	231.3	200	20	1
450	70.59	231.6	311	88	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
451	70.61	231.7	2	75	2
452	70.63	231.7	180	30	0
453	70.70	232.0	271	14	1
454	70.76	232.2	209	47	1
455	71.06	233.2	200	35	1
456	71.13	233.4	169	41	1
457	71.24	233.7	198	36	2
458	71.28	233.9	185	13	1
459	71.34	234.1	153	45	1
460	71.42	234.3	169	17	1
461	71.48	234.5	159	76	1
462	71.49	234.6	163	27	1
463	71.52	234.6	139	83	1
464	71.61	234.9	201	15	2
465	71.62	235.0	270	57	1
466	71.68	235.2	324	52	3
467	71.70	235.2	215	39	3
468	71.73	235.3	54	83	1
469	71.76	235.4	22	28	1
470	71.77	235.5	164	40	1
471	72.07	236.4	266	35	1
472	72.08	236.5	186	28	1
473	72.10	236.6	100	83	1
474	72.20	236.9	254	23	1
475	72.22	236.9	239	26	1
476	72.33	237.3	75	70	1
477	72.34	237.4	255	31	1
478	72.37	237.4	134	87	1
479	72.38	237.5	245	38	1
480	72.45	237.7	210	61	2
481	72.49	237.8	62	73	2
482	72.58	238.1	285	14	0
483	72.59	238.2	259	25	0
484	72.63	238.3	281	23	0
485	72.64	238.3	265	81	2
486	72.66	238.4	274	30	0
487	72.77	238.7	290	26	0
488	72.80	238.9	255	22	0
489	73.04	239.6	158	18	0
490	73.09	239.8	177	21	0
491	73.17	240.1	231	14	0
492	73.19	240.1	234	15	0
493	73.25	240.3	311	3	0
494	73.37	240.7	337	63	1
495	73.38	240.8	252	9	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-37

16 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
496	73.38	240.8	279	54	1
497	73.41	240.8	33	13	1
498	73.41	240.9	90	81	0
499	73.56	241.4	328	24	1
500	73.60	241.5	219	10	1
501	73.62	241.5	302	58	1
502	73.75	242.0	168	12	1
503	73.75	242.0	287	31	1
504	73.80	242.1	178	55	1
505	73.81	242.2	316	19	1
506	73.86	242.3	339	85	0
507	73.91	242.5	211	12	1
508	73.93	242.5	358	40	1
509	73.94	242.6	294	15	1
510	73.99	242.7	354	50	1
511	74.09	243.1	272	87	1
512	74.14	243.3	182	28	0
513	74.15	243.3	279	83	1
514	74.15	243.3	280	20	0
515	74.21	243.5	208	26	0
516	74.22	243.5	19	11	0
517	74.26	243.6	278	43	0
518	74.34	243.9	194	34	0
519	74.35	243.9	91	17	0
520	74.39	244.1	71	18	1
521	74.40	244.1	188	16	1
522	74.52	244.5	257	16	0
523	74.72	245.1	247	13	1
524	74.88	245.7	276	77	0
525	74.93	245.8	218	10	1
526	74.94	245.9	31	79	0
527	74.99	246.0	240	13	1
528	75.08	246.3	250	13	1
529	75.09	246.4	235	71	1
530	75.11	246.4	60	53	1
531	75.17	246.6	80	24	2
532	75.18	246.7	58	69	1
533	75.23	246.8	269	81	1
534	75.24	246.9	226	30	2
535	75.33	247.1	65	4	1
536	75.48	247.6	45	82	1
537	75.63	248.1	248	79	1
538	75.63	248.1	266	85	1

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-armed Caliper

Company WSP
Well BH19-37
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-37
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79428 N
Longitude: 84.77377 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 600.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	16 July 2019	16 July 2019	16 July 2019	
RUN NUMBER	3	6	5	
LOG TYPE	Fluid Temp & Cond	3-armed Caliper	Natural Gamma	
DEPTH-DRILLER	248.4'	248.4'	248.4'	
DEPTH-LOGGER	248.2'	248'	248'	
BTM LOG INTERVAL	248.2'	246'	245.7'	
TOP LOG INTERVAL	140.4'	139.7'	6.6'	
RECORDED BY	CKL	CKL	CKL	
WITNESSED BY				
PROBE TYPE, S/N	2PFA #5969	3ACS #6011	ELXG #4248	
LOGGING SPEED	25 fpm	10 fpm	30 fpm	
A.S.D.E. / Sample Interval	.0.65' / 0.10'	0.55' / 0.10'	0.55' / 0.1'	
Fluid Level / Fluid Type	NA/water	NA/water	NA/water	

BOREHOLE RECORD

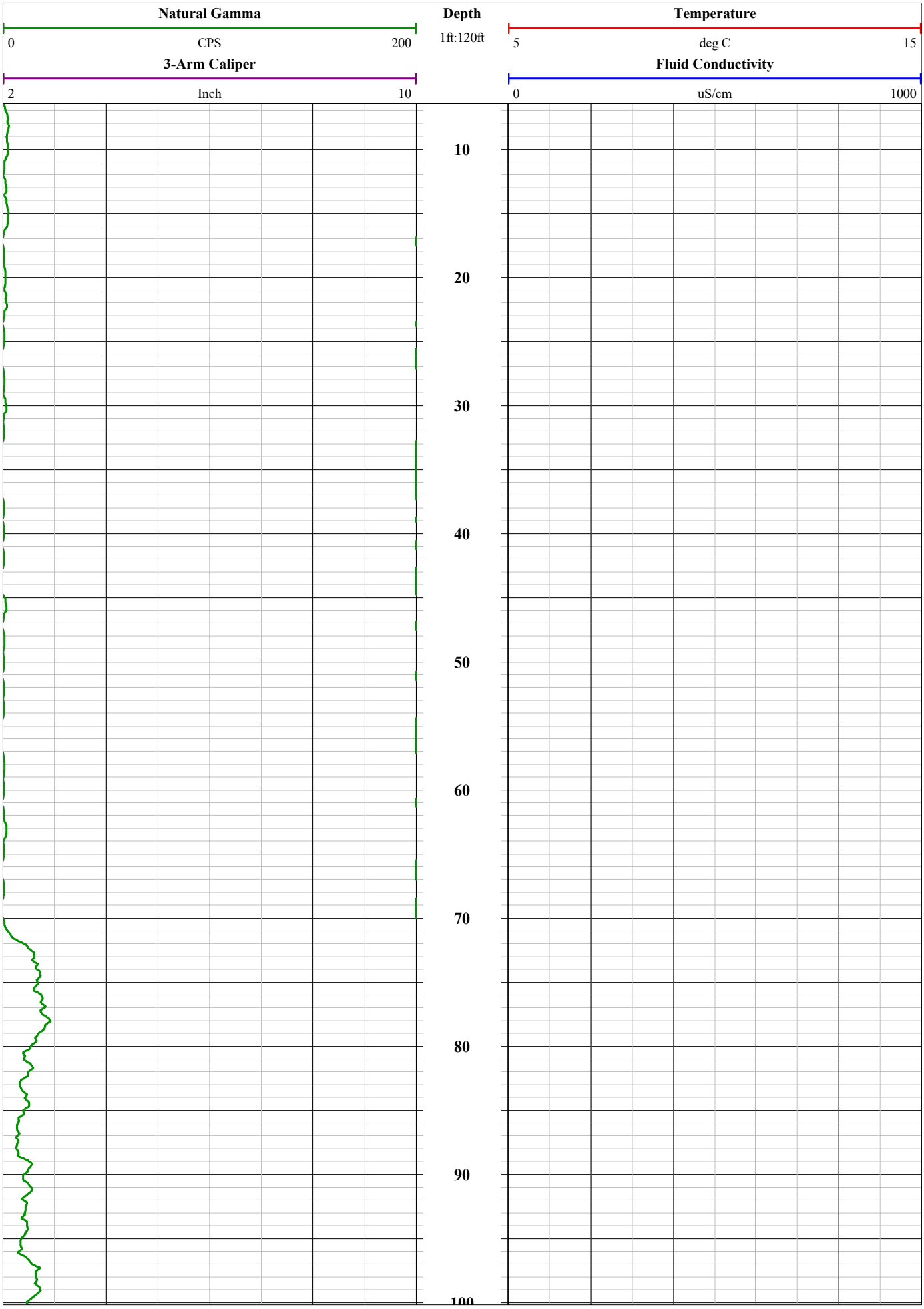
RUN No.	BIT	FROM	TO
1	HQ	0'	248.4'

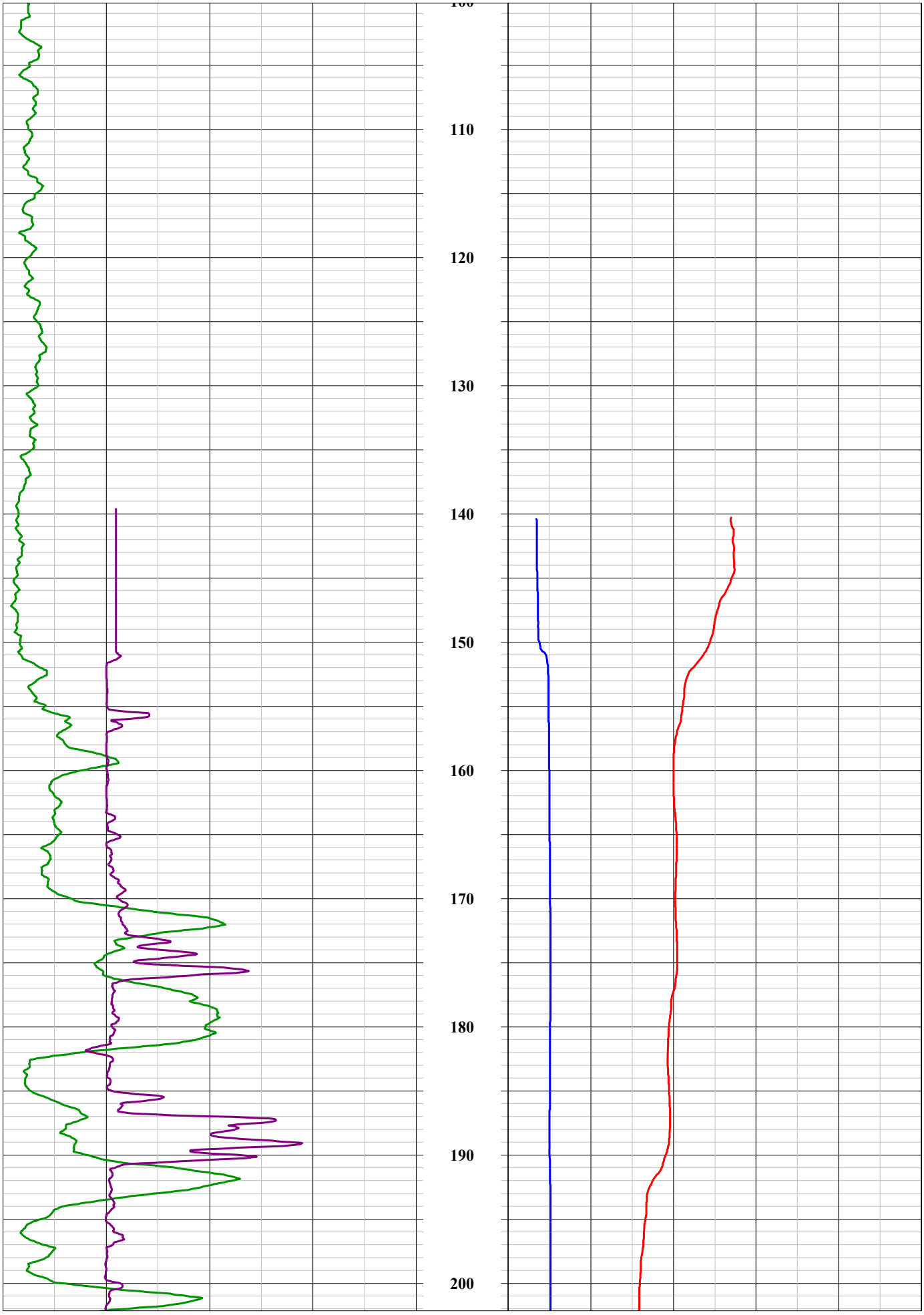
CASING RECORD

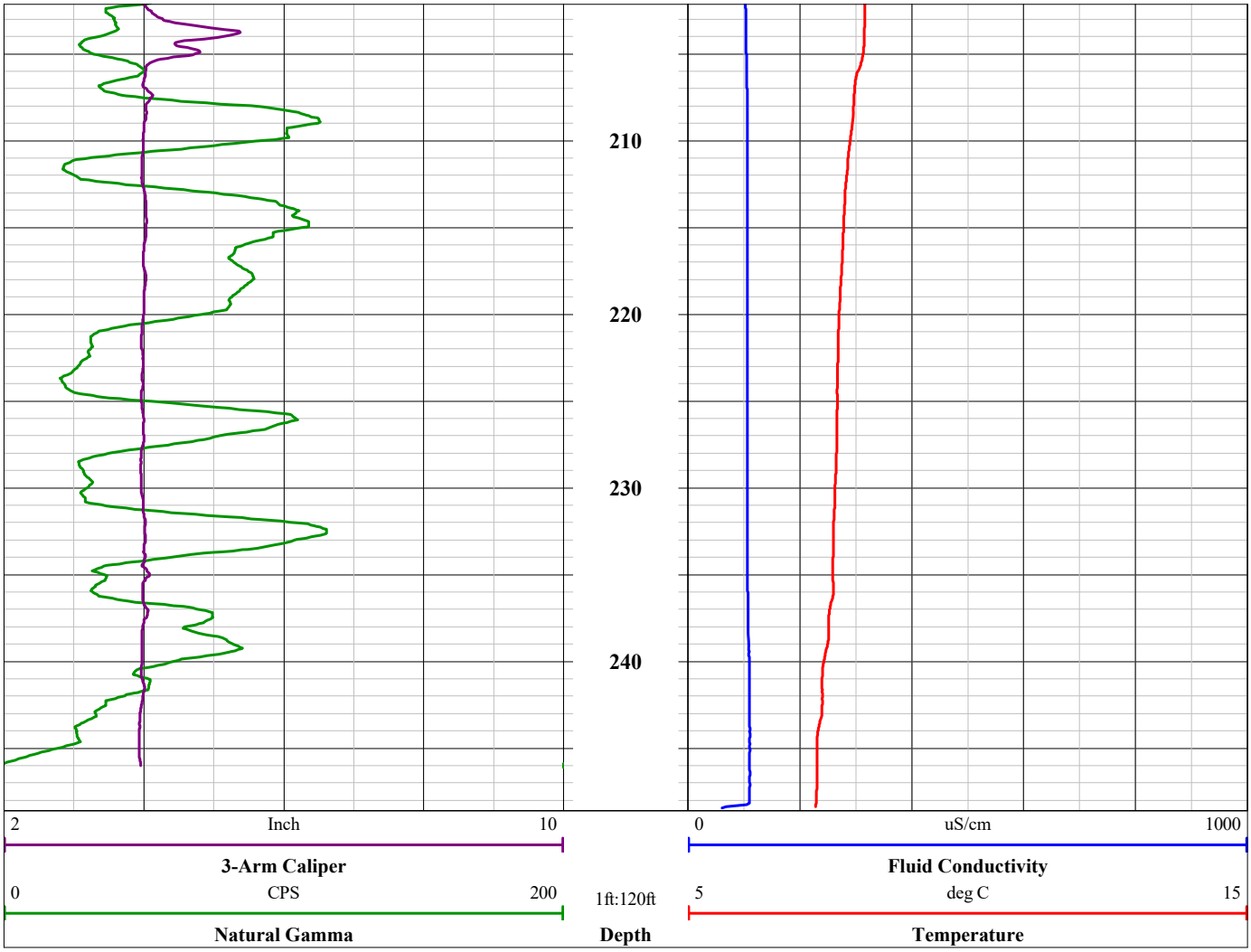
SIZE	WGT.	FROM	TO
HQ	Steel	0'	150'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
200
3-Arm Caliper
2
Inch
10
Depth
1ft:120ft
Temperature
5
deg C
15
Fluid Conductivity
0
uS/cm
1000
10
20
30
40
50
60
70
80
90
100


110
120
130
140
150
160
170
180
190
200


210
220
230
240
2
Inch
10
3-Arm Caliper
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
uS/cm
1000
Fluid Conductivity
5
deg C
15
Temperature

Borehole Deviation

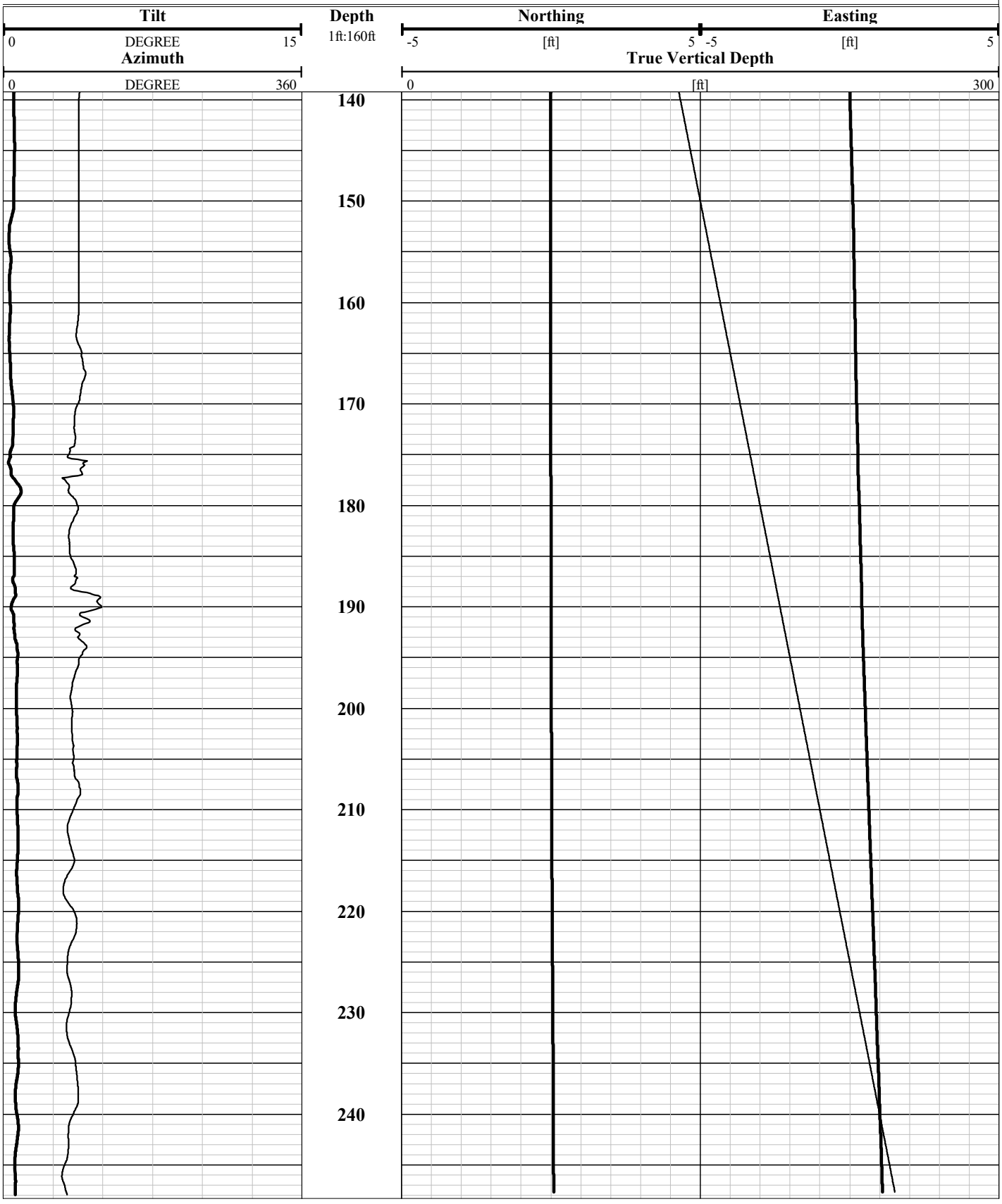
COLOG
borehole geophysics / hydrophysics

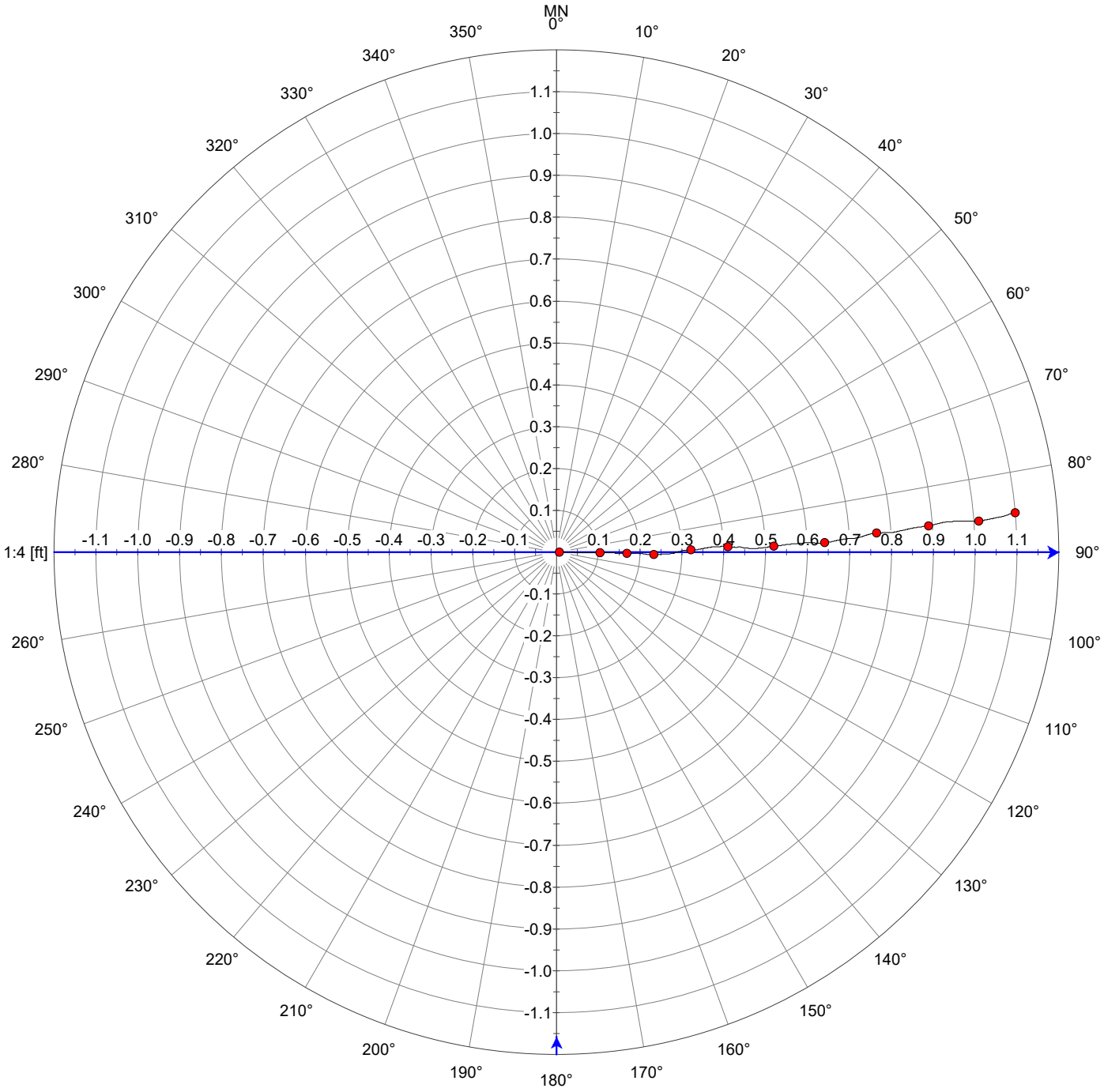
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 16 July 2019	WELL: BH19-37 - South Side

Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 600.7'** **Latitude: 45.79428 N** **Longitude: 84.77377 W**




MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
1:4 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-37
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-37
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79428 N
Longitude: 84.77377 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.

PERMANENT DATUM Top of Casing **ELEVATION** 600.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	16 July 2019			
RUN NUMBER	1	1		
LOG TYPE	Natural Gamma	Electric Log		
DEPTH-DRILLER	248.4'	248.4'		
DEPTH-LOGGER	248'	248'		
BTM LOG INTERVAL	245.7'	247.0'		
TOP LOG INTERVAL	6.6'	152'		
RECORDED BY	CKL	CKL		
WITNESSED BY				
PROBE TYPE, S/N	ELOG #4248	ELOG #4248		
LOGGING SPEED	30ft/min	30ft/min		
A.S.D.E. / Sample Interval	0.55'/0.1'	0.55'/0.1'		
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

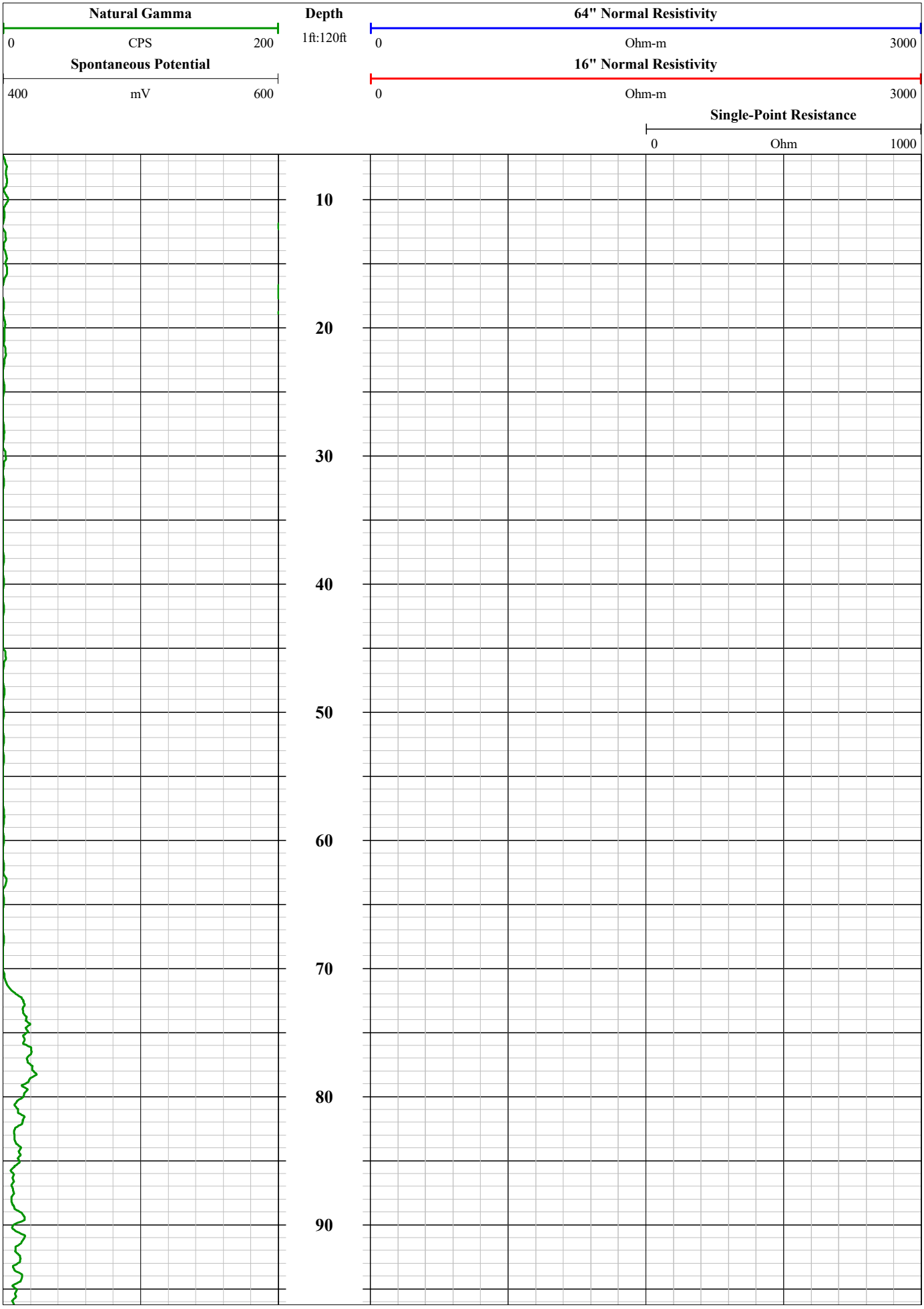
RUN No.	BIT	FROM	TO
1	HQ	0'	248.4'

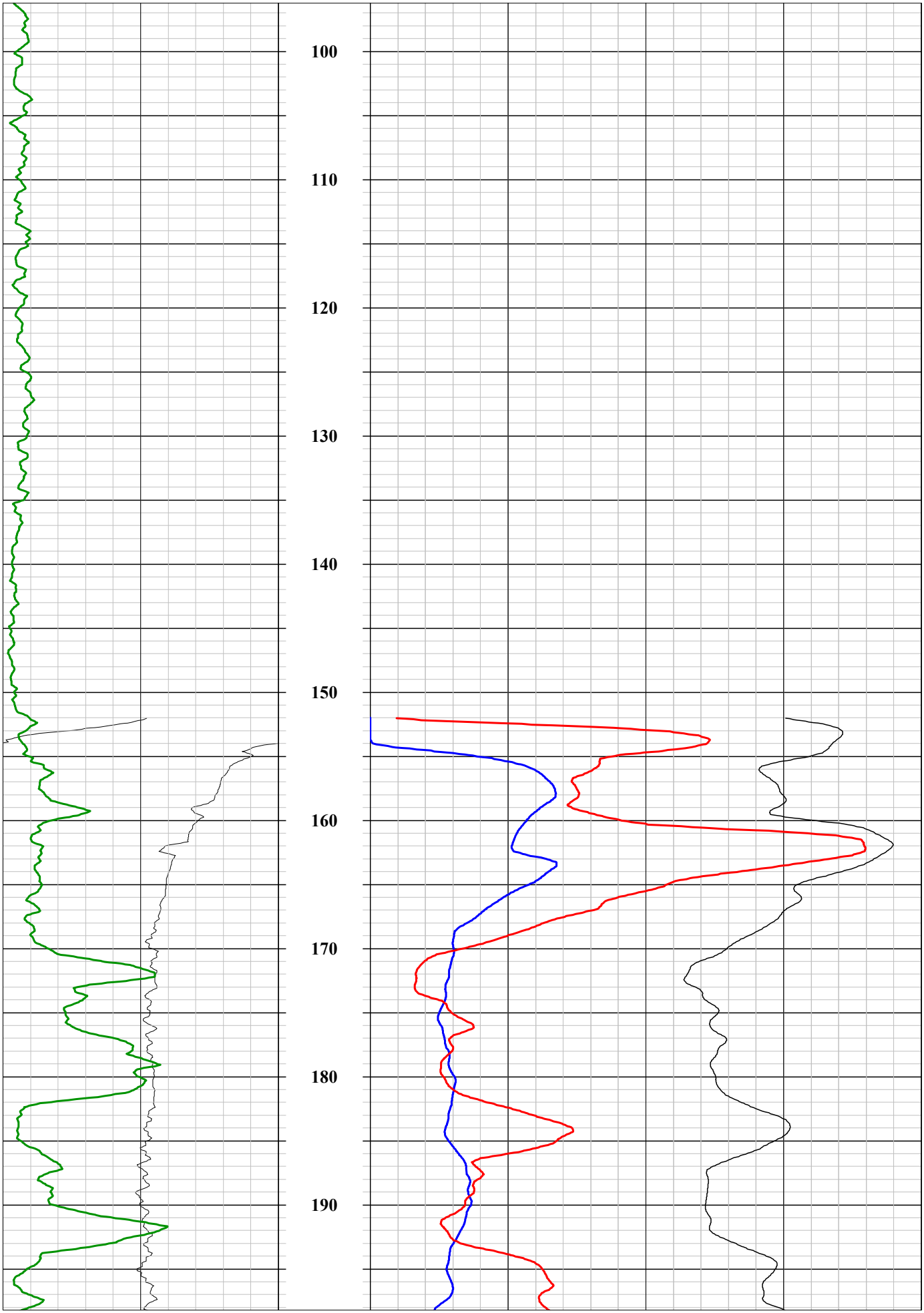
CASING RECORD

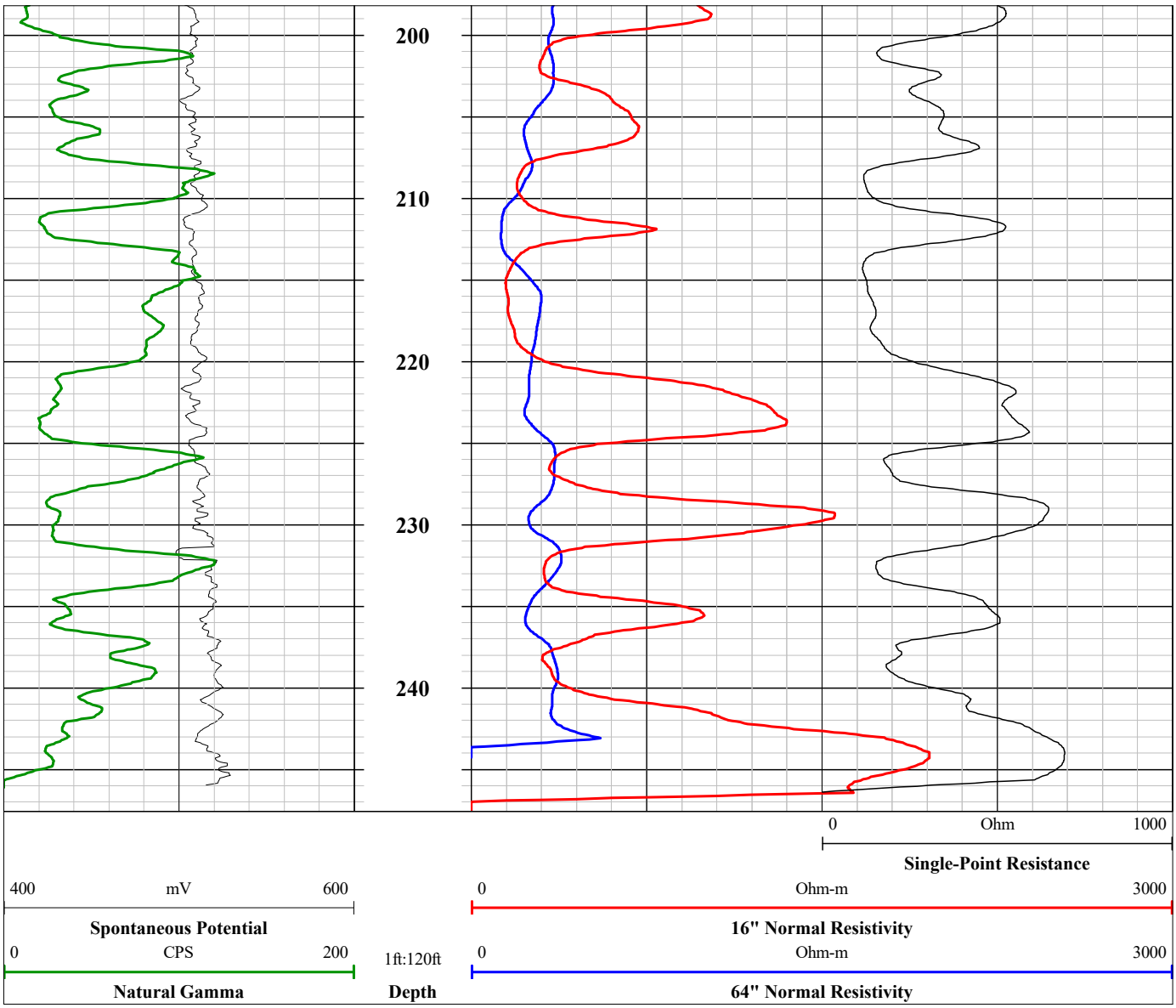
SIZE	WGT.	FROM	TO
HQ	Steel	0'	150'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
200
Spontaneous Potential
400
mV
600
Depth
1ft:120ft
64" Normal Resistivity
0
Ohm-m
3000
16" Normal Resistivity
0
Ohm-m
3000
Single-Point Resistance
0
Ohm
1000
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
180
190


200
210
220
230
240
0
Ohm
1000
Single-Point Resistance
400
mV
600
Spontaneous Potential
0
Ohm-m
3000
16" Normal Resistivity
0
CPS
200
Natural Gamma
1ft:120ft
Depth
0
Ohm-m
3000
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-37
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-37
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79428 N
Longitude: 84.77377 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond.
Electrical Log

PERMANENT DATUM Top of Casing **ELEVATION** 600.7'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	16 July 2019			
RUN NUMBER	1			
LOG TYPE	PSLog			
DEPTH-DRILLER	248.4'			
DEPTH-LOGGER	236'			
BTM LOG INTERVAL	236'			
TOP LOG INTERVAL	150'			
RECORDED BY	CKL			
WITNESSED BY				
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	NA/Water			

BOREHOLE RECORD

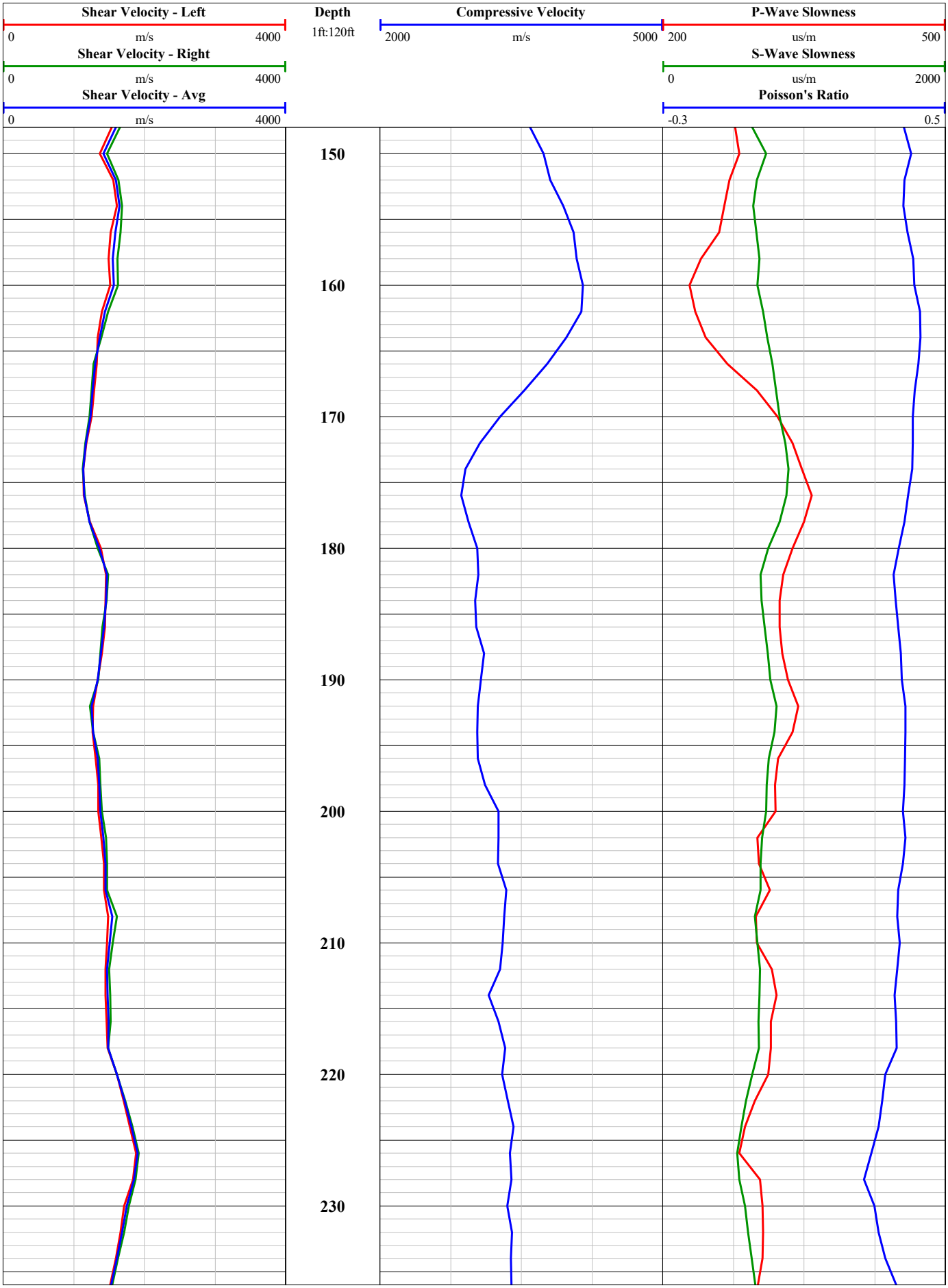
RUN No.	BIT	FROM	TO
1	HG	0'	248.4'

CASING RECORD

SIZE	WGT.	FROM	TO
HQ	Steel	0'	150'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Shear Velocity - Right
0
m/s
4000
Shear Velocity - Avg
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
2000
m/s
5000
P-Wave Slowness
200
us/m
500
S-Wave Slowness
0
us/m
2000
Poisson's Ratio
-0.3
0.5
150
160
170
180
190
200
210
220
230

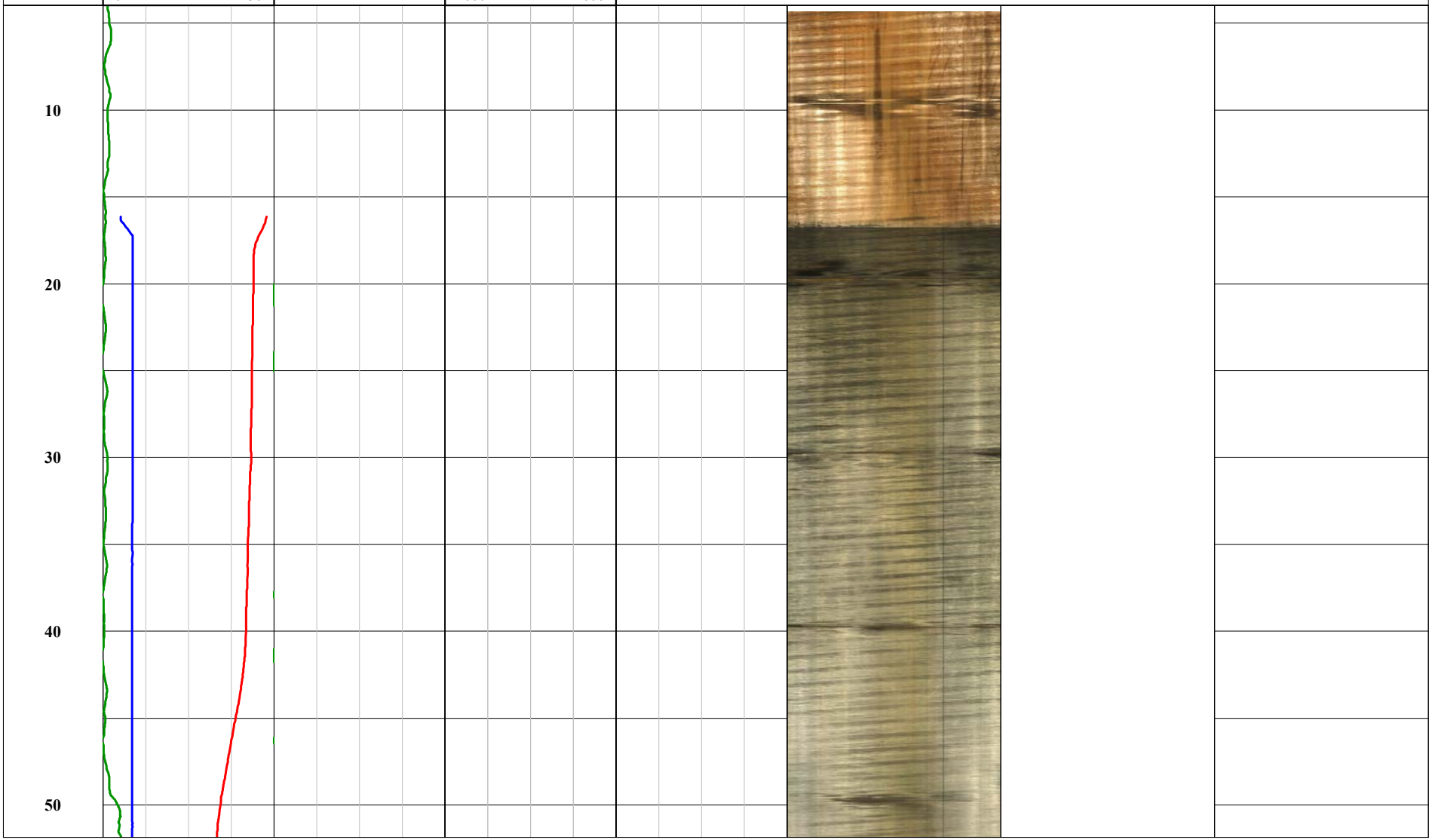
Geophysical Summary Plot

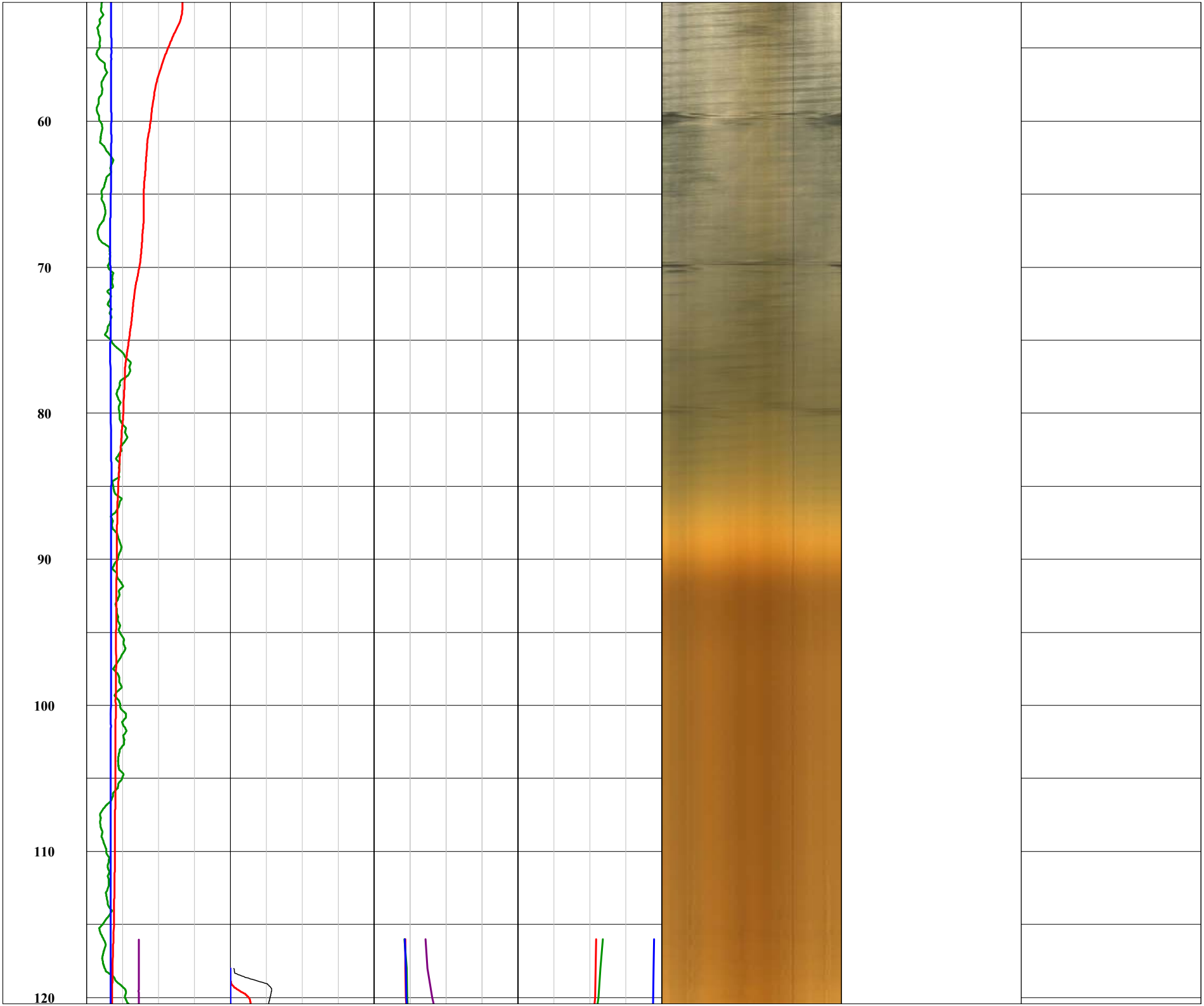
COLOG
borehole geophysics / hydrophysics

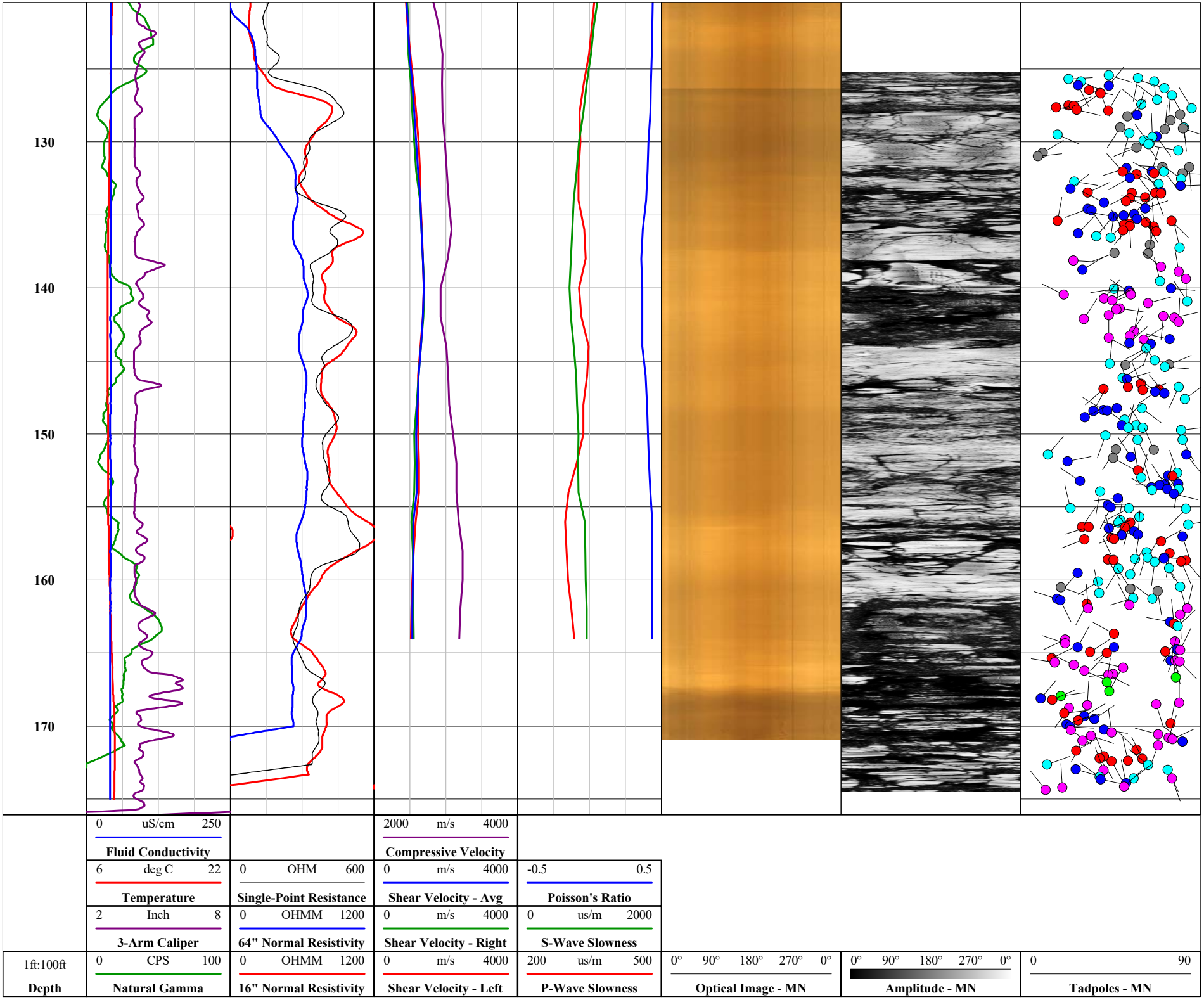
COMPANY: WSP
PROJECT: L5RT Project
DATE LOGGED: 20 July 2019
WELL: BH19-38 - South Side

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth	Natural Gamma	16" Normal Resistivity	Shear Velocity - Left	P-Wave Slowness	Optical Image - MN	Amplitude - MN	Tadpoles - MN
1ft:100ft	0 CPS 100	0 OHMM 1200	0 m/s 4000	200 us/m 500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90
	3-Arm Caliper	**64" Normal Resistivity**	**Shear Velocity - Right**	**S-Wave Slowness**			
	2 Inch 8	0 OHMM 1200	0 m/s 4000	0 us/m 2000			
	Temperature	**Single-Point Resistance**	**Shear Velocity - Avg**	**Poisson's Ratio**			
	6 deg C 22	0 OHM 600	0 m/s 4000	-0.5 0.5			
	Fluid Conductivity		**Compressive Velocity**				
	0 uS/cm 250		2000 m/s 4000				




60
70
80
90
100
110
120


130
140
150
160
170
0 uS/cm 250
Fluid Conductivity
6 deg C 22
Temperature
2 Inch 8
3-Arm Caliper
0 CPS 100
Natural Gamma
0 OHM 600
Single-Point Resistance
0 OHMM 1200
64" Normal Resistivity
0 OHMM 1200
16" Normal Resistivity
2000 m/s 4000
Compressive Velocity
0 m/s 4000
Shear Velocity - Avg
0 m/s 4000
Shear Velocity - Right
0 m/s 4000
Shear Velocity - Left
-0.5 0.5
Poisson's Ratio
0 us/m 2000
S-Wave Slowness
200 us/m 500
P-Wave Slowness
0° 90° 180° 270° 0°
Optical Image - MN
0° 90° 180° 270° 0°
Amplitude - MN
0 90
Tadpoles - MN
1ft:100ft
Depth

borehole geophysics / hydrophysics

810 Quail Street, Unit E

Lakewood, CO 80215

Office: (303) 279-0171

www.colog.com

Acoustic Televiewer

Company WSP
Well BH19-38
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-38
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79162 N
Longitude: 84.77478 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Optical Televiewer
Fluid Temp & Cond.
Electrical Log
P&S Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.2'

LOG MEAS. FROM Top of Casing 0.0 ft **ABOVE PERMINANT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	20 July 2019			
RUN NUMBER	Four			
LOG TYPE	ATV			
DEPTH-DRILLER	201.0 ft			
DEPTH-LOGGER	175.0 ft			
BTM LOG INTERVAL	174.5 ft			
TOP LOG INTERVAL	125.2 ft			
RECORDED BY	BEH			
WITNESSED BY				
PROBE TYPE, S/N	BHTV, 1730			
LOGGING SPEED	4.5 ft/min			
SAMPLE INTERVAL	0.00038'			
FLUID LEVEL	16.8 ft			

BOREHOLE RECORD

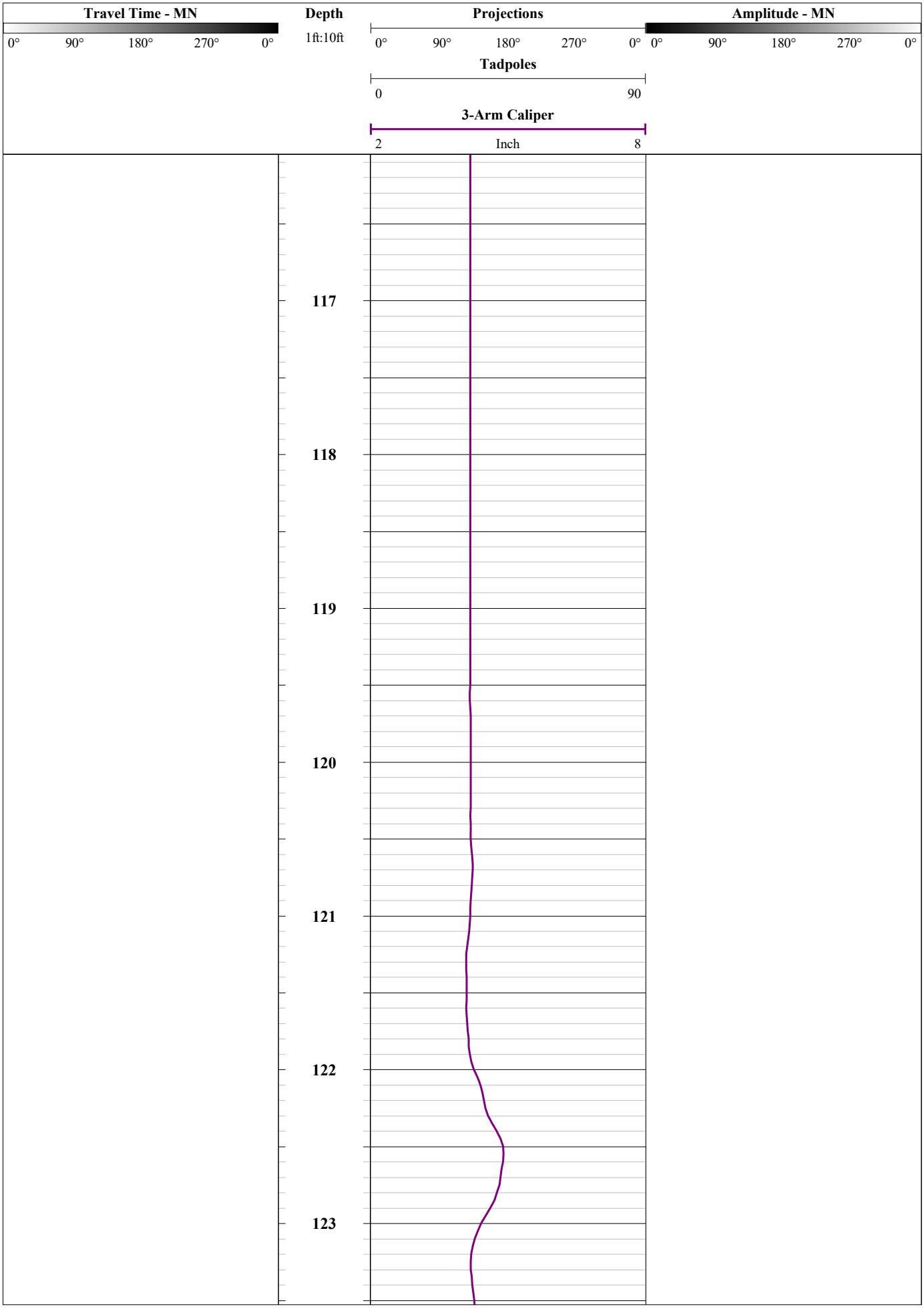
RUN No.	BIT	FROM	TO
1	HQ	0'	201'

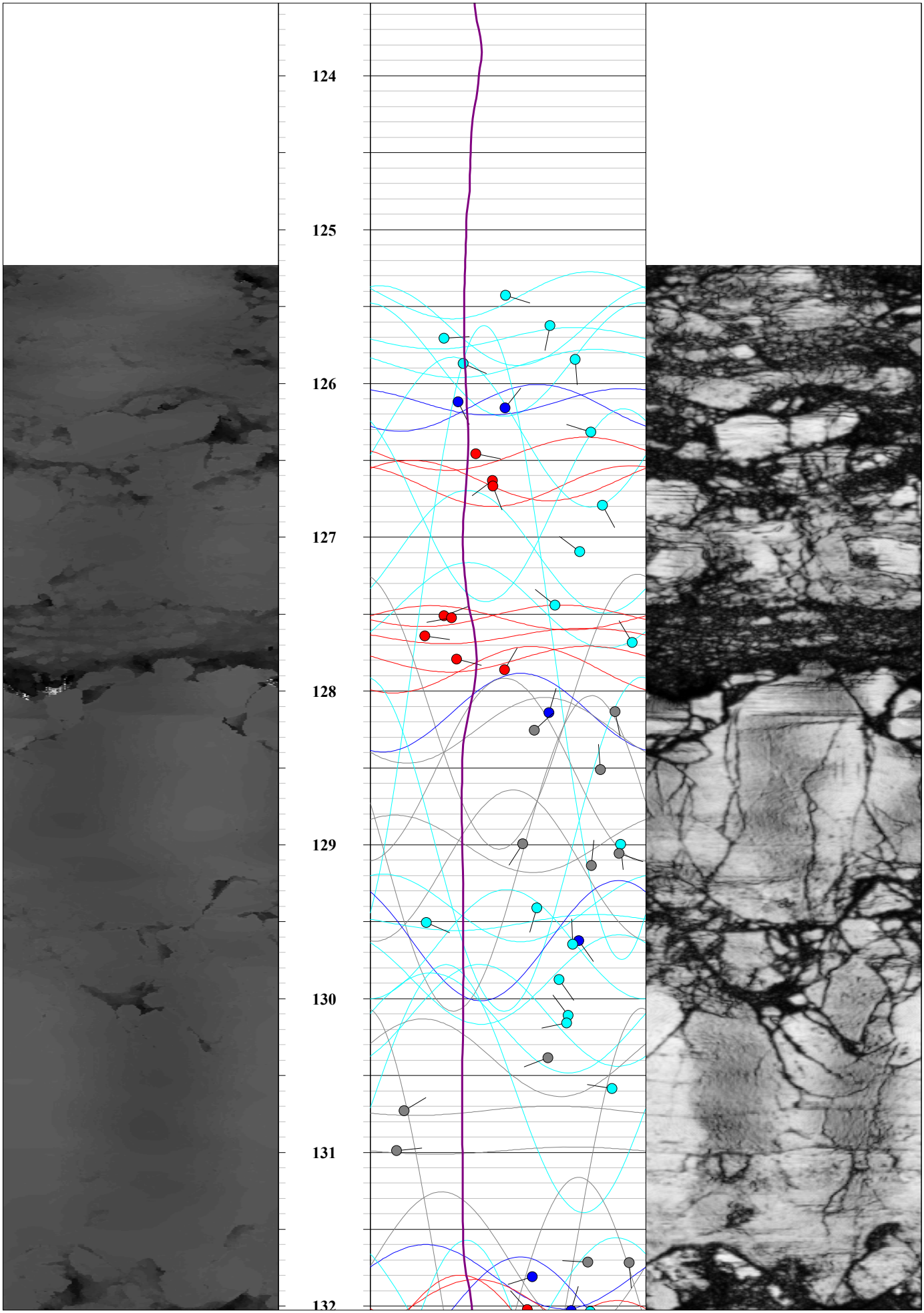
CASING RECORD

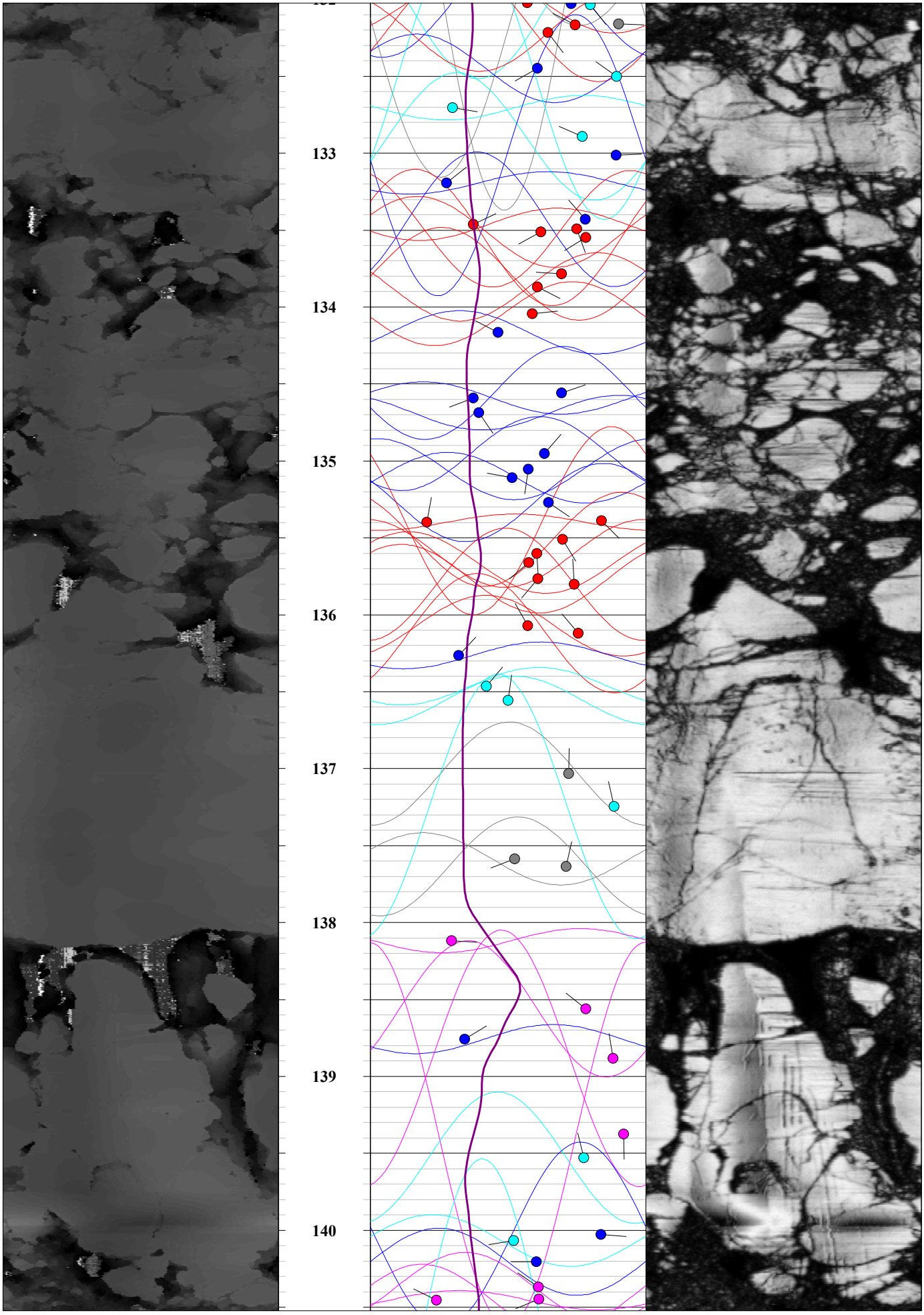
SIZE	WGT.	FROM	TO
HQ	Steel	0'	121'

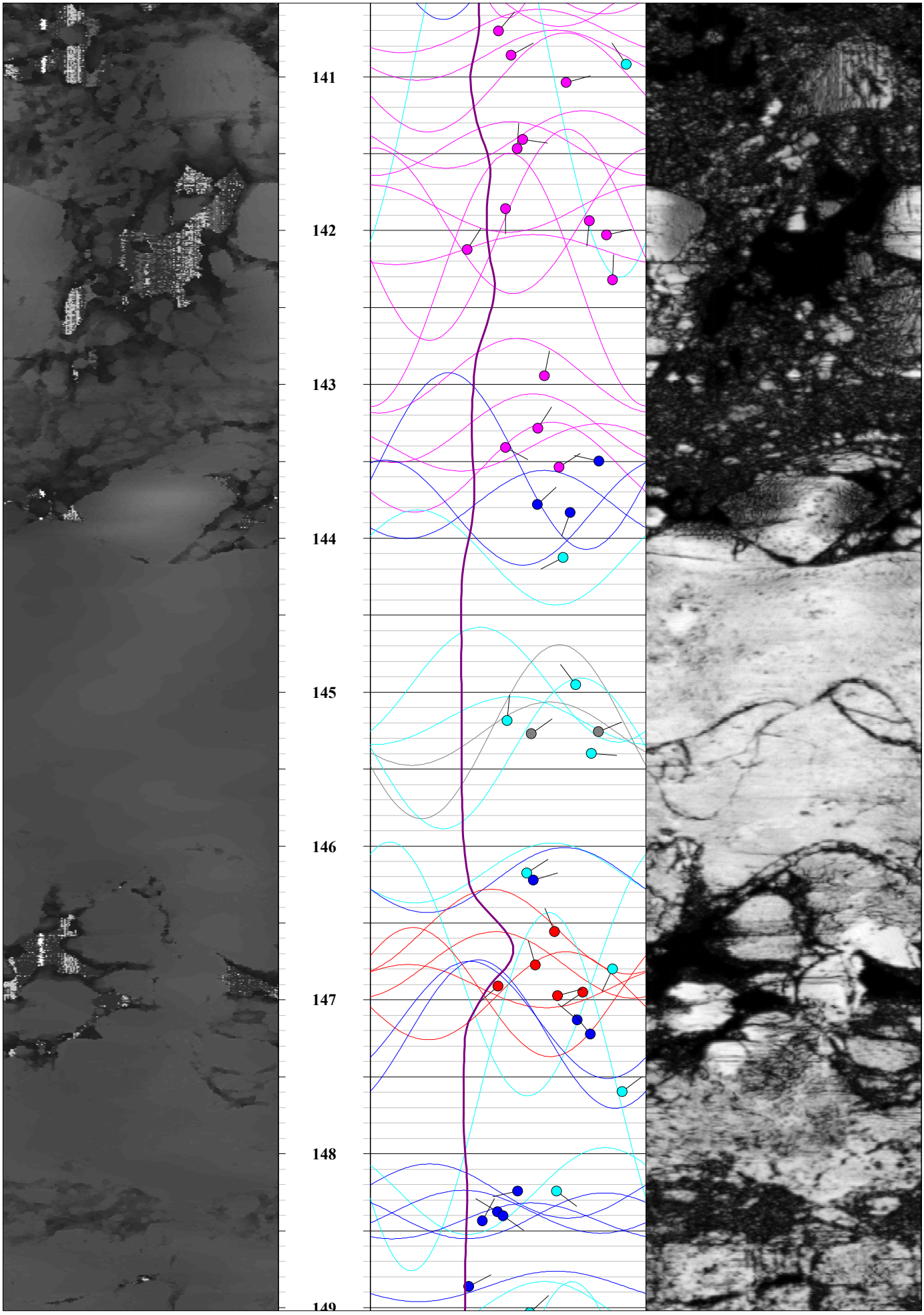
NA - Not Available, N/A - Not Applicable

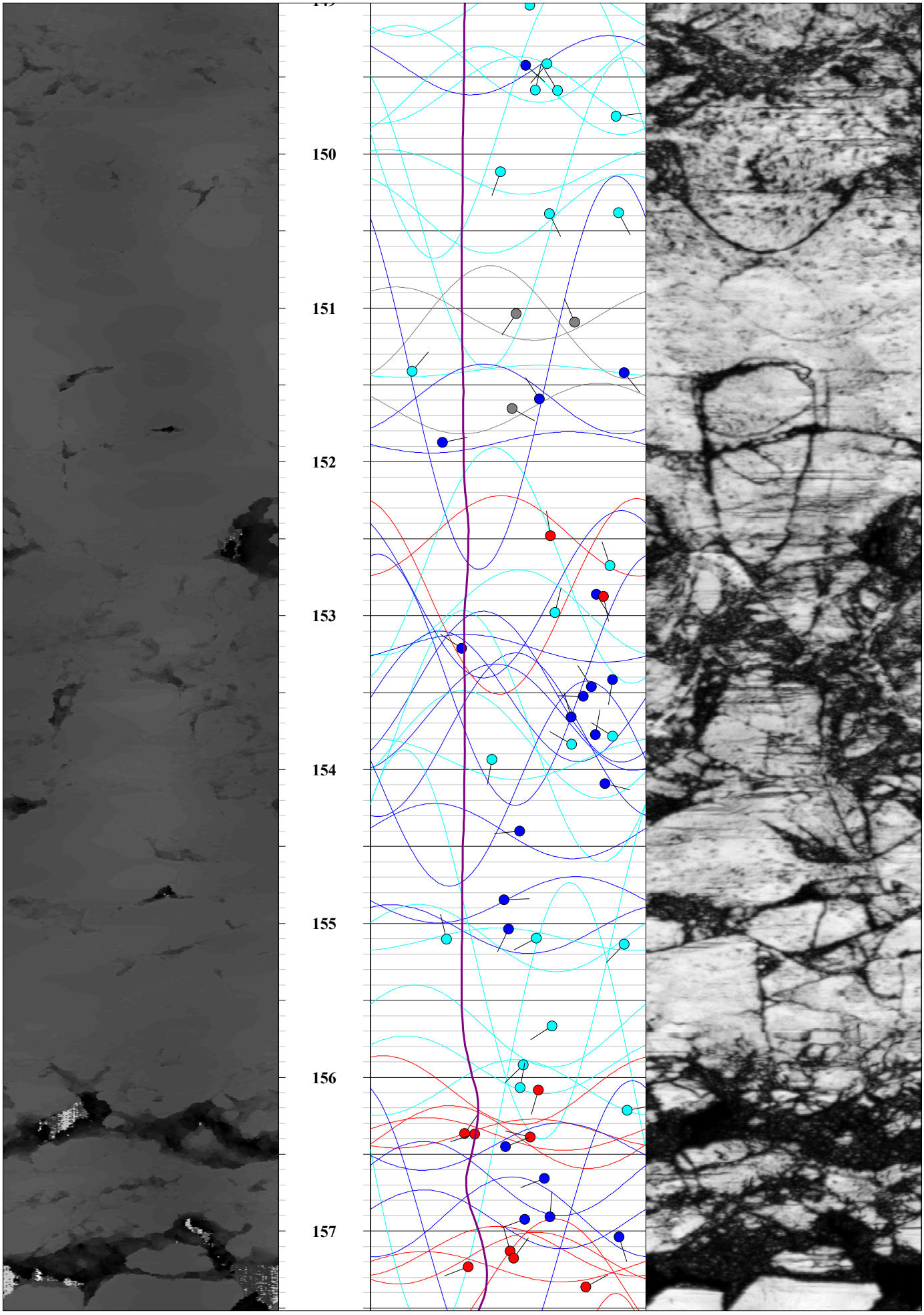
COMMENTS

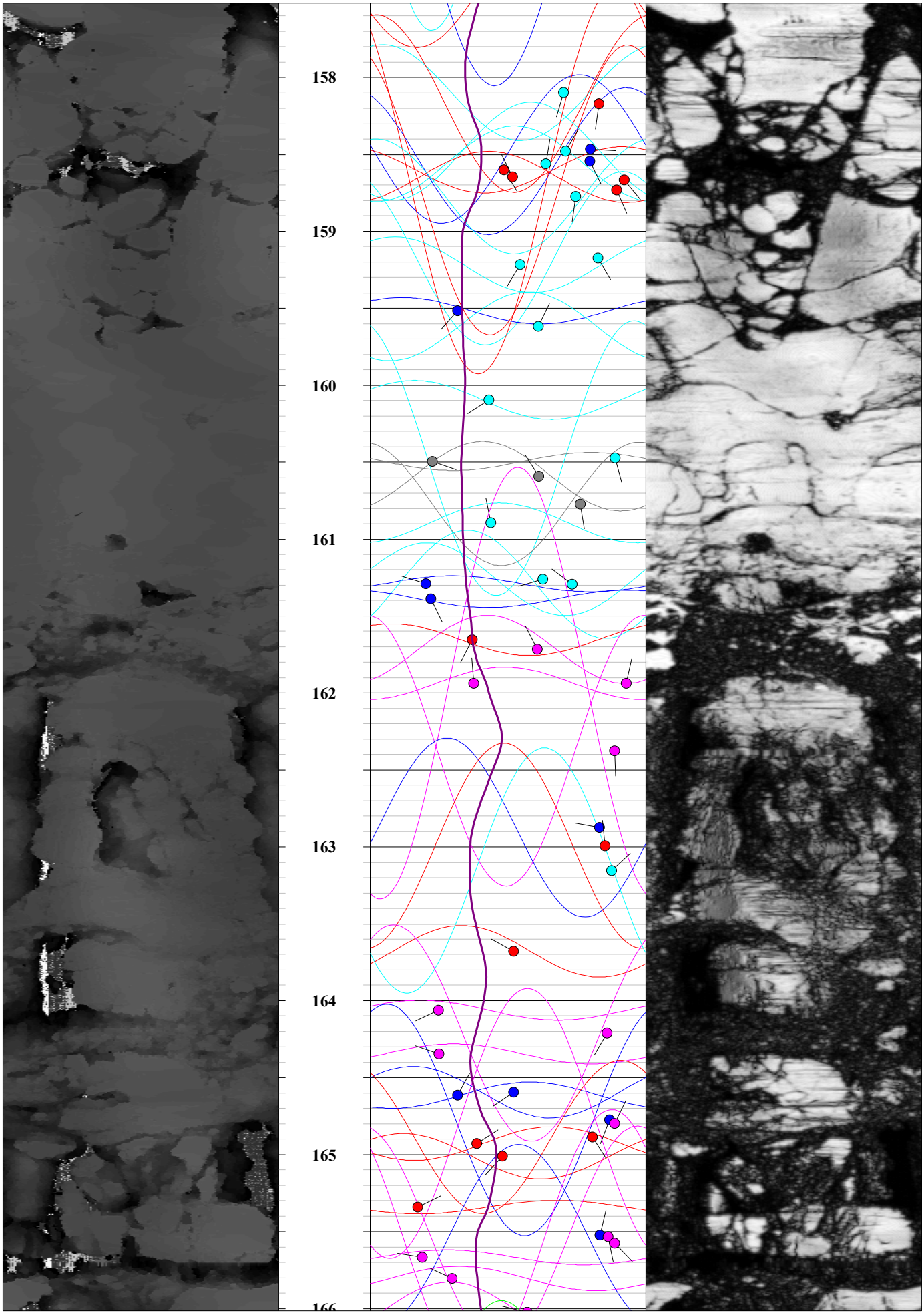

Travel Time - MN
0°
90°
180°
270°
0°
Depth
1ft:10ft
Projections
0°
90°
180°
270°
0°
Tadpoles
0
90
3-Arm Caliper
2
Inch
8
Amplitude - MN
0°
90°
180°
270°
0°
117
118
119
120
121
122
123

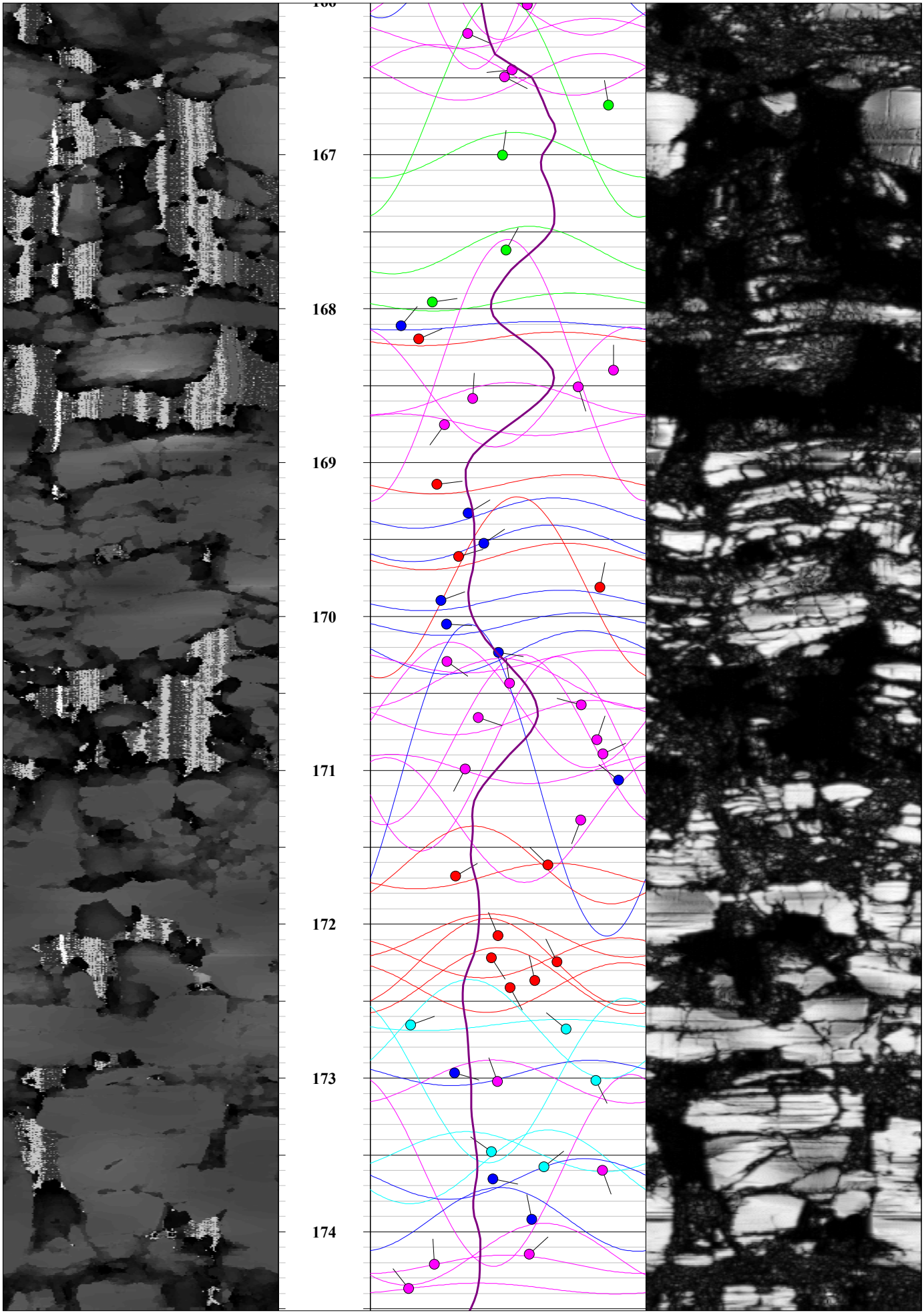

124
125
126
127
128
129
130
131
132

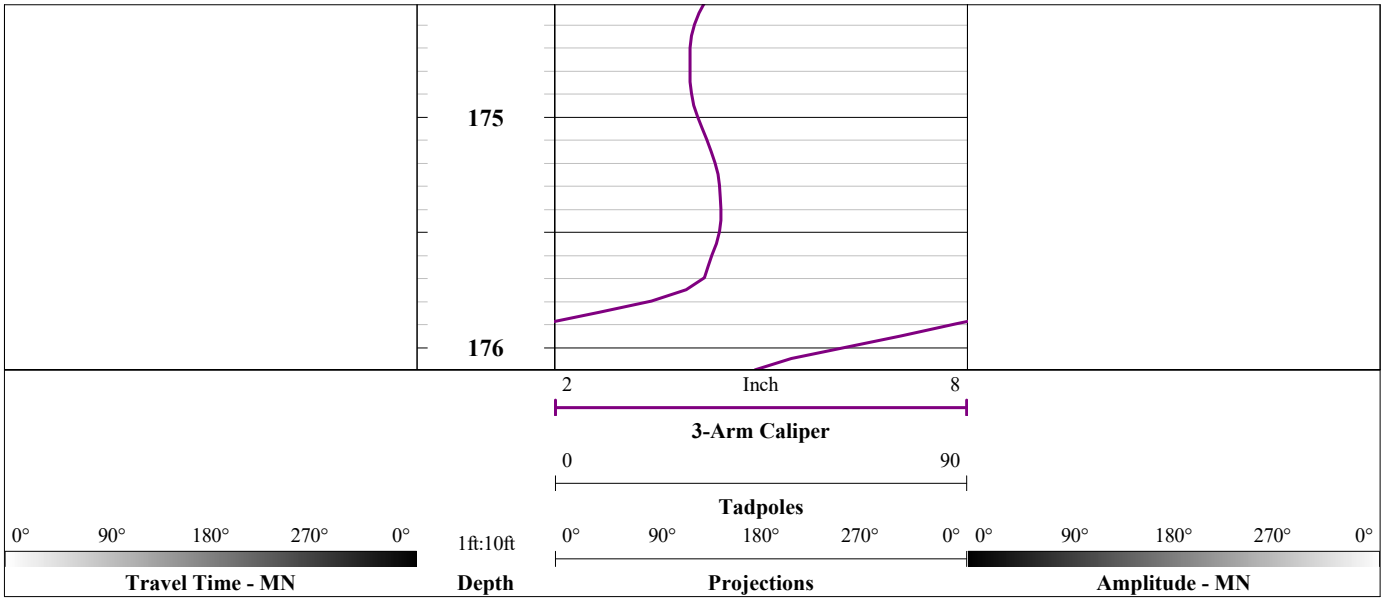

133
134
135
136
137
138
139
140


141
142
143
144
145
146
147
148
149


150
151
152
153
154
155
156
157


158
159
160
161
162
163
164
165
166


167
168
169
170
171
172
173
174


175
176
2
Inch
8
3-Arm Caliper
0
90
Tadpoles
0°
90°
180°
270°
0°
1ft:10ft
0°
90°
180°
270°
0°
0°
90°
180°
270°
0°
Travel Time - MN
Depth
Projections
Amplitude - MN

borehole geophysics / hydrophysics

810 Quail Street, Unit E

Lakewood, CO 80215

Office: (303) 279-0171

www.colog.com

Optical Televiewer

Company WSP
Well BH19-38
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-38
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79162 N
Longitude: 84.77478 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Fluid Temp & Cond.
Electrical Log
P&S Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.2'

LOG MEAS. FROM Top of Casing 0.0 ft **ABOVE PERMINANT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	20 July 2019			
RUN NUMBER	Two			
LOG TYPE	OTV			
DEPTH-DRILLER	201.0 ft			
DEPTH-LOGGER	175.0 ft			
BTM LOG INTERVAL	171.0 ft			
TOP LOG INTERVAL	4.3 ft			
RECORDED BY	BEH			
WITNESSED BY				
PROBE TYPE, S/N	OPTV, 1729			
LOGGING SPEED	4.5 ft/min			
SAMPLE INTERVAL	0.00038'			
FLUID LEVEL	16.8 ft			

BOREHOLE RECORD

RUN No.	BIT	FROM	TO
1	HQ	0'	201'

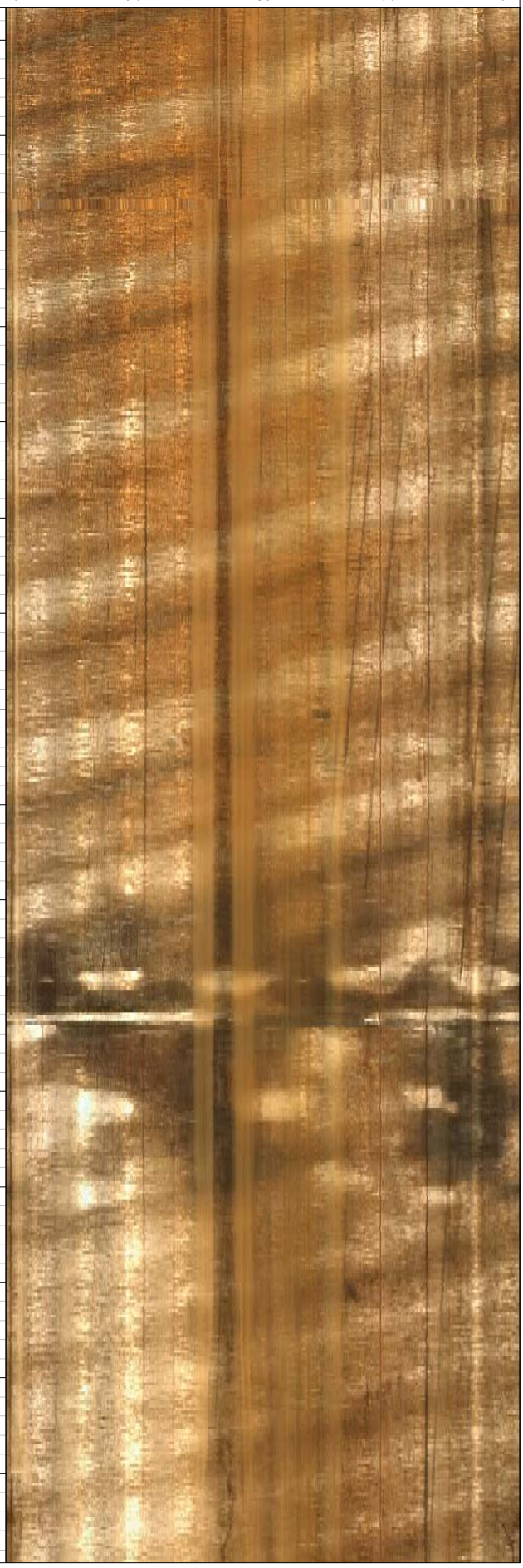
CASING RECORD

SIZE	WGT.	FROM	TO
HQ	Steel	0'	121'

NA - Not Available, N/A - Not Applicable

COMMENTS

3-Arm Caliper	Depth	Optical Image - MN
2 Inch 8	1ft:10ft	0° 90° 180° 270° 0°



13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

29

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51

52

53

54

55

56

57

58

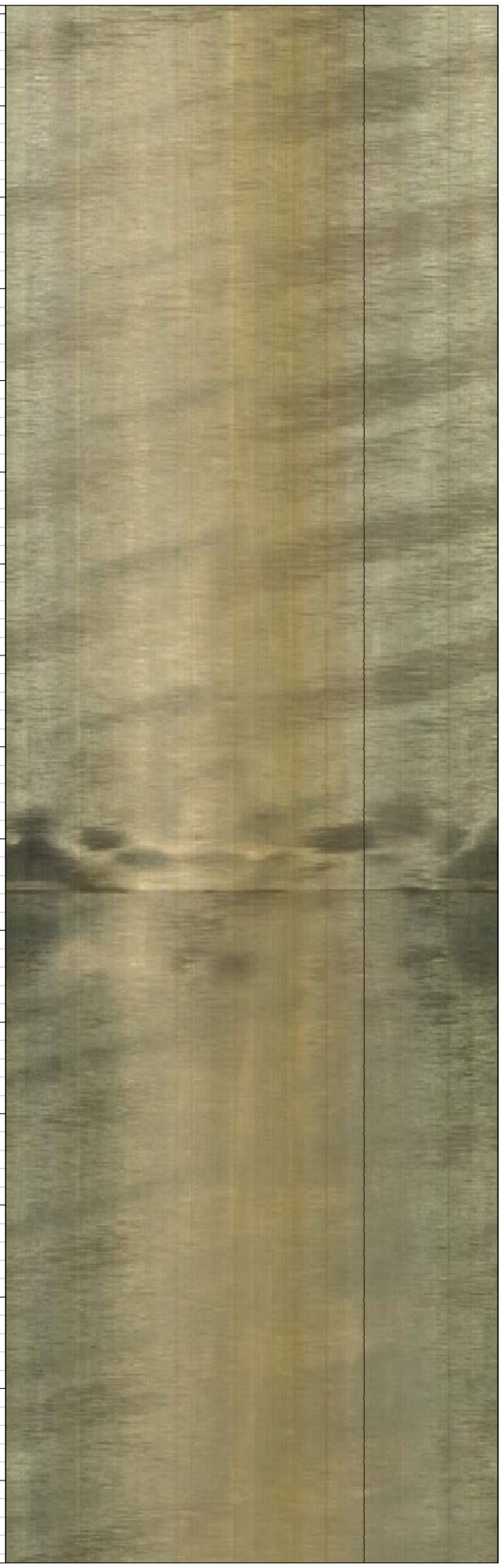
59

60

61

62

63



64

65

66

67

68

69

70

71

72

73

74

75

76

77

78

79

80

81

82

83

84

85

86

87

88

89

90

91

92

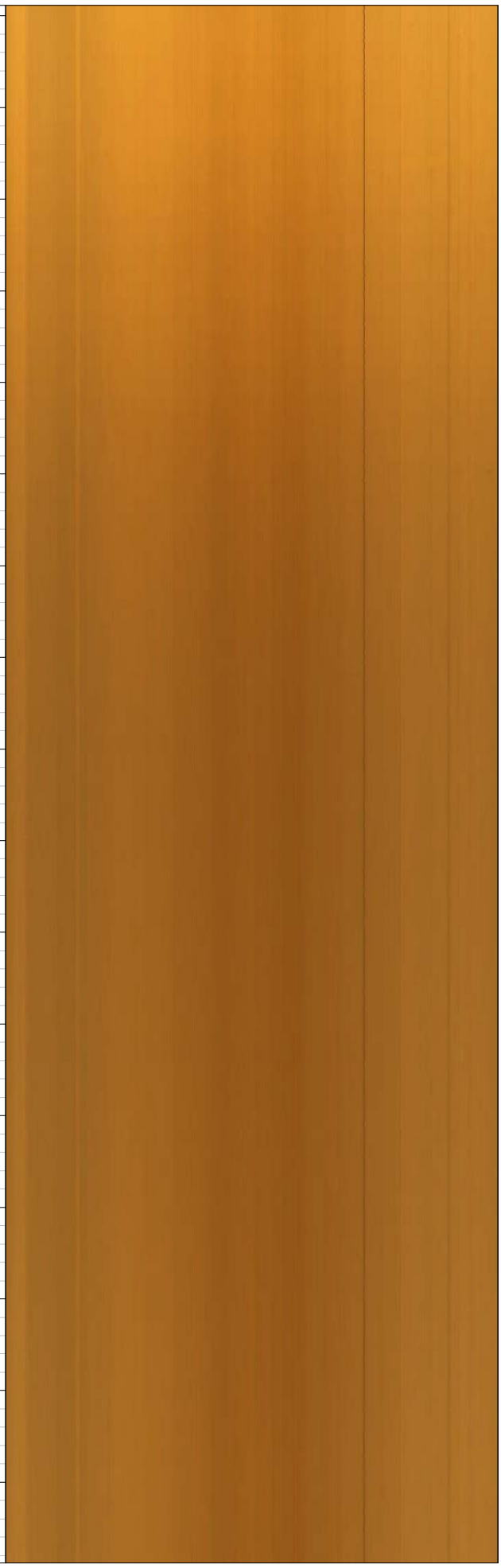
93

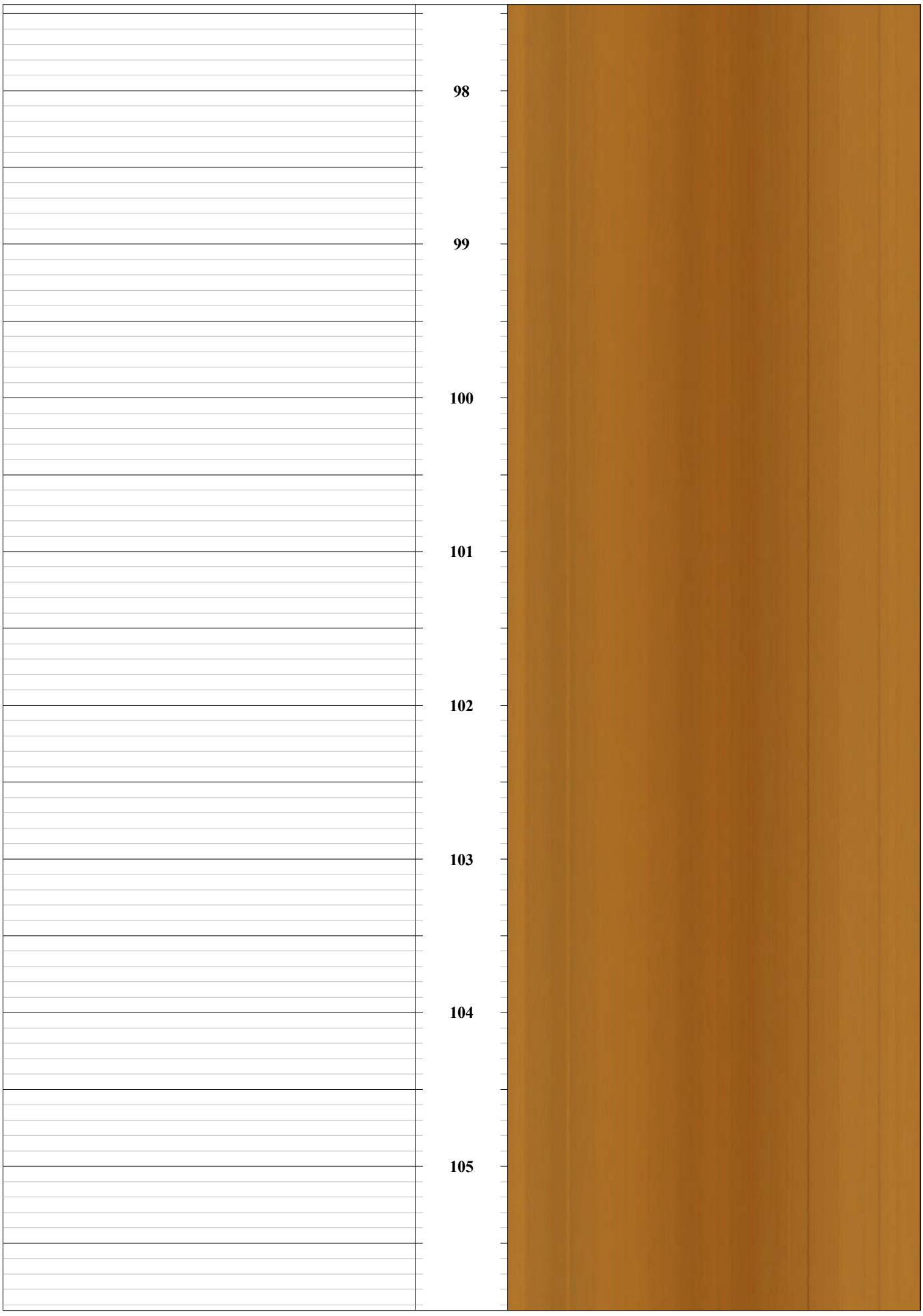
94

95

96

97




98
99
100
101
102
103
104
105

106

107

108

109

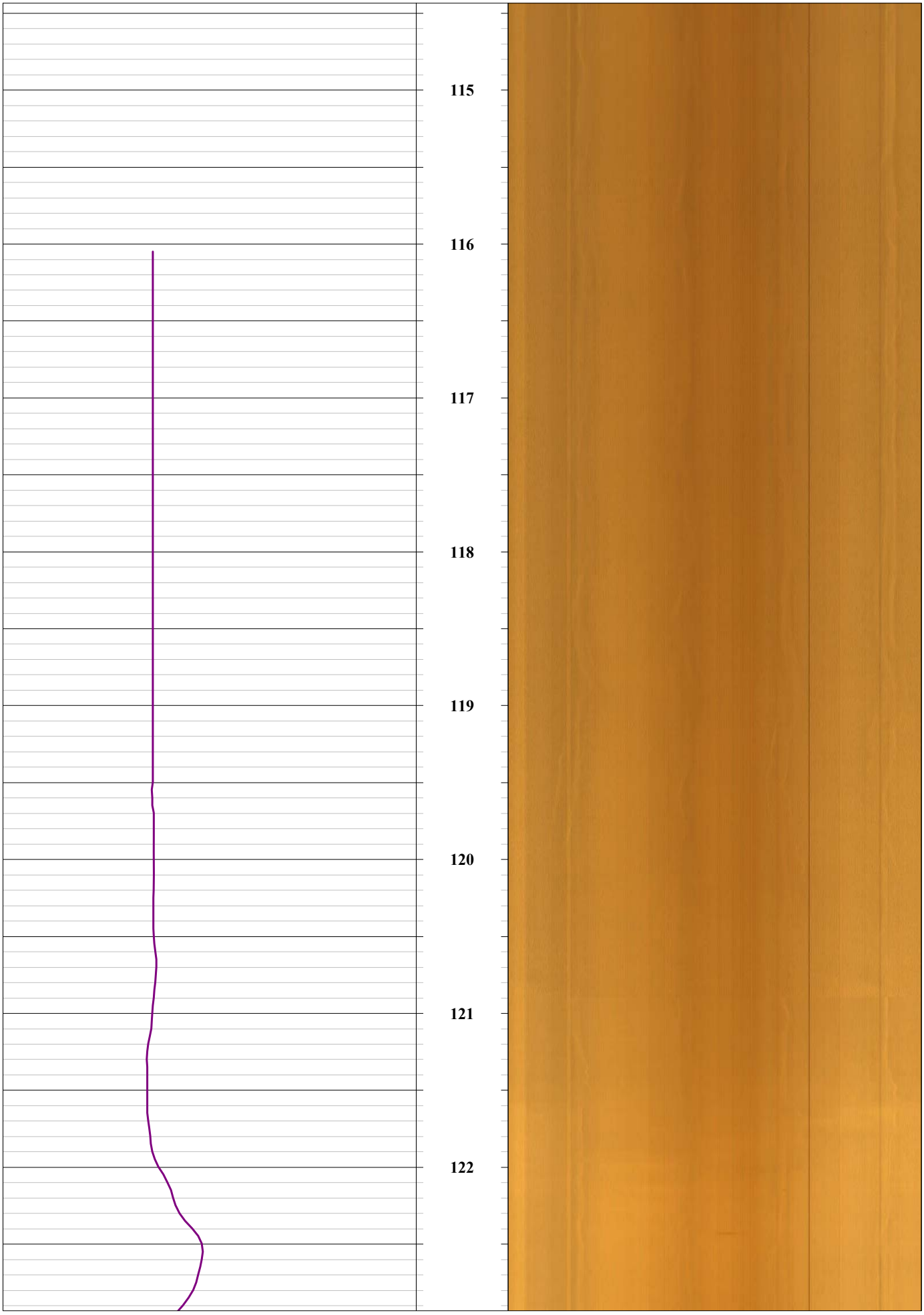
110

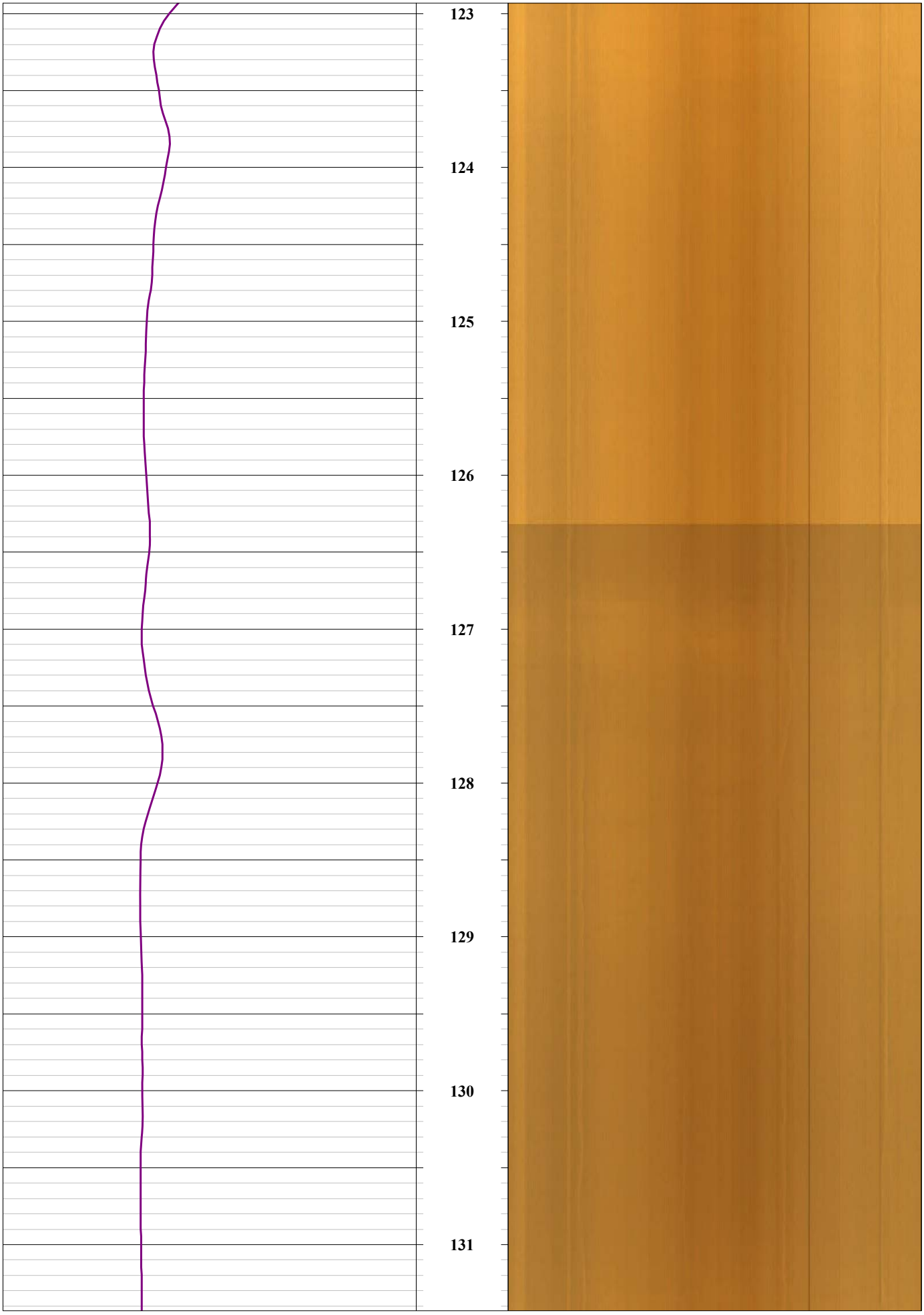
111

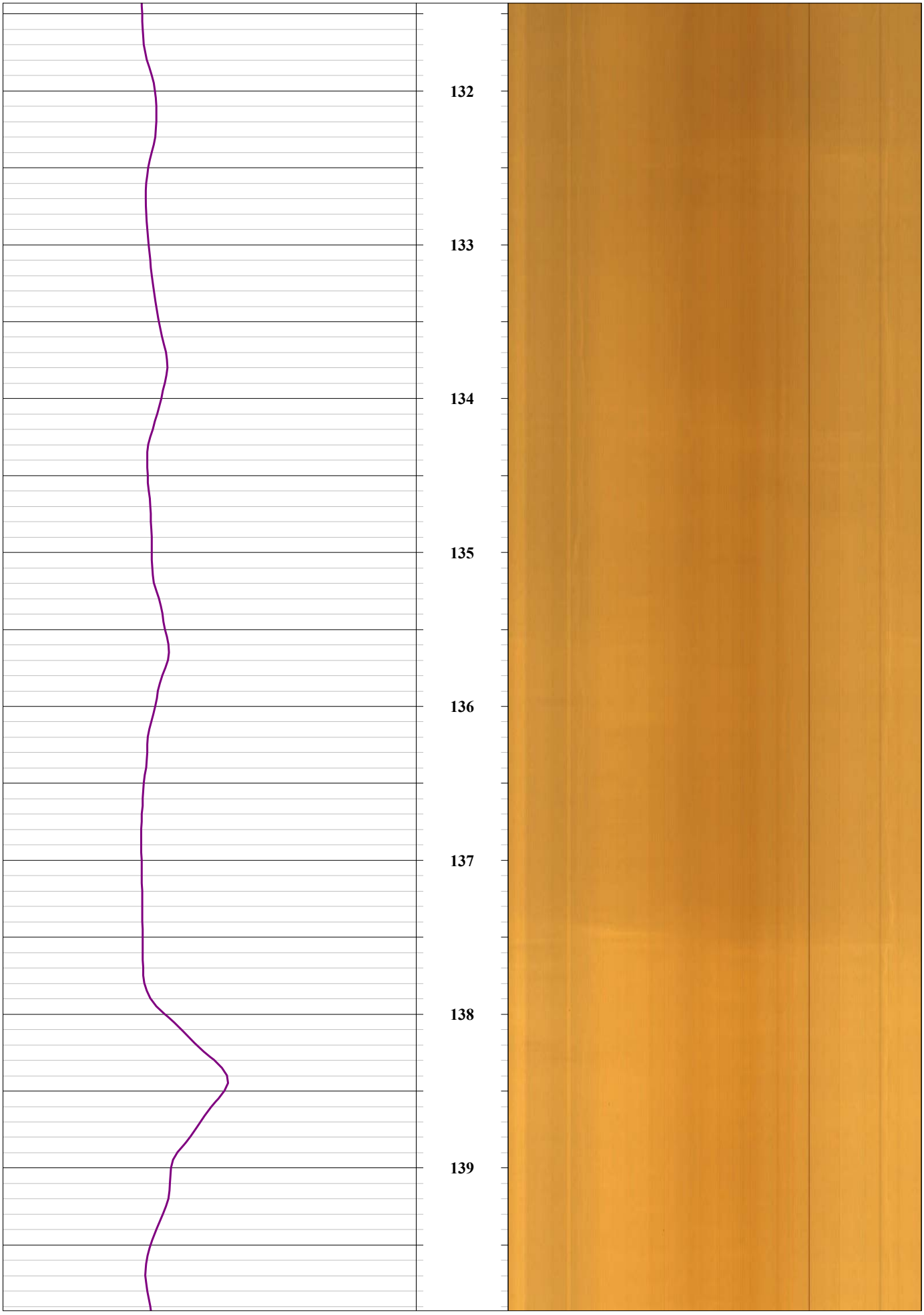
112

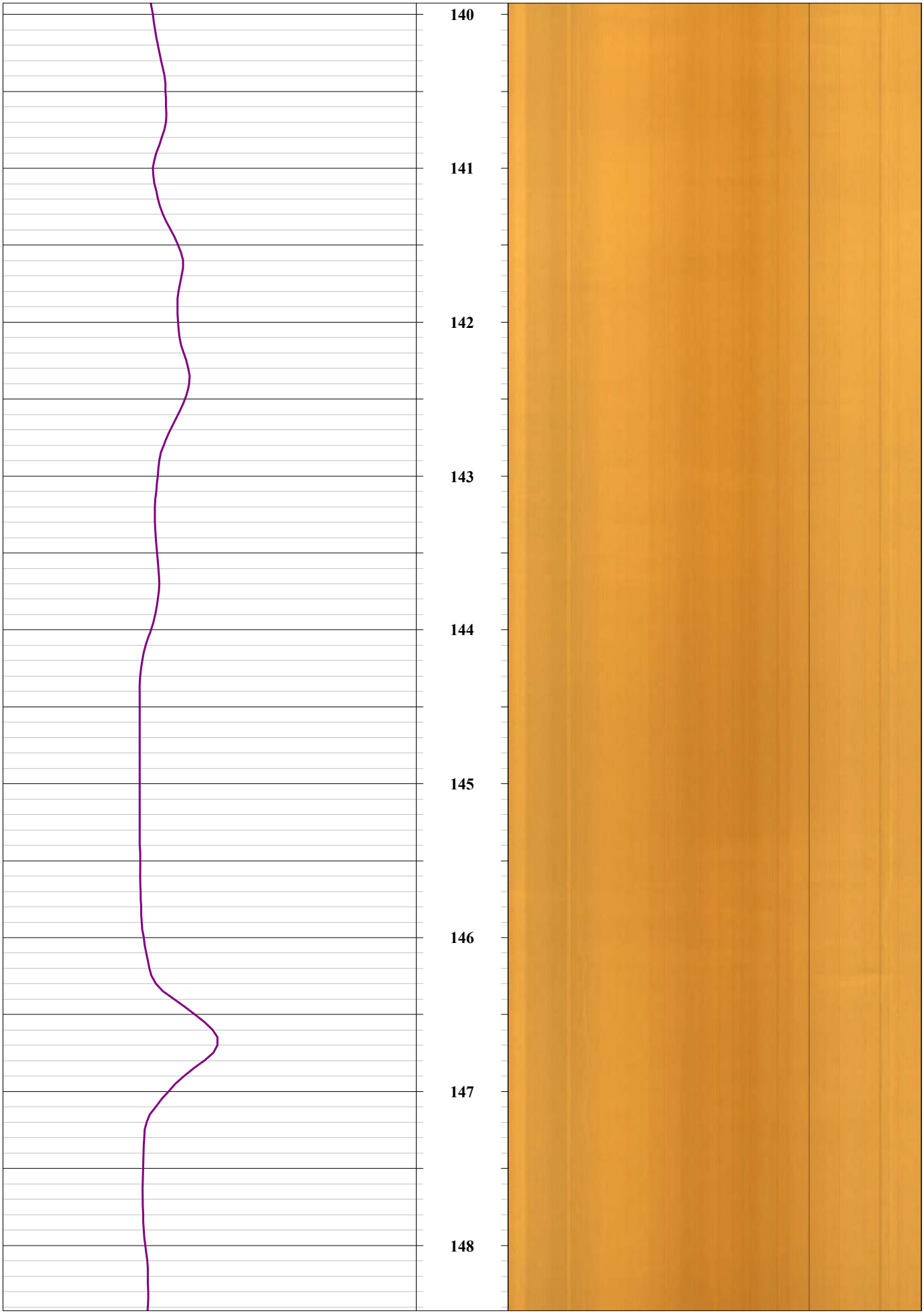
113

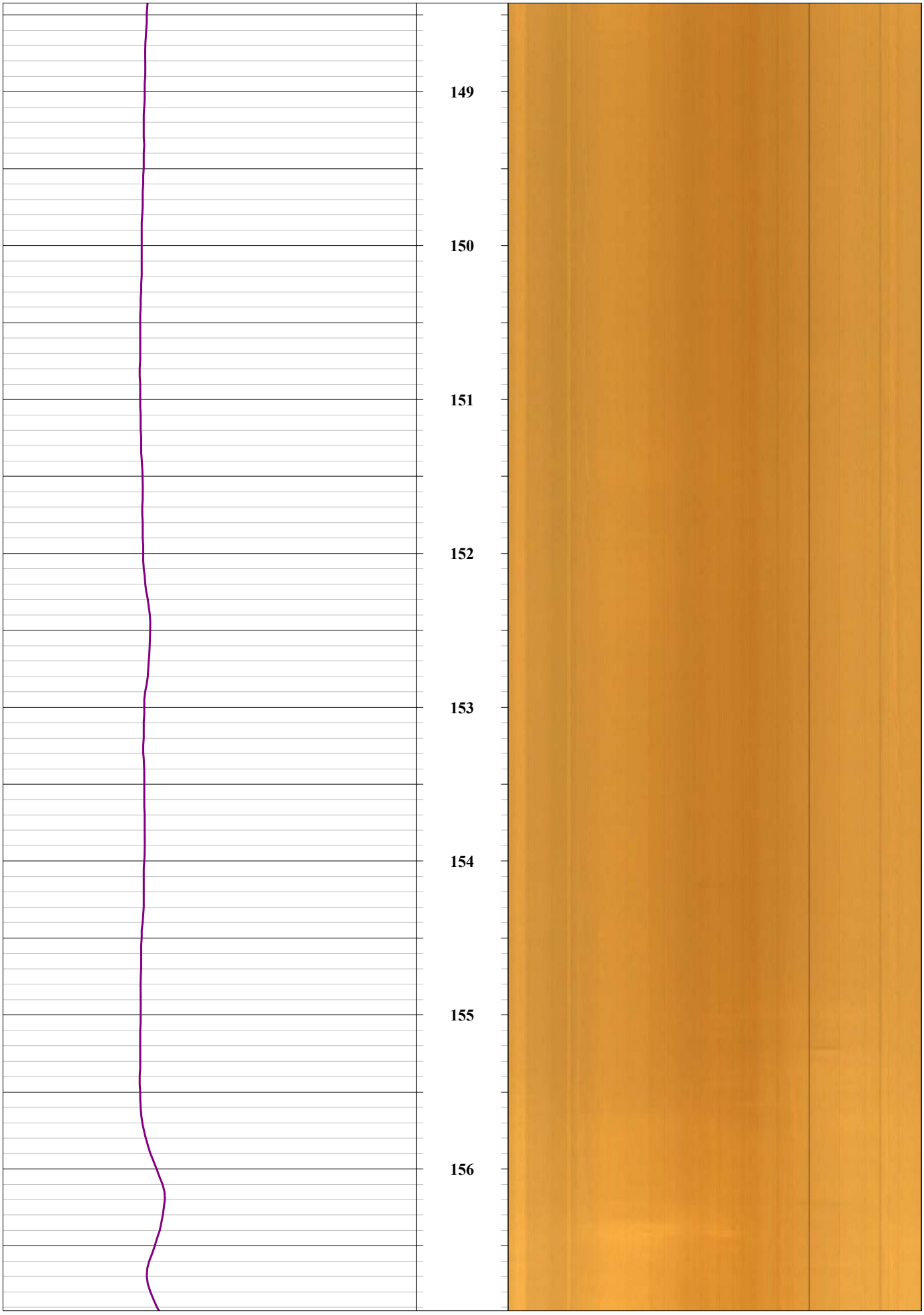
114

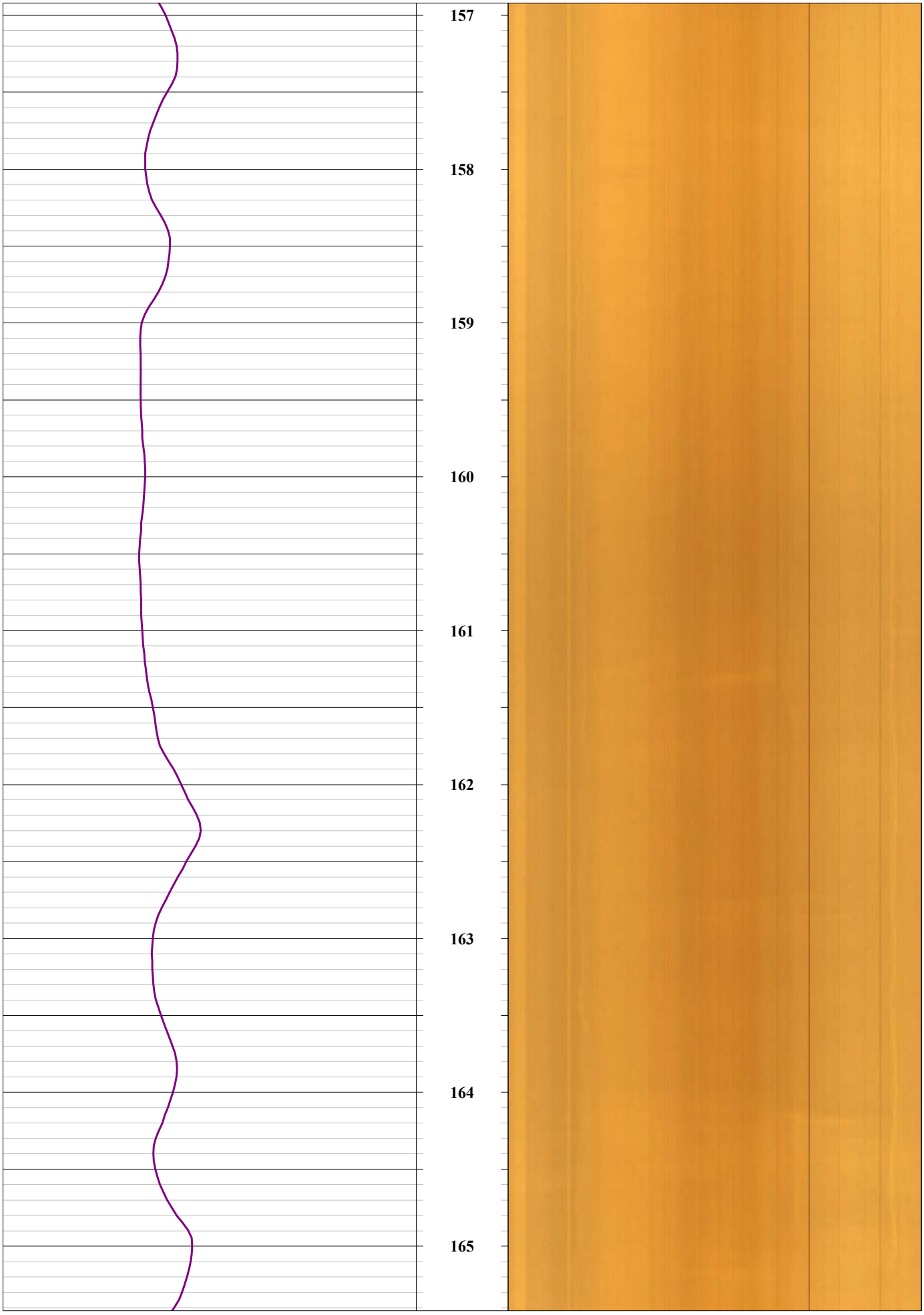

115
116
117
118
119
120
121
122

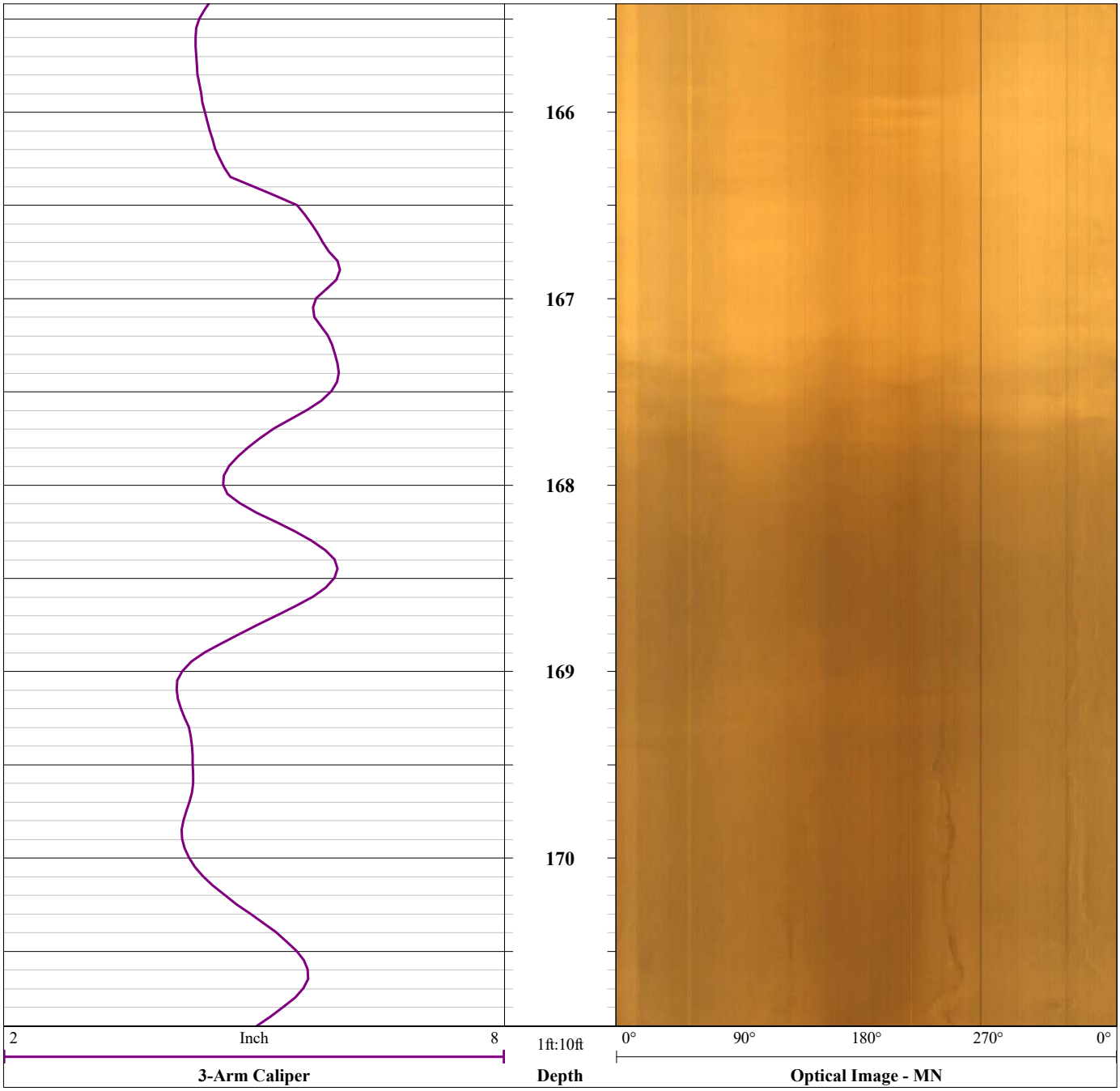

123
124
125
126
127
128
129
130
131


132
133
134
135
136
137
138
139

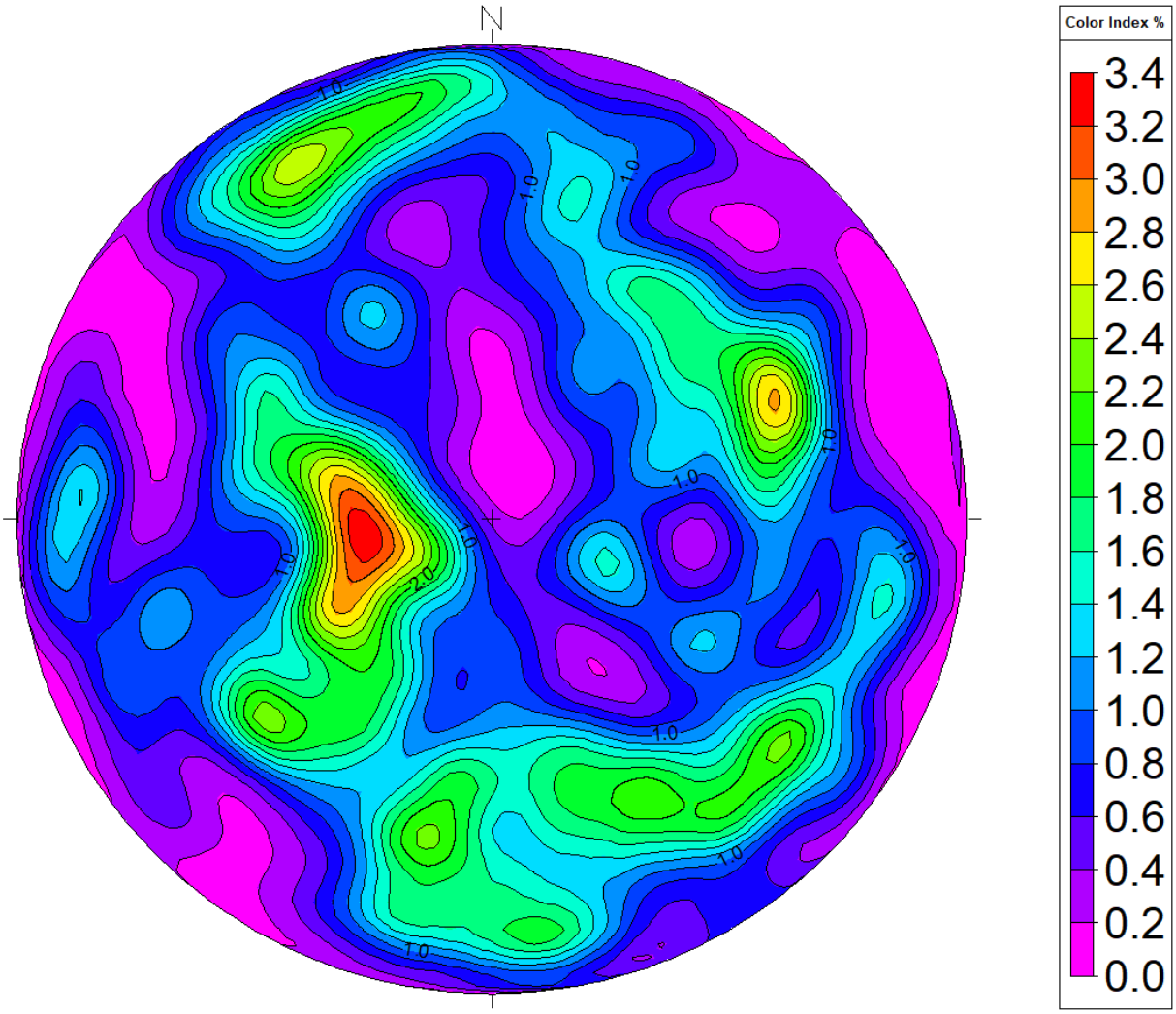

140
141
142
143
144
145
146
147
148


149
150
151
152
153
154
155
156


157
158
159
160
161
162
163
164
165

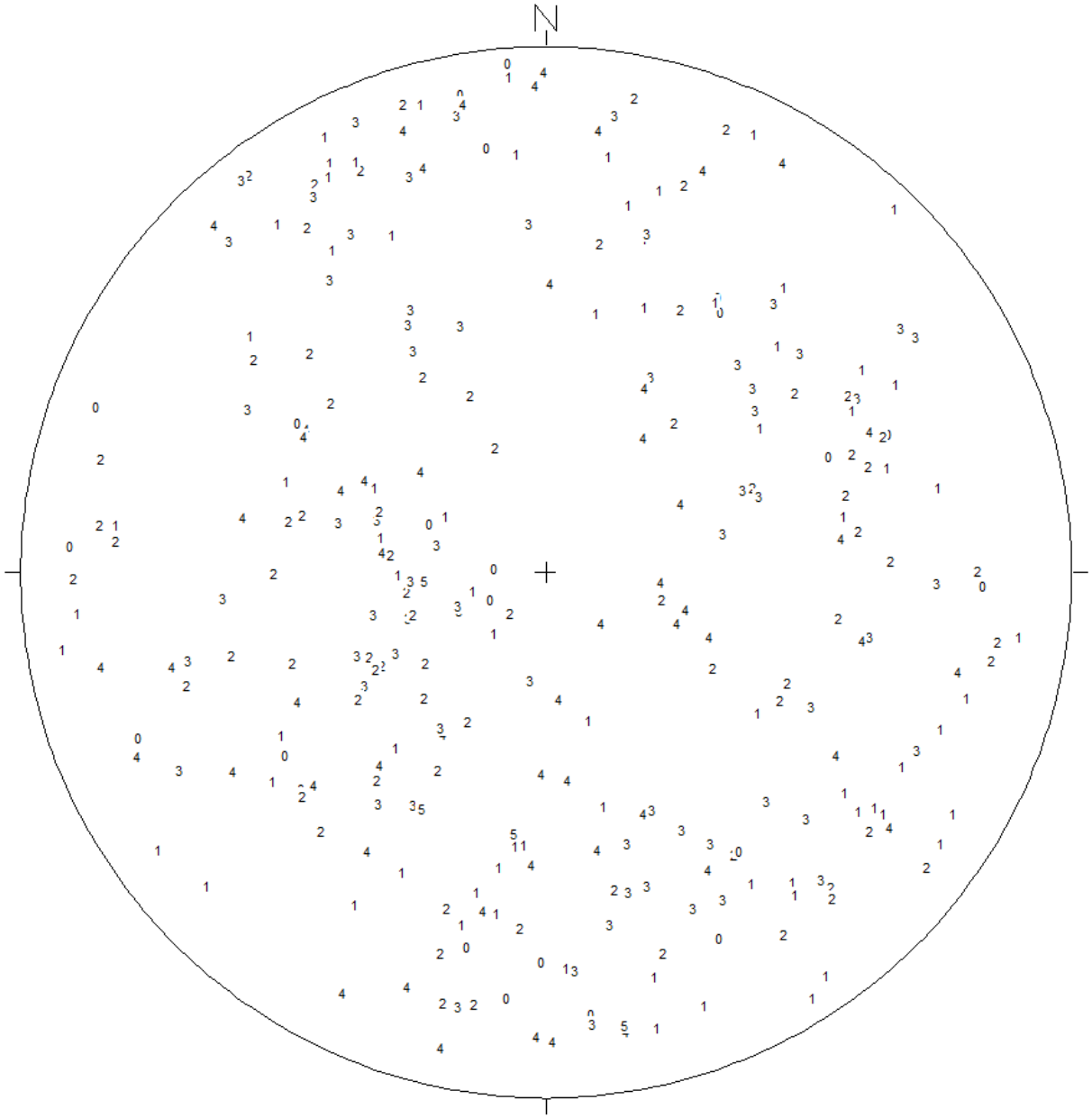

166
167
168
169
170
2
Inch
8
3-Arm Caliper
1ft:10ft
Depth
0°
90°
180°
270°
0°
Optical Image - MN

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-38
20 July 2019



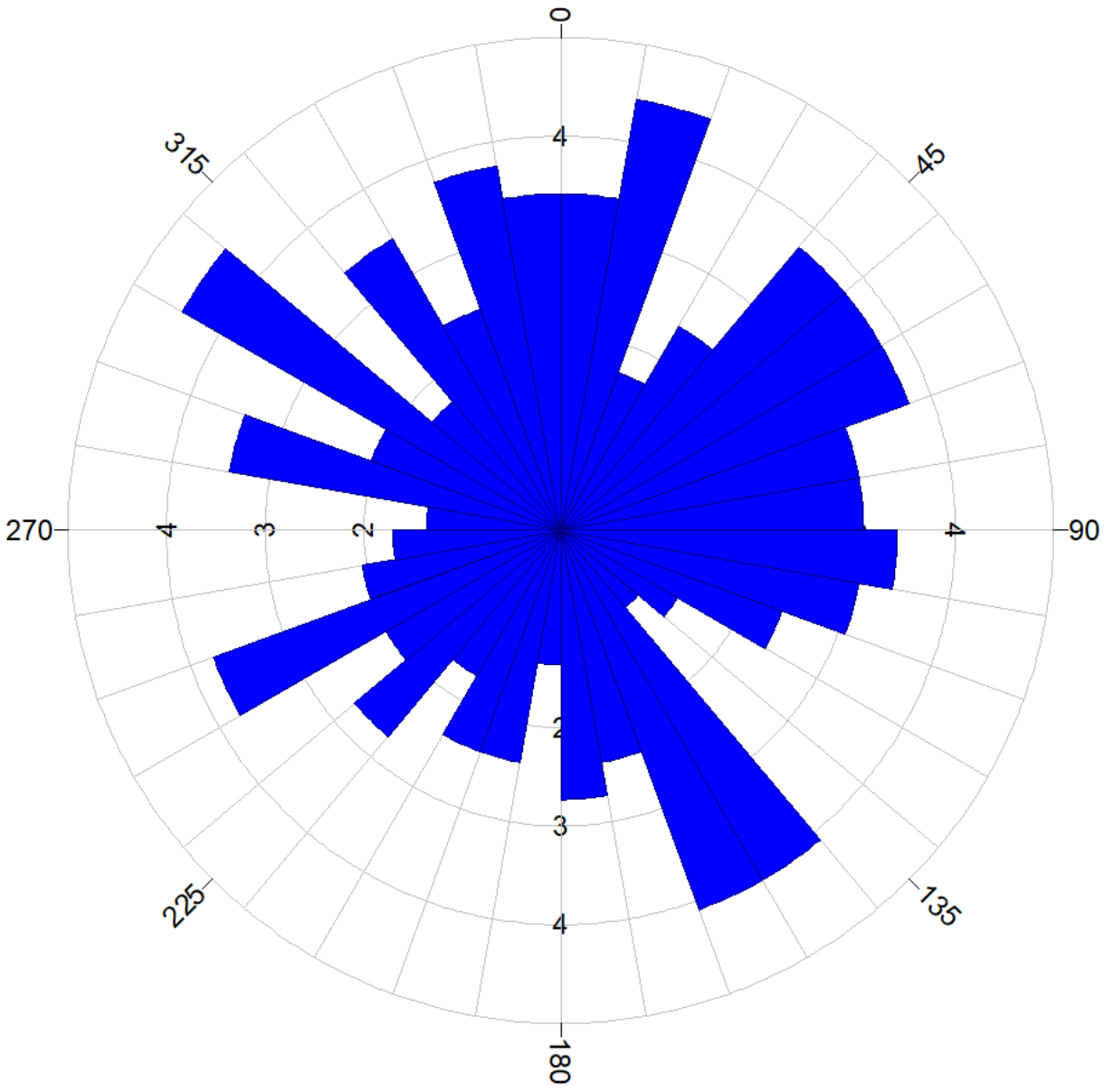
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Televiewer Image Features
WSP
L5RT Project
BH19-38
20 July 2019



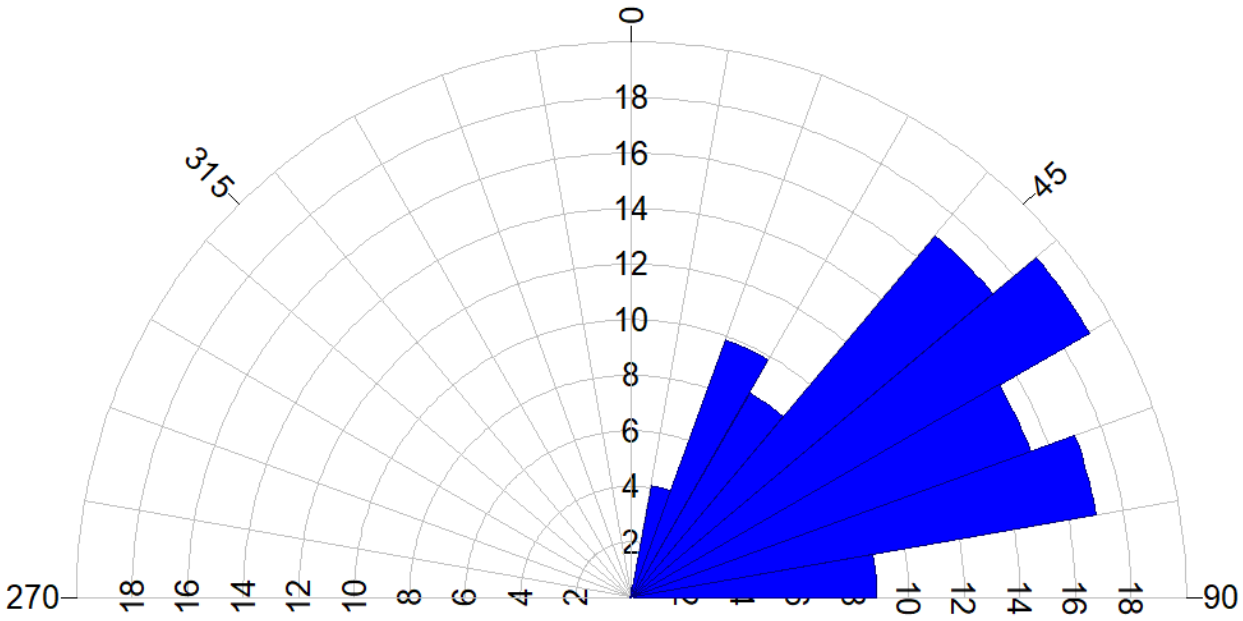
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Televiewer Image Features
WSP
L5RT Project
BH19-38
20 July 2019



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Televiewer Image Features
WSP
L5RT Project
BH19-38
20 July 2019



All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	38.23	125.4	107	44	1
2	38.29	125.6	192	59	1
3	38.31	125.7	86	24	1
4	38.36	125.8	175	67	1
5	38.37	125.9	113	30	1
6	38.44	126.1	154	29	2
7	38.45	126.2	39	44	2
8	38.50	126.3	288	72	1
9	38.55	126.5	101	34	3
10	38.60	126.6	233	40	3
11	38.61	126.7	159	40	3
12	38.65	126.8	151	76	1
13	38.74	127.1	307	68	1
14	38.84	127.4	308	60	1
15	38.87	127.5	69	24	3
16	38.87	127.5	260	27	3
17	38.90	127.6	99	18	3
18	38.92	127.7	329	86	1
19	38.95	127.8	104	28	3
20	38.97	127.9	30	44	3
21	39.05	128.1	169	80	0
22	39.06	128.1	17	58	2
23	39.09	128.3	48	54	0
24	39.17	128.5	355	75	0
25	39.32	129.0	212	50	0
26	39.32	129.0	175	82	1
27	39.34	129.1	109	81	0
28	39.36	129.1	6	72	0
29	39.44	129.4	196	54	1
30	39.47	129.5	114	18	1
31	39.51	129.6	144	68	2
32	39.52	129.7	358	66	1
33	39.59	129.9	145	62	1
34	39.66	130.1	323	65	1
35	39.67	130.2	259	64	1
36	39.74	130.4	249	58	0
37	39.80	130.6	279	79	1
38	39.85	130.7	59	11	0
39	39.93	131.0	85	9	0
40	40.15	131.7	273	71	0
41	40.15	131.7	175	85	0
42	40.18	131.8	253	53	2
43	40.24	132.0	318	51	3
44	40.24	132.0	16	66	2
45	40.25	132.0	141	72	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	40.28	132.2	92	81	0
47	40.29	132.2	297	67	3
48	40.30	132.2	142	58	3
49	40.37	132.5	240.6	54.6	2
50	40.39	132.5	305.8	80.4	1
51	40.45	132.7	98.8	26.9	1
52	40.50	132.9	293.1	69.2	1
53	40.54	133.0	88.2	80.2	2
54	40.60	133.2	51.8	24.9	2
55	40.67	133.4	319.3	70.2	2
56	40.68	133.5	64.7	33.6	3
57	40.69	133.5	159.7	67.4	3
58	40.69	133.5	241.5	55.7	3
59	40.71	133.6	238.2	70.4	3
60	40.78	133.8	273.0	62.4	3
61	40.80	133.9	116.8	54.6	3
62	40.86	134.0	83.9	52.9	3
63	40.89	134.2	296.8	41.7	2
64	41.01	134.6	71.6	62.4	2
65	41.02	134.6	249.3	33.6	2
66	41.05	134.7	145.4	35.5	2
67	41.13	135.0	40.9	56.8	2
68	41.16	135.1	188.4	51.6	2
69	41.18	135.1	280.9	46.3	2
70	41.23	135.3	124.4	58.2	2
71	41.27	135.4	134.9	75.6	3
72	41.27	135.4	10.5	18.5	3
73	41.30	135.5	148.6	62.7	3
74	41.33	135.6	176.1	54.5	3
75	41.35	135.7	229.7	51.8	3
76	41.38	135.8	220.4	54.8	3
77	41.39	135.8	356.7	66.6	3
78	41.47	136.1	330.5	51.4	3
79	41.49	136.1	319.6	67.9	3
80	41.53	136.3	43.4	28.9	2
81	41.59	136.5	40.4	37.9	1
82	41.62	136.6	7.5	45.1	1
83	41.77	137.0	1.6	64.8	0
84	41.83	137.3	347.2	79.6	1
85	41.94	137.6	248.9	47.1	0
86	41.95	137.6	12.6	63.9	0
87	42.10	138.1	93.9	26.5	4
88	42.23	138.6	308.0	70.4	4
89	42.29	138.8	59.0	30.9	2
90	42.33	138.9	351.1	79.3	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	42.48	139.4	179.0	82.8	4
92	42.53	139.5	346.1	69.8	1
93	42.68	140.0	94.8	75.3	2
94	42.69	140.1	260.8	46.9	1
95	42.73	140.2	269.7	54.2	2
96	42.78	140.4	304.0	54.9	4
97	42.81	140.5	247.5	55.1	4
98	42.81	140.5	295.6	21.5	4
99	42.89	140.7	40.5	41.9	4
100	42.93	140.9	61.4	45.9	4
101	42.95	140.9	326.3	83.5	1
102	42.99	141.0	74.8	64.0	4
103	43.10	141.4	98.5	49.8	4
104	43.12	141.5	3.8	48.0	4
105	43.24	141.9	179.5	44.2	4
106	43.26	141.9	186.1	71.6	4
107	43.29	142.0	77.1	77.1	4
108	43.32	142.1	32.5	31.7	4
109	43.38	142.3	1.9	79.2	4
110	43.57	143.0	11.3	56.9	4
111	43.67	143.3	32.6	54.8	4
112	43.71	143.4	118.6	44.2	4
113	43.74	143.5	282.5	74.7	2
114	43.75	143.5	56.9	61.7	4
115	43.82	143.8	47.0	54.6	2
116	43.84	143.8	199.3	65.2	2
117	43.93	144.1	242.5	63.0	1
118	44.18	145.0	323.7	67.1	1
119	44.25	145.2	5.8	44.7	1
120	44.28	145.3	67.2	74.4	0
121	44.28	145.3	54.2	52.5	0
122	44.32	145.4	95.0	72.2	1
123	44.55	146.2	57.7	51.1	1
124	44.57	146.2	73.9	53.3	2
125	44.67	146.6	337.8	60.2	3
126	44.74	146.8	343.5	53.9	3
127	44.74	146.8	205.2	79.2	1
128	44.78	146.9	229	42	3
129	44.79	147.0	236	69	3
130	44.80	147.0	75	61	3
131	44.85	147.1	310	68	2
132	44.87	147.2	320	72	2
133	44.99	147.6	54	82	1
134	45.18	148.2	257	48	2
135	45.18	148.2	127	61	1

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	45.23	148.4	301	42	2
137	45.23	148.4	126	43	2
138	45.24	148.4	29	37	2
139	45.37	148.9	63	32	2
140	45.42	149.0	47	52	1
141	45.54	149.4	220	58	1
142	45.54	149.4	131	51	2
143	45.59	149.6	13	54	1
144	45.60	149.6	328	61	1
145	45.65	149.8	84	80	1
146	45.76	150.1	200	43	1
147	45.84	150.4	152	81	1
148	45.84	150.4	154	59	1
149	46.04	151.0	214	48	0
150	46.05	151.1	336	67	0
151	46.15	151.4	40	14	1
152	46.15	151.4	142	83	2
153	46.20	151.6	328	55	2
154	46.22	151.7	119	46	0
155	46.29	151.9	79	23	2
156	46.48	152.5	351	59	3
157	46.53	152.7	341	78	1
158	46.59	152.9	148	74	2
159	46.60	152.9	168	76	3
160	46.63	153.0	14	60	1
161	46.70	153.2	303	30	2
162	46.76	153.4	190	79	2
163	46.77	153.5	328	72	2
164	46.79	153.5	271	70	2
165	46.84	153.7	344	66	2
166	46.87	153.8	10	74	2
167	46.87	153.8	302	79	1
168	46.89	153.8	300	66	1
169	46.92	153.9	190	40	1
170	46.97	154.1	103	77	2
171	47.06	154.4	264	49	2
172	47.20	154.9	88	44	2
173	47.26	155.0	207	45	2
174	47.27	155.1	243	54	1
175	47.27	155.1	347	25	1
176	47.29	155.1	224	83	1
177	47.45	155.7	238	59	1
178	47.52	155.9	226	50	1
179	47.57	156.1	10	49	1
180	47.57	156.1	196	55	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
181	47.62	156.2	80	84	1
182	47.66	156.4	34	31	3
183	47.66	156.4	252	34	3
184	47.67	156.4	283	52	3
185	47.69	156.5	69	44	2
186	47.75	156.7	249	57	2
187	47.83	156.9	5	59	2
188	47.83	156.9	250	51	2
189	47.87	157.0	162	81	2
190	47.89	157.1	345	46	3
191	47.91	157.2	36	47	3
192	47.92	157.2	249	32	3
193	47.96	157.4	61	70	3
194	48.19	158.1	196	63	1
195	48.21	158.2	188	75	3
196	48.30	158.5	93	72	2
197	48.30	158.5	30	64	1
198	48.32	158.5	154	72	2
199	48.33	158.6	9	57	1
200	48.34	158.6	149	44	3
201	48.36	158.7	334	47	3
202	48.36	158.7	141	83	3
203	48.38	158.7	156	81	3
204	48.39	158.8	188	67	1
205	48.52	159.2	150	74	1
206	48.53	159.2	212	49	1
207	48.62	159.5	221	29	2
208	48.65	159.6	26	55	1
209	48.80	160.1	237	39	1
210	48.91	160.5	164	80	1
211	48.92	160.5	108	20	0
212	48.95	160.6	327	55	0
213	49.00	160.8	171	69	0
214	49.04	160.9	348	39	1
215	49.15	161.3	254	56	1
216	49.16	161.3	288	18	2
217	49.16	161.3	307	66	1
218	49.19	161.4	154	20	2
219	49.27	161.7	208	33	3
220	49.29	161.7	333	55	4
221	49.36	161.9	13	84	4
222	49.36	161.9	356	34	4
223	49.49	162.4	178	80	4
224	49.65	162.9	280	75	2
225	49.68	163.0	355	77	3

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
226	49.73	163.2	47	79	1
227	49.89	163.7	299	47	3
228	50.01	164.1	245	22	4
229	50.05	164.2	210	77	4
230	50.09	164.4	289	22	4
231	50.17	164.6	235	47	2
232	50.17	164.6	28	28	2
233	50.22	164.8	202	78	2
234	50.23	164.8	26	80	4
235	50.26	164.9	147	72	3
236	50.27	164.9	57	35	3
237	50.30	165.0	223	43	3
238	50.40	165.3	63	16	3
239	50.45	165.5	14	75	2
240	50.45	165.5	169	78	4
241	50.47	165.6	135	80	4
242	50.50	165.7	280	17	4
243	50.54	165.8	295	27	4
244	50.61	166.0	284	51	4
245	50.66	166.2	114	32	4
246	50.73	166.5	265	46	4
247	50.75	166.5	117	44	4
248	50.80	166.7	351	78	5
249	50.90	167.0	8	43	5
250	51.09	167.6	28	44	5
251	51.19	168.0	82	20	5
252	51.24	168.1	40	10	2
253	51.27	168.2	66	16	3
254	51.33	168.4	360	80	4
255	51.36	168.5	162	68	4
256	51.38	168.6	3	33	4
257	51.44	168.8	216	24	4
258	51.55	169.1	83	22	3
259	51.61	169.3	59	32	2
260	51.67	169.5	55	37	2
261	51.70	169.6	74	29	3
262	51.76	169.8	12	75	3
263	51.79	169.9	70	23	2
264	51.83	170.1	93	25	2
265	51.89	170.2	99	42	2
266	51.90	170.3	125	25	4
267	51.95	170.4	351	46	4
268	51.99	170.6	285	69	4
269	52.02	170.7	109	35	4
270	52.06	170.8	19	74	4

All directions are with respect to Magnetic North.

Orientation Summary Table

Televiewer Image Features

WSP

L5RT Project

BH19-38

20 July 2019

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
271	52.09	170.9	65	76	4
272	52.12	171.0	208	31	4
273	52.14	171.1	309	81	2
274	52.22	171.3	201	69	4
275	52.31	171.6	315	58	3
276	52.33	171.7	60	28	3
277	52.45	172.1	338	42	3
278	52.49	172.2	147	40	3
279	52.50	172.3	333	61	3
280	52.54	172.4	347	54	3
281	52.55	172.4	151	46	3
282	52.63	172.7	71	13	1
283	52.63	172.7	309	64	1
284	52.72	173.0	107	28	2
285	52.73	173.0	154	74	1
286	52.74	173.0	340	42	4
287	52.88	173.5	306	40	1
288	52.91	173.6	52	57	1
289	52.91	173.6	161	76	4
290	52.93	173.7	101	40	2
291	53.01	173.9	349	53	2
292	53.08	174.2	47	52	4
293	53.10	174.2	357	21	4
294	53.15	174.4	321	12	4

All directions are with respect to Magnetic North.

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Fluid Temperature & Conductivity 3-Arm Caliper Natural Gamma

Company WSP
Well BH19-38
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-38
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79162 N
Longitude: 84.77478 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.2'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	20 July 2019	20 July 2019	20 July 2019	
RUN NUMBER	Nine	Eight	6-7	
LOG TYPE	FTC	Caliper	NGR	
DEPTH-DRILLER	201'	201'	201'	
DEPTH-LOGGER	175'	175'	175'	
BTM LOG INTERVAL	175'	175'	172.5'	
TOP LOG INTERVAL	16.1'	116.1'	4.0'	
RECORDED BY	BEH	BEH	BEH	
WITNESSED BY				
PROBE TYPE, S/N	2PFA #5969	3ACS #6011	ELXG #4248	
LOGGING SPEED	15 fpm	9fpm	15fpm	
A.S.D.E. / Sample Interval	0.13' / 0.0024'	0.14'/0.1'	0.1'/0.1'	
Fluid Level / Fluid Type	16'/Water	16'/Water	16'/Water	

BOREHOLE RECORD

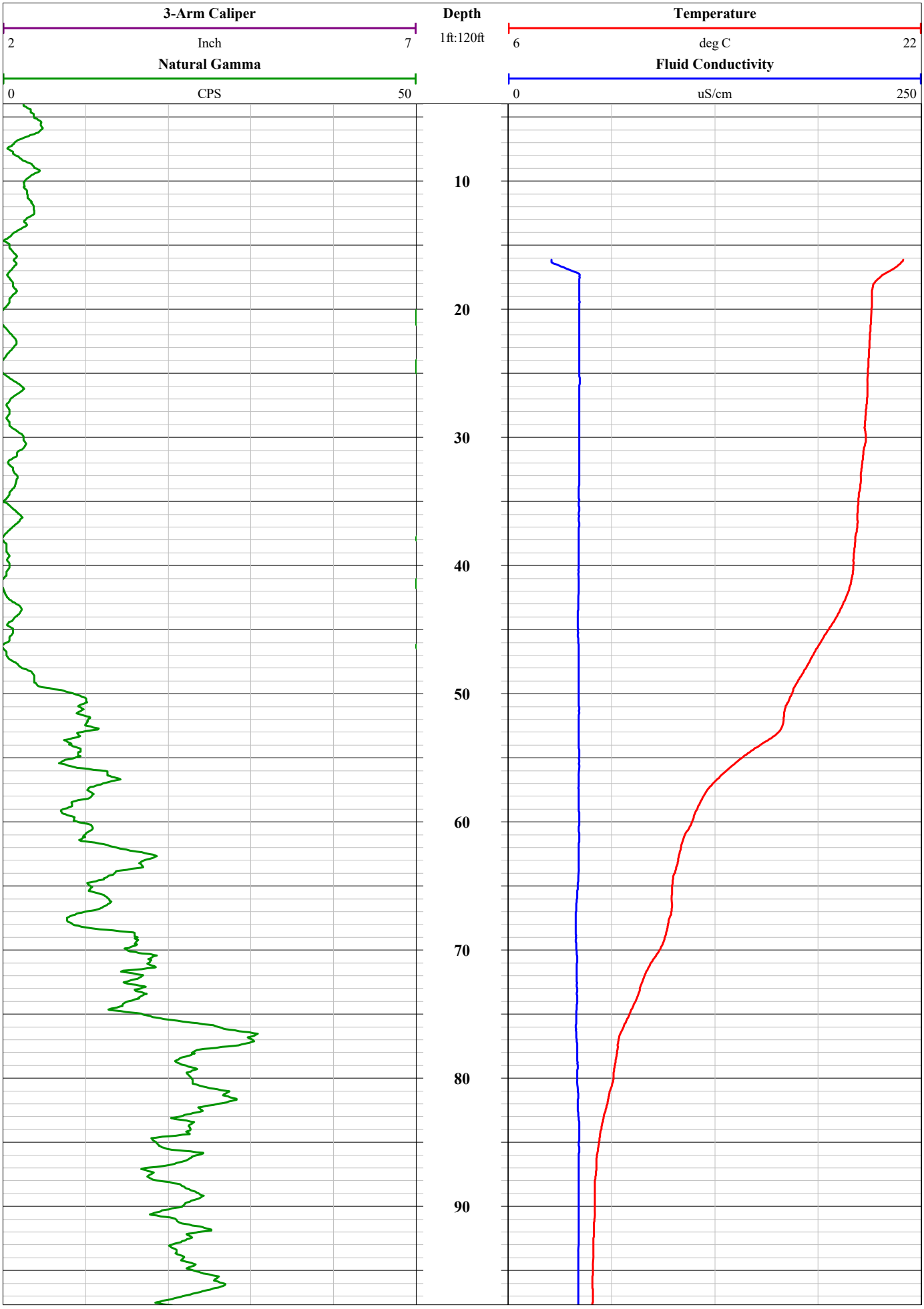
RUN No.	BIT	FROM	TO
1	HQ	0'	201'

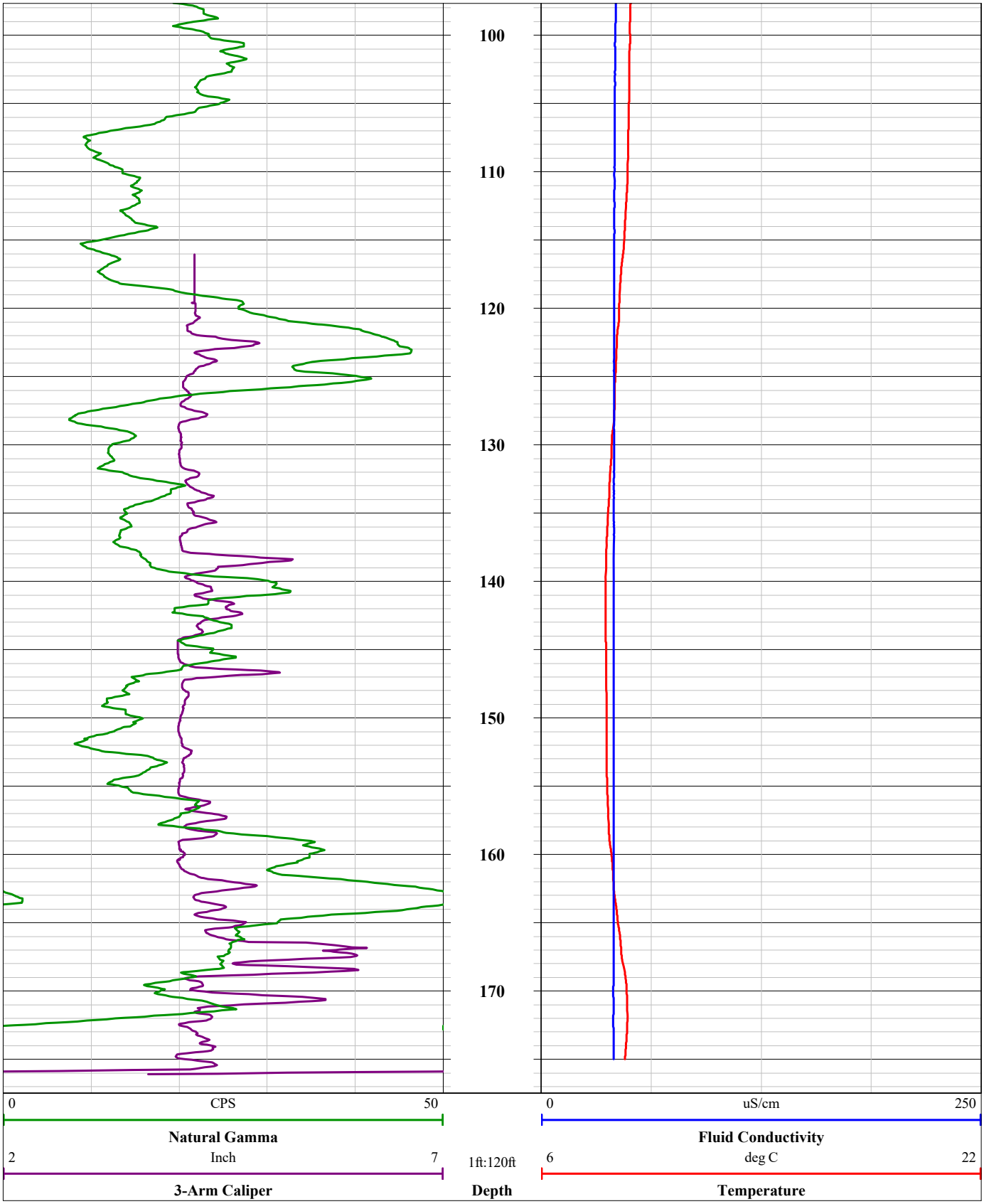
CASING RECORD

SIZE	WGT.	FROM	TO
HQ	Steel	0'	121'

NA - Not Available, N/A - Not Applicable

COMMENTS


3-Arm Caliper
2
Inch
7
Natural Gamma
0
CPS
50
Depth
1ft:120ft
10
20
30
40
50
60
70
80
90
Temperature
6
deg C
22
Fluid Conductivity
0
uS/cm
250


100
110
120
130
140
150
160
170
0
CPS
50
Natural Gamma
2
Inch
7
3-Arm Caliper
1ft:120ft
Depth
0
uS/cm
250
Fluid Conductivity
6
deg C
22
Temperature

Borehole Deviation

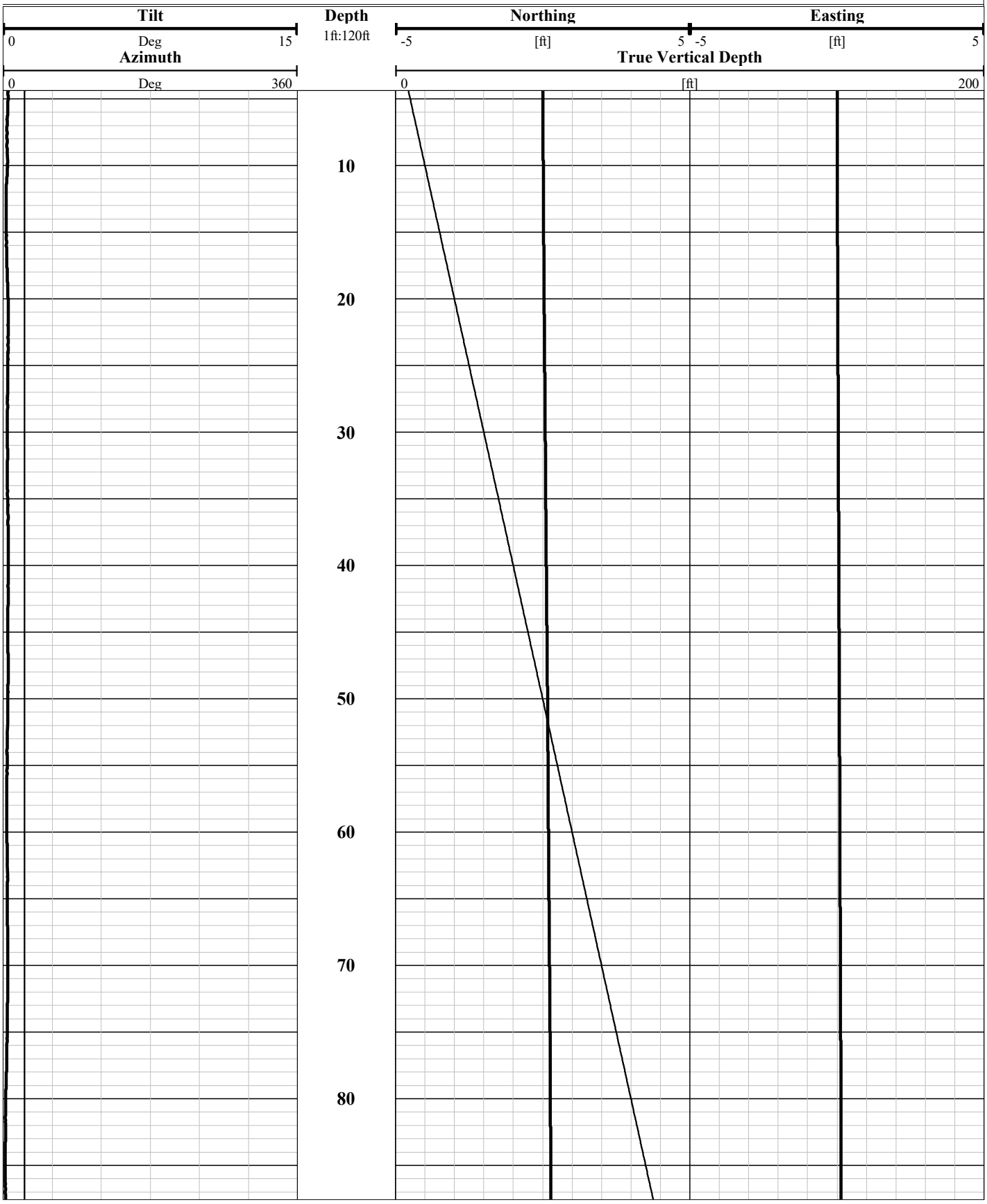
COLOG
borehole geophysics / hydrophysics

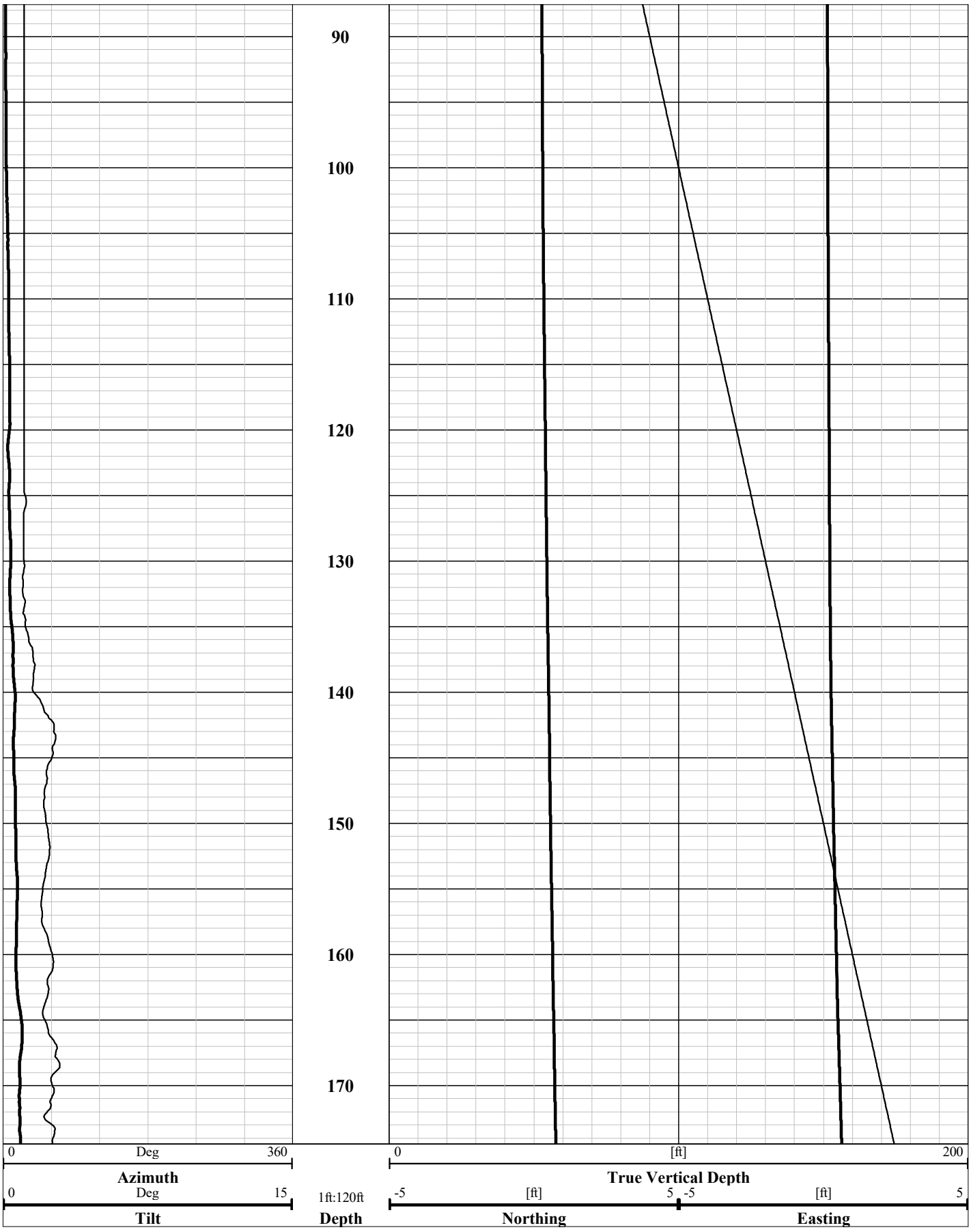
COMPANY: WSP	PROJECT: L5RT Project
DATE LOGGED: 20 July 2019	WELL: BH19-38 - South Side

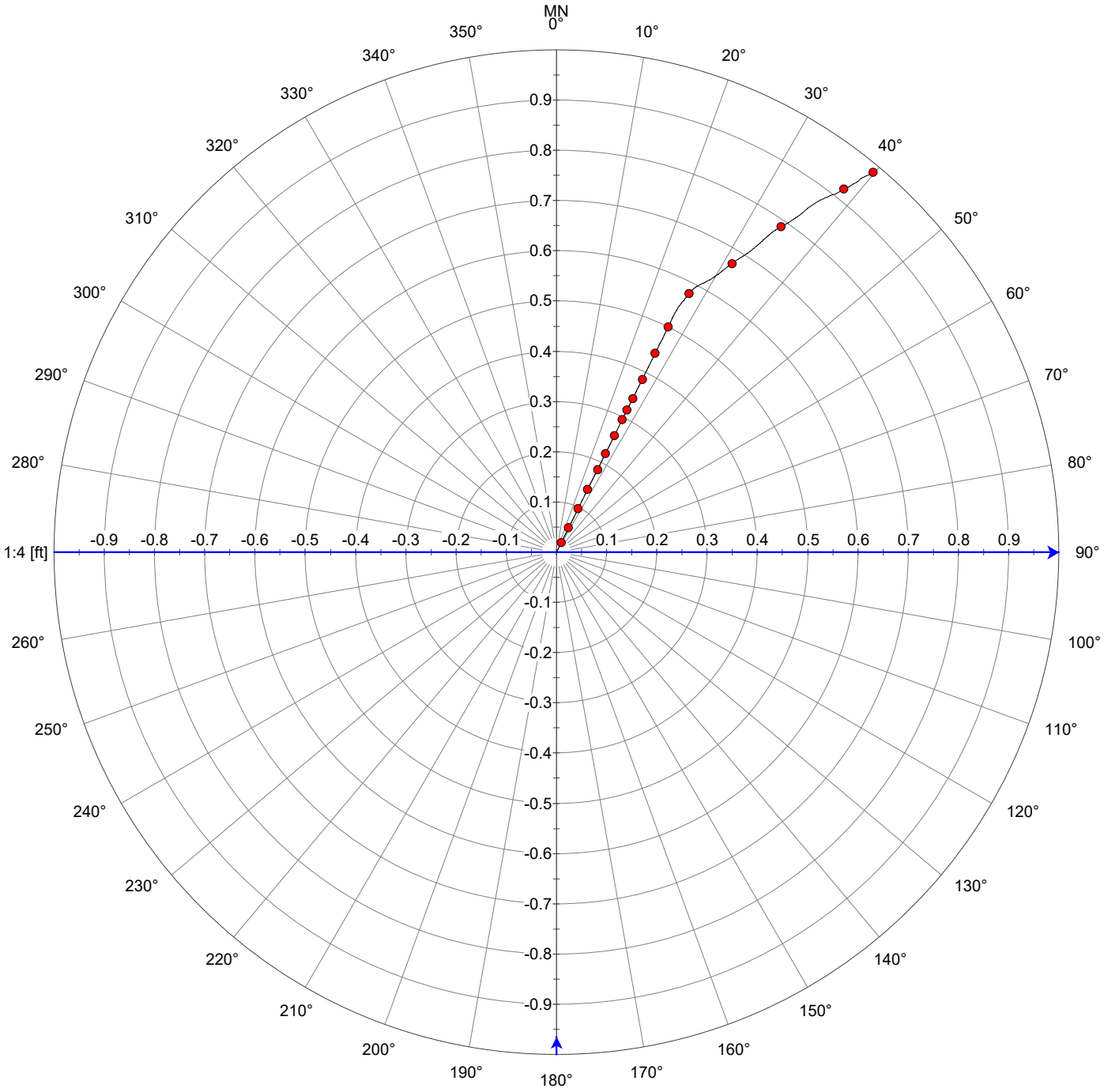
Colog, Inc.
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

COMMENTS:

Straits of Mackinac **Elevation: 598.2'** **Latitude: 45.79162 N** **Longitude: 84.77478 W**




90
100
110
120
130
140
150
160
170
0
Deg
360
Azimuth
0
Deg
15
Tilt
1ft:120ft
Depth
0
[ft]
200
True Vertical Depth
-5
[ft]
5
Northing
-5
[ft]
5
Easting


MN
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
1:4 [ft]

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Natural Gamma
16" 64" Normal Res.
Spontaneous Potential
Single Point
Resistance

Company WSP
Well BH19-38
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-38
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79162 N
Longitude: 84.77478 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
P&S Suspension Log
Fluid Temp. & Cond.
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.2'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	20 July 2019	20 July 2019		
RUN NUMBER	6-7	6-7		
LOG TYPE	Natural Gamma	Eletcric Log		
DEPTH-DRILLER	201'	201'		
DEPTH-LOGGER	175'	175'		
BTM LOG INTERVAL	172.5'	173.4'		
TOP LOG INTERVAL	4.0'	118.0'		
RECORDED BY	BEH	BEH		
WITNESSED BY				
PROBE TYPE, S/N	ELXG #4248	ELXG #4248		
LOGGING SPEED	15fpm	15fpm		
A.S.D.E. / Sample Interval	0.1'/0.1'	0.1'/0.1'		
Fluid Level / Fluid Type	16'/Water	16'/Water		

BOREHOLE RECORD

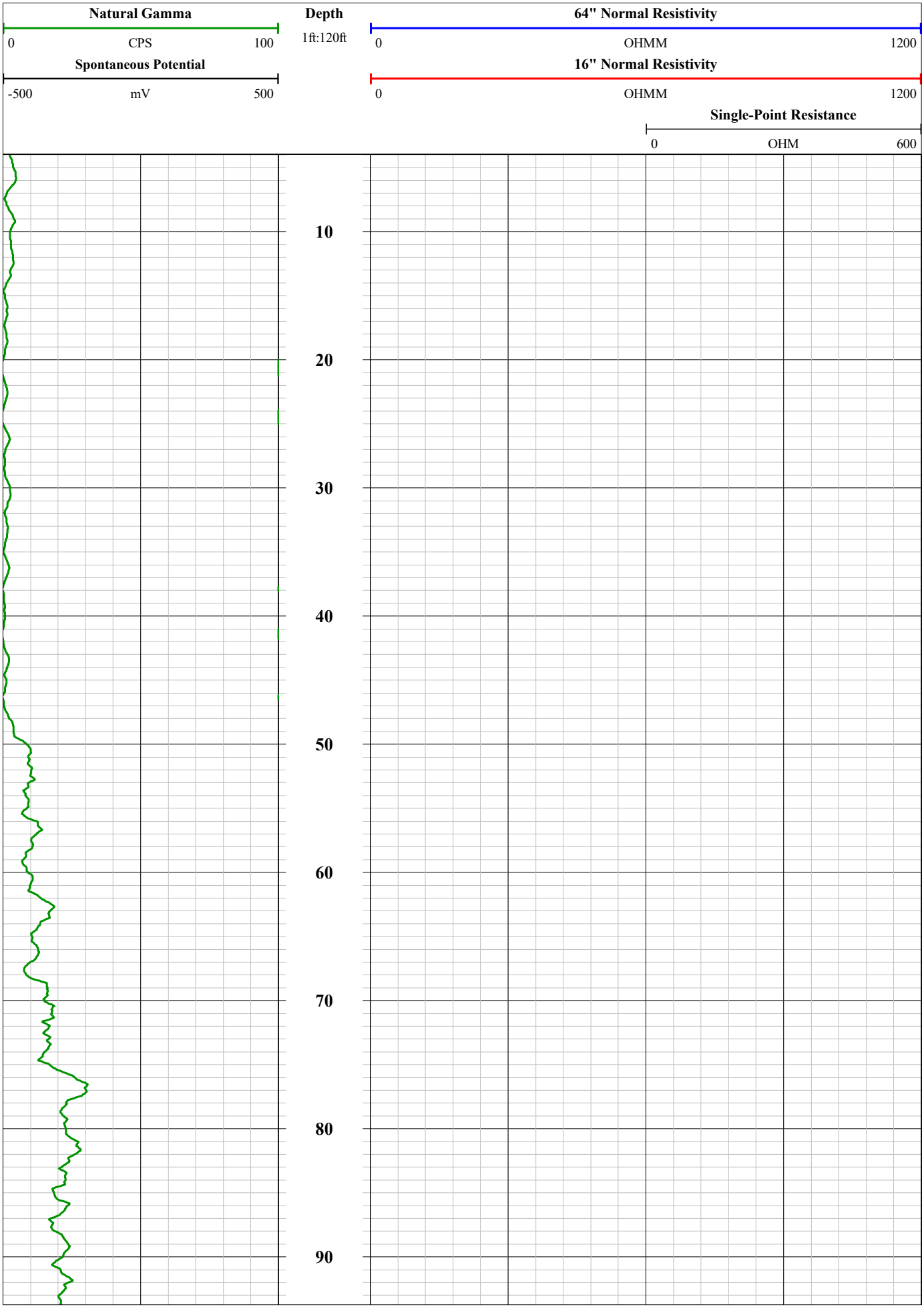
RUN No.	BIT	FROM	TO
1	HQ	0'	201'

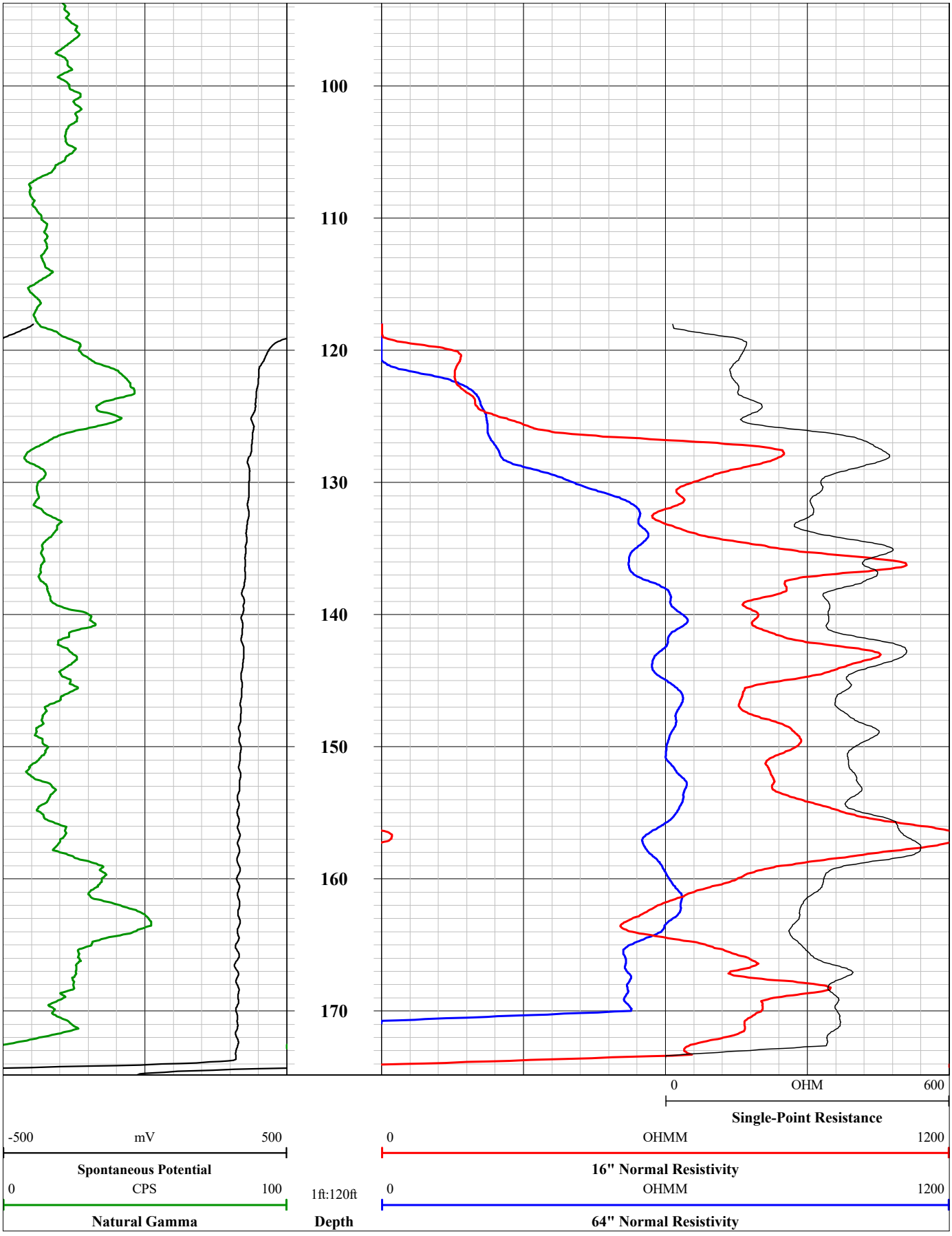
CASING RECORD

SIZE	WGT.	FROM	TO
HQ	Steel	0'	121'

NA - Not Available, N/A - Not Applicable

COMMENTS


Natural Gamma
0
CPS
100
Spontaneous Potential
-500
mV
500
Depth
1ft:120ft
64" Normal Resistivity
0
OHMM
1200
16" Normal Resistivity
0
OHMM
1200
Single-Point Resistance
0
OHM
600
10
20
30
40
50
60
70
80
90


100
110
120
130
140
150
160
170
0
OHM
600
Single-Point Resistance
-500
mV
500
Spontaneous Potential
0
OHMM
1200
16" Normal Resistivity
0
CPS
100
Natural Gamma
1ft:120ft
Depth
0
OHMM
1200
64" Normal Resistivity

COLOG
borehole geophysics / hydrophysics

810 Quail Street
Suite E
Lakewood, Colorado
80215
Office: 303.279.0171
Fax: 303.278.0135
www.colog.com

Compressive and Shear Velocity

Company WSP
Well BH19-38
Project L5RT Project
County Emmet
State MI

COMPANY WSP
WELL BH19-38
PROJECT L5RT Project
COUNTY Emmet **STATE** MI

LOCATION
Straits of Mackinac - South Side
Latitude: 45.79162 N
Longitude: 84.77478 W

QTR **SEC** **TWP** **RGE**

OTHER SERVICES
Acoustic Televiewer
Optical Televiewer
Fluid Temp & Cond.
Electrical Log
Dilatometer

PERMANENT DATUM Top of Casing **ELEVATION** 598.2'

LOG MEAS. FROM Top of Casing 0 **ABOVE PERMANENT DATUM**

DRILLING MEAS. FROM Top of Casing

DATE ACQUIRED	20 July 2019			
RUN NUMBER	1			
LOG TYPE	PSLog			
DEPTH-DRILLER	201'			
DEPTH-LOGGER	164'			
BTM LOG INTERVAL	164'			
TOP LOG INTERVAL	116'			
RECORDED BY	BEH			
WITNESSED BY				
PROBE TYPE, S/N	PSLogger #109026			
LOGGING SPEED	Stationary			
A.S.D.E. / Sample Interval	NA/2.0'			
Fluid Level / Fluid Type	16'/Water			

BOREHOLE RECORD

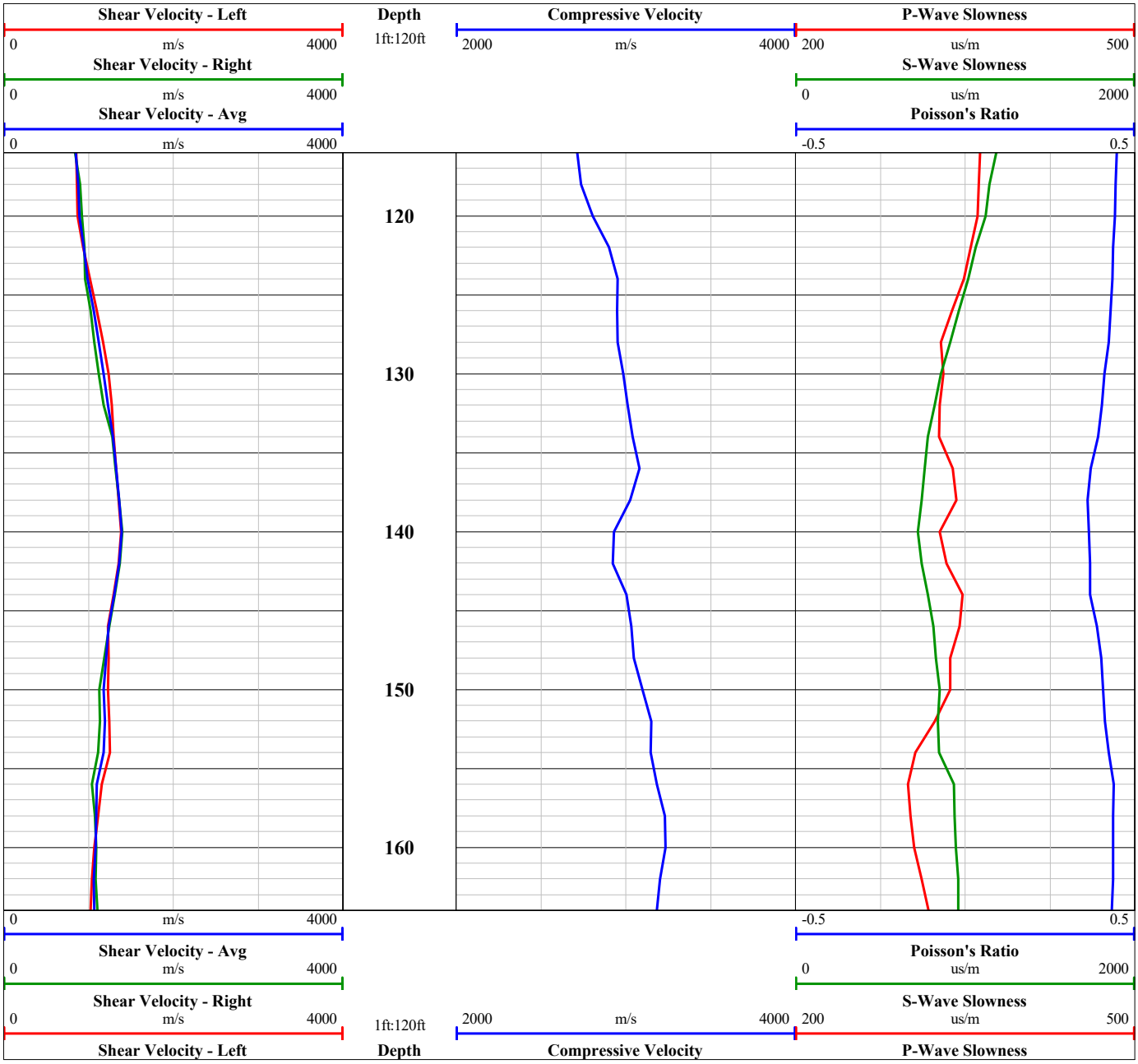
RUN No.	BIT	FROM	TO
1	HQ	0'	201'

CASING RECORD

SIZE	WGT.	FROM	TO
HQ	Steel	0'	121'

NA - Not Available, N/A - Not Applicable

COMMENTS


Shear Velocity - Left
0
m/s
4000
Depth
1ft:120ft
Compressive Velocity
2000
m/s
4000
P-Wave Slowness
200
us/m
500
Shear Velocity - Right
0
m/s
4000
S-Wave Slowness
0
us/m
2000
Shear Velocity - Avg
0
m/s
4000
Poisson's Ratio
-0.5
0.5
120
130
140
150
160
0
m/s
4000
-0.5
0.5
Shear Velocity - Avg
0
m/s
4000
Poisson's Ratio
0
us/m
2000
Shear Velocity - Right
0
m/s
4000
S-Wave Slowness
200
us/m
500
1ft:120ft
2000
m/s
4000
Shear Velocity - Left
Depth
Compressive Velocity
P-Wave Slowness

PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-38**	Test depth:	**130.60 ft**
Test date: (mm/dd/yyyy)	**7/19/2019**	C :	1.0287 cc/MPa
Test number:	1	Poisson's coefficient	0.20

Raw Readings		Corrected Readings		
Pressure kPa	Volume cm³	Pressure kPa	Volume cm³	ΔR/R$_{0\ Probe}$ %
0	0.00	209	0.00	0.00
-26	29.68	129	29.71	0.77
4093	201.55	3664	197.34	5.00
5782	216.12	5292	210.17	5.32
7208	230.00	6660	222.58	5.62
9093	245.53	8481	236.18	5.96
10880	260.23	10215	249.04	6.27
13206	276.00	12489	262.41	6.60
15033	290.71	14268	275.25	6.91
17004	306.36	16190	288.87	7.24
18823	321.34	17967	301.98	7.56
20598	336.63	19699	315.44	7.88

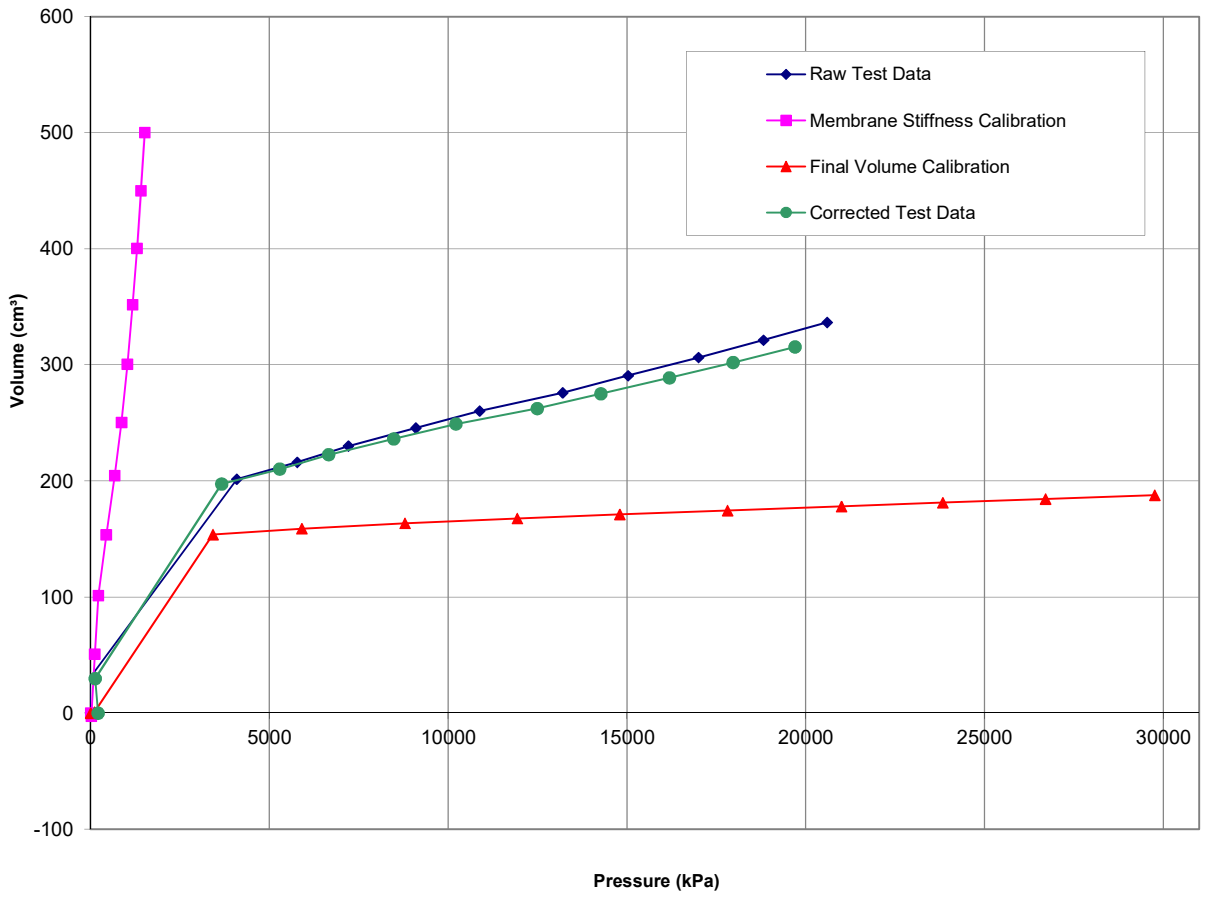
Test Results

PROBEX Modulus E:	**752,525 kPa**
Ultimate Pressure P_L:	**76,526**
Ratio E / P_L:	**9.83**

Volume & Pressure Calibrations ID

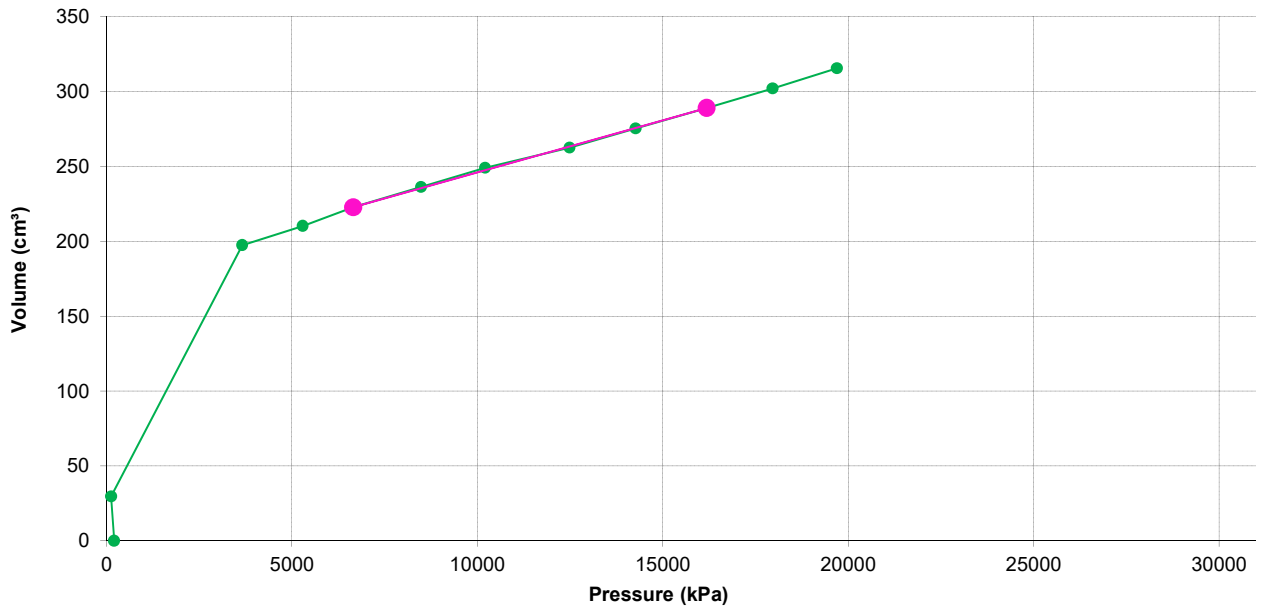
CalV3	CalP1

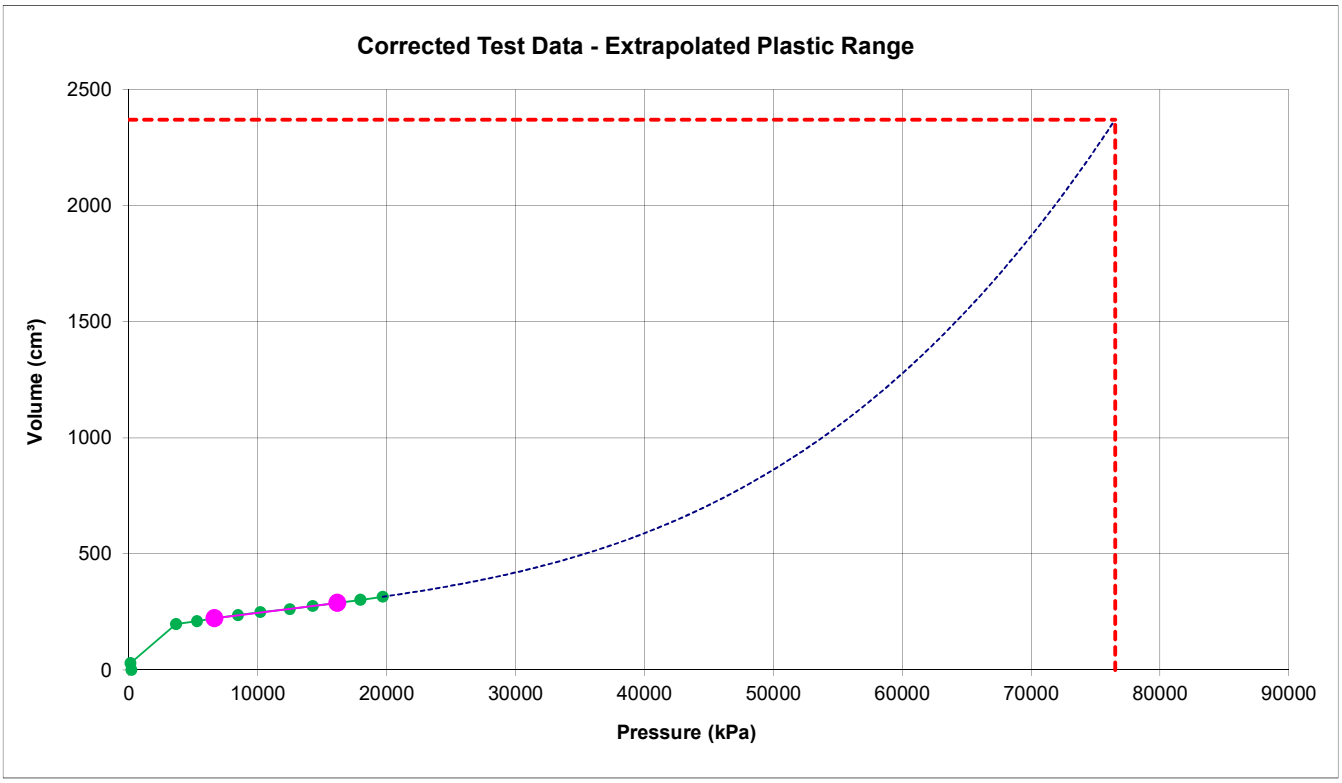
Test Data with Calibration Curves



PROBEX TEST RESULTS

Project name:	Line 5 Replacement and Tunnel Project	Delay	60 sec
Borehole name:	**BH-19-38**	Test depth:	**130.60 ft**
Test date: (mm/dd/yyyy)	**7/19/2019**	C :	1.0287 cc/MPa
Test number:	1	Poisson's coefficient	0.20





ROCTEST TELEMAC

APPENDIX

D-2 *DEEPWATER PRESSUREMETER AND CONE PENETROMETER TESTS*

APPENDIX

METHODOLOGY

INTRODUCTION

The cone penetration test (CPT) involves the measurement of the resistance of ground to steady and continuous penetration of a cone penetrometer equipped with internal sensors. The measurements comprise penetration depth, cone resistance, sleeve friction and, optionally, pore pressure and inclination from vertical. These measurements permit interpretation of ground conditions.

CPT apparatus and procedures adopted by Fugro are in general accordance ISSMGE (1999), ASTM (2012), ISO (2012) and ISO (2014). BS 5930 (BSI, 2015) refer to ISSMGE (1999). General agreement also applies to Eurocode 7 (CEN, 2007).

Fugro offers CPT systems operated from (1) ground surface and seafloor (non-drilling deployment mode) and (2) downhole in a borehole (drilling deployment mode).

CPT APPARATUS

GENERAL

CPT apparatus includes various parts as described below:
- Thrust machine: apparatus providing thrust to the push rods so that the recommended rate of penetration (20 mm/s) is controlled;
- Reaction equipment: reaction for the thrust machine;
- Push rod: thick-walled cylindrical tube used for advancing the penetrometer to the required test depth. Push rods may also consist of drill pipe;
- Friction-cone penetrometer (CPT): cylindrical terminal body mounted on the lower end of the push rods, including a cone, a friction sleeve and internal sensing devices for the measurement of cone resistance, sleeve friction and, optionally, inclination;
- Piezocone penetrometer (CPTU or PCPT): cylindrical terminal body mounted on the lower end of the push rods, including a cone, a friction sleeve, a filter and internal sensing devices for the measurement of cone resistance, sleeve friction, pressure and, optionally, inclination;
- Measuring system: apparatus and software, including sensors, data transmission apparatus, recording apparatus and data processing apparatus.

DEPLOYMENT FROM GROUND SURFACE OR SEAFLOOR

Specific additional apparatus for CPT deployment from ground surface and seafloor can include:
- Push rod casing: guide for the part of the push rods protruding above the soil, and for the push rod length exposed in water or soil, in order to prevent buckling when the required penetration pressure increases beyond the safe limit for the exposed upstanding length of push rods;
- Friction reducer: ring or special projections fixed on the outside of the push rods, with an outside diameter larger than the base of the cone, to reduce soil friction acting on the push rods.

DOWNHOLE BOREHOLE DEPLOYMENT

Downhole CPT systems latch into a bottom hole assembly at the lower end of a drill pipe. System options are:
1. Operation of a downhole thrust machine by applying mud pressure in the borehole;
2. Remote control of a downhole thrust machine by hydraulic pressure transmitted through an umbilical cable connected to a surface-based pump unit, together with;
3. Application of thrust to drill rods where CPT apparatus and a short push rod are latched in the bottom hole assembly; the thrust machine is at ground surface or seafloor.

Data recording can be surface-based and/or downhole.

Downhole CPTs require drilling apparatus for advancing the borehole. The maximum CPT stroke is generally 1.5 m or 3 m.

© Fugro 1995-2017
ISSUE 37

CONE PENETROMETER

Typical features of Fugro penetrometers (Figure 1) include:
- Cone base areas of 500 mm^2, 1000 mm^2 or 1500 mm^2; other sizes are also in use, e.g. 3300 $mm^{2;}$
- Cone and friction sleeve sensors placed in series, i.e. subtraction-type penetrometers;
- Pore pressure measurements either at the face of the cone (u_1) or at the cylindrical extension of the cone (u_2). Multiple-sensor penetrometers (u_1, u_2 and u_3) are also available. The u_3 location is immediately above the friction sleeve;
- Inclinometer;
- Storage of signals from the penetrometer in digital form for subsequent computer-based processing and presentation.

PROCEDURE

Figure 2 summarises the test procedure. The procedure includes several stages. The stage of Additional Measurements is optional.

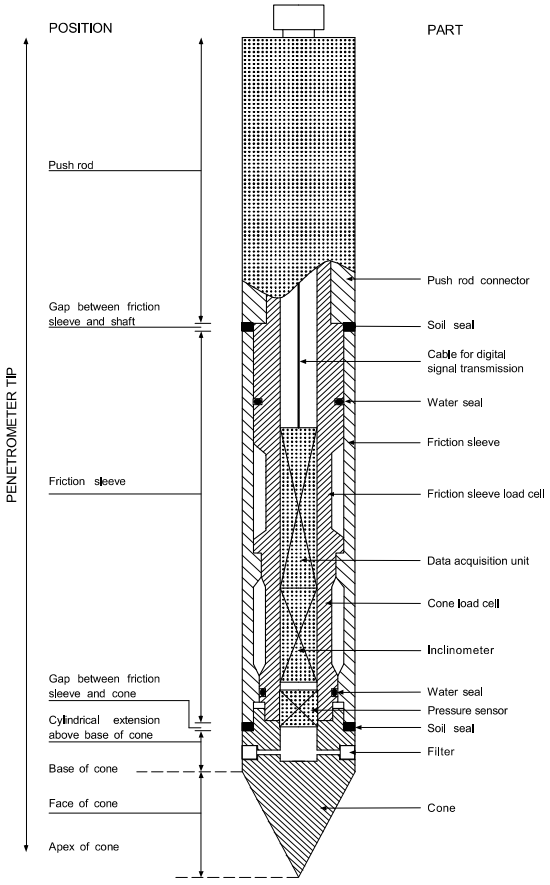


Figure 1 - Piezocone Penetrometer

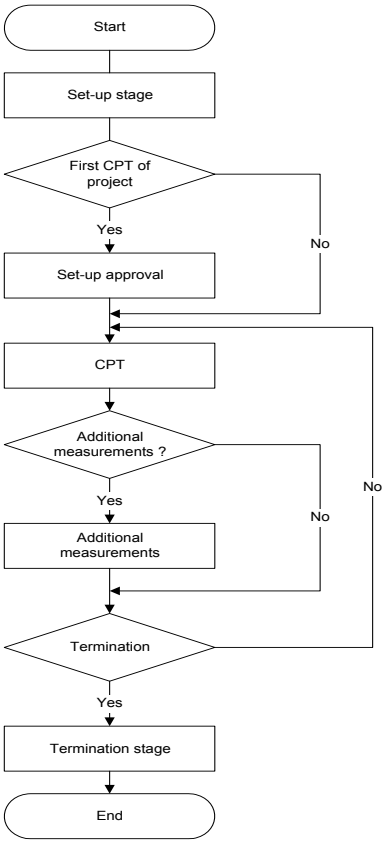


Figure 2 - Flow chart

Set-up requires a reasonably flat, accessible, ground surface with a slope of 5° or less. In other cases, set-up is at discretion of the equipment operator, considering risks such as damage to apparatus or safety of personnel. Most onshore thrust machines have levelling facilities allowing a vertical start of penetration. Seabed frames used for offshore CPT activities have no levelling facilities, i.e. start of penetration may not be vertical.

The set-up stage includes selection of equipment and procedures according to project-specific agreements, such as a required accuracy class or application class, penetration, type of cone penetrometer and data processing/ submission. Table 1 presents ISSMGE accuracy classes and Tables 2 and 3 summarise ISO application classes. The allowable minimum accuracy of a measured parameter is the larger value of the two quoted. A percentage value applies to the measured value and not to the measuring range. The concept of application classes considers intended soil conditions for selection of an application class. For example, Application Class 1 of ISO (2014) can be selected for “very soft to soft soil deposits”, which is

ISSUE 37

© Fugro 1995-2017

approximately equivalent to $q_c < 0.5$ to $q_c < 1$ MPa. In other words, Application Class 1 should not apply to "mixed bedded soil profiles with weak to strong layers".

The accuracy values apply to ground surface or seafloor as reference. They are uncoupled from uncertainty of spatial position below ground surface or seafloor.

Table 1 Accuracy Classes (ISSMGE, 1999)

Accuracy Class	Measured Parameter	Allowable Minimum Accuracy	Maximum Length between Measurements
1	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration depth, z	50 kPa or 3 % 10 kPa or 10 % 5 kPa or 2 % 2° 0.1 m or 1 %	20 mm
2	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration depth, z	200 kPa or 3 % 25 kPa or 15 % 25 kPa or 3 % 2° 0.2 m or 2 %	20 mm
3	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration depth, z	400 kPa or 5 % 50 kPa or 15 % 50 kPa or 5 % 5° 0.2 m or 2 %	50 mm
4	Cone resistance, q_c Sleeve friction, f_s Penetration length, l	500 kPa or 5 % 50 kPa or 20 % 0.1 m or 1 %	50 mm

Table 2 Application Classes (ISO, 2012)

Application Class	Measured Parameter	Allowable Minimum Accuracy	Maximum Length between Measurements
1	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration length, l	35 kPa or 5 % 5 kPa or 10 % 10 kPa or 2 % 2° 0.1 m or 1 %	20 mm
2	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration length, l	100 kPa or 5 % 15 kPa or 15 % 10 kPa or 3 % 2° 0.1 m or 1 %	20 mm
3	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration length, l	200 kPa or 5 % 25 kPa or 15 % 50 kPa or 5 % 5° 0.2 m or 2%	50 mm
4	Cone resistance, q_c Sleeve friction, f_s Penetration length, l	500 kPa or 5 % 50 kPa or 20 % 0.2 m or 2 %	50 mm

© Fugro 1995-2017 ISSUE 37

Table 3 Application Classes (ISO, 2014)

Application Class	Measured Parameter	Allowable Minimum Accuracy
1	Cone Resistance	35 kPa or 5 %
	Sleeve friction	5 kPa or 10 %
	Pore pressure	25 kPa or 5 %
2	Cone resistance	100 kPa or 5 %
	Sleeve friction	15 kPa or 15 %
	Pore pressure	50 kPa or 5 %
3	Cone Resistance	200 kPa or 5 %
	Sleeve friction	25 kPa or 15 %
	Pore pressure	100 kPa or 5 %

The set-up stage or the termination stage includes the location survey, i.e. the determination of the co-ordinates and the ground surface elevation (or the water depth).

The set-up stage and the termination stage for a downhole CPT include lowering of the CPT apparatus into the borehole and lifting respectively. Most projects require multiple downhole tests in a single borehole.

For piezocone testing, the set-up stage also includes the following steps:
- Office-based or site-based: de-airing of the filter in glycerine by application of 24-hour vacuum and storage in a glycerine-filled container;
- On-site: glycerine filling of hollow space in the cone penetrometer and subsequent mounting of the filter;
- On-site: application of a flexible membrane around the filter to prevent loss of saturating fluid prior to the start of a test.

Land-based tests may include specific measures to help retention of filter saturation during penetration of partially saturated zones. Relaxation of requirements typically applies to offshore tests where water pressures will force entrapped air into solution.

Criteria for test termination are as follows, unless specifically agreed otherwise:
- As instructed by Client;
- Reaching target penetration;
- Reaching maximum capacity of the thrust machine, reaction equipment, push rods and/or measuring sensors;
- Sudden increase in penetrometer inclination;
- Risk of damage to apparatus or safety of personnel, at discretion of equipment operator or as determined by software algorithms;

whichever occurs first and as applicable. Note that ASTM and ISO standards provide no specific requirements for maximum penetrometer inclination from vertical. A value of 15° is commonly considered.

A CPTU pore pressure measuring system is intended for use in water-saturated uncemented fine-grained soil. Pore pressure measurements (u) are commonly assumed to represent pore water pressures. This assumption is reasonable for soils saturated under in situ stress conditions and remaining saturated during penetration of the cone penetrometer. Results obtained for ground conditions such as partially saturated soils, very dense sands and cemented soils may not be reliable and/or repeatable. For example, stiffness differences between the steel components of the cone penetrometer and the piezocone filter can affect results for very dense sands. Also, loss of saturation of the pore pressure measuring system may occur during a test (Lunne et al., 1997; Peuchen and Terwindt, 2014). Reasons can include:
- penetration of partially saturated ground, for example ground containing significant amounts of gas;
- measurement of negative pore pressures such that cavitation occurs. For example, this is not uncommon for a piezocone filter located at the cylindrical extension above the base of the cone (u_2 location). Particularly, this may occur at the time of penetration of dense sand or overconsolidated clay layers. Loss of saturation usually causes a sluggish pore pressure response during penetration of ground below the zone causing desaturation of the pore pressure measuring system.

ISSUE 37
© Fugro 1995-2017

Measured pore pressures affected by desaturation of the pore pressure measurement system may not be representative of soil behaviour. Consequently, derived parameters that use pore pressure may also not be representative. Re-saturation of a pore pressure measurement system can take place upon further penetration into soil. In this regard it should be noted that pressure u_2 at the cylindrical extension is commonly assumed equal to u_{2g} in the gap. The assumption $u_2 = u_{2g}$ is probably reasonable for marine conditions, saturated low-permeability soils (clays) that are normally consolidated or lightly overconsolidated and where the gap can become saturated by adequate supply of water and/or water pressure. A similar comment applies to u_3.

Special apparatus and procedures may apply to:
- Specific additional measurements (for example shear wave velocity);
- Specific applications (for example deepwater tests or measurements for application (accuracy) Classes 1 and 2).

RESULTS

CPT PARAMETERS

Presentation of results from cone penetration tests typically includes:
- CPT parameters q_c, f_s and R_f versus depth below ground surface or versus elevation;
- Additional CPTU parameters u_1 or u_2 and, optionally, q_t, q_n, B_q, Q_t, Q_{tn}, F_r and I_c for tests with pore pressure measurements;
- Optionally, inclination i for tests with inclination measurements;
- Standard graphical format and optional ASCII and AGS formats.

Most standards specify scales for graphical presentation as follows:
- Axis for penetration depth z: 1 scale unit = 1 m;
- Axis for cone resistance q_c, corrected cone resistance q_t and net cone resistance q_n: 1 scale unit = 2 MPa or 0.5 MPa;
- Axis for sleeve friction f_s: 1 scale unit = 50 kPa;
- Axis for friction ratio R_f: 1 scale unit = 2 %;
- Axis for pore pressure u: 1 scale unit = 0.2 MPa or 0.02 MPa;
- Axis for pore pressure ratio B_q: 1 scale unit = 0.5.

Graphical presentation aims for these scale units and scale ratios, where suitable and practicable.

This reference level of a test is (1) the ground surface for onshore tests, (2) the seafloor for nearshore and offshore tests. Historically, the bottom of the borehole was used as the reference level of downhole tests. Data processing presumes a hydrostatic pore pressure profile relative to seafloor, unless specifically indicated otherwise. The definition of CPT parameters is as follows:

z = penetration depth relative to ground surface or seafloor, corrected for inclination from vertical (i) where a test includes inclination measurements, as follows:

$$z = \int_0^l \cos i \, . \, dl$$

where:
z = penetration depth for the conical base of the cone penetrometer
l = recorded penetration length
i = recorded inclination from vertical

q_c = cone resistance relative to the reference level of the test.

f_s = sleeve friction relative to the reference level of the test. A calculated depth correction applies so that the presented sleeve friction corresponds with the cone depth.

f_t = corrected sleeve friction relative to the reference level of the test. Sleeve friction is corrected for pore pressures acting on the end areas of the friction sleeve

ISSUE 37
© Fugro 1995-2017

$$f_t = f_s - \frac{(u_2 * A_{sb} - u_3 * A_{st})}{A_s}$$

or simplified to:

$$f_t = f_s - u_2 \frac{(A_{sb} - A_{st})}{A_s} \quad \text{or}$$

$$f_t = f_s - (u_2 * a_{fs})$$

where:
A_{sb} = cross sectional area in the gap between the friction sleeve and the cone
A_{st} = cross sectional area in the gap above the friction sleeve
A_s = surface area of the friction sleeve
a_{fs} = net area ratio of the friction sleeve $(A_{sb} – A_{st})/A_s$

R_f = ratio of sleeve friction to cone resistance (f_s/q_c). This calculated ratio is for the cone depth.

R_{ft} = corrected friction ratio (f_s/q_t). The ratio f_t/q_t applies if f_t is known.

I_{SBT} = non-normalized soil behaviour type index (Robertson, 2010)

$$I_{SBT} = [(3.47 – \log(q_c/P_a))^2 + (\log R_f + 1.22)^2]^{0.5}$$

where:
P_a = atmospheric pressure

u_1 = pore pressure at the face of the cone, relative to the reference level of the test.

u_2 = pore pressure at the cylindrical extension above the base of the cone or in the gap between the friction sleeve and the cone, relative to the reference level of the test.

u_3 = pore pressure immediately above the friction sleeve or in the gap above the friction sleeve, relative to the reference level of the test.

q_t = corrected cone resistance (also called total cone resistance). This includes corrections for hydrostatic and transient pore pressures, and cone construction. The corrected cone resistance is relative to ground surface or seafloor:

Ground surface / seafloor:
$q_t = q_c+(1-a)u_2$ or
$q_t = q_c+(1-a)\{K(u_1-u_o)+u_o\}$

Downhole (historic):
$q_t = q_c+(1-a)u_2+u_{oi}$ or
$q_t = q_c+(1-a)\{K(u_1+u_{oi}-u_o)+u_o\}+au_{oi}$

where:
a = net area ratio of the cross-sectional steel area at the gap between cone and friction sleeve to the cone base area. This ratio is penetrometer-type dependent. The a-factor indicates the effect of pore pressure on unequal cross-sectional areas of the cone.

u_o = hydrostatic pore pressure at the cone, relative to the phreatic surface or the seafloor. This is a calculated value.

u_{oi} = hydrostatic pore pressure at the bottom of the borehole, relative to seafloor. This is a calculated value.

K = adjustment factor for the ratio of pore pressure at the cylindrical extension above the base of the cone to pore pressure on the cone face.

Ground surface / seafloor:
$K = (u_2-u_o)/(u_1-u_o)$

Downhole (historic):
$K = (u_2+u_{oi}-u_o)/(u_1+u_{oi}-u_o)$

The term u_2-u_o or $u_2+u_{oi}-u_o$ refers to excess pore pressure (with respect to hydrostatic pore pressure). Common symbols for excess pore pressure are du_2 or Δu_2. Similarly, du_1 or Δu_1 may represent the term u_1-u_o or $u_1+u_{oi}-u_o$.

ISSUE 37

© Fugro 1995-2017

The K-factor is only of interest for processing of CPTU results with pore pressure measurement at the cone face (u_1). The factor depends on soil characteristics as fabric, overconsolidation ratio, compressibility and crushability. The K-factor is estimated from:

$$K = 0.91e^{-0.09Q_t^{0.47}}\left(\frac{1}{1+F_r(0.17+0.061(Q_t-21.6)^{1/3})}-e^{-2F_r}\right)$$ (Peuchen et al., 2010)

q_n = q_t-σ_{vo} = net cone resistance. This includes corrections for hydrostatic and transient pore pressures, in situ stress, and cone construction. The symbol for q_n may also be q_{net}.

where:
σ_{vo} = total in situ vertical stress at the cone base, relative to ground surface or seafloor. This is a calculated value.

Q_t = q_n/σ'_{vo} = normalized cone resistance

where:
σ'_{vo} = effective in situ vertical stress at the cone base, relative to ground surface or seafloor. This is a calculated value.

Q_{tn} = normalized cone resistance with variable stress exponent n, where:

$$Q_{tn} = [(q_t - \sigma_{vo})/P_a]\,(P_a/\sigma'_{vo})^n$$

$$n = 0.381\,(I_c) + 0.05\,(\sigma'_{vo}/P_a) - 0.15 \text{ and } n \le 1$$ (Zhang et al., 2002)

I_c = soil behaviour type index (Robertson and Wride,1998)

$$I_c = [(3.47 - \log Q_{tn})^2 + (\log F_r + 1.22)^2]^{0.5}$$

F_r = f_t/q_n = normalized friction ratio.

B_q = pore pressure ratio.

Ground surface / seafloor:
B_q = $K(u_1-u_o)/q_n$ or
B_q = $(u_2-u_o)/q_n$

Downhole (historic):
B_q = $K(u_1+u_{oi}-u_o)/q_n$ or
B_q = $(u_2+u_{oi}-u_o)/q_n$

Presented values for u_2, q_t, q_n and B_q may be denoted by u_2*, q_t*, q_n*, B_q*, Q_t* and F_r* if u_2 is derived rather than measured, for example if derived by applying a K-factor.

Some deployment systems allow monitoring of CPT parameters in reverse mode, i.e. upon retraction of the cone penetrometer. This optional feature presents additional information that can improve interpretation of ground behaviour, for example strength sensitivity of fine-grained soil.

ACCURACY OF MEASUREMENTS

Accuracy Classes and Application Classes

Cone penetration test standards can follow a “prescriptive” approach, whereby specific detailed measures provided a “deemed to comply” practice. ASTM (2012) is an example of this approach. ISSMGE (1999) and ISO (2012, 2014) specify “performance” criteria for cone penetration test measurements. The ISO standard on metrological confirmation (ISO, 2003) provides the general framework for assessment of performance compliance. Peuchen and Terwindt (2014, 2015) provide guidance on uncertainty estimation for cone penetration test results.
The following comments apply:

- Accuracy is the “closeness of a measurement to the true value of the quantity being measured”. It is the accuracy as a whole that is ultimately important not the individual parts. Precision is the “closeness of each set of measurements to each other”. The resolution of a measuring system is the “minimum size of the change in the value of a quantity that it can detect”. It will influence the accuracy and precision of a measurement.

ISSUE 37
© Fugro 1995-2017

- Accuracy Class 3 and Application Class 3 typically represents industry practice. They are approximately equivalent to the more implicit requirements of ASTM International. Class 3 applies, unless specifically agreed otherwise.

So-called “zero drift” of a measured parameter is an approximate performance indicator for the measuring system (Peuchen and Terwindt, 2014). Zero drift is the absolute difference of the zero readings, reference readings or zero reference reading of a measuring system between the start and completion of the cone penetration test. The reference readings can be taken at (1) atmospheric pressure at ground surface or above water level or (2) under hydrostatic water pressure close to seafloor. The zero drift of the measured parameters can be compared with the allowable minimum accuracy according to the selected application class, per test. This comparison considers the maximum range of values of q_c, f_s and, where applicable, u_1 or u_2 for calculation of the percentage box values (Tables 1, 2 or 3).

Accuracy considerations for strongly layered soils should allow for heat flux phenomena. Heat flux gives an apparent shift in cone resistance (Post and Nebbeling, 1995). For example, friction in dense sand causes a cone to heat by about 1°C/MPa cone resistance. Resulting heat flux decreases cone resistance by an apparent shift in the order of 100 kPa to 200 kPa for a penetrating probe going from dense sand into clay. This is a temporary decrease lasting about 5 minutes. Ambient temperature compensation systems cannot avoid heat flux effects. Penetration interruption can serve as mitigation measure.

Shallow Penetration

Use of reaction equipment will affect stress conditions for shallow penetration. Particularly, offshore conditions may include extremely soft ground at seafloor. Soil disturbance, pore pressure build-up and consolidation of near-surface soft soil may take place. This will affect the measurements.

Downhole borehole deployment implies a typical limiting CPT stroke of 1.5 m or 3 m. It is common to perform multiple semi-continuous tests. Graphics for such tests typically show a build-up of CPT values for the initial 0.1 m to 0.5 m penetration. This penetration zone is immediately below the required borehole and represents complex ground stress conditions and/or borehole-induced ground disturbance that cannot be avoided.

Penetration Interruption

A penetration interruption may be unavoidable, for example to add a push rod or to perform a pore pressure dissipation test. This will affect test results.

Consolidation of low-permeability soil around a cone tip is of particular interest. A stationary cone penetrometer can apply local stresses that approach failure conditions, i.e. about 9 times the undrained shear strength or about 2 times the in situ mean effective stress. Pore pressure re-distribution and dissipation occur, resulting in a local increase in undrained shear strength and hence cone (bearing) resistance. A doubling of cone resistance may not be unreasonable for 100 % consolidation. Supplementary considerations include:

- Small downward movement of a penetrometer (order of millimetres) during a test can contribute to maintaining local stresses approaching failure conditions;
- Soil consolidation around a cone penetrometer may lead to soil/penetrometer adhesion that is sufficient to give an increase in “cone” diameter. Resumption of penetration will lead to loss of adhered soil, usually within an equivalent distance of a few times the cone diameter;
- A low B_q value may imply partially drained penetration conditions. It is likely that any steady-state penetration conditions will not apply instantaneously upon resumption of penetration;
- Measuring sensors in a probe generate heat, but this is probably not significant for any stationary measurement. Fugro’s strain-gauge load sensors are compensated for ambient temperature fluctuations.

ISSUE 37
© Fugro 1995-2017

Depth Measurement for Offshore Conditions

Offshore definition of the seafloor (ground surface) is difficult for extremely soft ground at seafloor. Penetration of the reaction equipment into a near-fluid zone of the seabed may take place unnoticed. Such settlement affects the start of penetration depth z. Also, settlement may continue at the time of testing.

Downhole CPT systems rely on depth control applicable to borehole drilling. Depth control according to Z2 of Table 4 is feasible for drilling systems deployed from a fixed platform, for example a jack-up. This value excludes uncertainty associated with determination of seafloor level. Drilling control from floating equipment, for example a geotechnical survey vessel, may be subject to the additional influence of waves and tides. Z2 is typically feasible for favourable conditions. Z3 or Z4 may apply for adverse conditions.

Table 4 Depth Accuracy Classes According to ISO (2014)

Depth Accuracy Class	Maximum Data Point Depth Uncertainty [m]
Z1	0.1
Z2	0.5
Z3	1.0
Z4	2.0
Z5	> 2.0

Zero-Correction for Offshore Conditions

Water pressures generate significant values of cone resistance and pore pressure. The standardised practice is to correct these reference readings to zero at seafloor. CPT systems for non-drilling mode and for seafloor drilling mode allow zero-correction to hydrostatic conditions prior to the start of a test, typically with a zero-correction uncertainty approaching the resolution of the CPT system. Downhole borehole CPT systems latch into the lower end of a drill pipe. The pressure conditions in the drill pipe may not be in full equilibrium with the surrounding ground water pressure and zero-correction will be subject to increased uncertainty, i.e. uncertainty for pore pressure in the order of 100 kPa for deepwater tests (Peuchen, 2000). This uncertainty depends on factors such as the free-flow and viscosity of drill fluid between the drill bit and the seafloor. The uncertainty typically decreases with decreasing depth of the drill bit below sea level and below seafloor. Uncertainty for the zero-correction of cone resistance is approximately equivalent, but by a factor representing the net area ratio effect.

Deepwater Tests

A deepwater environment presents some favourable conditions for cone penetration tests, notably temperature. Ambient temperature conditions are practically constant and the measuring system has ample time to adjust to these temperatures. In addition, transient heat flow phenomena in a cone penetrometer are usually not applicable. This is because a cone penetrometer accumulates negligible (frictional) heat when penetrating the generally prevalent soils of very soft consistency.

Deepwater (piezocone) pore pressure measurements are essentially similar to shallow-water measurements, with the exception of an increased measuring range for pore pressure leading to some reduction in sensor accuracy. Saturation of a pore pressure measuring system is excellent for a deepwater environment, as the high pressures will force any gas bubbles into solution.

Currently available evidence indicates that a high-quality subtraction-type cone penetrometer is adequate for very soft soil characterisation to a water depth of 3000 metres and probably beyond.

ADDITIONAL MEASUREMENTS

Friction-cone and piezocone penetrometers allow specific additional measurements, such as friction set-up tests, pore pressure dissipation tests and measurements of ground water pressure. These additional measurements require a penetration interruption or may be feasible at the end of a test. It is also common to add other in situ test devices to a cone penetrometer. Table 5 presents the more common types.

© Fugro 1995-2017

Table 5 Probes for Additional In Situ Tests

Type of Probe	Properties	Units
Electrical Conductivity Penetrometer (ECPT)	Electrical conductivity, K	S/m
Temperature Cone Penetrometer (TCPT)	Temperature, T, and thermal conductivity, k	K, W/(m·K)
Seismic Cone Penetrometer (SCPT)	S-wave velocity, v_s, and P-wave velocity, v_p	m/s
Cone Pressuremeter (CPMT)	Shear stress-strain-time response, σ, ε, t	MPa, -, s
Natural Gamma Penetrometer (GCPT)	Natural gamma ray, γ	CPS
Cone Magnetometer (CMMT)	Magnetic flux density B, magnetic field horizontal angle θ and vertical angle ϕ	μT, °, °
Hydraulic Profiling Tool (HPT)	Permeability, k	m/s
S = Siemens	s = second	
m = metre	Pa = Pascal	
K = Kelvin (or °C)	CPS = counts per second	
W = Watt	T = Tesla	

REFERENCES

ASTM International, 2012. *ASTM D5778-12 Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils.* West Conshohocken: ASTM International.

British Standards Institution, 2015. *BS 5930:2015 Code of practice for ground investigations*. London: BSI.

European Committee for Standardization, 2007. *EN 1997-2:2007 Eurocode 7 - Geotechnical Design – Part 2: Ground Investigation and Testing.* Brussels: CEN. (With Corrigendum EN 1997-2:2007/AC, June 2010).

International Organization for Standardization, 2003. *ISO 10012:2003 Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment*. Geneva: ISO.

International Organization for Standardization, 2012. *ISO 22476-1:2012 Geotechnical Investigation and Testing – Field Testing – Part 1: Electrical Cone and Piezocone Penetration Tests.* Geneva: ISO. (With Technical Corrigendum 1, January 2013).

International Organization for Standardization, 2014. *ISO 19901-8:2014 Petroleum and Natural Gas Industries - Specific Requirements for Offshore Structures – Part 8: Marine Soil Investigations.* Geneva: ISO.

International Society for Soil Mechanics and Geotechnical Engineering, 1999. International Reference Test Procedure for the Cone Penetration Test CPT) and the Cone Penetration Test with Pore Pressure CPTU): Report of the ISSMGE Technical Committee 16 on Ground Property Characterisation from In-Situ Testing. In Barends, F.B.J. et al. Eds. *Geotechnical Engineering for Transportation Infrastructure: Proceedings of the Twelfth European Conference on Soil Mechanics and Geotechnical Engineering, Amsterdam, Netherlands, 7-10 June 1999, Vol. 3,* Rotterdam: Balkema, pp. 2195-2222.

Lunne, T., Robertson, P.K. and Powell, J.J.M. 1997. *Cone Penetration Testing in Geotechnical Practice*. London: Blackie Academic & Professional.

Peuchen, J. 2000. Deepwater Cone Penetration Tests. In *32nd Annual Offshore Technology Conference, 2000: Proceedings, Vol. 1, OTC Paper 12094,* pp. 469-477.

Peuchen, J., VandenBerghe, J.F. and Coulais, C. 2010, Estimation of u_1/u_2 Conversion Factor for Piezocone. In *CPT'10: 2nd International Symposium on Cone Penetration Testing, Huntington Beach, California: Conference Proceedings*.

Peuchen, J. and Terwindt, J. 2014. Introduction to CPT accuracy. In *3rd International Symposium on Cone Penetration Testing CPT14 : May 12-14, 2014 - Las Vegas, Nevada,* 45 pp.

Peuchen, J. and Terwindt, J. 2015. Measurement uncertainty of offshore Cone Penetration Tests. In Meyer, V. ed. *Frontiers in Offshore Geotechnics III: proceedings of the Third International Symposium on Frontiers in Offshore Geotechnics ISFOG 2015), Oslo, Norway, 10-12 June 2015*, Boca Raton: CRC Press, pp. 1209-1214.

ISSUE 37

© Fugro 1995-2017

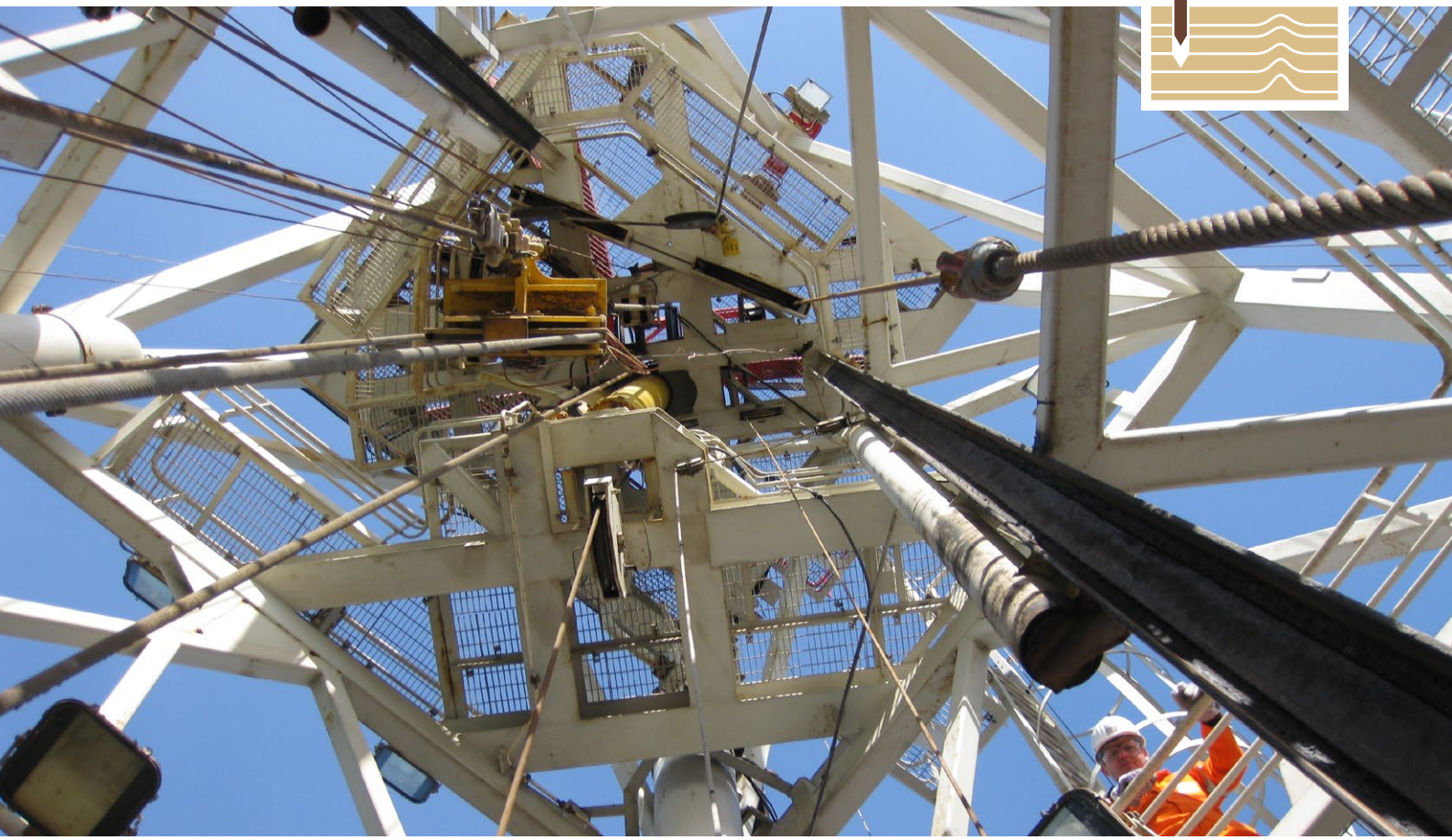
Post, M.L. and Nebbeling, H. 1995. Uncertainties in Cone Penetration Testing. In *International Symposium on Cone Penetration Testing CPT'95, Linköping, Sweden, October 4-5, 1995, Vol. 2,* Linköping: Swedish Geotechnical Society, SGF Report, No. 3:95, pp. 73-78.

Robertson, P.K. and Wride (Fear), C.E. 1998. Evaluating Cyclic Liquefaction Potential Using the Cone Penetration Test. *Canadian Geotechnical Journal*, Vol. 35, No. 3, pp. 442-459.

Robertson, P.K. 2010. Soil Behaviour type from the CPT: an update. In *2nd International Symposium on Cone Penetration Testing, Huntington Beach, CA, Vol.2.* pp. 575-583..

Zhang, G., Robertson, P.K. and Brachman, R.W.I. 2002. Estimating Liquefaction induced Ground Settlements from CPT for Level Ground. *Canadian Geotechnical Journal*, Vol. 39. Issue 5, pp.1168-1180.

© Fugro 1995-2017



FUGRO
WISON® MKV

The WISON® MK V Cone Penetration Test (CPT) System enables in-situ soil properties to be measured from the base of a borehole either offshore or on land.Tests can be performed at any depth down to 2000 m below drill floor level if the depth limitations of the drilling system permit.

The tests can be performed consecutively or intermittently throughout the borehole providing a continuous or semicontinuous profile of measured parameters.

EQUIPMENT

The WISON® consists of a wireline downhole jacking unit with a 3 metre stroke and a thrust capacity of 90 kN.

TESTING PROCEDURES

The WISON® is normally used in conjunction with a straight flush rotary drilling system and open bit. After the borehole has been advanced to the required test level it is cleaned by mud flushing and if there is a centre plug in the bit it is retrieved. The WISON® is lowered by its electro-hydraulic umbilical to the bit, where It seats and latches under its own weight. The test sequence is then activated from a surface control cabin and the cone penetrometer is hydraulically pushed into the soil at a constant rate of 20 mm/s. Throughout the test the measurements of cone resistance, sleeve friction and pore pressure, if measured, are displayed graphically in the control cabin. These data are simultaneously recorded by computer on disk. This facilitates detailed data processing, interpretation and presentation both offshore and onshore. Upon reaching the maximum achievable stroke of 3 m, or the limiting thrust capacity of 90 kN, the

Engineers assembling WISON®

Drill pipe

test is terminated and the system depressurised. The drill string is lifted to retract the test rod and the WISON® unit is retrieved; the complete operation having taken 10 to 15 minutes.

REACTION FORCE

During the test sufficient reaction force is required to balance the penetration thrust.

TEST INTERPRETATION

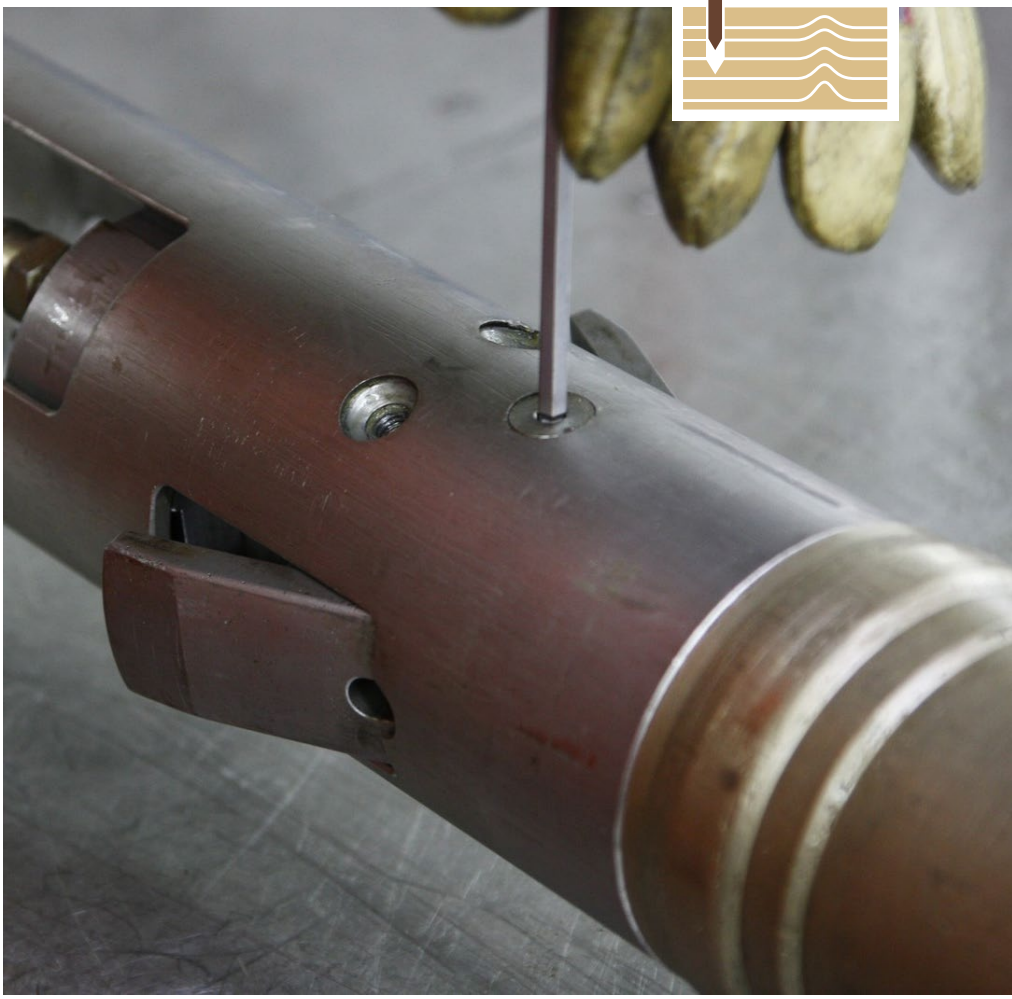
With the aid of empirical correlations the cone measurements can be used to estimate soil type, relative density and angle of internal friction of granular soils and undrained shear strength of cohesive soils as well as other factors such as stress history.

EXPERIENCE

Since its debut in 1973 some 160,000 tests have been performed throughout the world with the WISON® system.

CONE PENETROMETER SELECTION

To cope with the wide variety of soil and soft rock types that can be encountered, a range of cones of varying size, capacity and function have been developed. A list of the different cone types currently available is given below.



WISON® disassembly

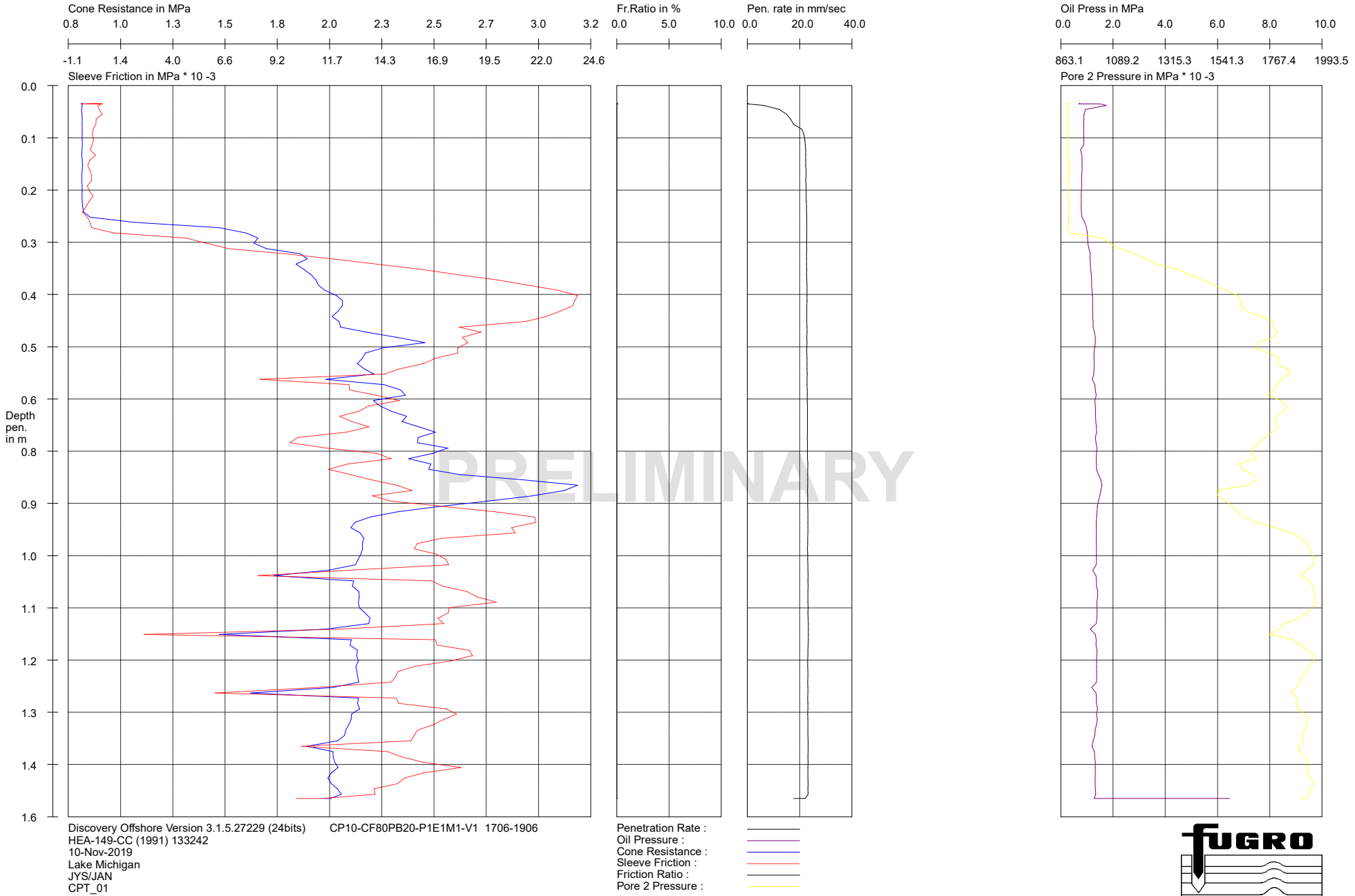
Equipment specifications

Design depth below drill floor :	2000 m
Max. depth below drill floor :	2000 m
(based on maximum umbilical length currently available)	
Maximum thrust :	90 kN
Penetrometer sensors :	- sleeve cone
	- temperature cone
	- piezo-cone
	- shear wave and compression wave velocity
	- ball penetrometer
	- electrical conductivity cone
	- thermal conductivity probe
	- natural gamma sensor
Natural gamma Cone base area:	500 and 1000 mm^2

© FUGRO 07 2016 / FCST

APPENDIX

TEST RESULTS



Discovery Offshore Version 3.1.5.27229 (24bits) CP10-CF80PB20-P1E1M1-V1 1706-1906
HEA-149-CC (1991) 133242
10-Nov-2019
Lake Michigan
JYS/JAN
CPT_01
MV Highland Eagle
09:21:34 09:44:37
Predrilled depth in m. 29.00
Penetration depth in m. 1.51

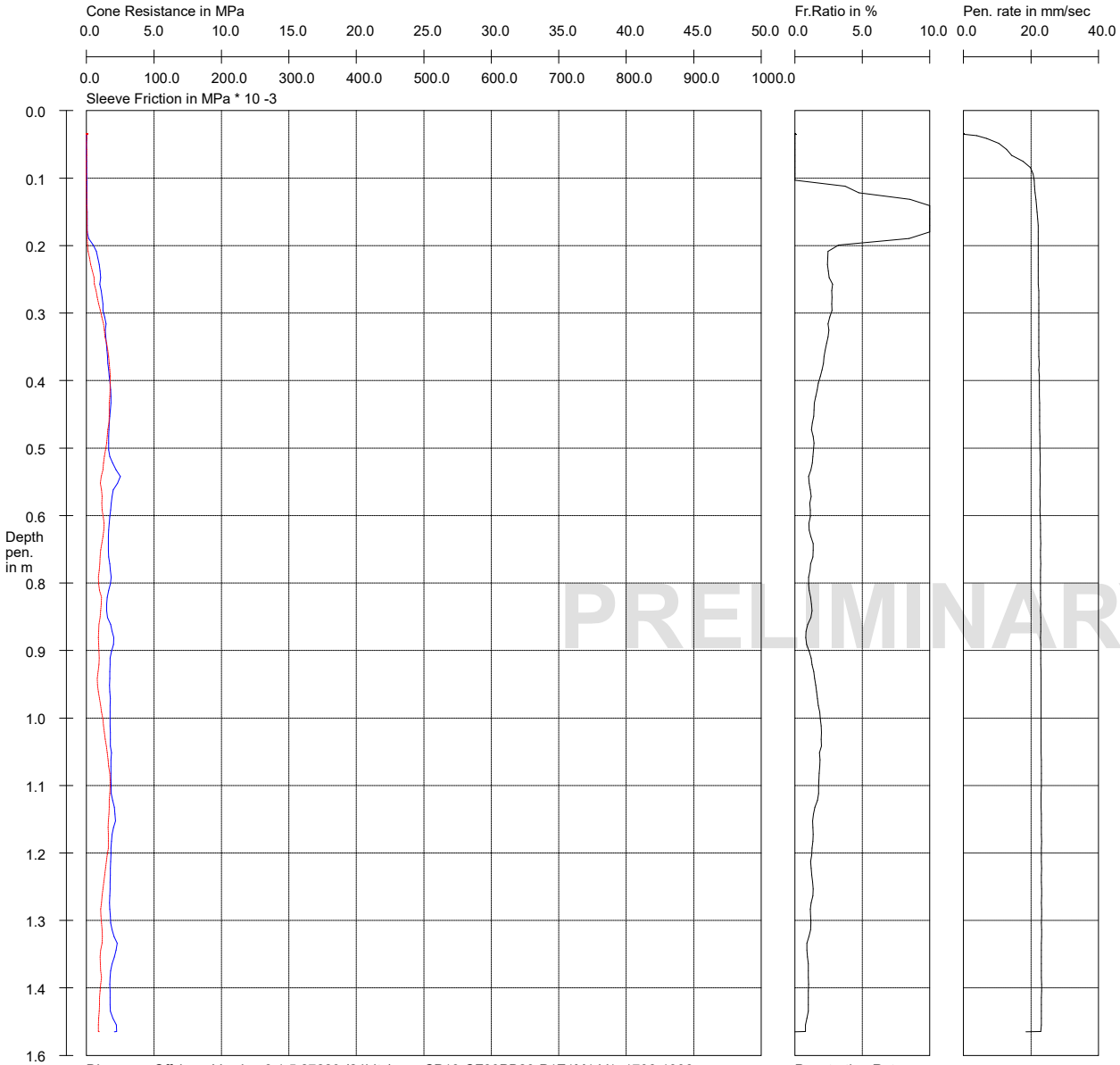
Penetration Rate :
Oil Pressure :
Cone Resistance :
Sleeve Friction :
Friction Ratio :
Pore 2 Pressure :

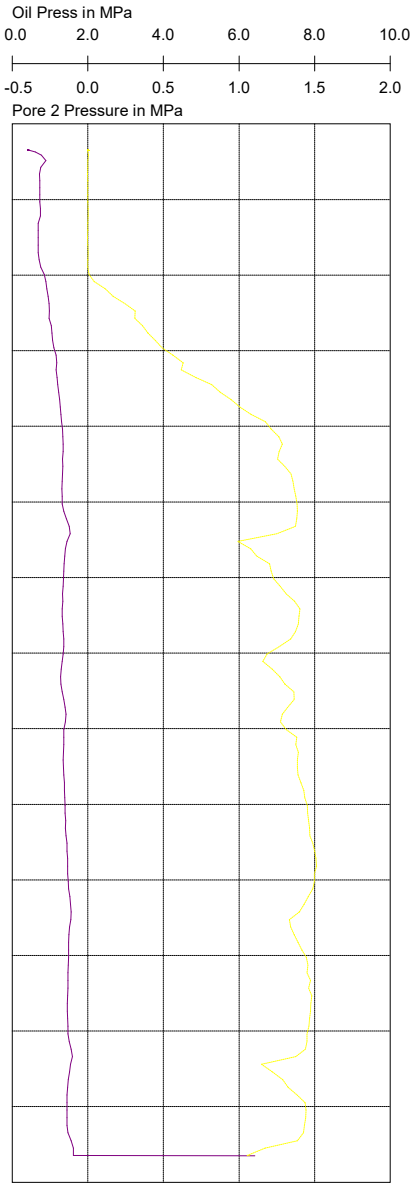
Filename:
C:\DISCOVERY\CPTFILES\HEA-149-CC (1991) 133242\LAKE MICHIGAN\BH19-26\CPT_01.001

Boring: BH19-26

FUGRO

RAW DATA PLOT





Discovery Offshore Version 3.1.5.27229 (24bits)
HEA-149-CC (1991) 133242
29-Oct-2019
Lake Michigan
RIK
CPT_02
MV Highland Eagle
11:28:23 11:58:06
Predrilled depth in m. 49.80
Penetration depth in m. 1.52

CP10-CF80PB20-P1E1M1-V1 1706-1906

Penetration Rate :
Oil Pressure :
Cone Resistance :
Sleeve Friction :
Friction Ratio :
Pore 2 Pressure :

Filename:
C:\DISCOVERY\CPTFILES\HEA-149-CC (1991) 133242\LAKE MICHIGAN\BH-19-27\CPT_02.000

FUGRO

RAW DATA PLOT

Boring: BH19-27

Straits of Mackinac
BH19-33-Test 1 - SUMMARY OF RESULTS
[File made with WinSitu Version 3.9.1.1]

[DETAILS OF TEST]
Project : G190026W
Site : Straits of Mackinac
Borehole : BH19-33
Test name : BH19-33-Test 1
Test date : 20 Jul 19
Test depth : 45.10 mBSB
Water table : Nothing entered
Ambient PWP : 743.7 kPa
Material : Limestone
Probe : 95mm High Pressure Dilatometer
Diameter : 97.0 mm
Data analysed using average arm displacement curve

Analysed by MB on 22 Jul 19

Remarks: Double CHL, both TPC. Pocket 44.10m to 46.10. Base of probe 45.80m. First Fracture at 2.5 MPa so P0 cannot be more than 1.25 MPa. First cycle probably not valid.

[RESULTS FOR CAVITY REFERENCE PRESSURE]
Strain Origin (mm) : "Arm ave=3.89"
Best estimate of Po (kPa) : "Arm ave=1250.0"

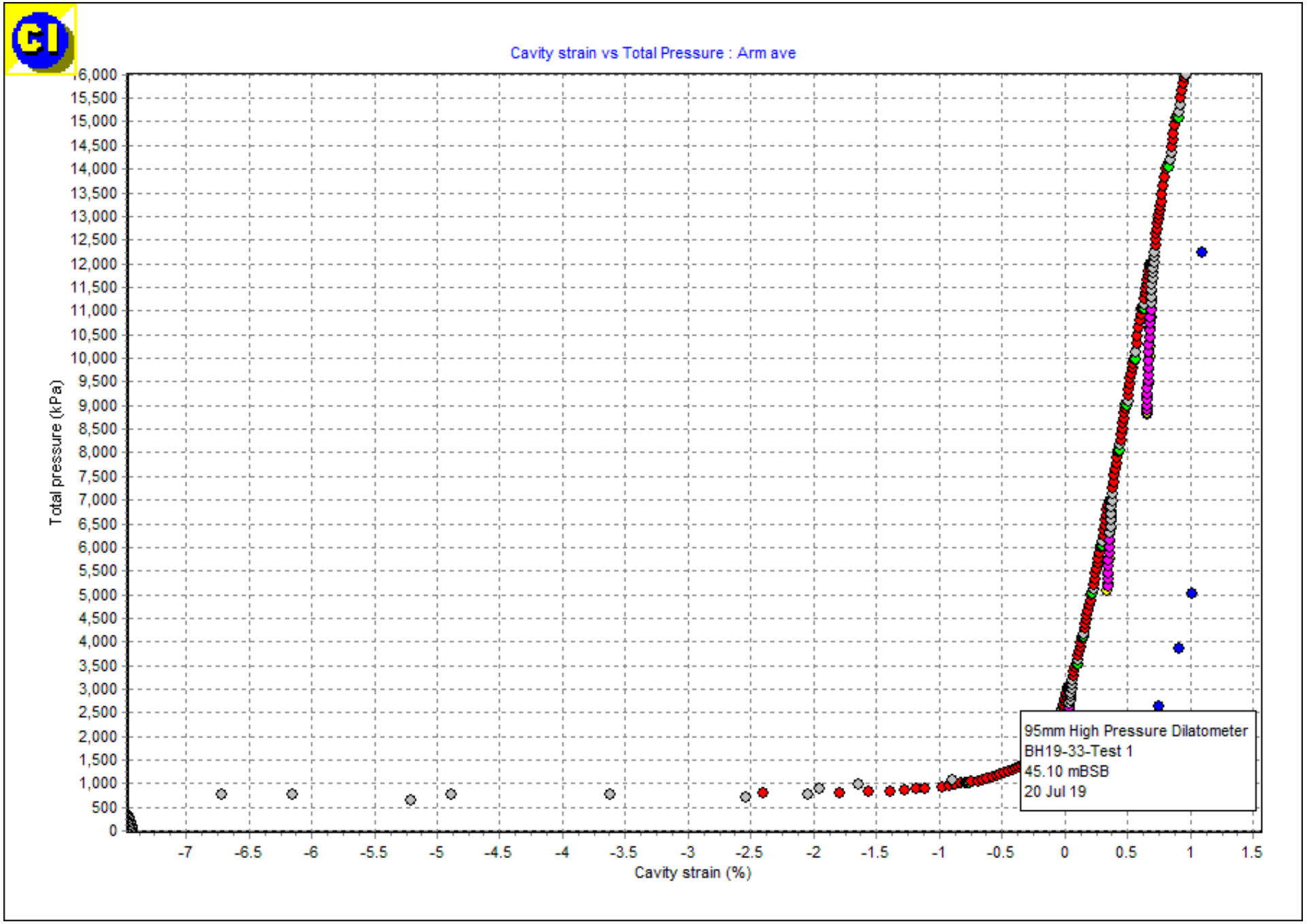
[DRAINED ANALYSIS OF SANDS]
[Withers et al 1989]
Constant volume friction angle (°) : 28.0
Angle of internal friction (°) : "Arm ave=25.1"
Dilation angle (°) : "Arm ave=-3.2"
Gradient of log-log plot : "Arm ave=-1.596"

[LINEAR INTERPRETATION OF SHEAR MODULUS G]
Initial slope shear modulus (MPa) :"Arm ave=782.6"

Axis	Loop No	Value (MPa)	Mean Strain (%)	Mean Pc (kPa)	dE (%)	dPc (kPa)
Arm ave	1	1285.6	0.026	2297	0.049	626
Arm ave	2	2608.7	0.350	5611	0.041	1082
Arm ave	3	3026.3	0.672	9939	0.074	2239

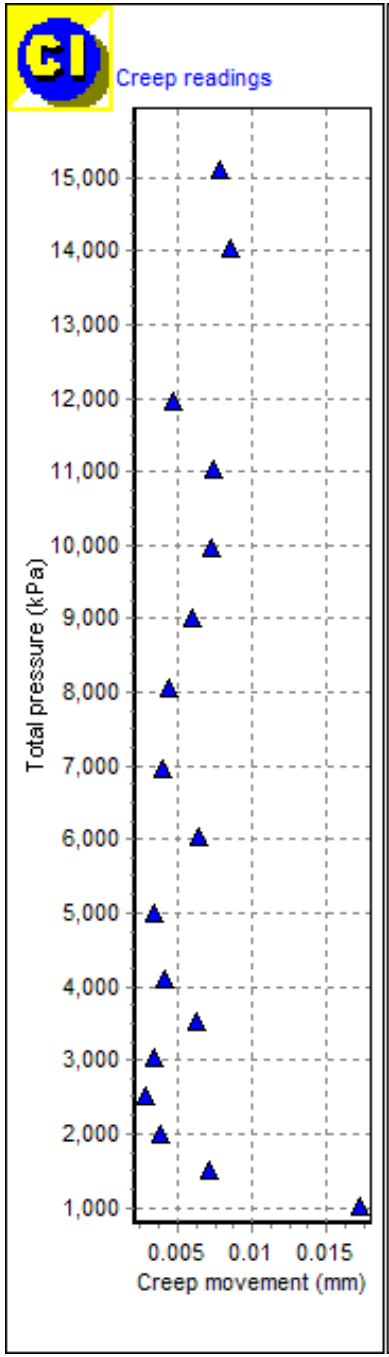
G190026W

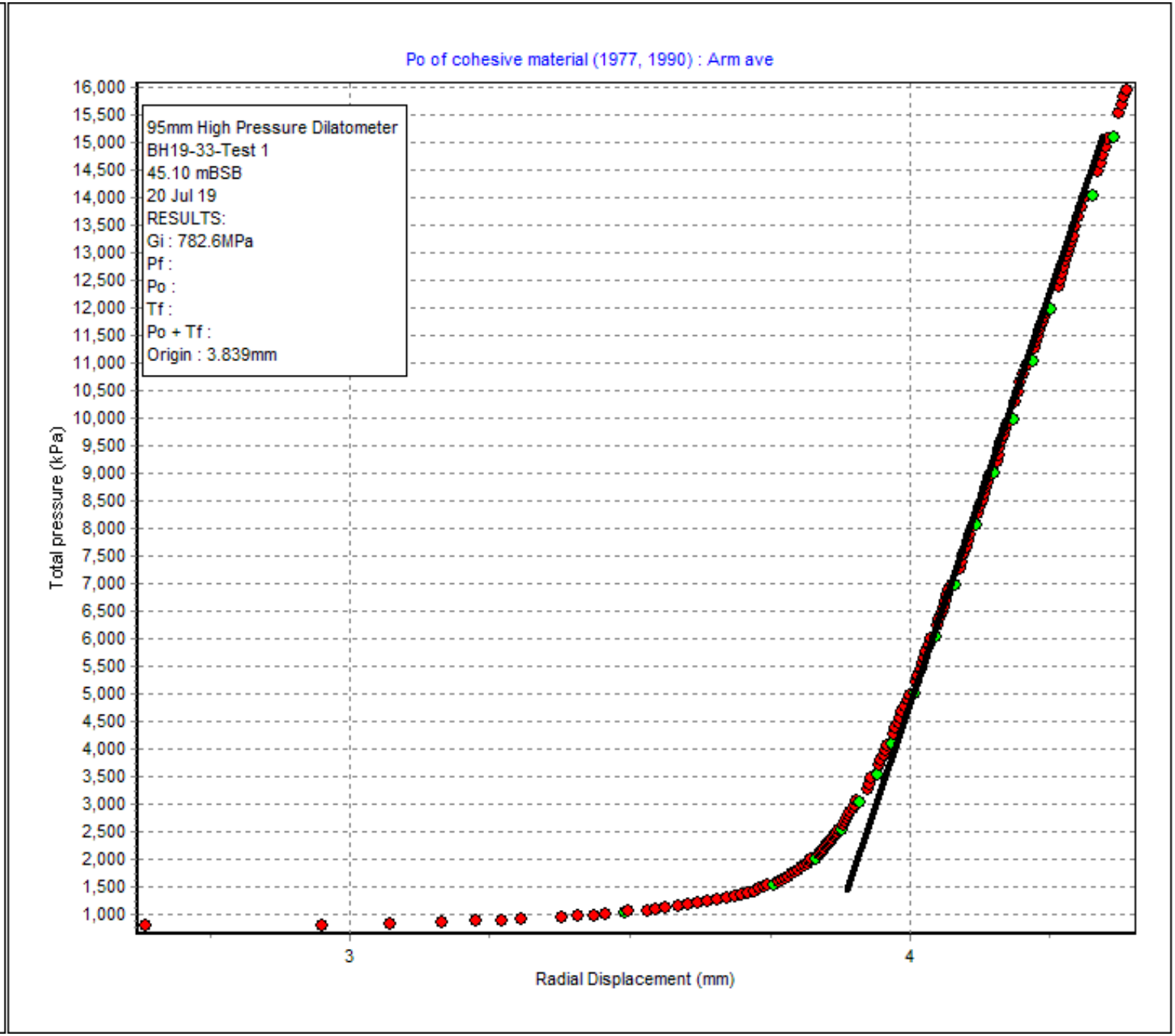
Straits of Mackinac



G190026W

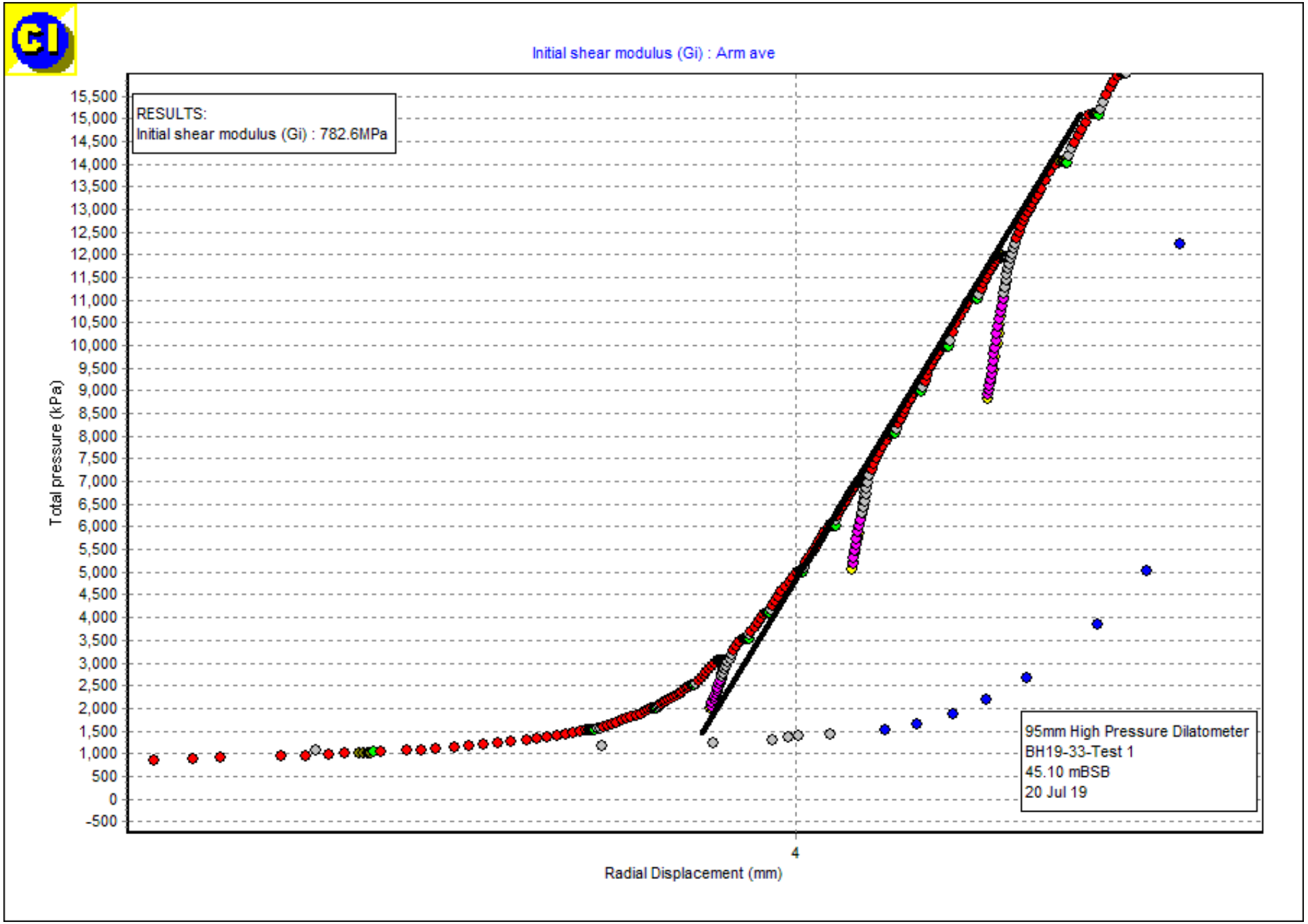
Straits of Mackinac





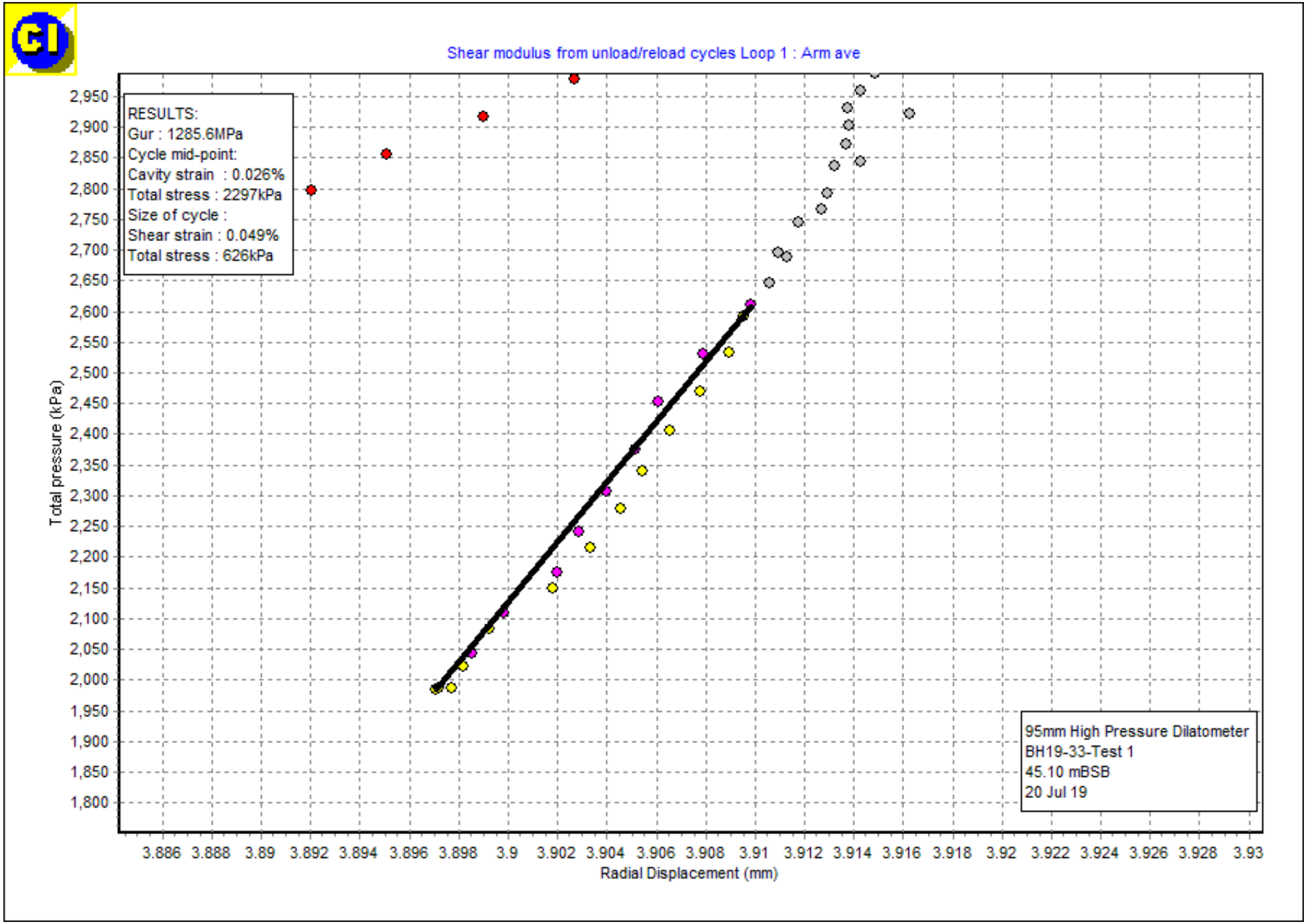
G190026W

Straits of Mackinac



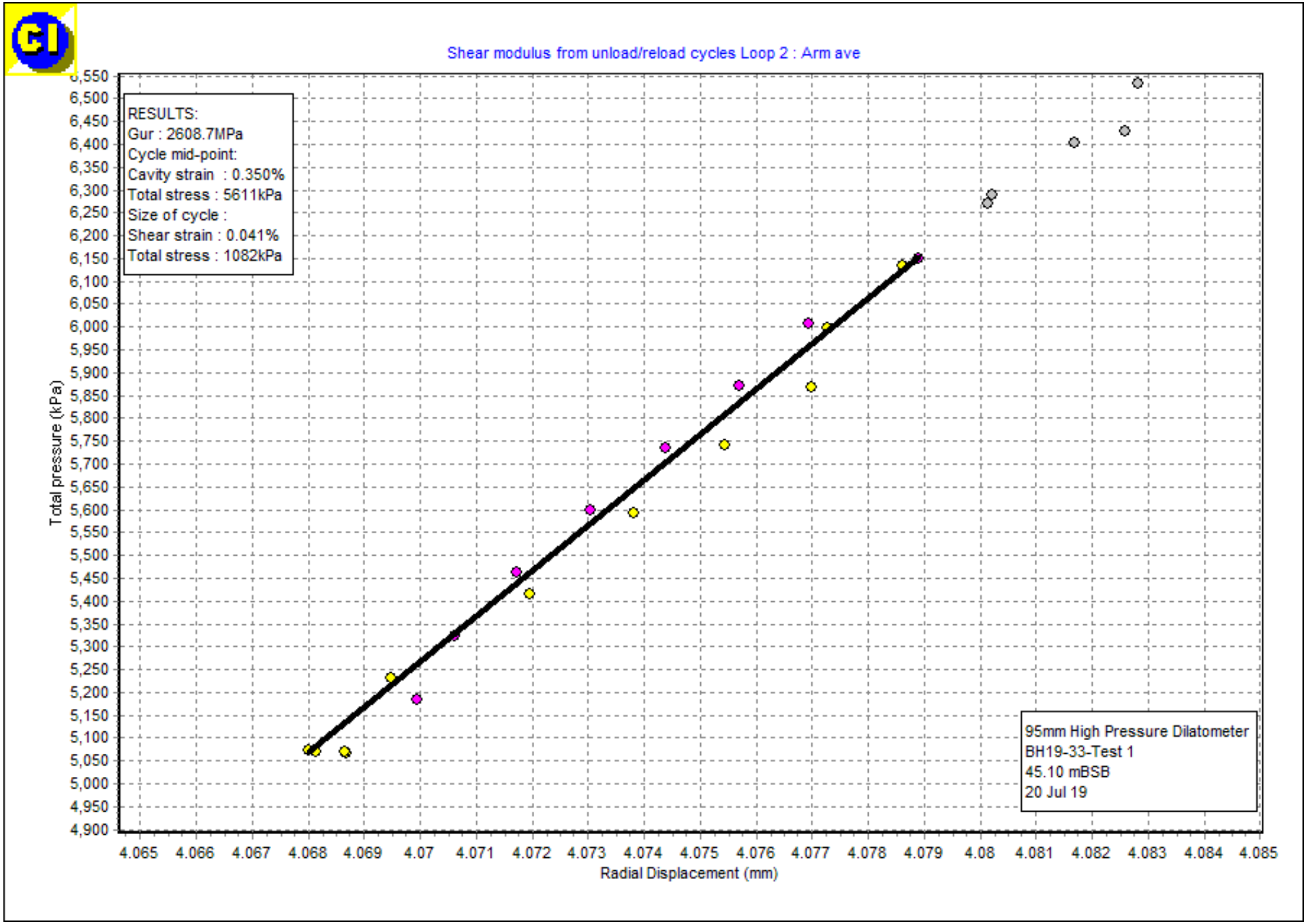
G190026W

Straits of Mackinac



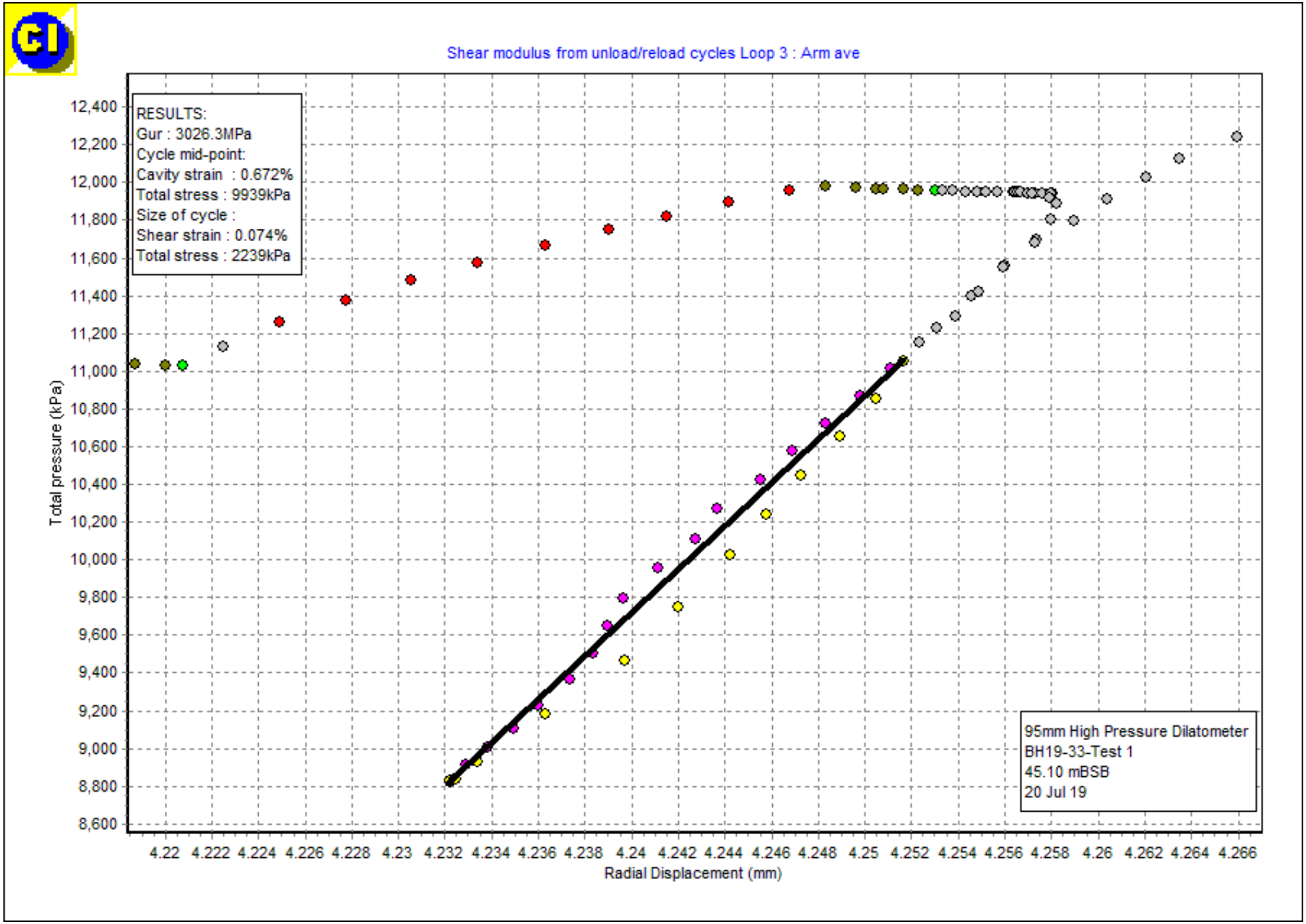
G190026W

Straits of Mackinac



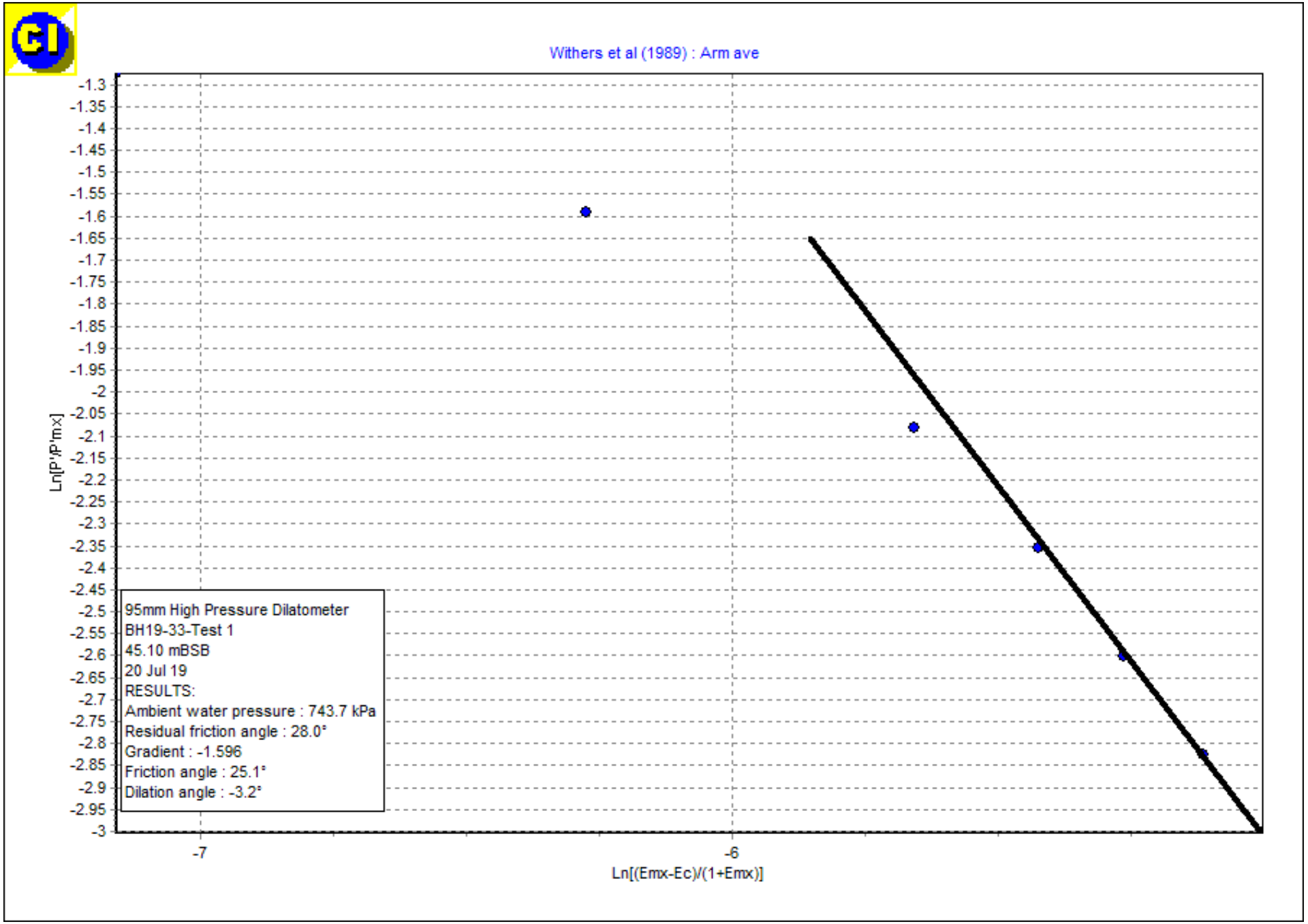
G190026W

Straits of Mackinac



G190026W

Straits of Mackinac



Straits of Mackinac
B33T1 - TEST & CALIBRATION DETAILS

[PROJECT DETAILS]
Contract name : Straits of Mackinac

[BOREHOLE DETAILS]
Borehole : BH19-33

[TEST DETAILS]
Test name : B33T1
Test date : 20/07/19
Depth (M) : 45.10
Material: : Limestone
Heading (deg) : n/a
Data Rate (secs) : 10
Start Line : 1
Stop Line : 521

[COMMENTS]
Pocket 44.10m to 46.10. Base of probe 45.80m.

[PROBE DETAILS]
Type : Digital High Pressure Dilatometer
Diameter over probe : 97.00mm
Diameter under membrane : 81.00mm
CHL strip thickness : 1.0000mm

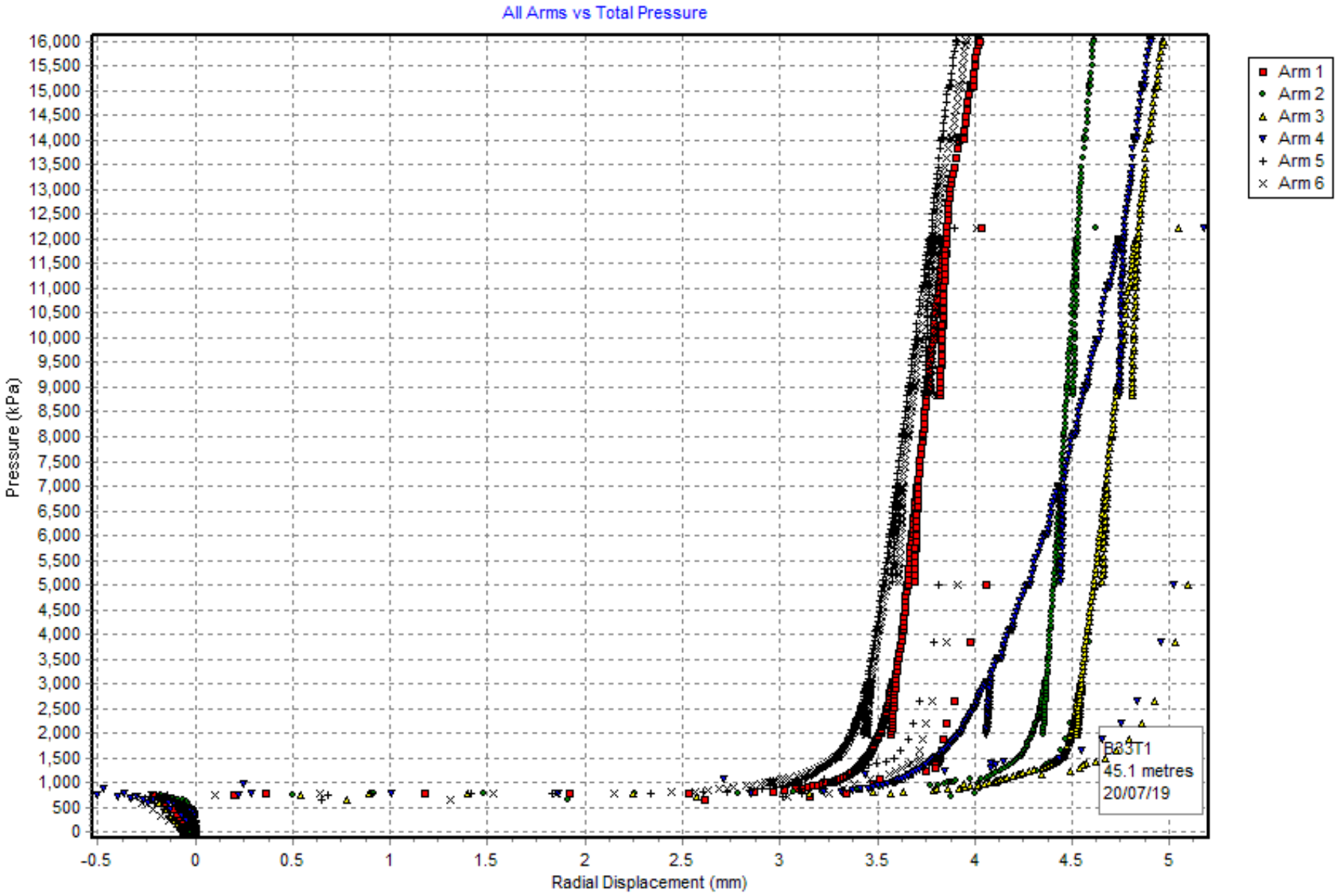
[CALIBRATION FACTORS]

	TRANSDUCERS	MEMBRANE	COMPLIANCE
ARM 1	-2132.2 mV and 137.4 mV/mm	24.4 kPa and 8.6 kPa/mm	3.1 mm/GPa
ARM 2	-2195.4 mV and 135.5 mV/mm	24.4 kPa and 8.6 kPa/mm	3.1 mm/GPa
ARM 3	-1895.0 mV and 138.0 mV/mm	24.4 kPa and 8.6 kPa/mm	3.1 mm/GPa
ARM 4	-2009.3 mV and 138.1 mV/mm	24.4 kPa and 8.6 kPa/mm	3.1 mm/GPa
ARM 5	-1889.8 mV and 138.6 mV/mm	24.4 kPa and 8.6 kPa/mm	3.1 mm/GPa
ARM 6	-2189.6 mV and 137.6 mV/mm	24.4 kPa and 8.6 kPa/mm	3.1 mm/GPa
TPC A	-213.4 mV and 102.2 mV/MPa *		
TPC B	-1475.5 mV and 113.6 mV/MPa *		

[COMPASS FACTORS (units in millivolts)]
Sin Sensor : Min: -1000.0000 Max: 1000.0000
Cos Sensor : Min: -1000.0000 Max: 1000.0000

G190026W

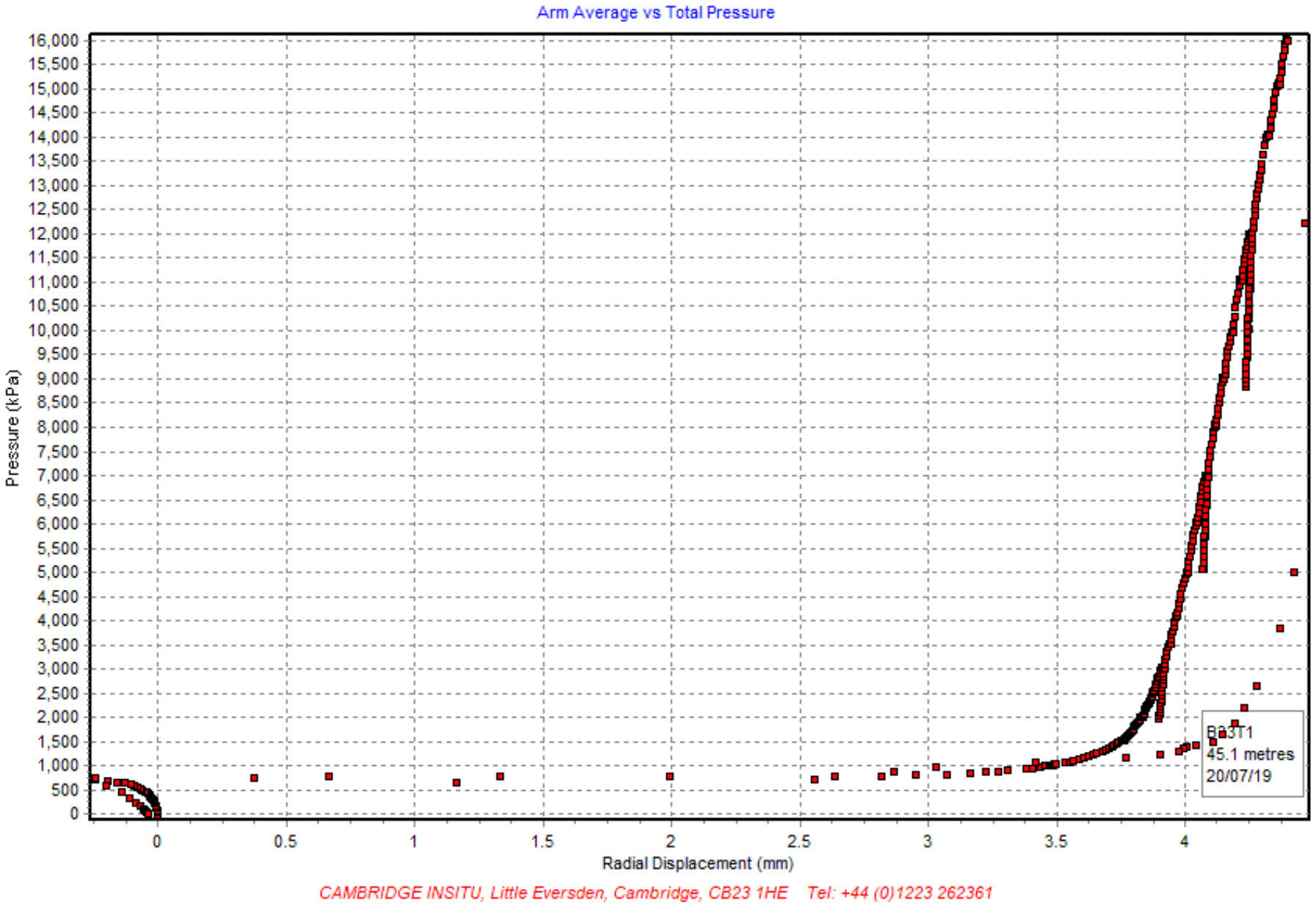
Straits of Mackinac



CAMBRIDGE INSITU, Little Eversden, Cambridge, CB23 1HE Tel: +44 (0)1223 262361

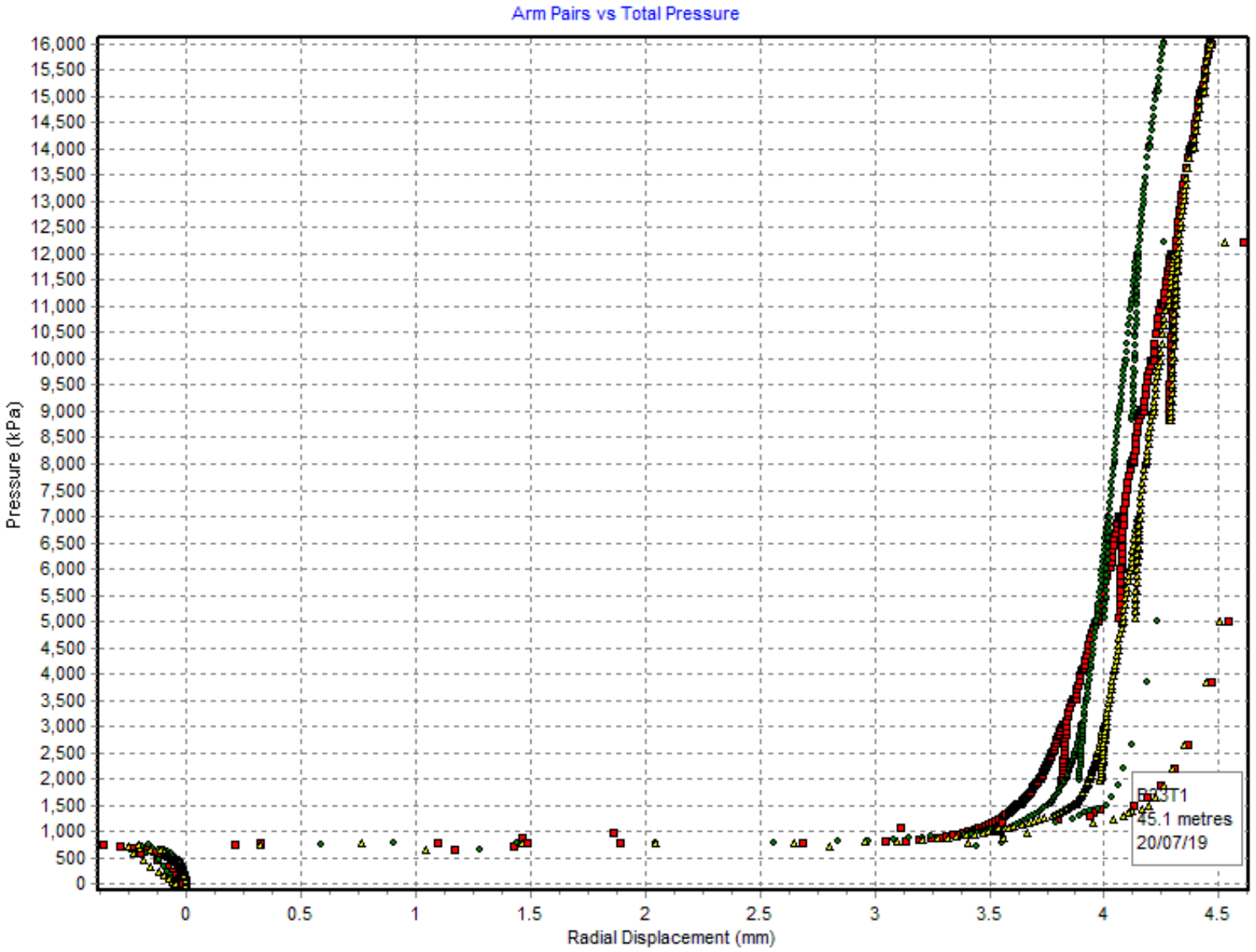
G190026W

Straits of Mackinac



G190026W

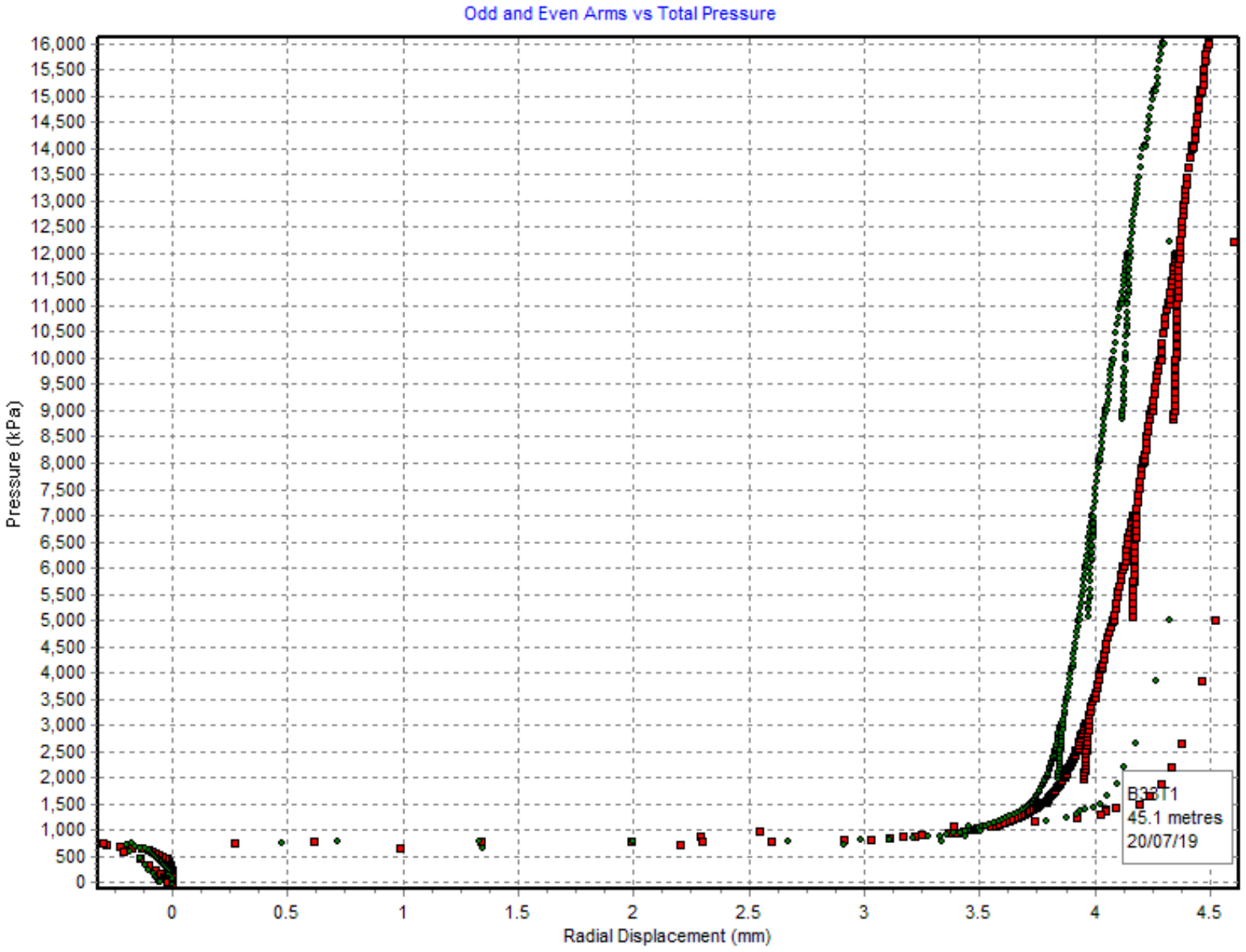
Straits of Mackinac



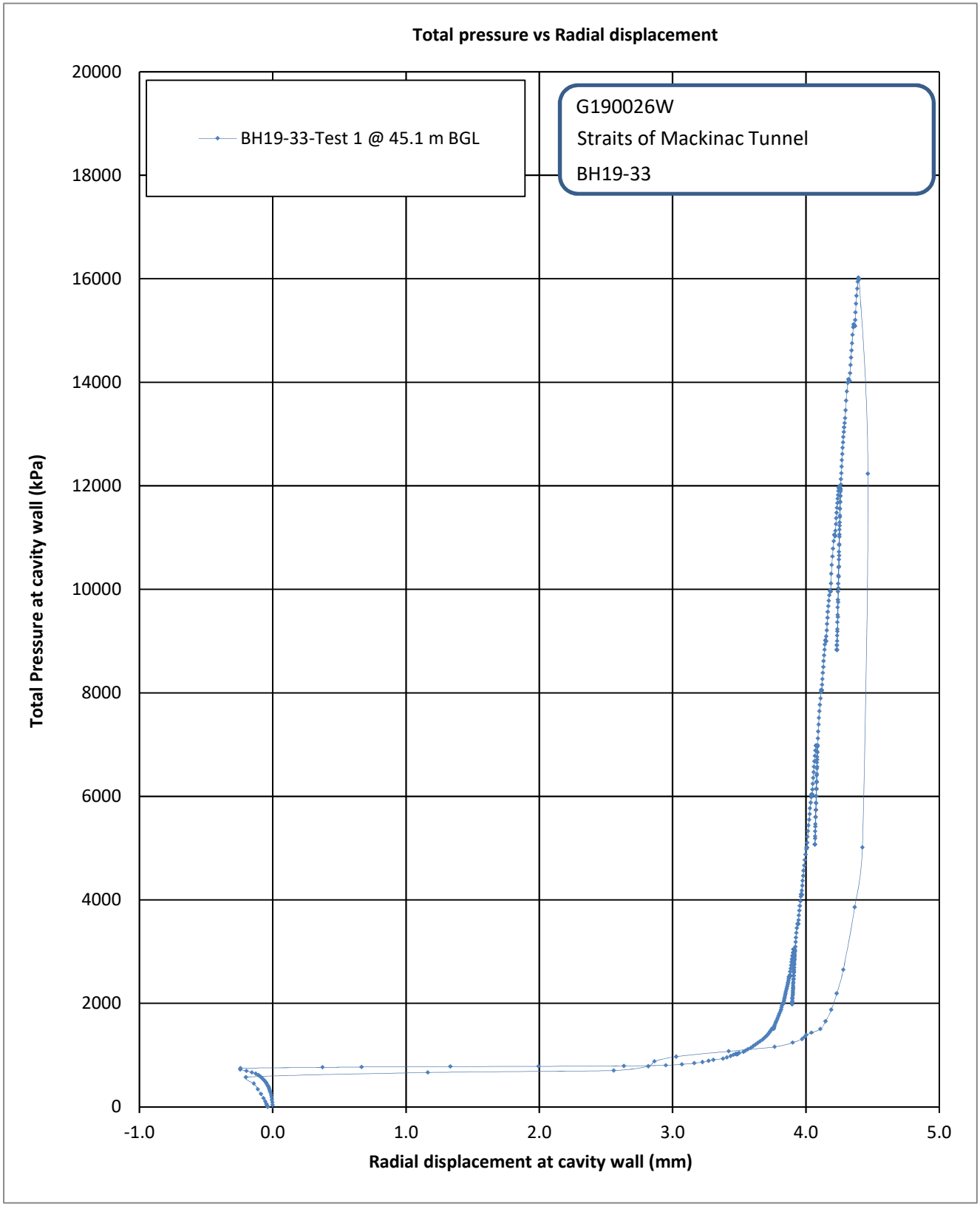
CAMBRIDGE INSITU, Little Eversden, Cambridge, CB23 1HE Tel: +44 (0)1223 262361

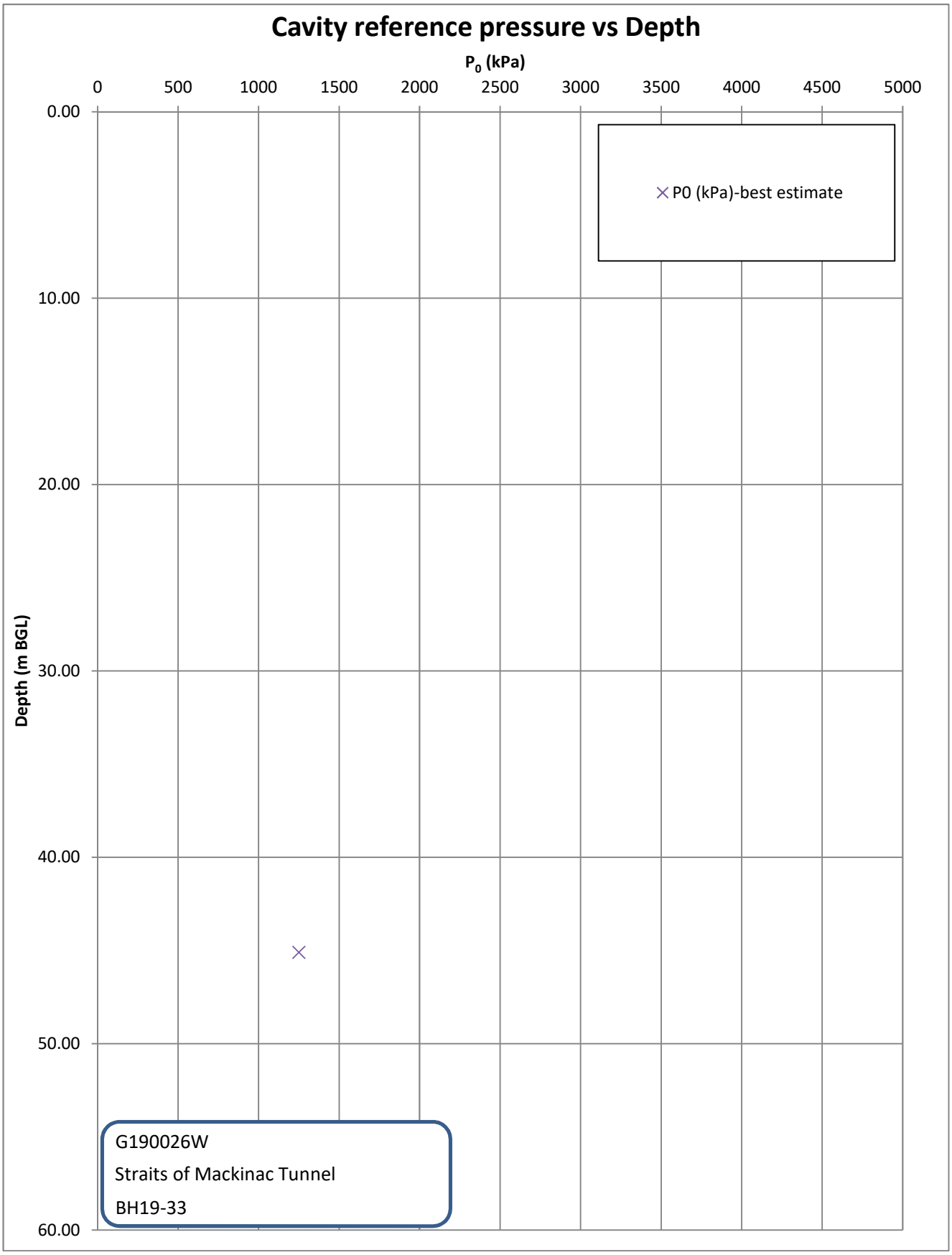
G190026W

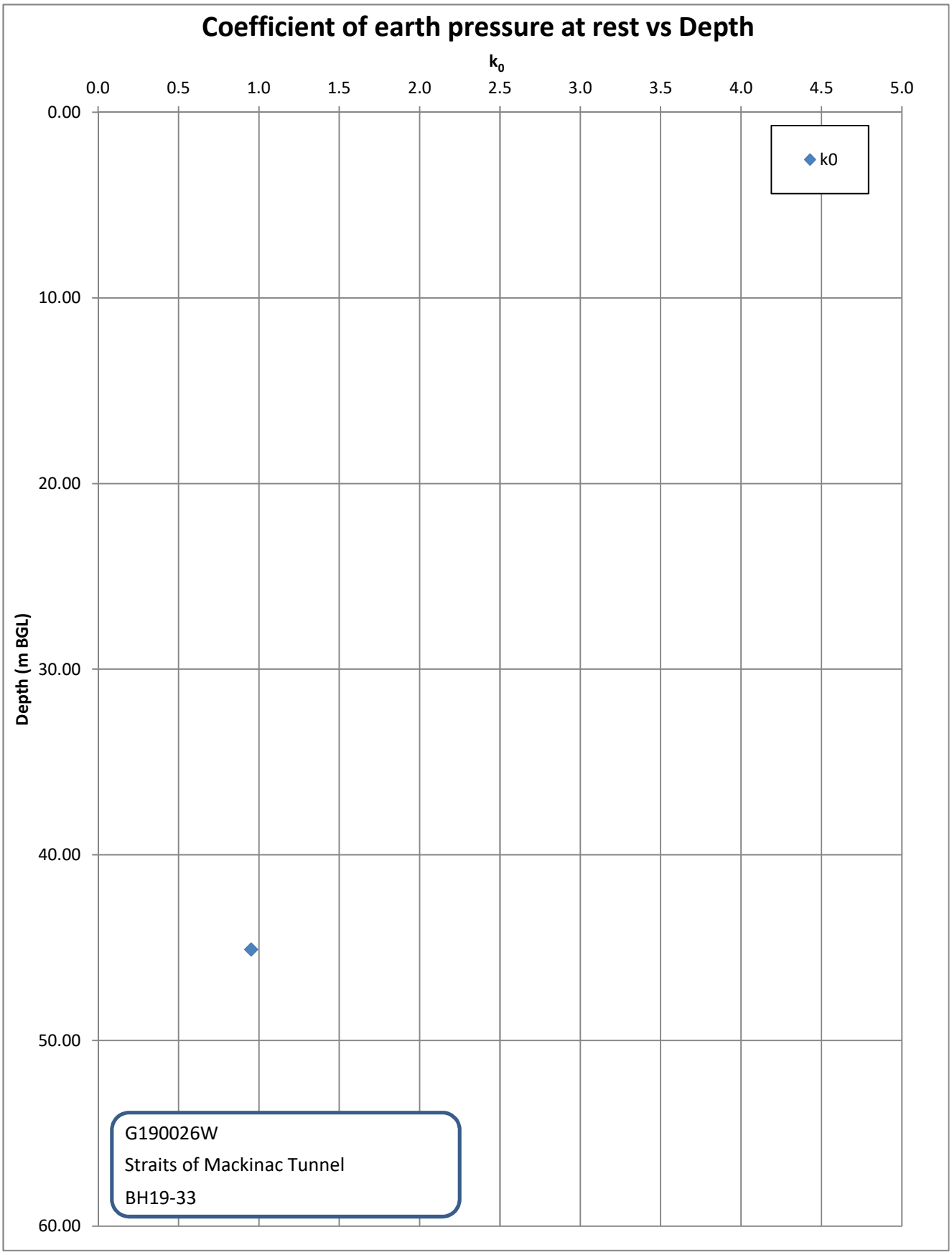
Straits of Mackinac

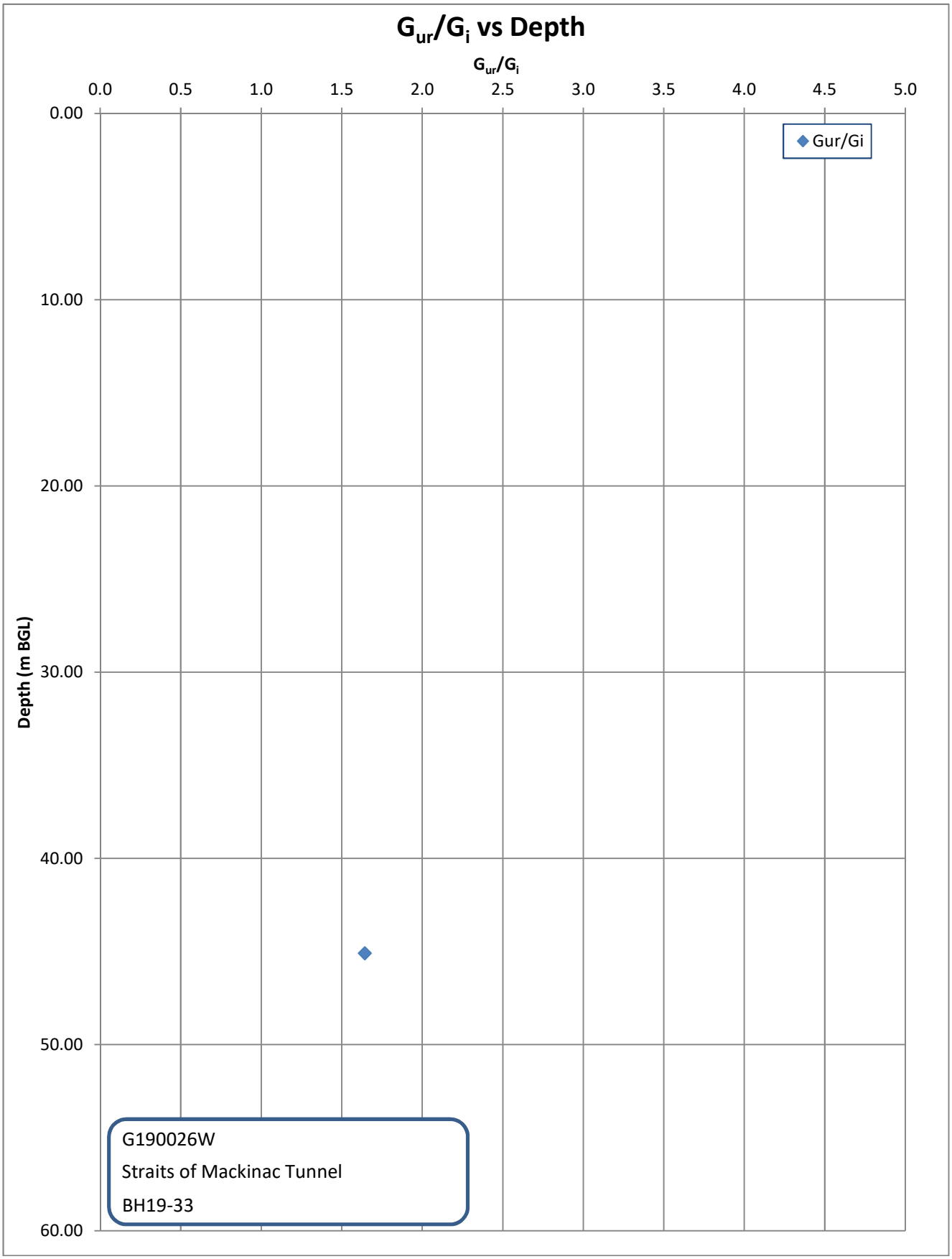


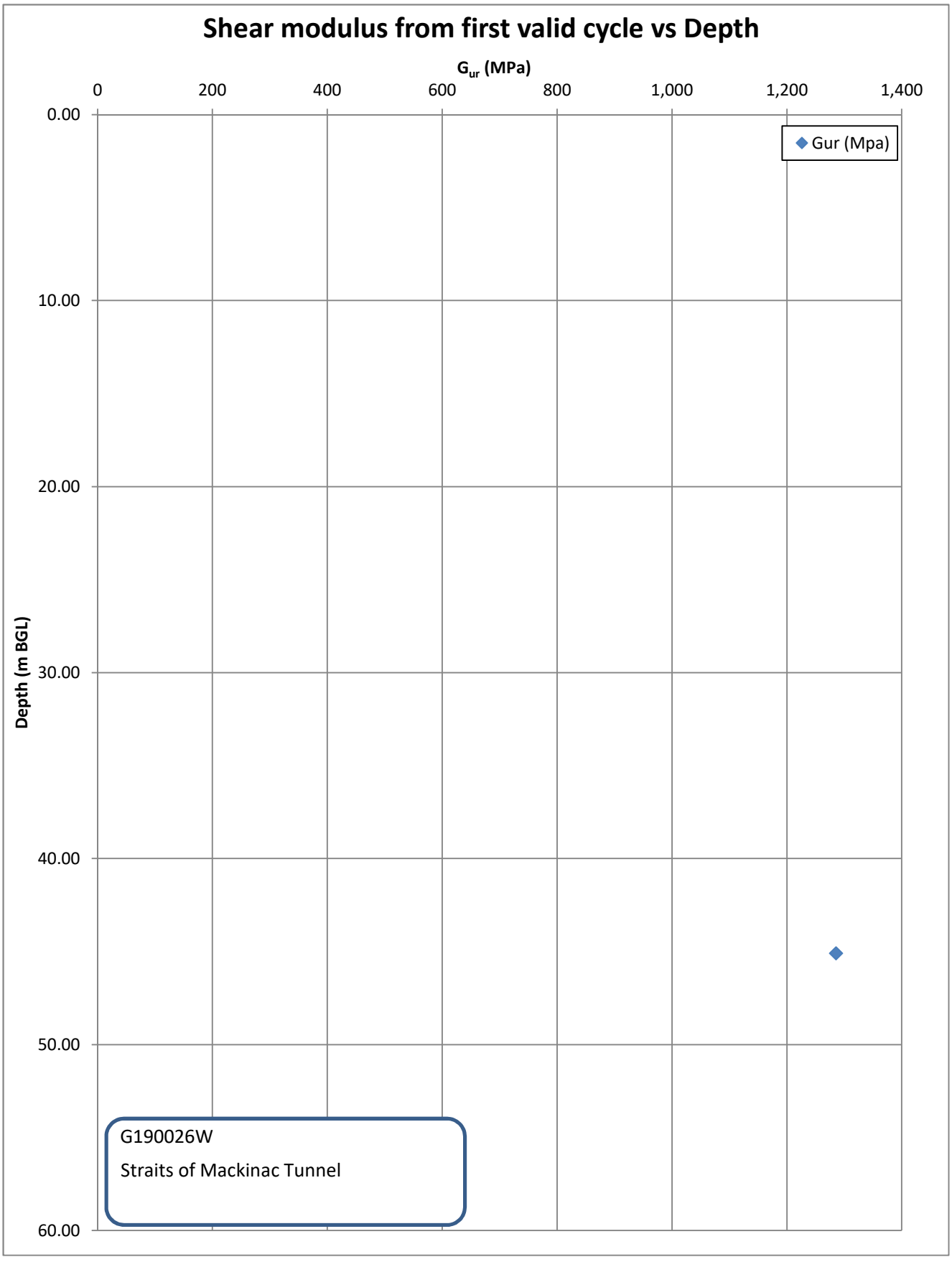
CAMBRIDGE INSITU, Little Eversden, Cambridge, CB23 1HE Tel: +44 (0)1223 262361

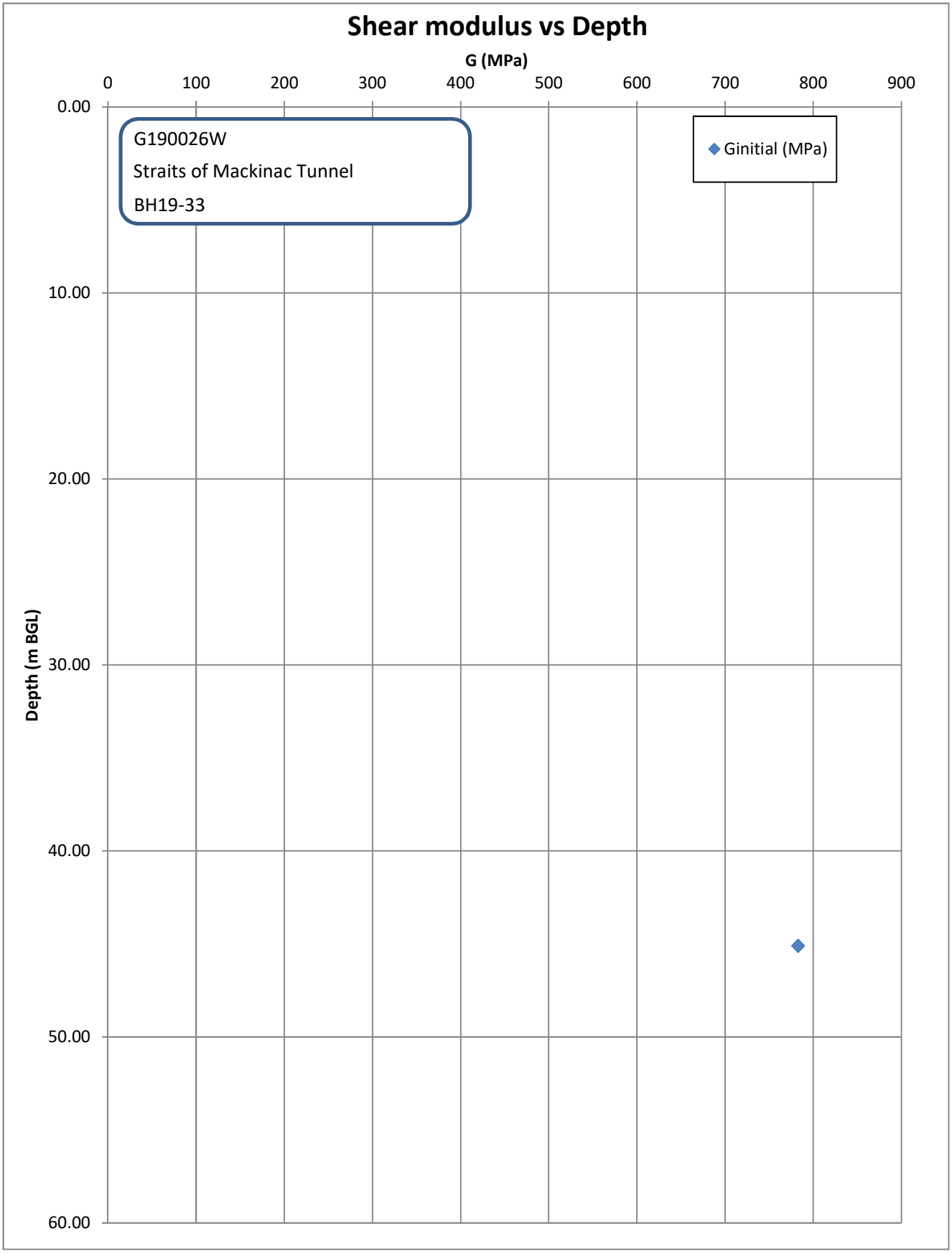

Total pressure vs Radial displacement
BH19-33-Test 1 @ 45.1 m BGL
G190026W
Straits of Mackinac Tunnel
BH19-33
Total Pressure at cavity wall (kPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Radial displacement at cavity wall (mm)


Cavity reference pressure vs Depth
P0 (kPa)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Depth (m BGL)
P0 (kPa)-best estimate
G190026W
Straits of Mackinac Tunnel
BH19-33


Coefficient of earth pressure at rest vs Depth
k_0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Depth (m BGL)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
k0
G190026W
Straits of Mackinac Tunnel
BH19-33


G_{ur}/G_i vs Depth
G_{ur}/G_i
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Depth (m BGL)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Gur/Gi
G190026W
Straits of Mackinac Tunnel
BH19-33


Shear modulus from first valid cycle vs Depth
G_{ur} (MPa)
0
200
400
600
800
1,000
1,200
1,400
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Depth (m BGL)
Gur (Mpa)
G190026W
Straits of Mackinac Tunnel


Shear modulus vs Depth
G (MPa)
0
100
200
300
400
500
600
700
800
900
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Depth (m BGL)
G190026W
Straits of Mackinac Tunnel
BH19-33
Ginitial (MPa)

APPENDIX

E LABORATORY TESTING

APPENDIX

E-1 *SOIL TEST RESULTS*

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	ckg
Sample ID:	---	Test Date:	07/01/19	Checked By:	jsc
Depth :	---	Test Id:	510679		

Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content,%
BH19-07	LSB- 001	55-60 ft	Moist, red silty, clayey sand with gravel	.6
BH19-09	SS- 001	0-2 ft	Moist, pale brown silty sand with gravel	6.3
BH19-09	SS- 002	2-4 ft	Moist, very pale brown silty sand	6.0
BH19-12A	SS- 001	0-2 ft	Moist, brown clayey silt with gravel	28.3
BH19-12A	SS- 002	2-4 ft	Moist, light yellowish brown sand with gravel	15.0
BH19-12A	SS- 003	4-5 ft	Moist, light yellowish brown sand with gravel	11.9
BH19-13A	SS- 001	0-2 ft	Moist, brownish gray clay with gravel	14.1
BH19-13A	SS- 002	2-4 ft	Moist, light yellowish brown clayey sand with gravel	9.6
BH19-13A	SS- 003	4-6 ft	Moist, yellowish brown silty sand with gravel	7.4
BH19-13A	SS- 004	6-7 ft	Moist, pale brown silty clayey sand with gravel	11.0

Notes: Temperature of Drying : 110º Celsius

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	ckg
Sample ID:	---	Test Date:	08/14/19	Checked By:	jsc
Depth :	---	Test Id:	516907		

Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content,%
BH19-14A	SS- 001A	0-2 ft	Moist, dark brown clayey silt with gravel	25.9
BH19-14A	SS- 001B	0-2 ft	Moist, light yellowish brown clay with gravel	8.1
BH19-14A	SS- 002	2-4 ft	Moist, light yellowish brown clayey sand with gravel	8.7
BH19-14A	SS- 003	4-4.5 ft	Moist, brownish gray silty sand with gravel	8.3
BH19-15	SS- 001A	60-60.5	Moist, light brownish gray sand	14.8
BH19-15	SS- 002	70-72	Moist, light brownish gray sand with gravel	15.8
BH19-15	SS- 005	100-102	Moist, gray silty clay with sand	13.3
BH19-16	LSB- 001	69-70 ft	Moist, brown silty sand	15.6
BH19-16	LSB- 002	100-102 ft	Moist, light yellowish brown silty sand	8.8
BH19-17	LSB- 001	94-95 ft	Moist, pale red silty with gravel and sand	14.0

Notes: Temperature of Drying : 110º Celsius

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-001	Test Date:	08/08/19	Checked By:	jsc
Depth :	70-72 ft	Test Id:	516909		
Test Comment:	---				
Visual Description:	Moist, light pale brown sand				
Sample Comment:	---				

Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content,%
BH19-38	LSB- 001	70-72 ft	Moist, light pale brown sand	13.4

Notes: Temperature of Drying : 110º Celsius

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	jar	Tested By:	ckg
Sample ID:	SS-002	Test Date:	08/14/19	Checked By:	bfs
Depth :	2-4 ft	Test Id:	516898		
Test Comment:	---				
Visual Description:	Moist, very pale brown silty sand				
Sample Comment:	---				

Laboratory Determination of Density (Unit Weight) of Soil Specimens by ASTM D7263

Boring ID	Sample ID	Depth	Visual Description	Bulk Density pcf	Moisture Content %	Dry Density pcf
BH19-09	SS- 002	2-4 ft	Moist, very pale brown silty sand	132.4	6.032	124.9

* Sample Comments

(1): Method B-Cylinder, Reconstituted (compacted)

Notes: Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	ckg
Sample ID:	---	Test Date:	08/12/19	Checked By:	jsc
Depth :	---	Test Id:	516912		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-07	LSB- 001	55-60 ft	Moist, red silty, clayey sand with gravel	2.76	
BH19-15	SS- 001A	60-60.5	Moist, light brownish gray sand	2.64	
BH19-15	SS- 002	70-72	Moist, light brownish gray sand with gravel	2.65	
BH19-15	SS- 005	100-102	Moist, gray silty clay with sand	2.84	
BH19-16	LSB- 001	69-70 ft	Moist, brown silty sand	2.74	
BH19-16	LSB- 003	90-92 ft	Moist, pink sand	2.71	
BH19-17	LSB- 001	94-95 ft	Moist, pale red silty with gravel and sand	2.78	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	12/31/19	Checked By:	jsc
Depth :	---	Test Id:	533682		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-024A	LSB- 002	68.24-68.73 ft	Moist, pale brown silty sand	2.61	
BH19-024A	LSB- 004	120.08-120.57 ft	Dry, pale brown silty clayey sand	2.59	
BH19-024A	LSB- 006	156.66-157.32 ft	Dry, pale brown clayey sand with gravel	2.61	
BH19-024A	LSB- 007	174.54-175.03 ft	Dry, pale brown clayey sand with gravel	2.61	
BH19-024A	LSB- 009	185.20-185.70 ft	Moist, pale brown clay	2.69	
BH19-024A	LSB- 011	193.96-194.42 ft	Moist, brown clay	2.65	
BH19-024A	LSB- 013	204.33-204.92 ft	Moist, brown clay	2.70	
BH19-024A	LSB- 015	218.50-219.00 ft	Dry, pale brown silty sand	2.71	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	12/31/19	Checked By:	jsc
Depth :	---	Test Id:	532869		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-21	LSB- 001	34.91-35.30 ft	Moist, brown clay	2.62	
BH19-21	LSB- 003	44.55-44.94 ft	Moist, brown clay	2.63	
BH19-23	LSB- 001	29.40-29.95 ft	Dry, pale brown clay	2.67	
BH19-23	LSB- 003	94.26-94.78 ft	Dry, pale brown silty clayey sand	2.65	
BH19-24	LSB- 002	83.20-83.89 ft	Dry, pale brown silty sand	2.60	
BH19-24	LSB- 004	130.51-131.07 ft	Dry, pale brown silty clayey gravel with sand	2.66	
BH19-24	LSB- 006	148.06-148.62 ft	Dry, pale brown clay	2.65	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/09/20	Checked By:	jsc
Depth :	---	Test Id:	537498		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-25	LSB- 001	86.84-87.40 ft	Moist, brown clay with sand	2.65	
BH19-25	LSB- 003	111.35-111.94 ft	Moist, brown clay with sand	2.62	
BH19-25	LSB- 005	126.44-127.03 ft	Moist, brown sandy silty clay	2.57	
BH19-25	LSB- 007	145.83-146.46 ft	Moist, brown sandy silty clay	2.61	
BH19-25	LSB- 012	210.20-210.73 ft	Moist, brown sandy clay	2.61	
BH19-25	LSB- 013	220.37-220.93 ft	Moist, brown clay	2.69	
BH19-25	LSB- 015	240.55-241.08 ft	Moist, brown clay	2.66	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/03/20	Checked By:	jsc
Depth :	---	Test Id:	532695		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-26	LSB- 001	100.62-101.12 ft	Moist, brown silty sand	2.63	
BH19-26	ST-001	104.99-107.35 ft	Moist, brown silty clay with sand	2.65	
BH19-26	LSB- 003	126.02-126.58 ft	Moist, brown sandy silty clay	2.68	
BH19-26	ST-002	134.51-135.47 ft	Moist, brown clay with sand	2.63	
BH19-26	LSB- 005	152.56-153.22 ft	Moist, brown sandy clay	2.66	
BH19-26	LSB- 007	172.28-172.83 ft	Moist, brown sandy clay	2.62	
BH19-26	LSB- 009	191.37-191.96 ft	Moist, brown clay	2.66	
BH19-26	LSB- 011	209.94-210.50 ft	Moist, brown sandy clay	2.60	
BH19-26	LSB- 013	228.02-228.54 ft	Moist, grayish brown clay	2.68	
BH19-26	LSB- 015	250.85-251.38 ft	Moist, brown clay	2.65	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	12/31/19	Checked By:	jsc
Depth :	---	Test Id:	536927		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-26	LSB- 017	267.82-268.44 ft	Moist, pale brown silt with sand	2.66	
BH19-26	LSB- 022	321.75-322.18 ft	Moist, gray silty clayey sand	2.67	
BH19-27	LSB- 001	120.31-120.90 ft	Moist, brown clay with sand	2.60	
BH19-27	LSB- 003	144.26-144.75 ft	Dry, brown sandy clay	2.63	
BH19-27	LSB- 005	162.40-162.86 ft	Dry, brown sandy clay	2.61	
BH19-27	LSB- 008	195.37-195.87 ft	Moist, brown sandy clay	2.63	
BH19-27	LSB- 009	198.33-198.82 ft	Moist, grayish brown clay	2.67	
BH19-27	LSB- 011	217.06-217.49 ft	Moist, brown clayey sand with gravel	2.63	
BH19-27	LSB- 013	232.28-232.81 ft	Wet, brown silty sand	2.61	
BH19-27	LSB- 015	252.40-252.95 ft	Moist, brown silty clay	2.71	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/03/20	Checked By:	jsc
Depth :	---	Test Id:	532748		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-27	LSB- 017	271.10-271.62 ft	Moist, brown silty clay	2.66	
BH19-27	ST-002	127.95-129.92 ft	Moist, brown silty sand	2.60	
BH19-27	ST-003	260.83-263.45 ft	Moist, grayish brown silty clay	2.73	
BH19-28	LSB- 001	87.5-88.12 ft	Moist, brown clay	2.62	
BH19-28	LSB- 004	152.72-153.31 ft	Dry, silty clayey sand	2.60	
BH19-28	LSB- 005	156.46-156.92 ft	Dry, pale brown sandy silty clay	2.64	
BH19-31	LSB- 001	131.23-131.56 ft	Moist, light brownish gray sandy clay	2.71	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	ckg
Sample ID:	---	Test Date:	08/12/19	Checked By:	jsc
Depth :	---	Test Id:	516910		

Specific Gravity of Soils by ASTM D854

Boring ID	Sample ID	Depth	Visual Description	Specific Gravity	Comment
BH19-37	LSB- 002	75-80 ft	Moist, light brown sand	2.73	
BH19-37	LSB- 003	100-110 ft	Moist, light pale brown silty sand	2.72	
BH19-37	LSB- 004	130-135 ft	Moist, pale brown silty gravel with sand	2.66	
BH19-38	LSB- 002	69-70 ft	Moist, light brown sand	2.74	

Notes: Specific Gravity performed by using method B (oven dried specimens) of ASTM D854
Moisture Content determined by ASTM D2216.

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/16/20	Checked By:	jsc
Depth :	---	Test Id:	532845		

USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
BH19-024A	LSB-001	47.90-48.56 ft	Sandy Silty CLAY	CL-ML	0.0	38.4	61.6
BH19-024A	LSB-003	93.01-93.50 ft	Silty SAND	SM	0.0	69.7	30.3
BH19-024A	LSB-005	141.90-152.55 ft	Silty SAND	SM	3.1	55.0	41.9
BH19-024A	LSB-008	180.94-181.43 ft	Lean CLAY with Sand	CL	4.8	17.7	77.5
BH19-024A	LSB-010	189.57-190.22 ft	Lean CLAY	CL	0.0	0.6	99.4
BH19-024A	LSB-012	200.85-201.41 ft	Lean CLAY	CL	0.0	2.7	97.3
BH19-024A	LSB-013	204.33-204.92 ft	Lean CLAY	CL	0.0	6.8	93.2
BH19-024A	LSB-015	218.50-219.00 ft	Silty SAND	SM	3.0	53.7	43.3
BH19-23	LSB-002	68.01-68.64 ft	Silty SAND	SM	0.0	68.2	31.8
BH19-24	LSB-002	83.20-83.89 ft	Silty SAND	SM	0.0	65.8	34.2

Remarks: Grain Size analysis performed by ASTM D422 results enclosed

Atterberg Limits performed by ASTM D4318, results enclosed

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/16/20	Checked By:	jsc
Depth :	---	Test Id:	533674		

USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
BH19-24	LSB-005	141.50-142.16 ft	Sandy SILT	ML	1.9	41.1	57.0
BH19-25	LSB-002	102.69-103.28 ft	Silty SAND	SM	0.0	74.4	25.6
BH19-25	LSB-006	136.98-137.43 ft	Sandy Silty CLAY	CL-ML	0.4	37.8	61.8
BH19-25	LSB-008	155.94-156.56 ft	Sandy Silty CLAY	CL-ML	0.0	34.8	65.2
BH19-25	LSB-011	201.44-202.00 ft	Sandy Lean CLAY	CL	2.4	31.8	65.8
BH19-26	ST-001	104.99-107.35 ft	Silty CLAY with Sand	CL-ML	0.0	18.4	81.6
BH19-26	LSB-002	116.17-116.67 ft	Sandy Silty CLAY	CL-ML	0.6	38.0	61.4
BH19-26	ST-002	134.51-135.47 ft	Lean CLAY with Sand	CL	0.0	28.4	71.6
BH19-26	LSB-004	141.83-142.45 ft	Lean CLAY with Sand	CL	0.5	16.7	82.8
BH19-26	LSB-006	189.12-159.68 ft	Clayey SAND	SC	0.0	57.1	42.9

Remarks: Grain Size analysis performed by ASTM D422 results enclosed

Atterberg Limits performed by ASTM D4318, results enclosed

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/16/20	Checked By:	jsc
Depth :	---	Test Id:	533975		

USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
BH19-26	LSB-008	180.48-181.07 ft	Lean CLAY with Sand	CL	1.7	24.6	73.7
BH19-26	LSB-012	219.03-219.55 ft	Lean CLAY	CL	0.0	0.1	99.9
BH19-26	LSB-014	237.30-237.83 ft	Lean CLAY	CL	0.0	0.4	99.6
BH19-26	LSB-016	257.64-258.20 ft	SILT	ML	0.0	7.5	92.5
BH19-27	LSB-001	120.31-120.90 ft	Lean CLAY with Sand	CL	0.7	22.2	77.1
BH19-27	ST-002	127.95-129.92 ft	Silty SAND	SM	0.0	73.7	26.3
BH19-27	LSB-003	144.26-144.75 ft	Sandy Lean CLAY	CL	8.3	32.0	59.7
BH19-27	LSB-005	162.40-162.86 ft	Sandy Lean CLAY	CL	7.8	35.7	56.5
BH19-27	LSB-007	182.09-182.58 ft	Poorly graded SAND	SP	0.0	95.6	4.4
BH19-27	LSB-009	198.33-198.82 ft	Lean CLAY	CL	0.0	1.4	98.6

Remarks: Grain Size analysis performed by ASTM D422 results enclosed

Atterberg Limits performed by ASTM D4318, results enclosed

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	GA
Sample ID:	---	Test Date:	01/16/20	Checked By:	jsc
Depth :	---	Test Id:	532746		

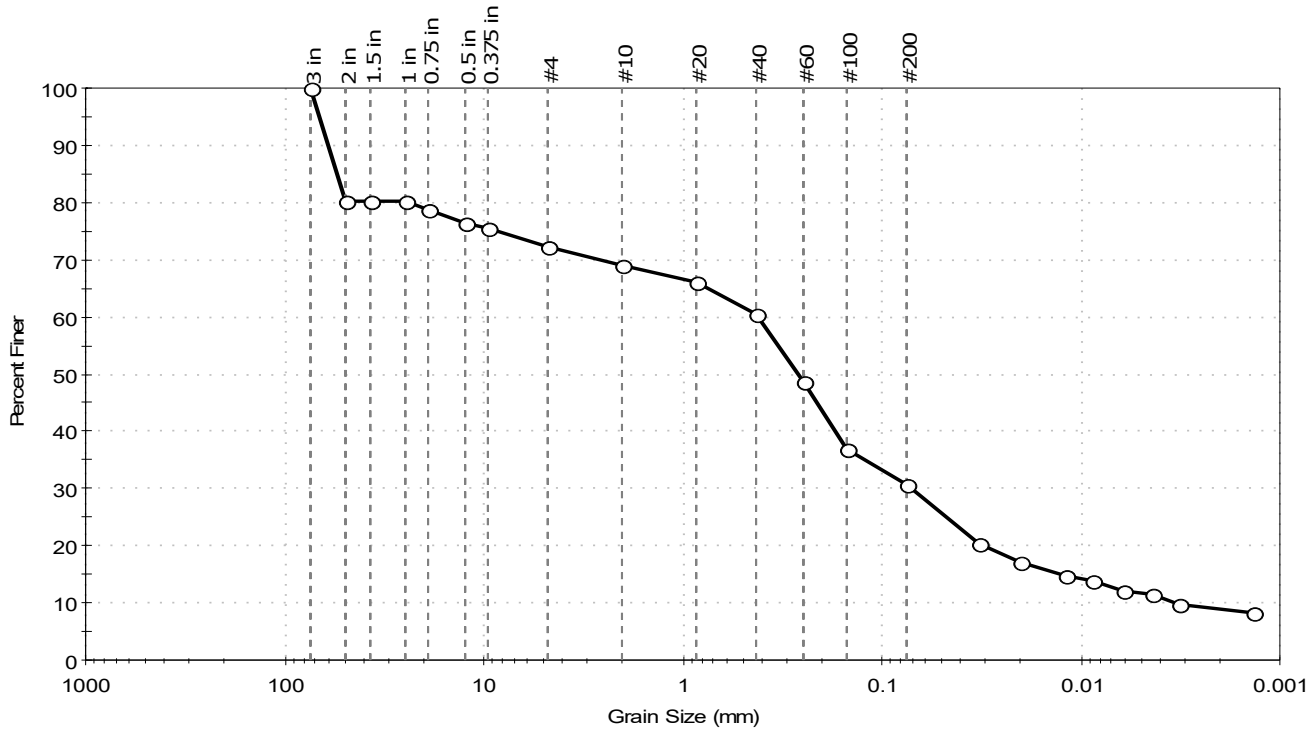
USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
BH19-27	LSB-014	242.55-243.11 ft	Lean CLAY	CL	0.0	2.0	98.0
BH19-27	ST-003	260.83-263.45 ft	Silty CLAY	CL-ML	0.0	0.8	99.2
BH19-27	LSB-016	262.80-263.32 ft	Lean CLAY	CL	0.0	0.9	99.1
BH19-27	LSB-018	281.17-280.68 ft	Sandy SILT	ML	0.0	35.7	64.3
BH19-28	LSB-001	87.5-88.12 ft	Lean CLAY	CL	1.9	6.5	91.6
BH19-28	LSB-003	142.82-143.27 ft	Poorly graded SAND	SP	0.0	98.2	1.8
BH19-28	LSB-005	156.46-156.92 ft	Sandy Silty CLAY	CL-ML	3.3	38.8	57.9
BH19-31	LSB-001	131.23-131.56 ft	Sandy Lean CLAY	CL	10.1	23.8	66.1

Remarks: Grain Size analysis performed by ASTM D422 results enclosed
Atterberg Limits performed by ASTM D4318, results enclosed

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-001	Test Date:	08/13/19	Checked By:	jsc
Depth :	55-60 ft	Test Id:	516901		
Test Comment:	---				
Visual Description:	Moist, red silty, clayey sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	27.9	41.5	30.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3 in	75.00	100		
2 in	50.00	80		
1.5 in	37.50	80		
1 in	25.00	80		
0.75 in	19.00	79		
0.5 in	12.50	76		
0.375 in	9.50	76		
#4	4.75	72		
#10	2.00	69		
#20	0.85	66		
#40	0.42	60		
#60	0.25	49		
#100	0.15	37		
#200	0.075	31		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0328	20		
---	0.0202	17		
---	0.0119	15		
---	0.0087	14		
---	0.0061	12		
---	0.0044	11		
---	0.0032	10		
---	0.0014	8		

Coefficients

D_{85} = 55.0862 mm	D_{30} = 0.0712 mm
D_{60} = 0.4157 mm	D_{15} = 0.0129 mm
D_{50} = 0.2650 mm	D_{10} = 0.0034 mm
C_u = 122.265	C_c = 3.587

Classification

ASTM — Silty, Clayey SAND with Gravel (SC-SM)

AASHTO — Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

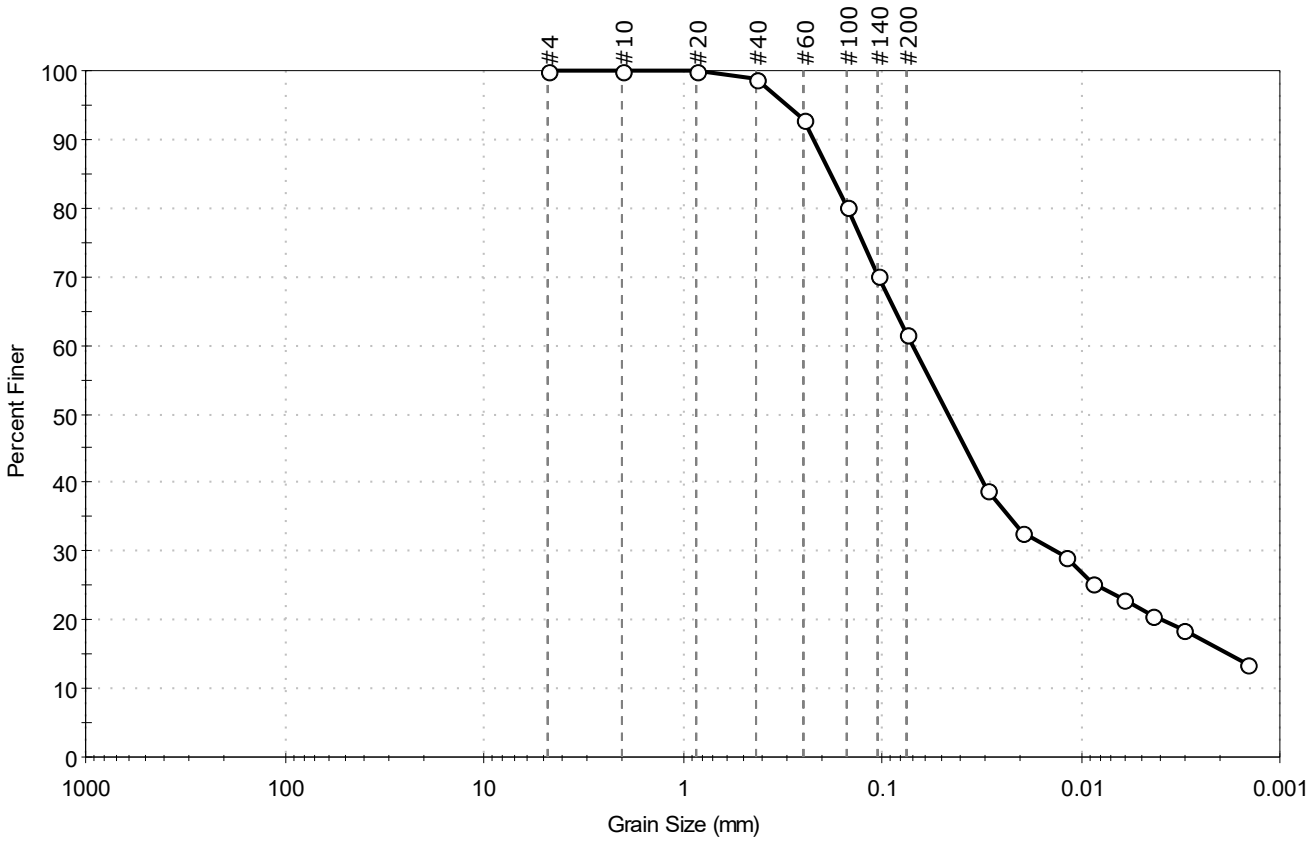
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/19/19	Checked By:	bfs
Depth :	47.90-48.56 ft	Test Id:	532662		
Test Comment:	---				
Visual Description:	Moist, pale brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	38.4	61.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	93		
#100	0.15	80		
#140	0.11	70		
#200	0.075	62		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0299	39		
---	0.0195	33		
---	0.0119	29		
---	0.0087	25		
---	0.0062	23		
---	0.0044	21		
---	0.0031	18		
---	0.0015	14		

Coefficients

D_{85} = 0.1812 mm	D_{30} = 0.0134 mm
D_{60} = 0.0702 mm	D_{15} = 0.0018 mm
D_{50} = 0.0468 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

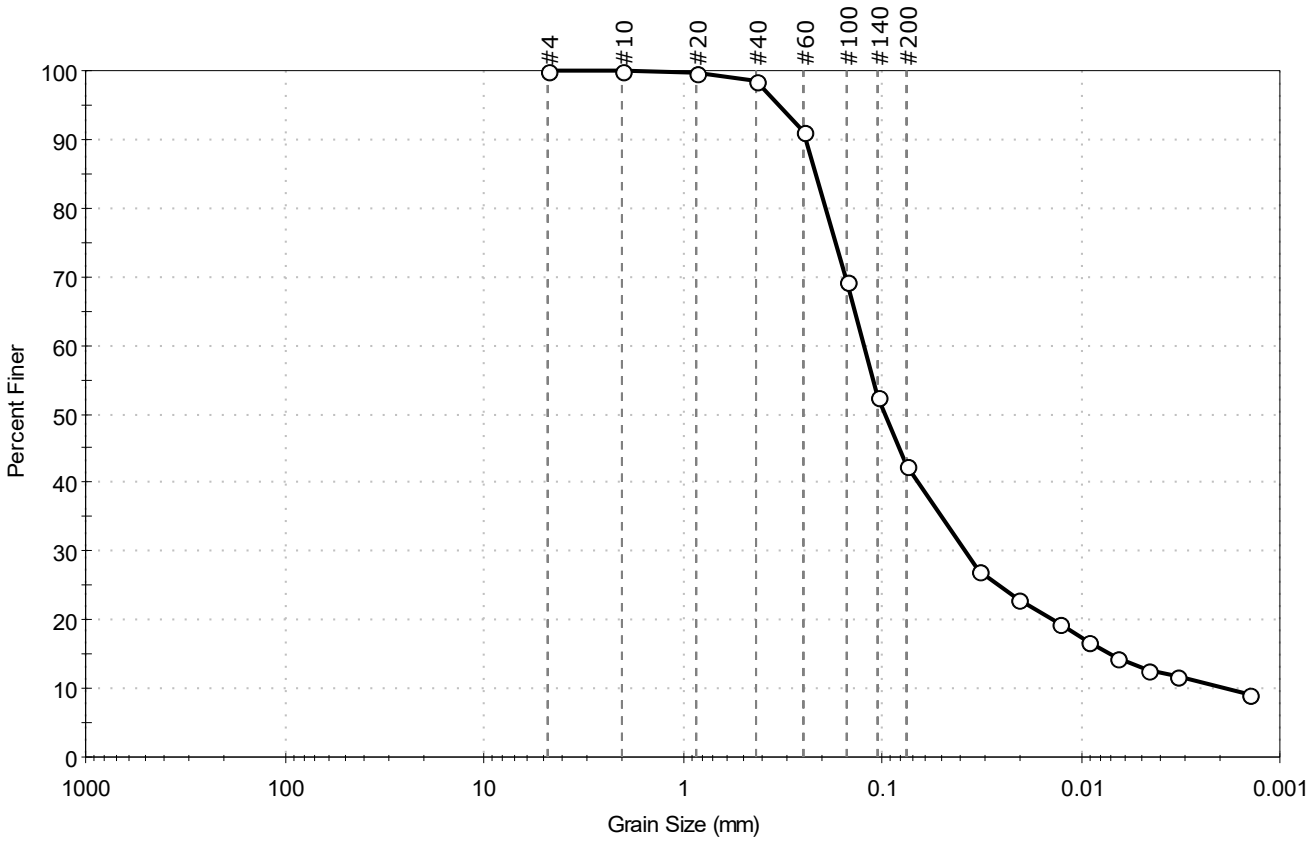
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/31/19	Checked By:	jsc
Depth :	68.24-68.73 ft	Test Id:	532663		
Test Comment:	---				
Visual Description:	Moist, pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	57.5	42.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	91		
#100	0.15	69		
#140	0.11	53		
#200	0.075	43		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0329	27		
---	0.0209	23		
---	0.0127	19		
---	0.0091	17		
---	0.0065	14		
---	0.0046	13		
---	0.0033	12		
---	0.0014	9		

Coefficients

D_{85} =0.2163 mm	D_{30} =0.0382 mm
D_{60} =0.1237 mm	D_{15} =0.0071 mm
D_{50} =0.0971 mm	D_{10} =0.0018 mm
C_u =68.722	C_c =6.554

Classification

ASTM Silty SAND (SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

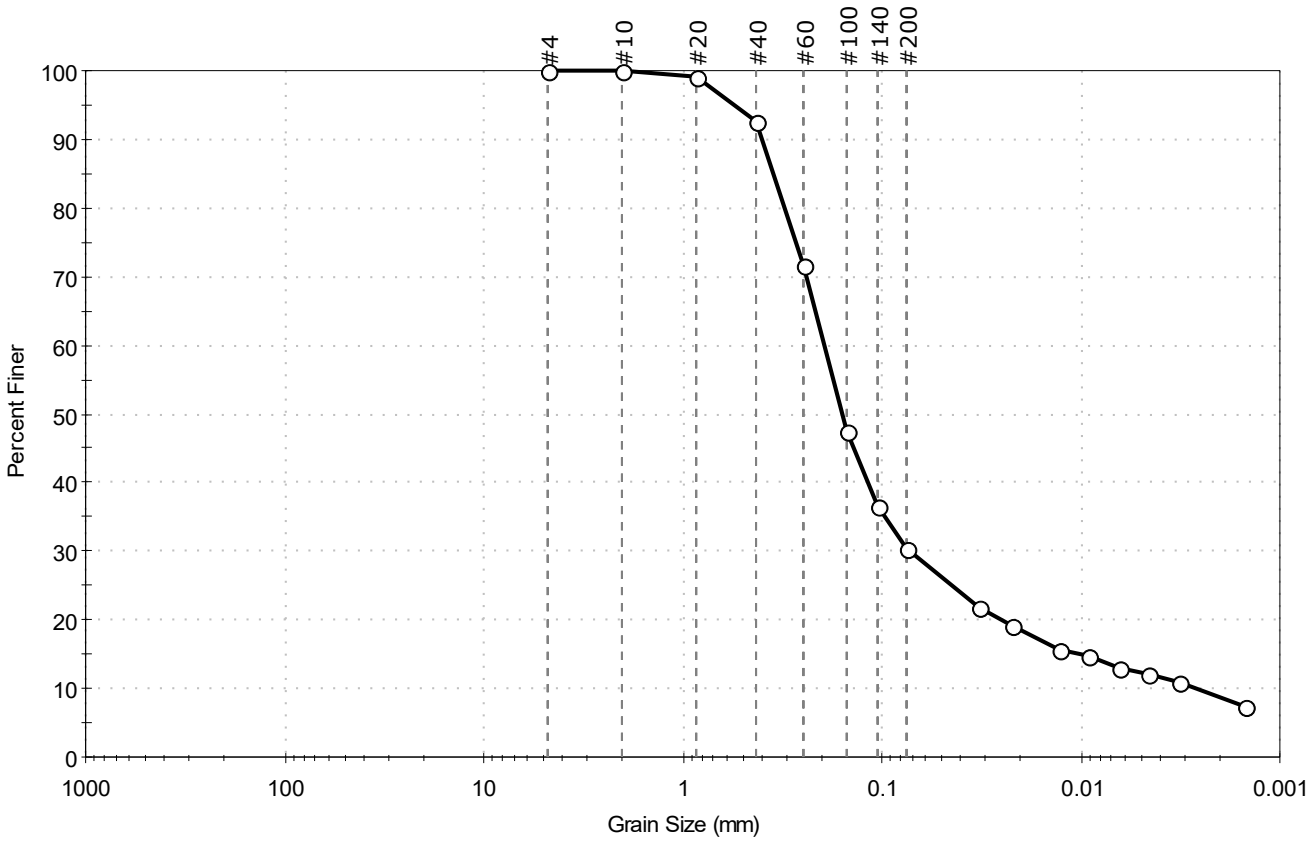
Dispersion Period : 1 minute

Est. Specific Gravity : 2.608

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/20/19	Checked By:	bfs
Depth :	93.01-93.50 ft	Test Id:	532664		
Test Comment:	---				
Visual Description:	Moist, pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	69.7	30.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	93		
#60	0.25	72		
#100	0.15	48		
#140	0.11	37		
#200	0.075	30		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0328	22		
---	0.0222	19		
---	0.0129	16		
---	0.0092	15		
---	0.0065	13		
---	0.0046	12		
---	0.0032	11		
---	0.0015	7		

Coefficients

D_{85} =0.3513 mm	D_{30} =0.0728 mm
D_{60} =0.1953 mm	D_{15} =0.0105 mm
D_{50} =0.1578 mm	D_{10} =0.0026 mm
C_u =75.115	C_c =10.437

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

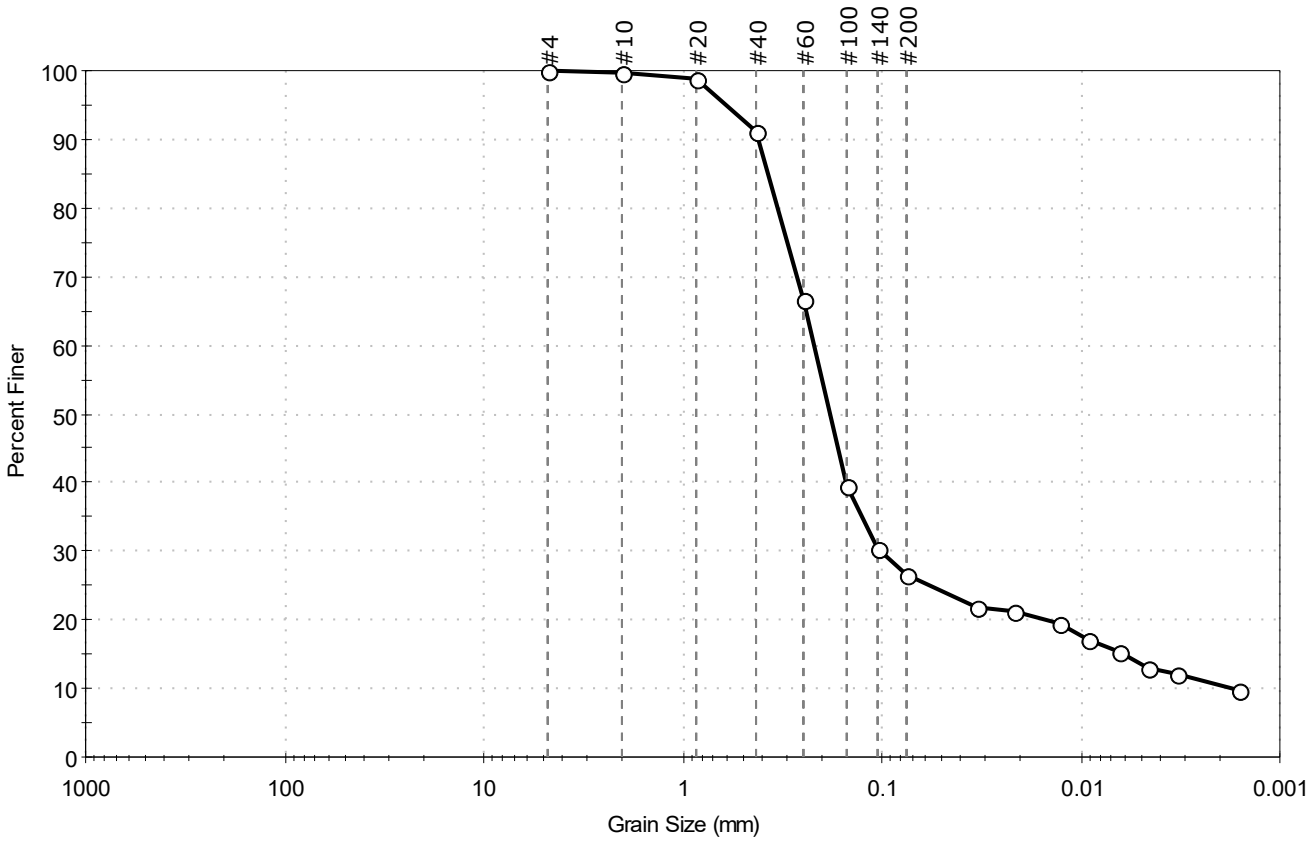
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/31/19	Checked By:	jsc
Depth :	120.08-120.57 ft	Test Id:	532665		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	73.5	26.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	91		
#60	0.25	67		
#100	0.15	40		
#140	0.11	30		
#200	0.075	26		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0334	22		
---	0.0218	21		
---	0.0127	19		
---	0.0091	17		
---	0.0065	15		
---	0.0046	13		
---	0.0033	12		
---	0.0016	10		

Coefficients

D_{85} =0.3715 mm	D_{30} =0.1036 mm
D_{60} =0.2207 mm	D_{15} =0.0062 mm
D_{50} =0.1828 mm	D_{10} =0.0018 mm
C_u =122.611	C_c =27.017

Classification

ASTM Silty, Clayey SAND (SC-SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

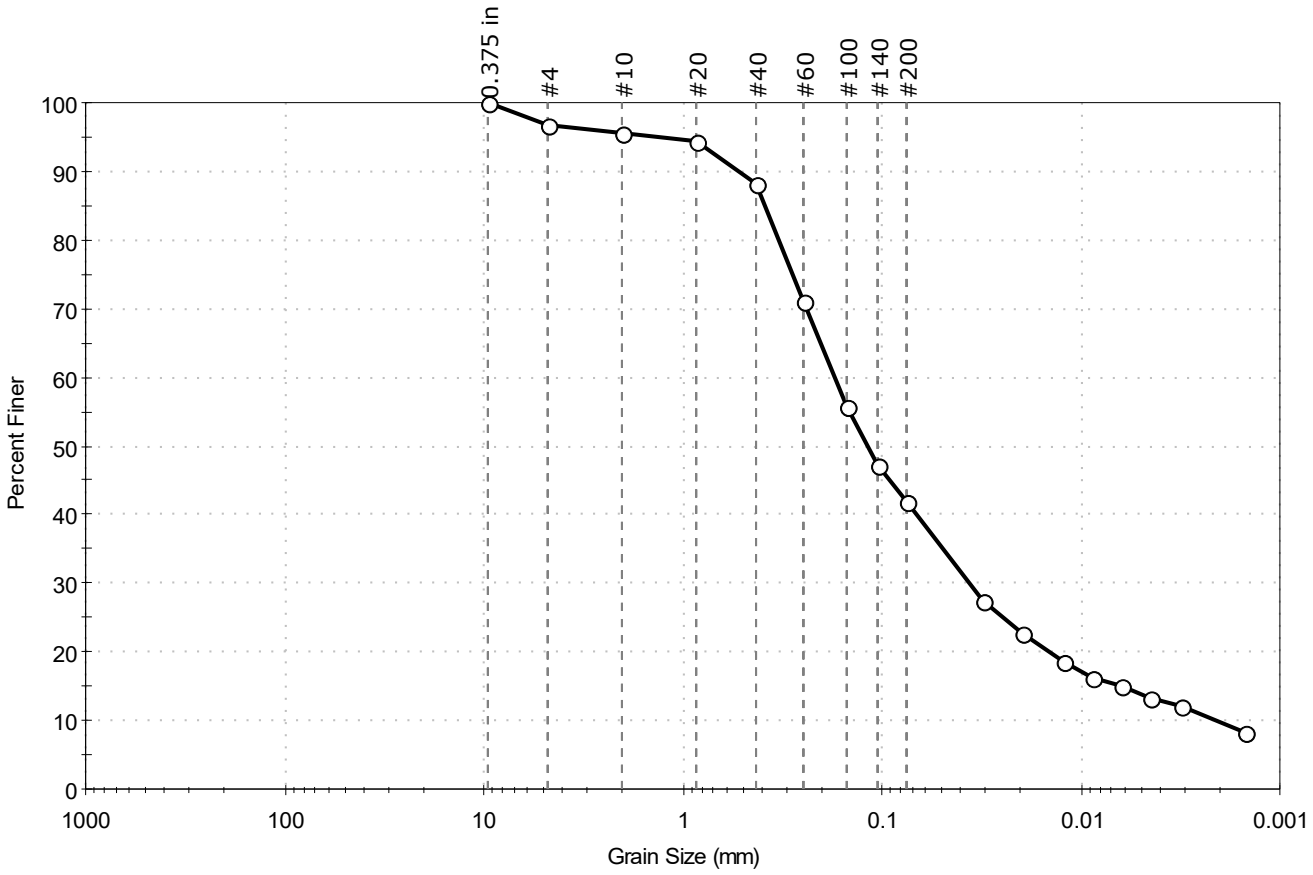
Dispersion Period : 1 minute

Est. Specific Gravity : 2.593

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/19/19	Checked By:	bfs
Depth :	141.90-152.55 ft	Test Id:	532666		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	3.1	55.0	41.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	97		
#10	2.00	96		
#20	0.85	94		
#40	0.42	88		
#60	0.25	71		
#100	0.15	56		
#140	0.11	47		
#200	0.075	42		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0308	27		
---	0.0199	23		
---	0.0123	19		
---	0.0088	16		
---	0.0063	15		
---	0.0045	13		
---	0.0031	12		
---	0.0015	8		

Coefficients

D_{85} =0.3838 mm	D_{30} =0.0361 mm
D_{60} =0.1732 mm	D_{15} =0.0063 mm
D_{50} =0.1185 mm	D_{10} =0.0021 mm
C_u =82.476	C_c =3.583

Classification

ASTM Silty SAND (SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

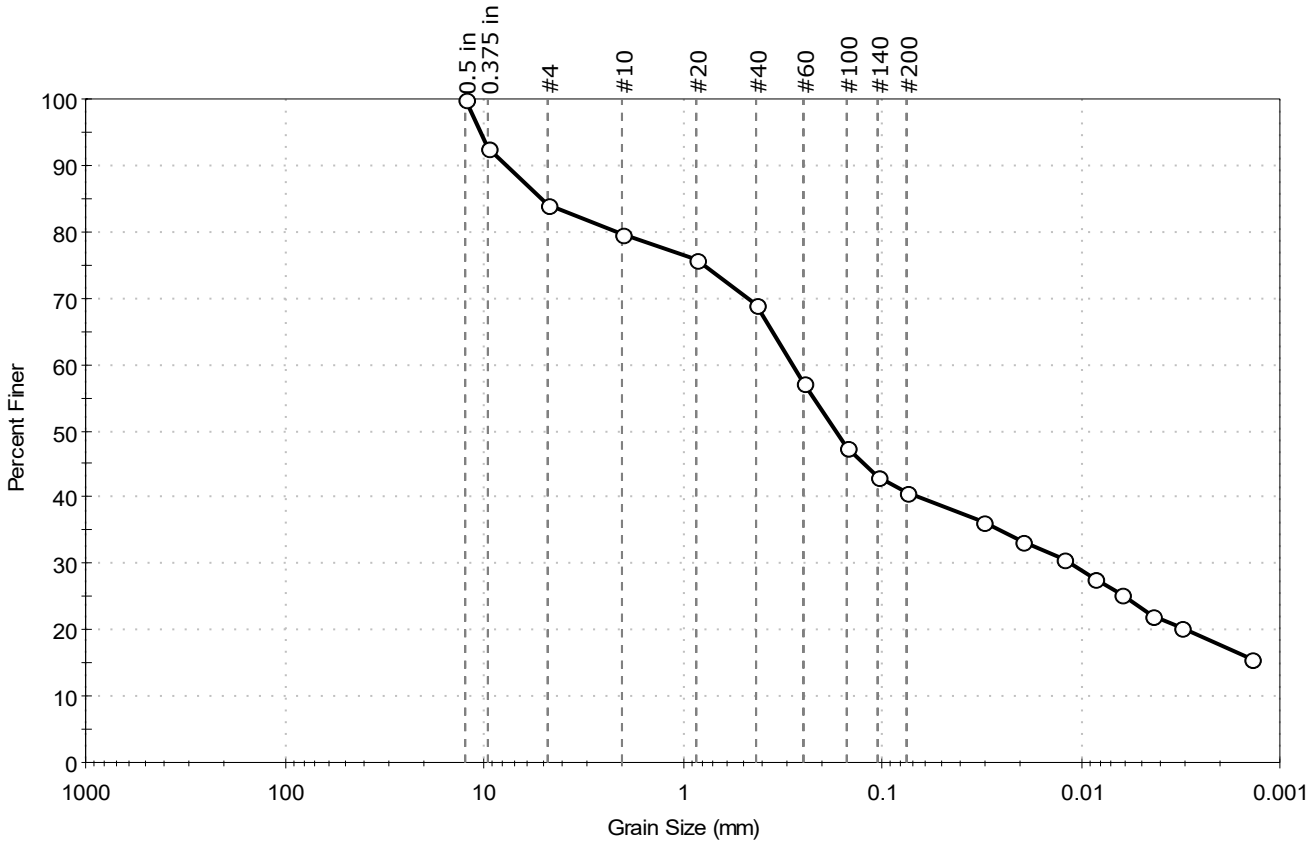
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	12/31/19	Checked By:	jsc
Depth :	156.66-157.32 ft	Test Id:	532667		
Test Comment:	---				
Visual Description:	Dry, pale brown clayey sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	16.1	43.2	40.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	93		
#4	4.75	84		
#10	2.00	80		
#20	0.85	76		
#40	0.42	69		
#60	0.25	57		
#100	0.15	47		
#140	0.11	43		
#200	0.075	41		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0311	36		
---	0.0199	33		
---	0.0121	31		
---	0.0087	28		
---	0.0062	25		
---	0.0044	22		
---	0.0032	20		
---	0.0014	16		

Coefficients

D_{85} = 5.1656 mm	D_{30} = 0.0111 mm
D_{60} = 0.2830 mm	D_{15} = N/A
D_{50} = 0.1711 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Clayey SAND with Gravel (SC)

AASHTO Silty Soils (A-4 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

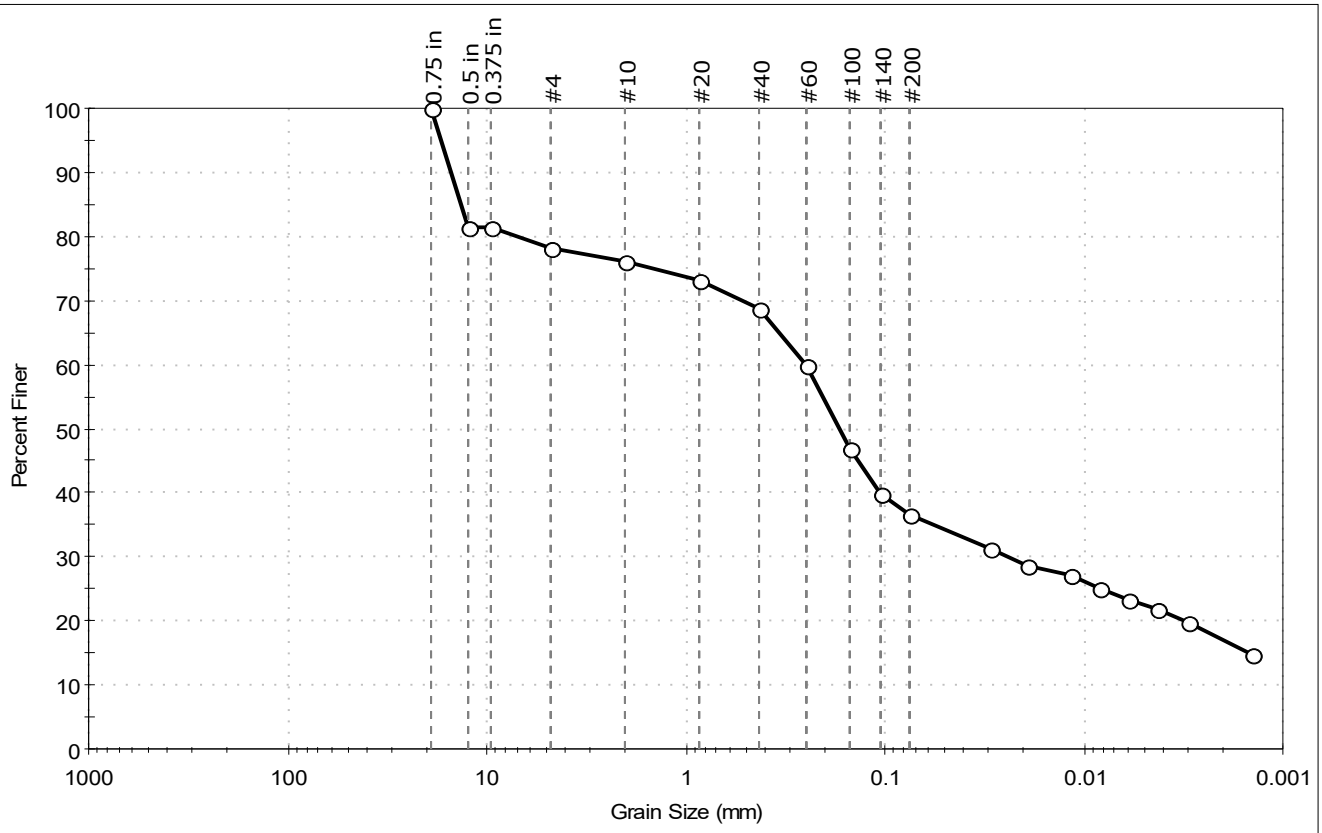
Dispersion Period : 1 minute

Est. Specific Gravity : 2.614

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	12/19/19	Checked By:	bfs
Depth :	174.54-175.03 ft	Test Id:	532641		
Test Comment:	---				
Visual Description:	Dry, pale brown clayey sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	21.7	41.7	36.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	81		
0.375 in	9.50	81		
#4	4.75	78		
#10	2.00	76		
#20	0.85	73		
#40	0.42	69		
#60	0.25	60		
#100	0.15	47		
#140	0.11	40		
#200	0.075	37		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0299	31		
---	0.0191	29		
---	0.0117	27		
---	0.0084	25		
---	0.0060	23		
---	0.0043	22		
---	0.0030	20		
---	0.0014	15		

Coefficients

D_{85} = 13.5585 mm	D_{30} = 0.0238 mm
D_{60} = 0.2514 mm	D_{15} = 0.0015 mm
D_{50} = 0.1694 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Clayey SAND with Gravel (SC)

AASHTO Clayey Soils (A-6 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

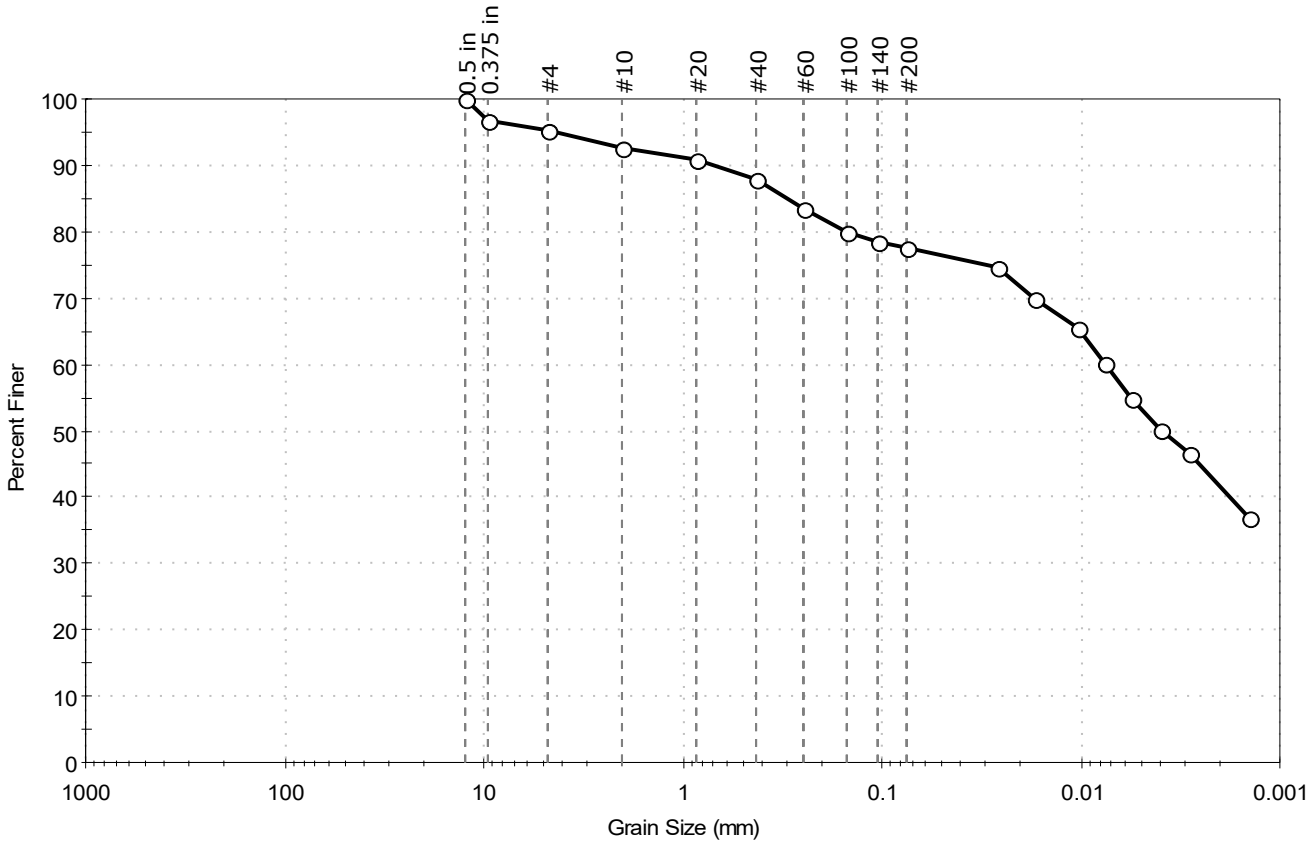
Dispersion Period : 1 minute

Est. Specific Gravity : 2.606

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	12/27/19	Checked By:	jsc
Depth :	180.94-181.43 ft	Test Id:	532642		
Test Comment:	---				
Visual Description:	Moist, pale brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	4.8	17.7	77.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	95		
#10	2.00	93		
#20	0.85	91		
#40	0.42	88		
#60	0.25	83		
#100	0.15	80		
#140	0.11	78		
#200	0.075	77		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0266	75		
---	0.0170	70		
---	0.0105	66		
---	0.0076	60		
---	0.0055	55		
---	0.0040	50		
---	0.0029	47		
---	0.0014	37		

Coefficients

D_{85} =0.3019 mm	D_{30} =N/A
D_{60} =0.0075 mm	D_{15} =N/A
D_{50} =0.0039 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (15))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

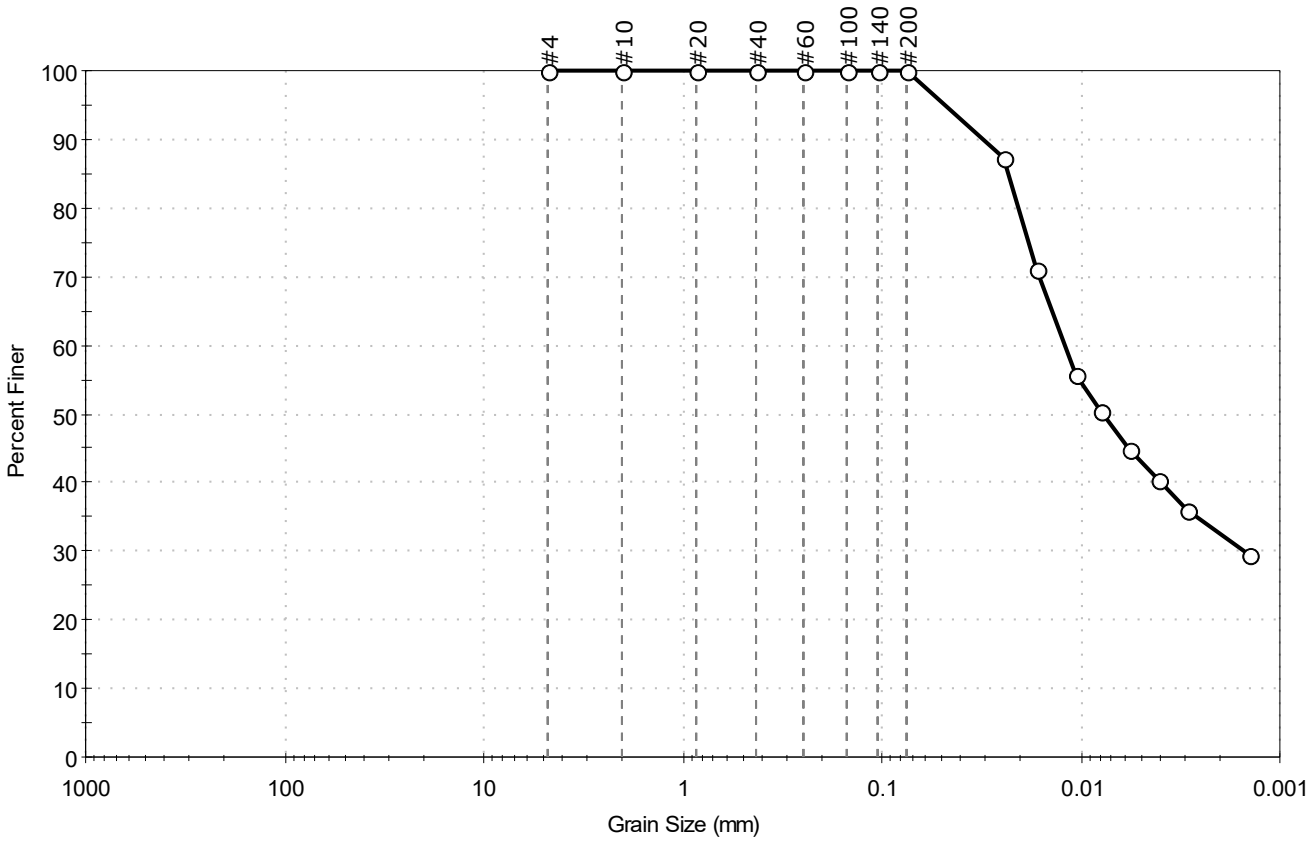
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	12/19/19	Checked By:	bfs
Depth :	185.20-185.70 ft	Test Id:	532643		
Test Comment:	---				
Visual Description:	Moist, pale brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.1	99.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0244	87		
---	0.0168	71		
---	0.0106	56		
---	0.0079	50		
---	0.0057	45		
---	0.0041	40		
---	0.0029	36		
---	0.0014	30		

Coefficients

D_{85} = 0.0231 mm	D_{30} = 0.0015 mm
D_{60} = 0.0120 mm	D_{15} = N/A
D_{50} = 0.0077 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (13))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

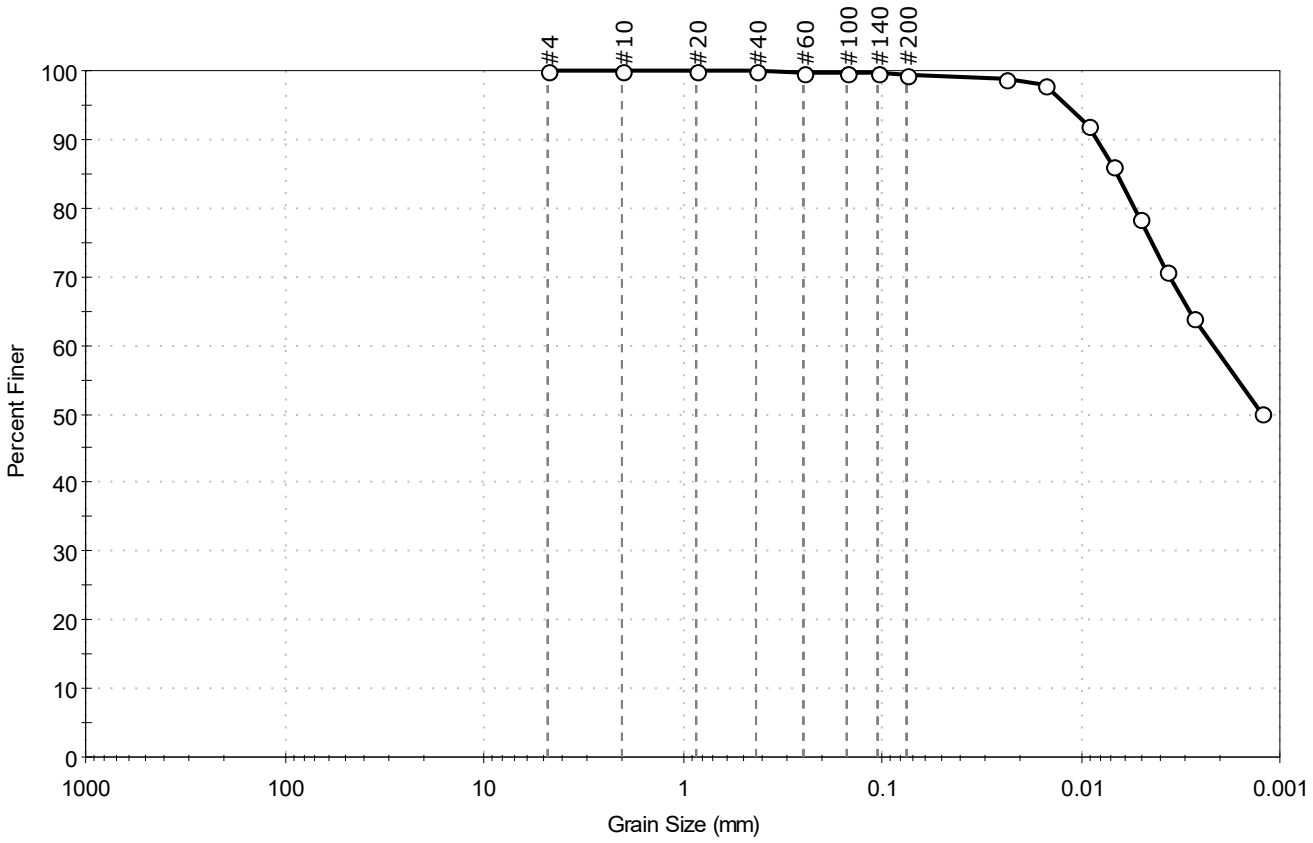
Dispersion Period : 1 minute

Est. Specific Gravity : 2.69

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-010	Test Date:	12/31/19	Checked By:	jsc
Depth :	189.57-190.22 ft	Test Id:	532644		
Test Comment:	---				
Visual Description:	Moist, pale brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.6	99.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	99		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0239	99		
---	0.0151	98		
---	0.0093	92		
---	0.0068	86		
---	0.0051	78		
---	0.0037	71		
---	0.0027	64		
---	0.0012	50		

Coefficients

D_{85} = 0.0065 mm	D_{30} = N/A
D_{60} = 0.0022 mm	D_{15} = N/A
D_{50} = N/A	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-7-6 (29))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

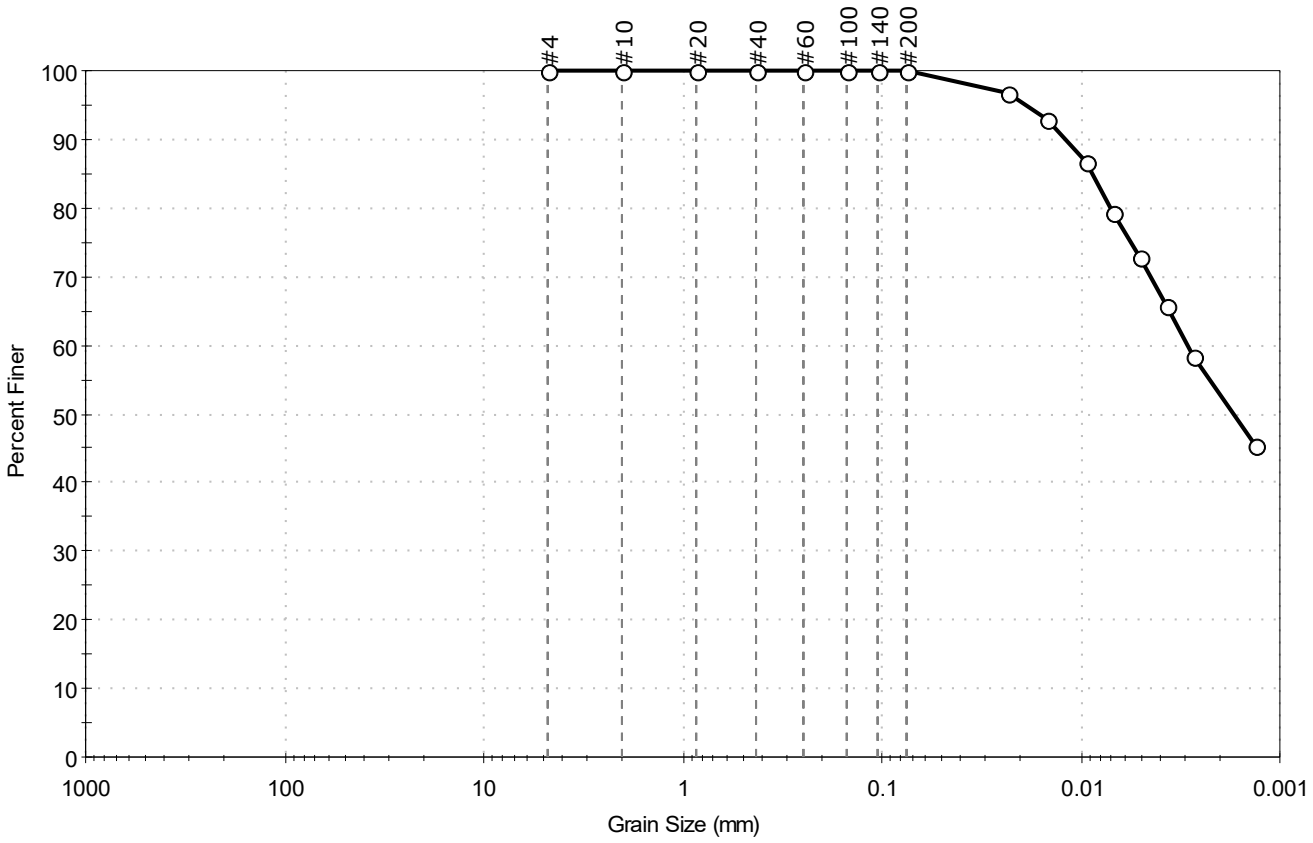
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	12/19/19	Checked By:	bfs
Depth :	193.96-194.42 ft	Test Id:	532645		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.1	99.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0234	97		
---	0.0150	93		
---	0.0094	87		
---	0.0070	79		
---	0.0051	73		
---	0.0037	66		
---	0.0027	58		
---	0.0013	45		

Coefficients

D_{85} = 0.0088 mm	D_{30} = N/A
D_{60} = 0.0029 mm	D_{15} = N/A
D_{50} = 0.0017 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-7-6 (25))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

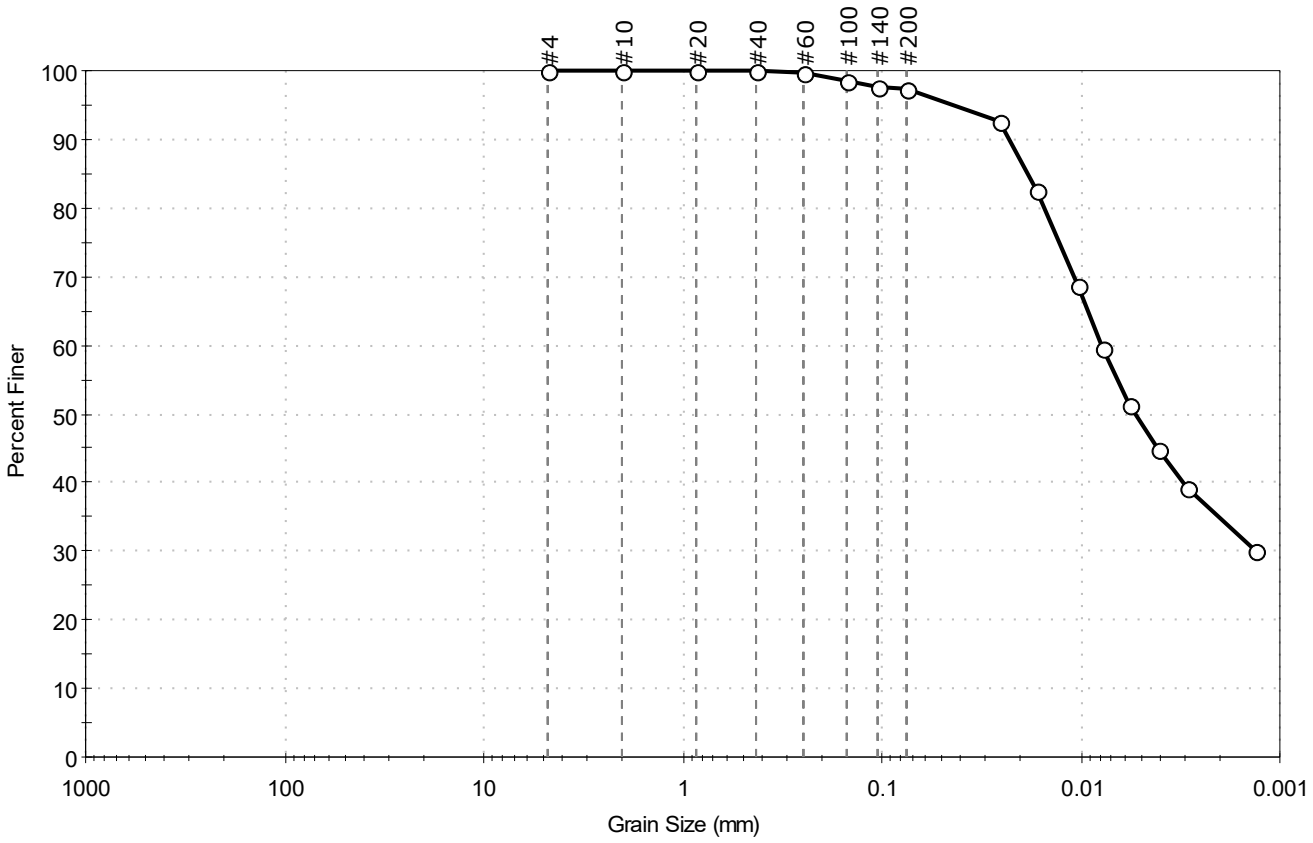
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-012	Test Date:	12/31/19	Checked By:	jsc
Depth :	200.85-201.41 ft	Test Id:	532646		
Test Comment:	---				
Visual Description:	Moist, pale brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.7	97.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	99		
#140	0.11	98		
#200	0.075	97		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0259	93		
---	0.0168	83		
---	0.0104	69		
---	0.0077	60		
---	0.0056	51		
---	0.0041	45		
---	0.0030	39		
---	0.0013	30		

Coefficients

D_{85} = 0.0186 mm	D_{30} = N/A
D_{60} = 0.0078 mm	D_{15} = N/A
D_{50} = 0.0053 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (12))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

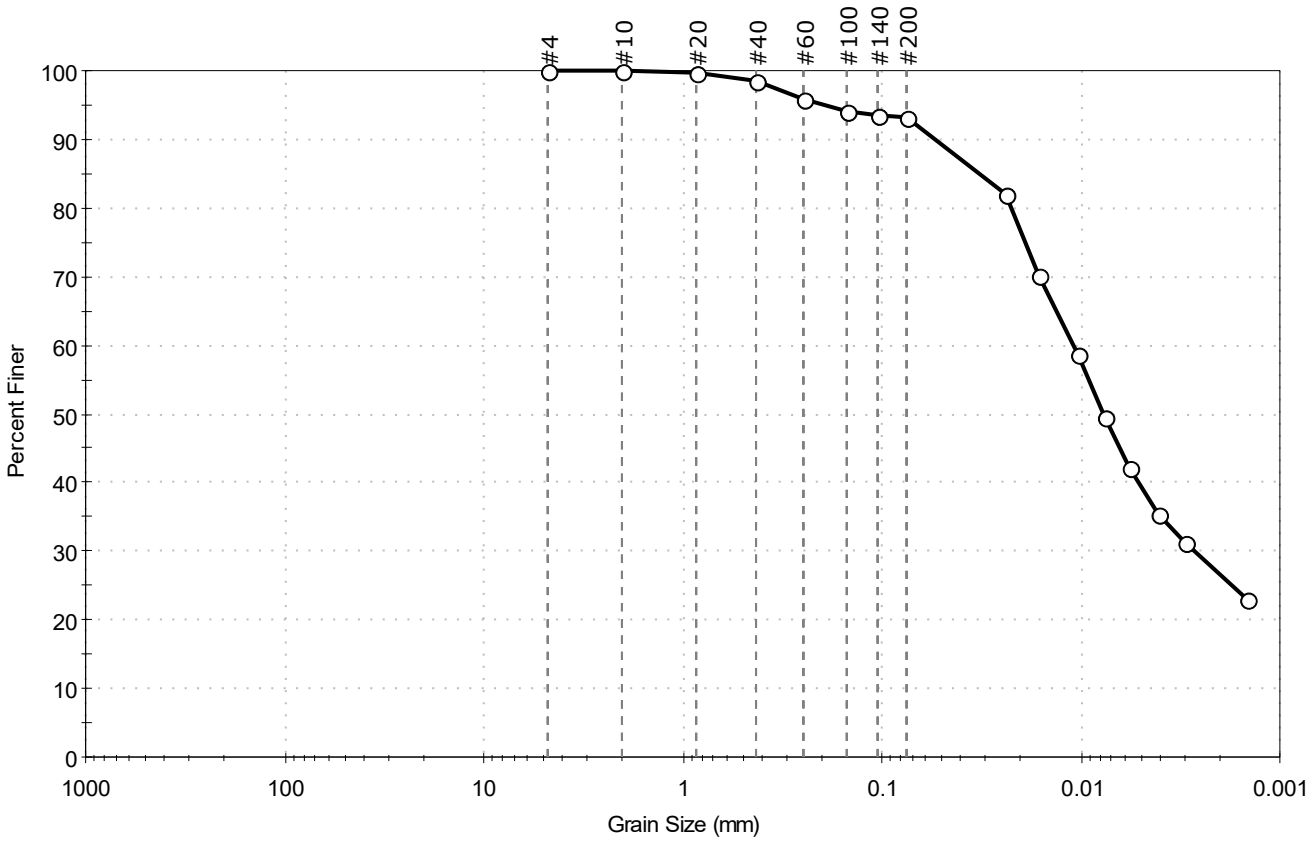
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	12/27/19	Checked By:	jsc
Depth :	204.33-204.92 ft	Test Id:	533653		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	6.8	93.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	96		
#100	0.15	94		
#140	0.11	93		
#200	0.075	93		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0240	82		
---	0.0161	70		
---	0.0104	59		
---	0.0077	50		
---	0.0057	42		
---	0.0041	35		
---	0.0030	31		
---	0.0015	23		

Coefficients

D_{85} = 0.0329 mm	D_{30} = 0.0026 mm
D_{60} = 0.0110 mm	D_{15} = N/A
D_{50} = 0.0078 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Silty Soils (A-4 (5))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

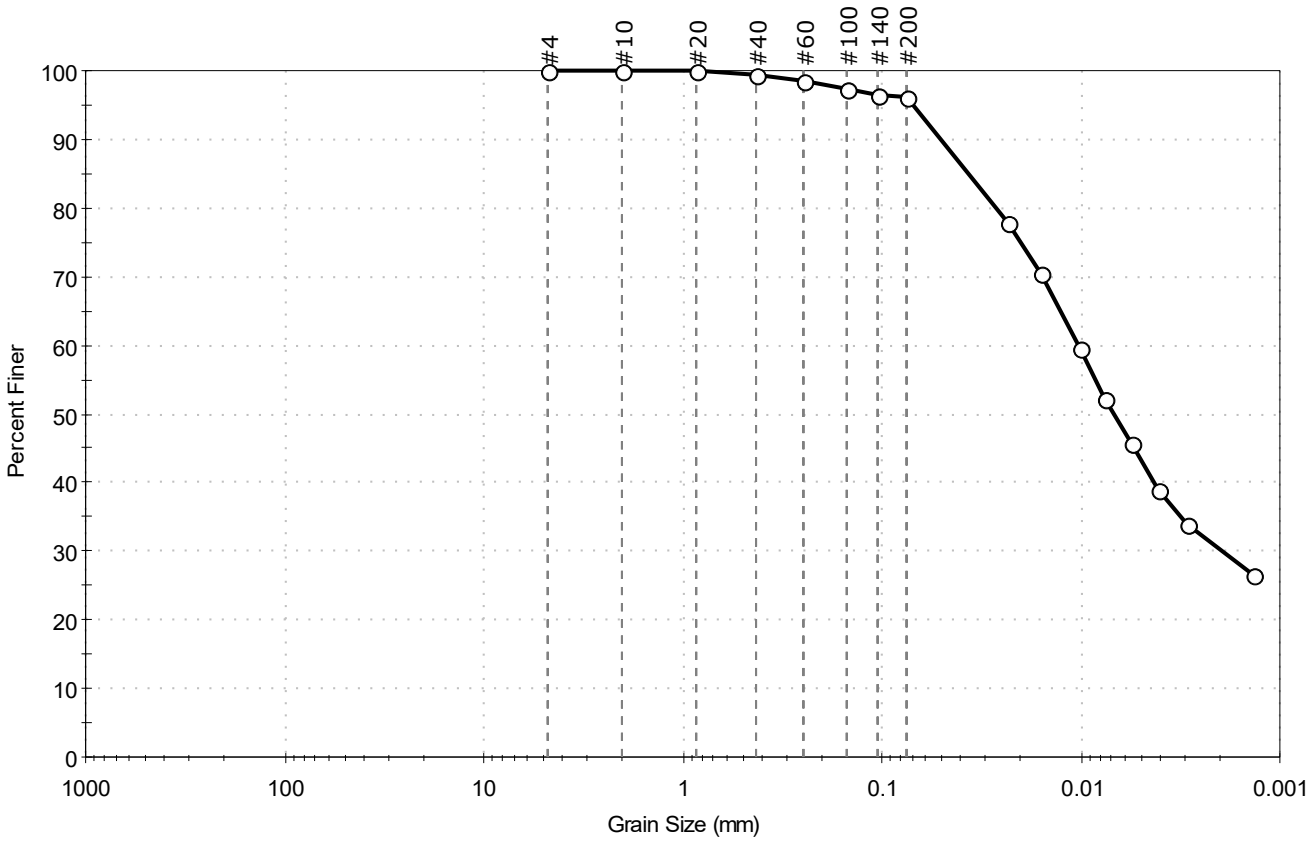
Dispersion Period : 1 minute

Est. Specific Gravity : 2.705

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	12/20/19	Checked By:	bfs
Depth :	208.75-209.42 ft	Test Id:	533654		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	4.0	96.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	98		
#100	0.15	97		
#140	0.11	97		
#200	0.075	96		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0233	78		
---	0.0160	71		
---	0.0102	60		
---	0.0075	52		
---	0.0055	46		
---	0.0040	39		
---	0.0029	34		
---	0.0014	27		

Coefficients

D_{85} = 0.0368 mm	D_{30} = 0.0019 mm
D_{60} = 0.0103 mm	D_{15} = N/A
D_{50} = 0.0068 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (8))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

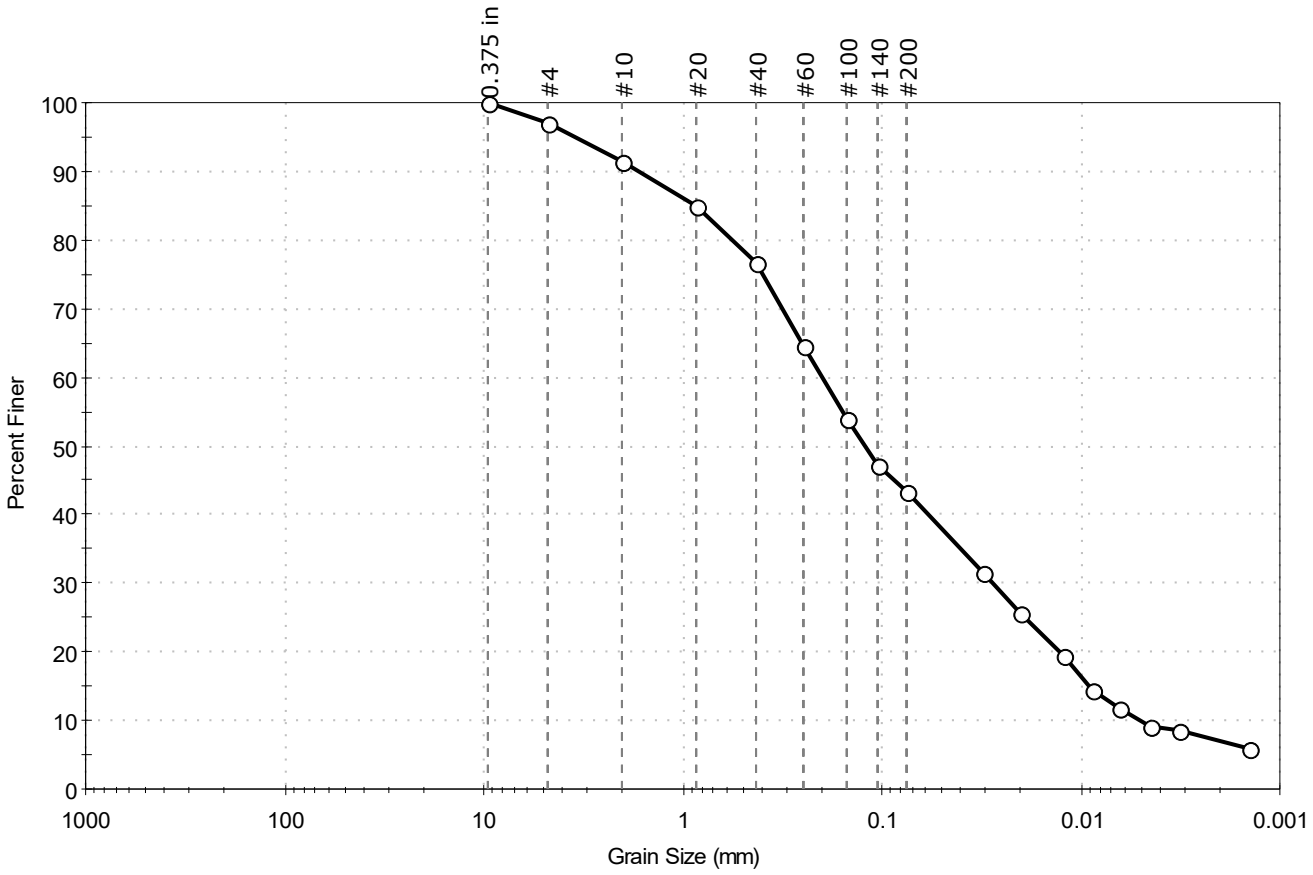
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	12/31/19	Checked By:	jsc
Depth :	218.50-219.00 ft	Test Id:	533655		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	3.0	53.7	43.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	97		
#10	2.00	91		
#20	0.85	85		
#40	0.42	77		
#60	0.25	65		
#100	0.15	54		
#140	0.11	47		
#200	0.075	43		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0312	32		
---	0.0200	26		
---	0.0123	20		
---	0.0089	14		
---	0.0064	12		
---	0.0045	9		
---	0.0032	8		
---	0.0014	6		

Coefficients

D_{85} =0.8506 mm	D_{30} =0.0278 mm
D_{60} =0.2008 mm	D_{15} =0.0092 mm
D_{50} =0.1227 mm	D_{10} =0.0050 mm
C_u =40.160	C_c =0.770

Classification

ASTM Silty SAND (SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

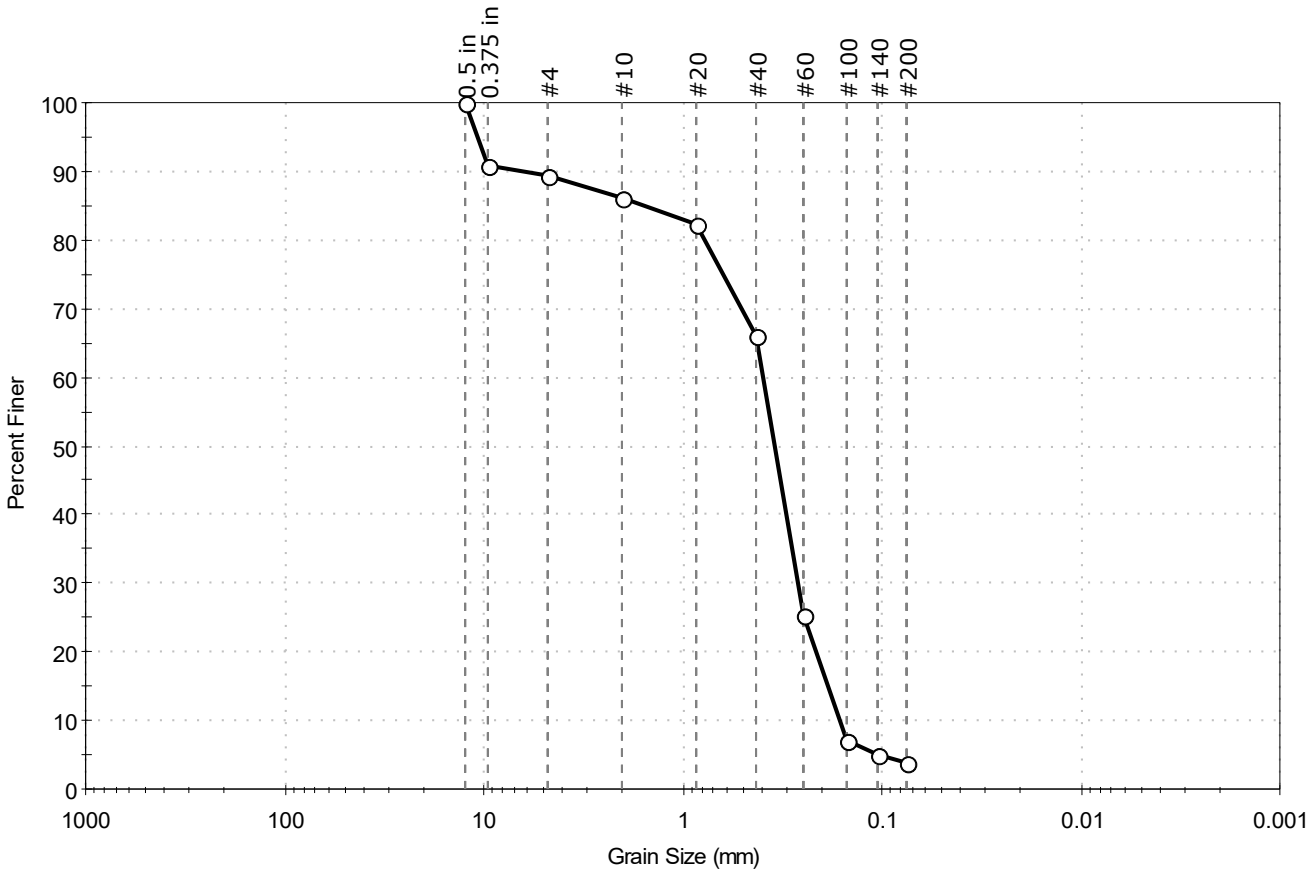
Dispersion Period : 1 minute

Est. Specific Gravity : 2.707

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	jar	Tested By:	GA
Sample ID:	SS-001A	Test Date:	07/31/19	Checked By:	jsc
Depth :	60-60.5	Test Id:	514356		
Test Comment:	---				
Visual Description:	Moist, light brownish gray sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	10.7	85.4	3.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	91		
#4	4.75	89		
#10	2.00	86		
#20	0.85	82		
#40	0.42	66		
#60	0.25	25		
#100	0.15	7		
#140	0.11	5		
#200	0.075	3.9		

Coefficients

D_{85} = 1.5138 mm
D_{30} = 0.2658 mm
D_{60} = 0.3932 mm
D_{15} = 0.1875 mm
D_{50} = 0.3451 mm
D_{10} = 0.1630 mm
C_u = 2.412
C_c = 1.102

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

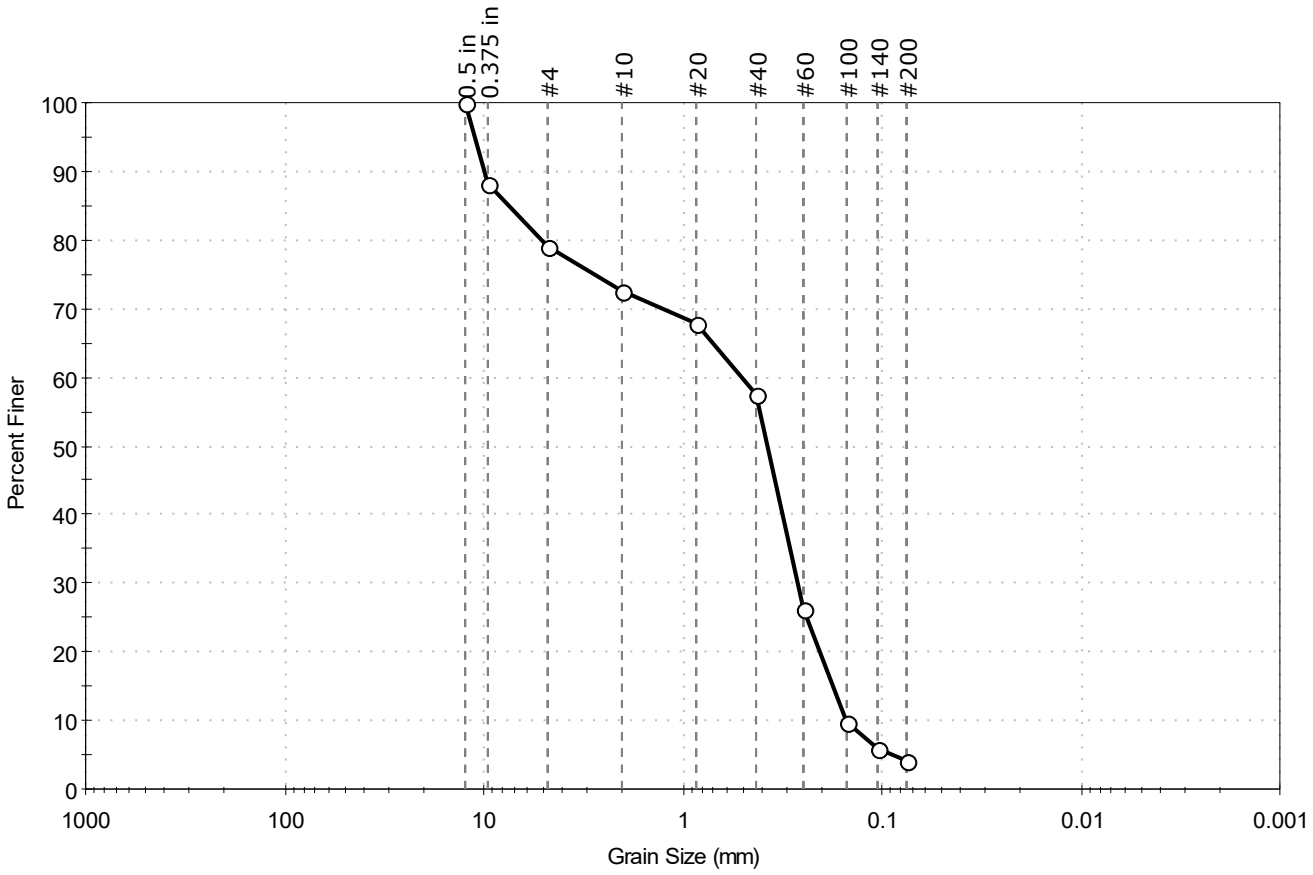
Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	jar	Tested By:	GA
Sample ID:	SS-002	Test Date:	07/31/19	Checked By:	jsc
Depth :	70-72	Test Id:	514357		
Test Comment:	---				
Visual Description:	Moist, light brownish gray sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	20.8	75.1	4.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	88		
#4	4.75	79		
#10	2.00	72		
#20	0.85	68		
#40	0.42	58		
#60	0.25	26		
#100	0.15	10		
#140	0.11	6		
#200	0.075	4.1		

Coefficients

D_{85} = 7.3935 mm D_{30} = 0.2667 mm

D_{60} = 0.5028 mm D_{15} = 0.1768 mm

D_{50} = 0.3741 mm D_{10} = 0.1515 mm

C_u = 3.319 C_c = 0.934

Classification

ASTM Poorly graded SAND with Gravel (SP)

AASHTO Fine Sand (A-3 (1))

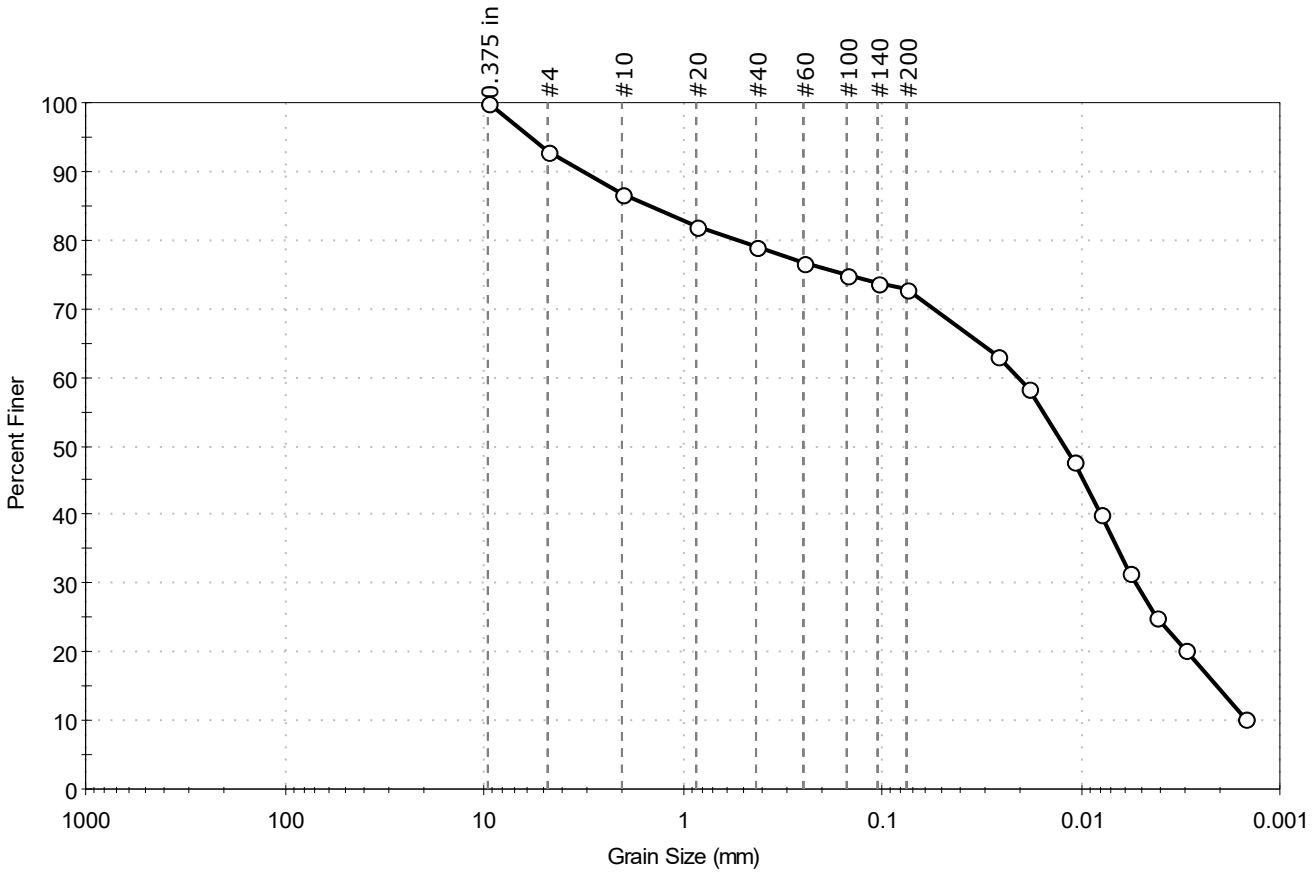
Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	jar	Tested By:	GA
Sample ID:	SS-005	Test Date:	07/31/19	Checked By:	jsc
Depth :	100-102	Test Id:	514358		
Test Comment:	---				
Visual Description:	Moist, gray silty clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	7.1	20.0	72.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	93		
#10	2.00	87		
#20	0.85	82		
#40	0.42	79		
#60	0.25	77		
#100	0.15	75		
#140	0.11	74		
#200	0.075	73		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0266	63		
---	0.0182	58		
---	0.0109	48		
---	0.0079	40		
---	0.0058	32		
---	0.0042	25		
---	0.0030	20		
---	0.0015	10		

Coefficients

D_{85} = 1.4415 mm	D_{30} = 0.0053 mm
D_{60} = 0.0208 mm	D_{15} = 0.0021 mm
D_{50} = 0.0121 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty CLAY with Sand (CL-ML)

AASHTO Silty Soils (A-4 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

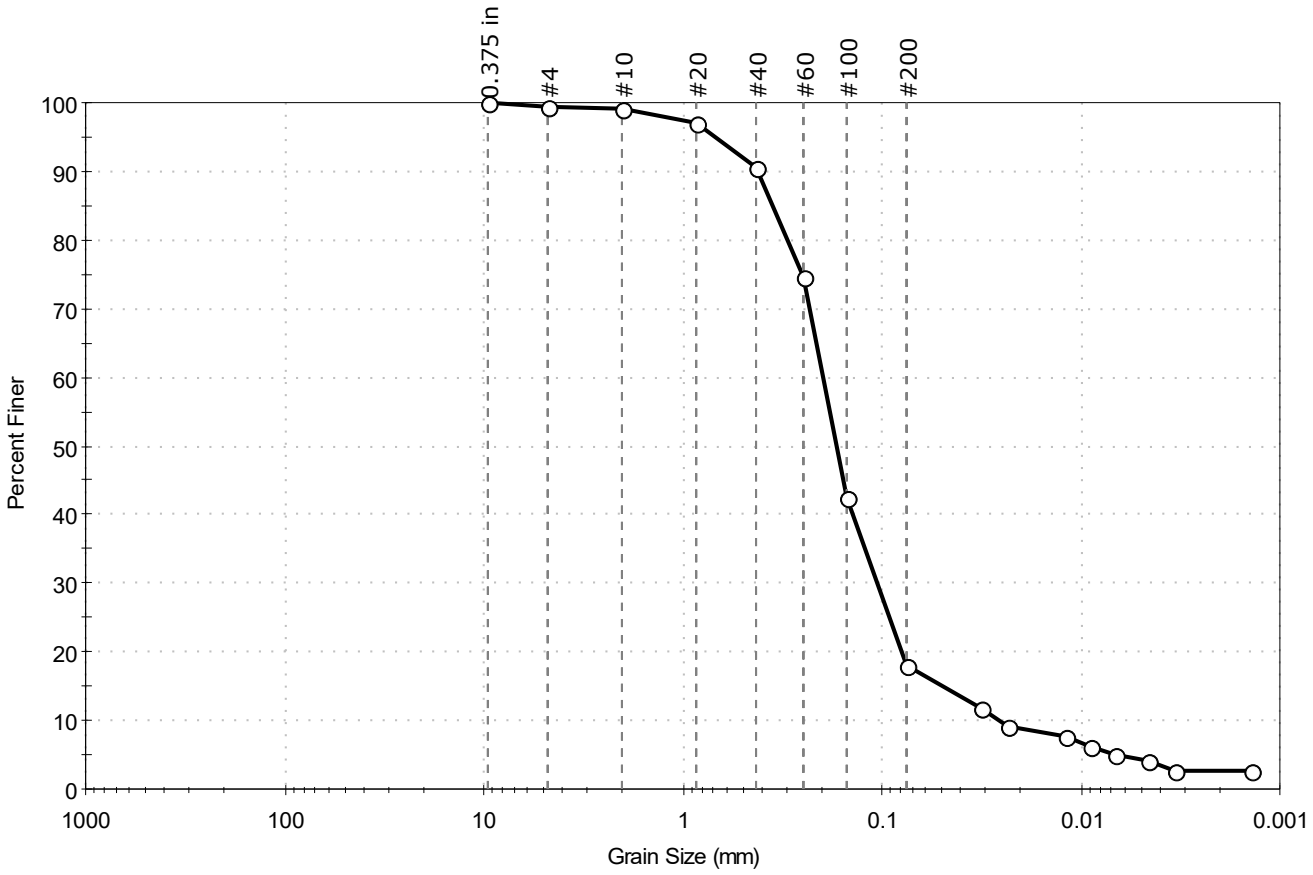
Dispersion Period : 1 minute

Est. Specific Gravity : 2.838

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-001	Test Date:	07/29/19	Checked By:	jsc
Depth :	69-70 ft	Test Id:	514185		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.7	81.3	18.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	99		
#20	0.85	97		
#40	0.42	91		
#60	0.25	75		
#100	0.15	42		
#200	0.075	18		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0319	12		
---	0.0231	9		
---	0.0121	8		
---	0.0090	6		
---	0.0067	5		
---	0.0046	4		
---	0.0033	3		
---	0.0014	3		

Coefficients

D_{85} = 0.3533 mm	D_{30} = 0.1055 mm
D_{60} = 0.1982 mm	D_{15} = 0.0491 mm
D_{50} = 0.1692 mm	D_{10} = 0.0256 mm
C_u = 7.742	C_c = 2.194

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

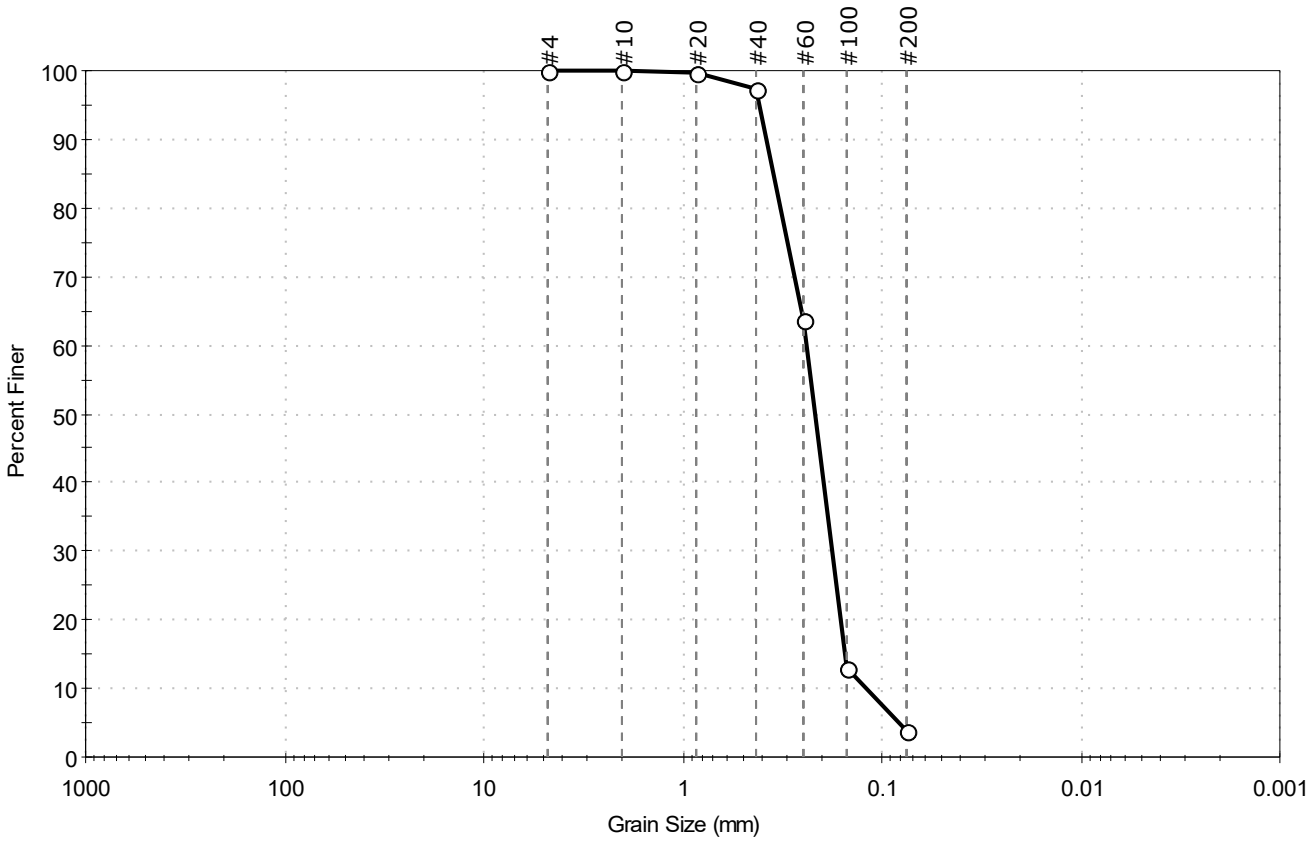
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-003	Test Date:	07/29/19	Checked By:	jsc
Depth :	90-92 ft	Test Id:	514186		
Test Comment:	---				
Visual Description:	Moist, pink sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	96.1	3.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	97		
#60	0.25	64		
#100	0.15	13		
#200	0.075	3.9		

Coefficients

D_{85} = 0.3495 mm	D_{30} = 0.1780 mm
D_{60} = 0.2406 mm	D_{15} = 0.1532 mm
D_{50} = 0.2176 mm	D_{10} = 0.1198 mm
C_u = 2.008	C_c = 1.099

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

Sample/Test Description

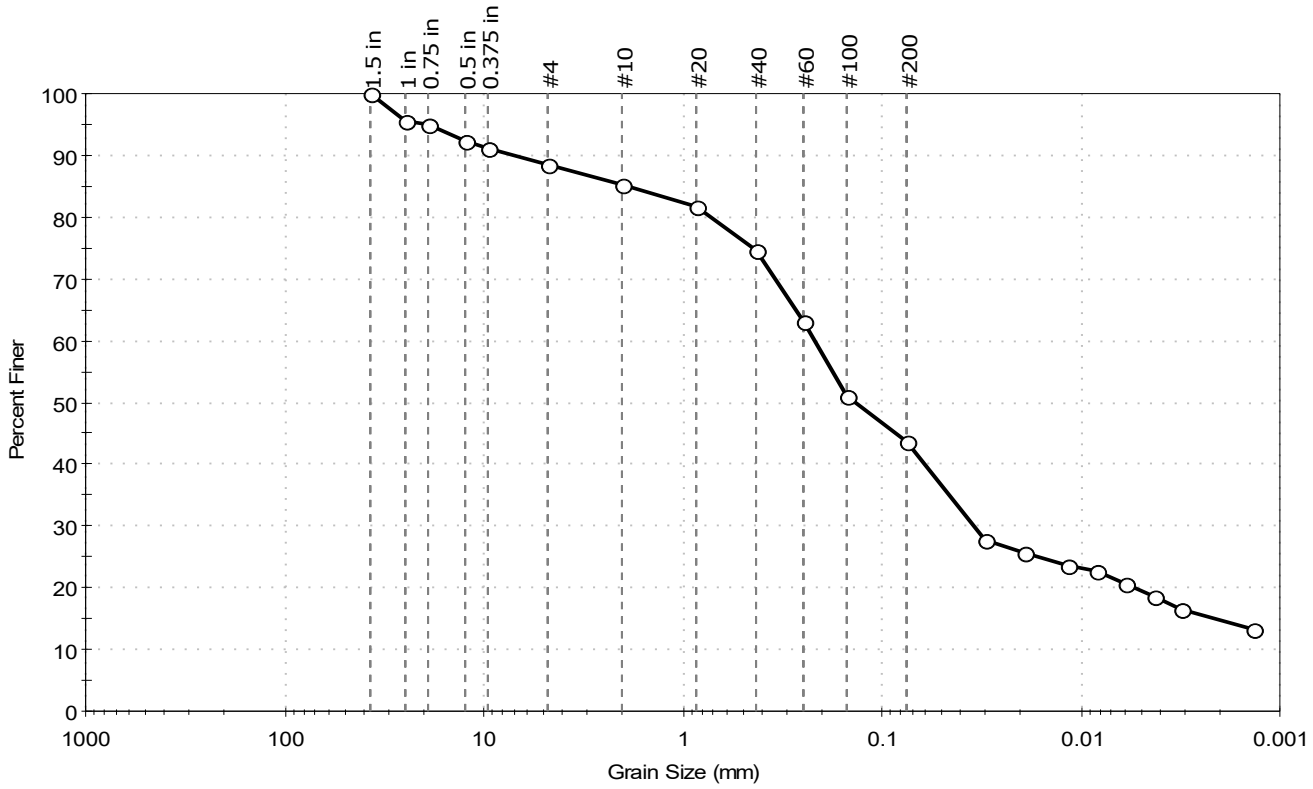
Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-001	Test Date:	08/13/19	Checked By:	jsc
Depth :	94-95 ft	Test Id:	516902		
Test Comment:	---				
Visual Description:	Moist, pale red silty with gravel and sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
--	11.6	44.7	43.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	96		
0.75 in	19.00	95		
0.5 in	12.50	92		
0.375 in	9.50	91		
#4	4.75	88		
#10	2.00	85		
#20	0.85	82		
#40	0.42	75		
#60	0.25	63		
#100	0.15	51		
#200	0.075	44		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0300	28		
---	0.0194	26		
---	0.0117	24		
---	0.0084	23		
---	0.0060	21		
---	0.0043	19		
---	0.0031	16		
---	0.0014	13		

Coefficients

D_{85} = 1.8712 mm D_{30} = 0.0340 mm
D_{60} = 0.2192 mm D_{15} = 0.0021 mm
D_{50} = 0.1346 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM N/A

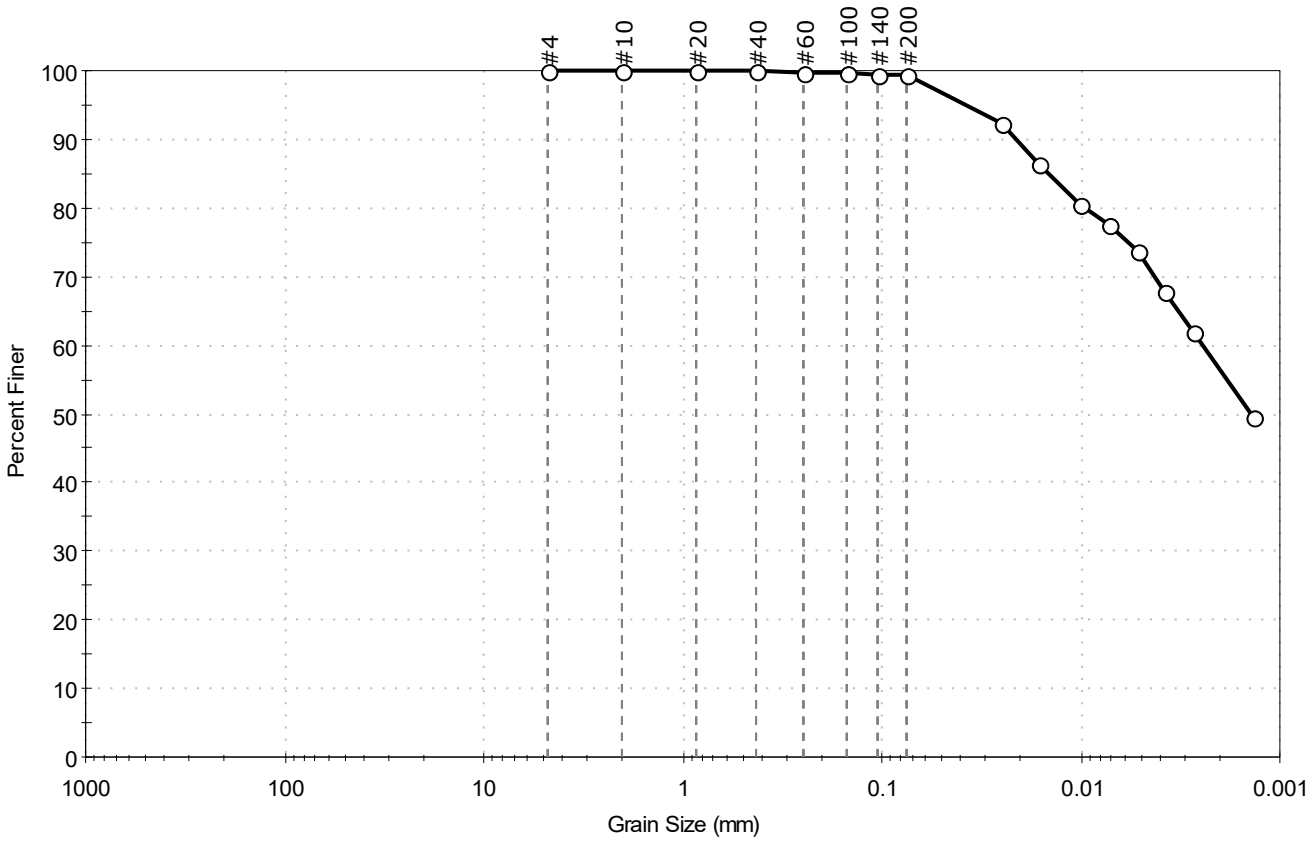
AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.65
Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/19/19	Checked By:	bfs
Depth :	34.91-35.30 ft	Test Id:	532760		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.6	99.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	99		
#200	0.075	99		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0252	92		
---	0.0164	86		
---	0.0101	81		
---	0.0073	78		
---	0.0052	74		
---	0.0038	68		
---	0.0028	62		
---	0.0014	49		

Coefficients

D_{85} = 0.0146 mm D_{30} = N/A
D_{60} = 0.0025 mm D_{15} = N/A
D_{50} = 0.0014 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM Fat CLAY (CH)

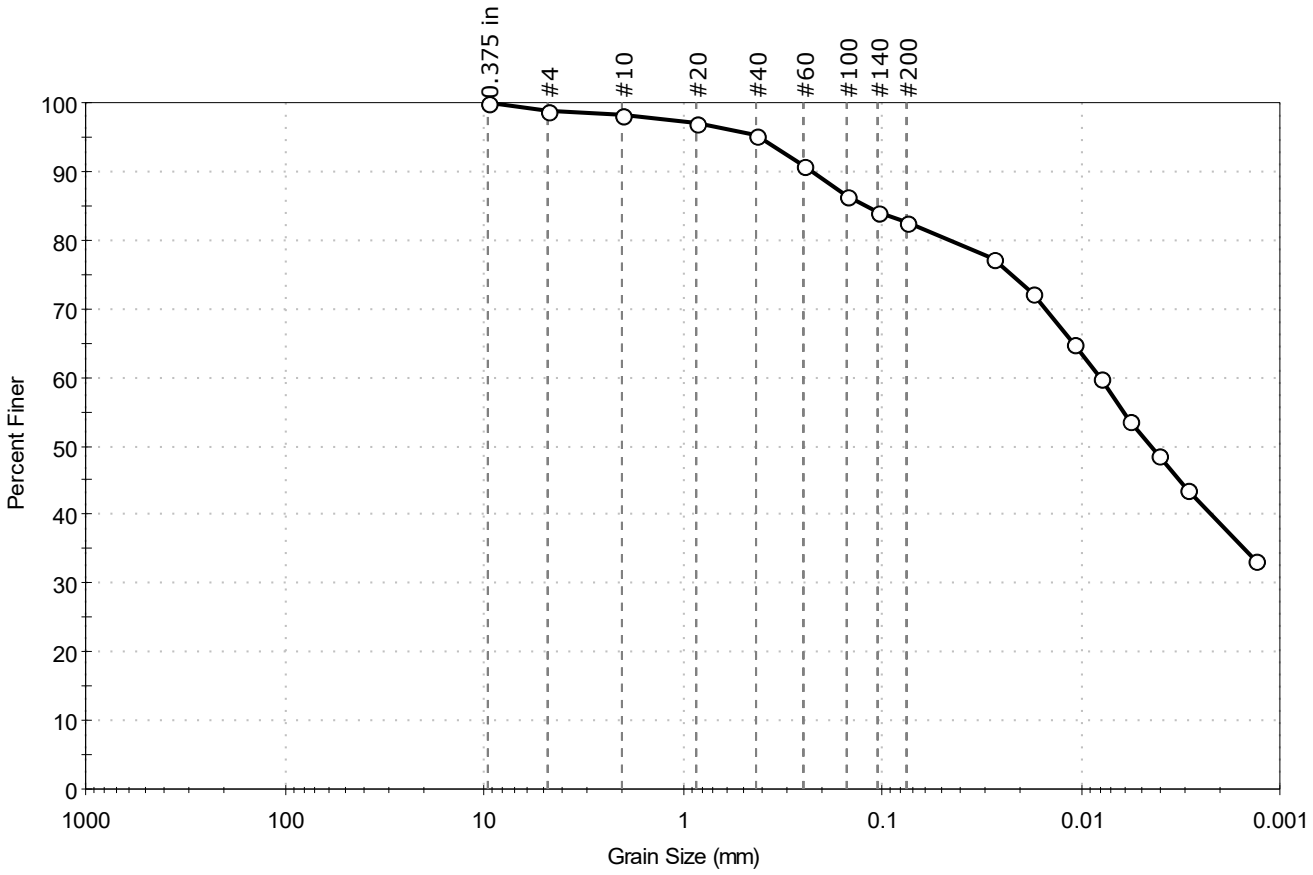
AASHTO Clayey Soils (A-7-6 (41))

Sample/Test Description

Sand/Gravel Particle Shape : ---
Sand/Gravel Hardness : ---
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.615
Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/31/19	Checked By:	jsc
Depth :	39.24-39.70 ft	Test Id:	532761		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.1	16.3	82.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	98		
#20	0.85	97		
#40	0.42	95		
#60	0.25	91		
#100	0.15	86		
#140	0.11	84		
#200	0.075	83		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0274	77		
---	0.0175	72		
---	0.0110	65		
---	0.0079	60		
---	0.0057	54		
---	0.0041	49		
---	0.0030	44		
---	0.0013	33		

Coefficients

D_{85} = 0.1220 mm	D_{30} = N/A
D_{60} = 0.0080 mm	D_{15} = N/A
D_{50} = 0.0045 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (11))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

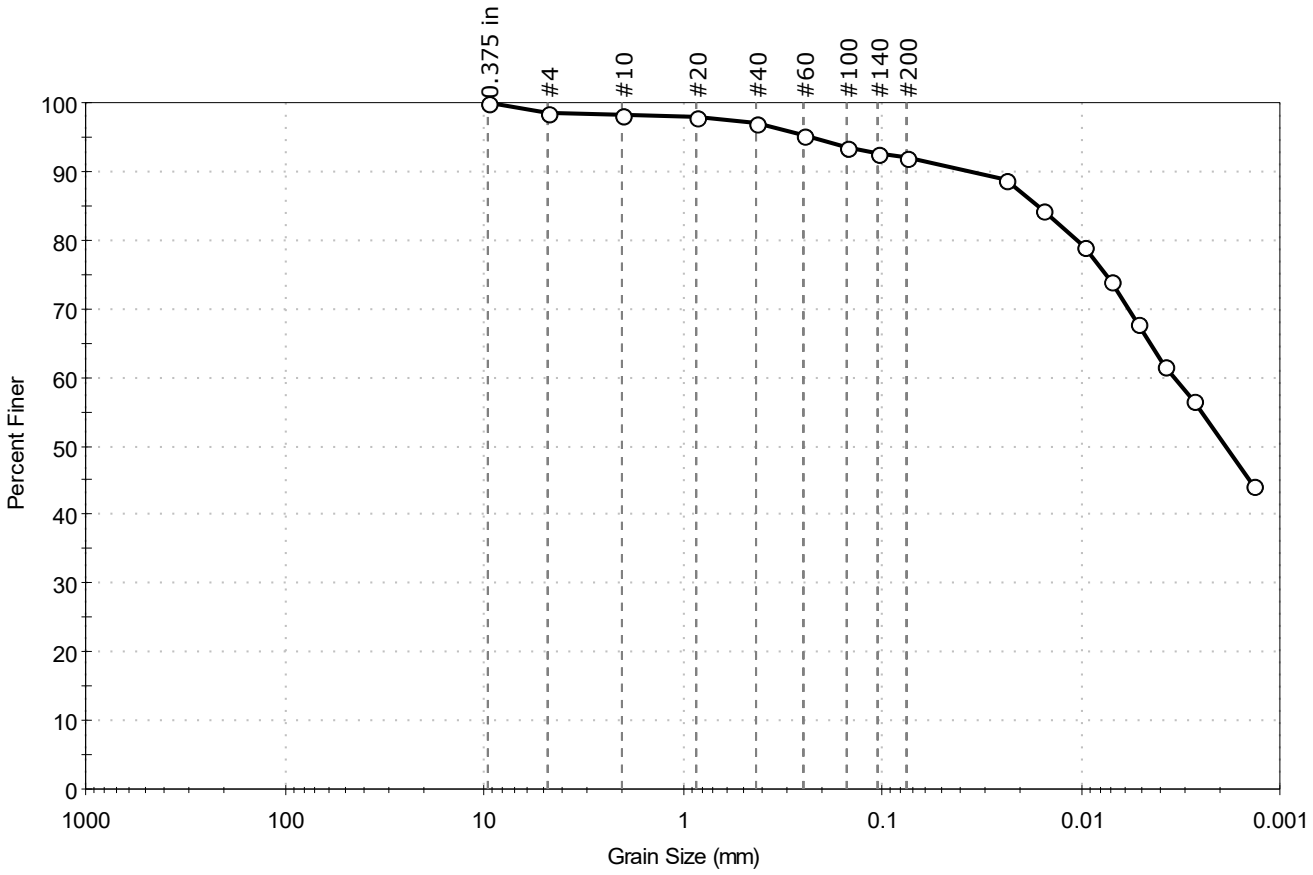
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/19/19	Checked By:	bfs
Depth :	44.55-44.94 ft	Test Id:	532762		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.5	6.6	91.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	98		
#20	0.85	98		
#40	0.42	97		
#60	0.25	95		
#100	0.15	93		
#140	0.11	93		
#200	0.075	92		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0241	89		
---	0.0155	84		
---	0.0096	79		
---	0.0071	74		
---	0.0052	68		
---	0.0038	62		
---	0.0027	57		
---	0.0014	44		

Coefficients

D_{85} = 0.0165 mm	D_{30} = N/A
D_{60} = 0.0034 mm	D_{15} = N/A
D_{50} = 0.0019 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-7-6 (23))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

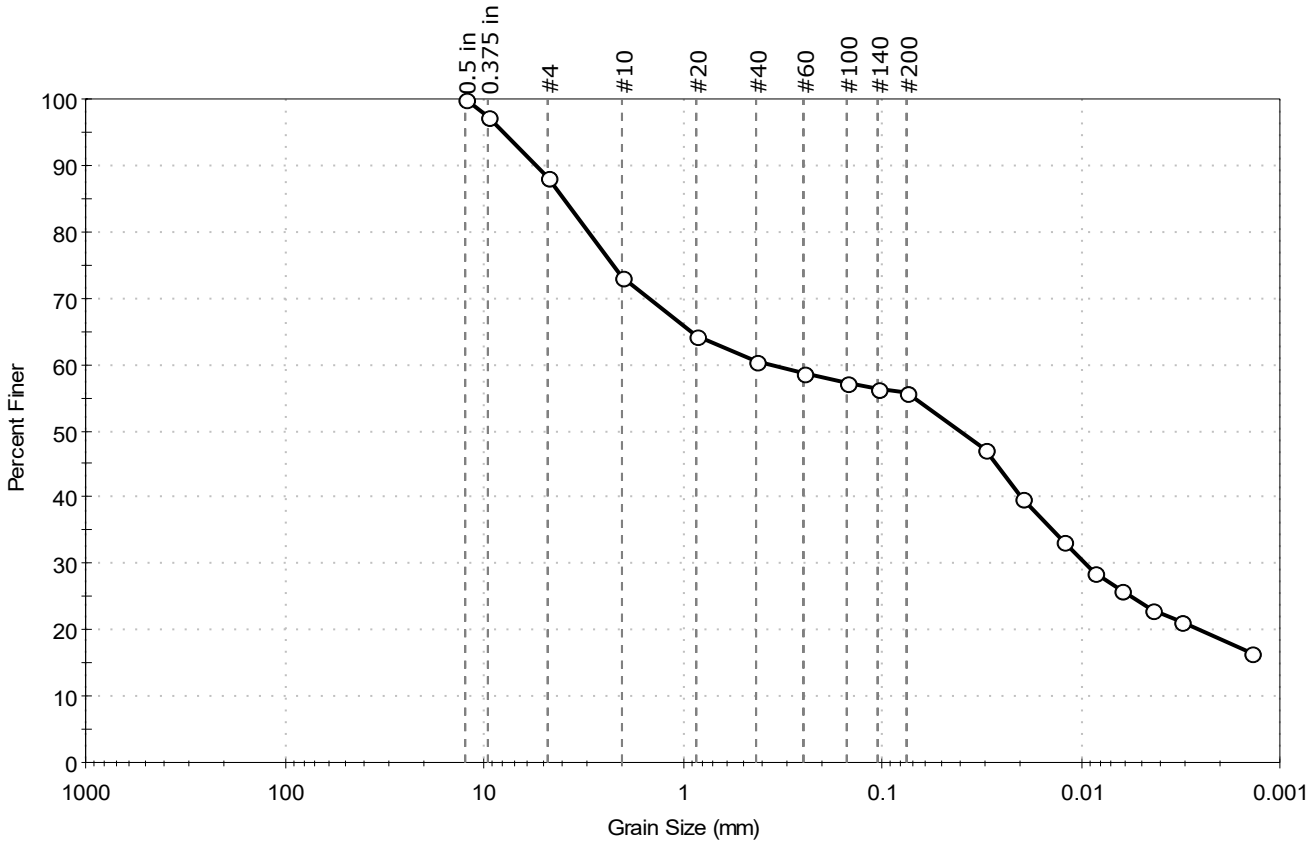
Dispersion Period : 1 minute

Est. Specific Gravity : 2.628

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/31/19	Checked By:	jsc
Depth :	48.10-48.56 ft	Test Id:	532763		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	11.9	32.4	55.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	88		
#10	2.00	73		
#20	0.85	64		
#40	0.42	61		
#60	0.25	59		
#100	0.15	57		
#140	0.11	56		
#200	0.075	56		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0304	47		
---	0.0196	40		
---	0.0122	33		
---	0.0086	29		
---	0.0062	26		
---	0.0044	23		
---	0.0032	21		
---	0.0014	17		

Coefficients

D_{85} = 3.9788 mm
D_{30} = 0.0095 mm
D_{60} = 0.3616 mm
D_{15} = N/A
D_{50} = 0.0406 mm
D_{10} = N/A
C_u = N/A
C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

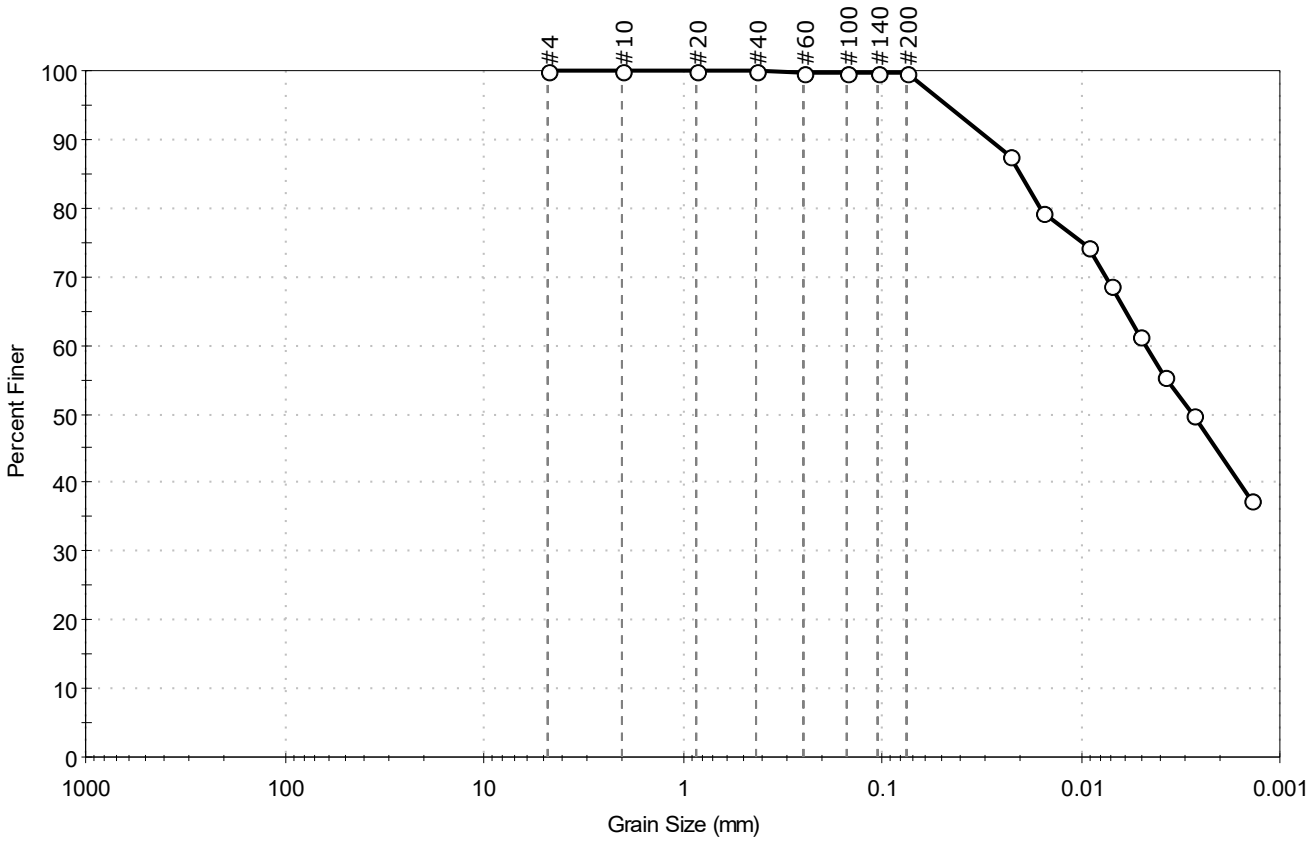
AASHTO Clayey Soils (A-6 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.65
Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/27/19	Checked By:	jsc
Depth :	29.40-29.95 ft	Test Id:	534005		
Test Comment:	---				
Visual Description:	Dry, pale brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.3	99.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0230	87		
---	0.0154	79		
---	0.0093	74		
---	0.0070	69		
---	0.0051	61		
---	0.0038	56		
---	0.0027	50		
---	0.0014	38		

Coefficients

D_{85} = 0.0204 mm	D_{30} = N/A
D_{60} = 0.0048 mm	D_{15} = N/A
D_{50} = 0.0028 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (23))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

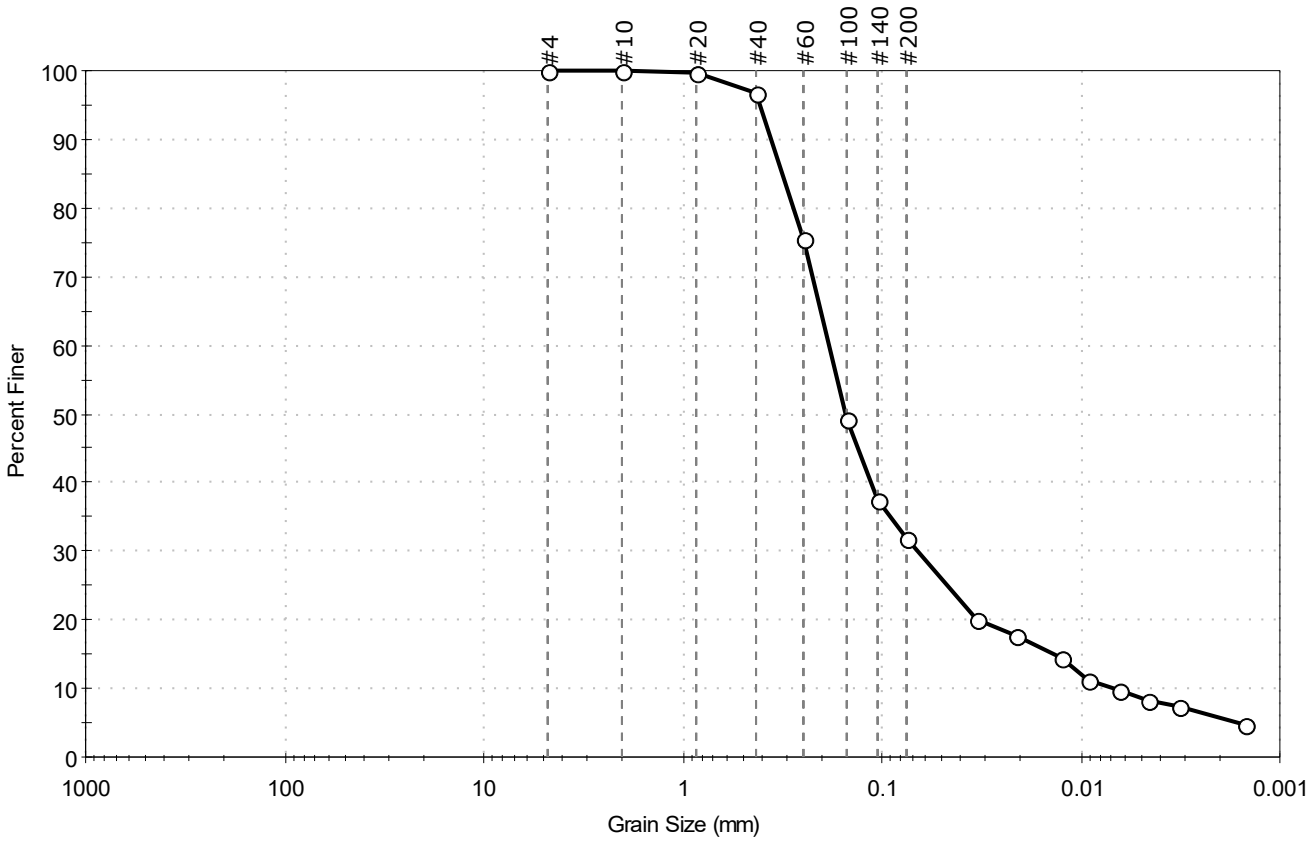
Dispersion Period : 1 minute

Est. Specific Gravity : 2.672

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/19/19	Checked By:	bfs
Depth :	68.01-68.64 ft	Test Id:	534006		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	68.2	31.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	97		
#60	0.25	75		
#100	0.15	49		
#140	0.11	38		
#200	0.075	32		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0330	20		
---	0.0210	18		
---	0.0126	14		
---	0.0092	11		
---	0.0064	10		
---	0.0046	8		
---	0.0032	7		
---	0.0015	5		

Coefficients

D_{85} =0.3169 mm	D_{30} =0.0660 mm
D_{60} =0.1849 mm	D_{15} =0.0138 mm
D_{50} =0.1520 mm	D_{10} =0.0069 mm
C_u =26.797	C_c =3.414

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

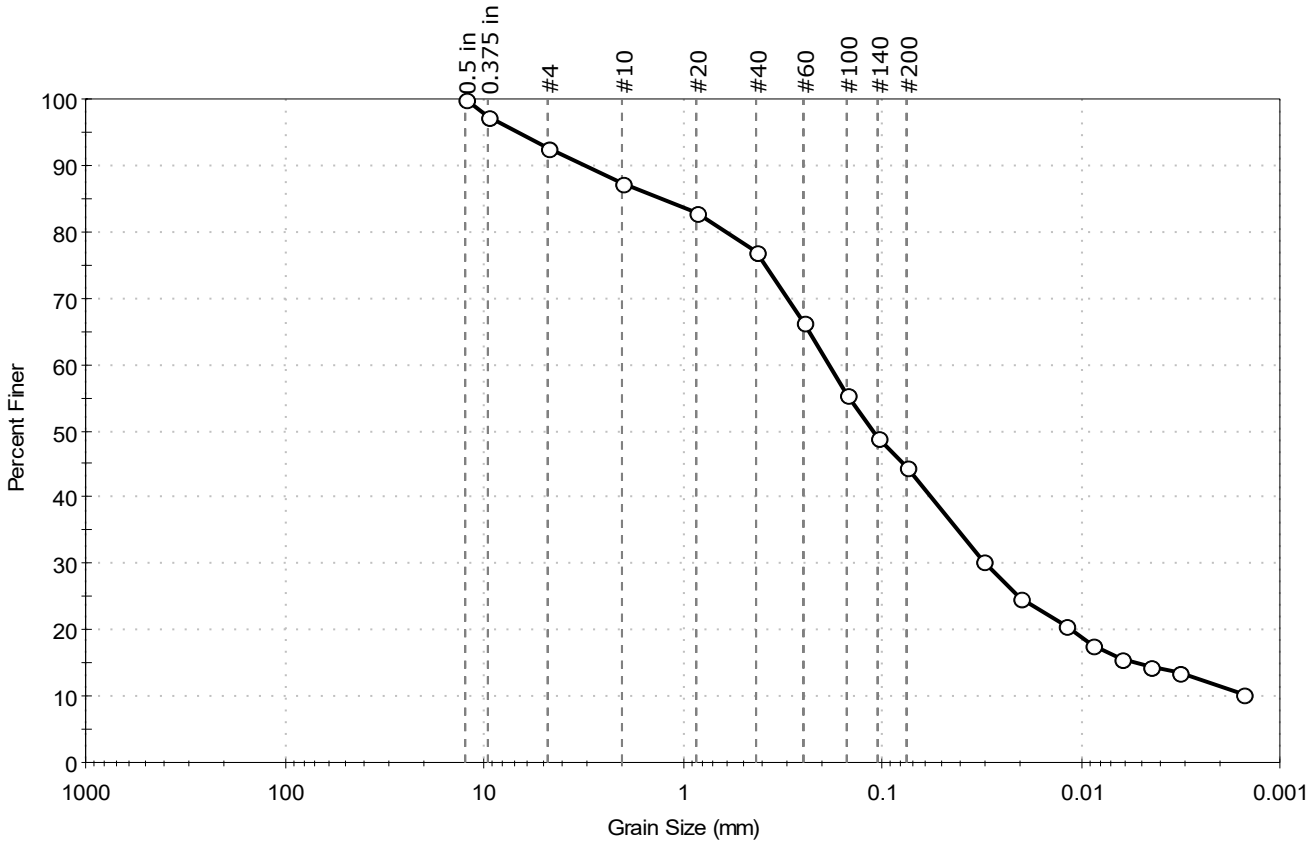
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	94.26-94.78 ft	Test Id:	534007		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	7.3	48.2	44.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	93		
#10	2.00	87		
#20	0.85	83		
#40	0.42	77		
#60	0.25	66		
#100	0.15	55		
#140	0.11	49		
#200	0.075	45		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	30		
---	0.0200	25		
---	0.0121	21		
---	0.0087	18		
---	0.0062	16		
---	0.0045	14		
---	0.0032	14		
---	0.0015	10		

Coefficients

D_{85} = 1.2885 mm	D_{30} = 0.0303 mm
D_{60} = 0.1858 mm	D_{15} = 0.0052 mm
D_{50} = 0.1115 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty, Clayey SAND (SC-SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

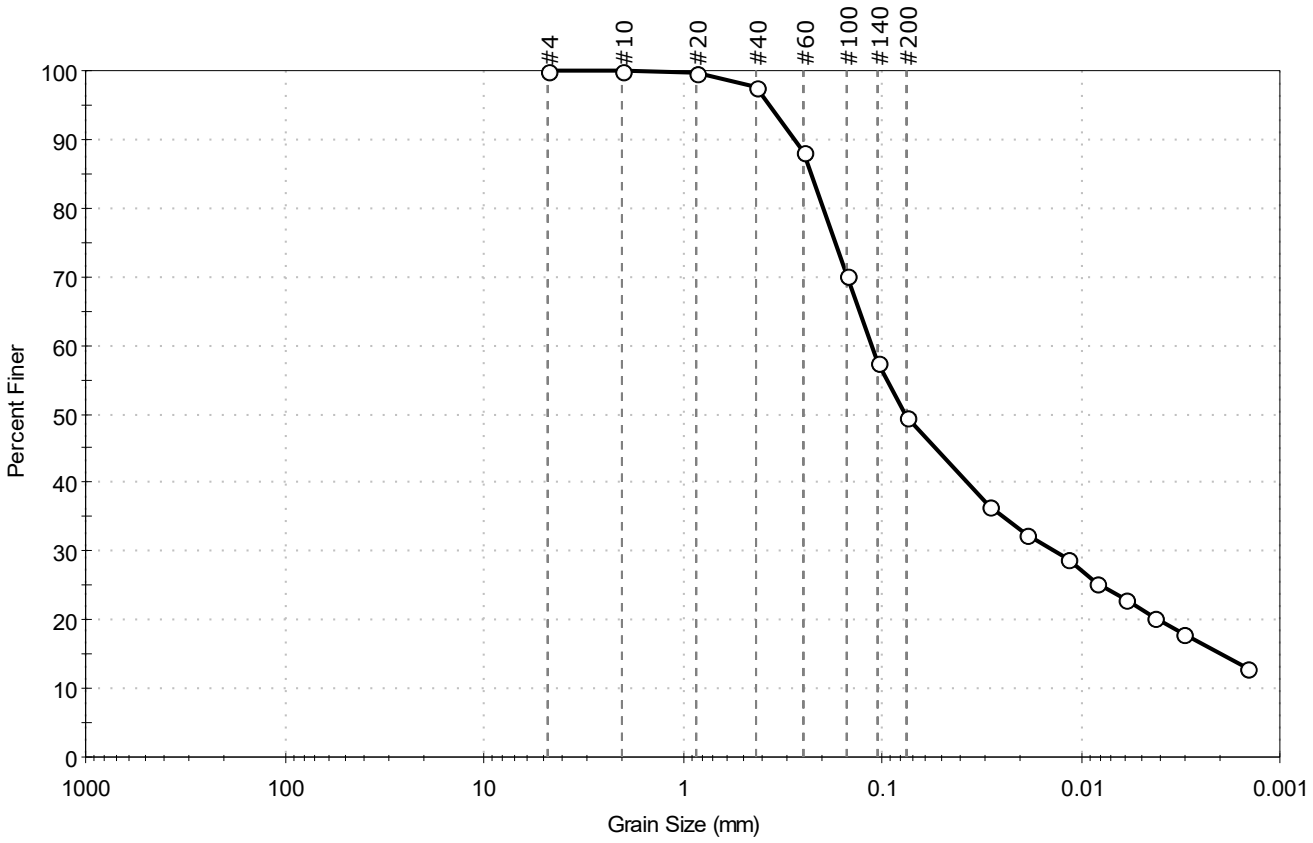
Dispersion Period : 1 minute

Est. Specific Gravity : 2.654

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/19/19	Checked By:	bfs
Depth :	66.89-67.42 ft	Test Id:	532861		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	50.4	49.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	98		
#60	0.25	88		
#100	0.15	70		
#140	0.11	58		
#200	0.075	50		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0292	37		
---	0.0189	32		
---	0.0115	29		
---	0.0084	25		
---	0.0060	23		
---	0.0043	20		
---	0.0030	18		
---	0.0015	13		

Coefficients

D_{85} = 0.2281 mm	D_{30} = 0.0135 mm
D_{60} = 0.1131 mm	D_{15} = 0.0019 mm
D_{50} = 0.0762 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty, Clayey SAND (SC-SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

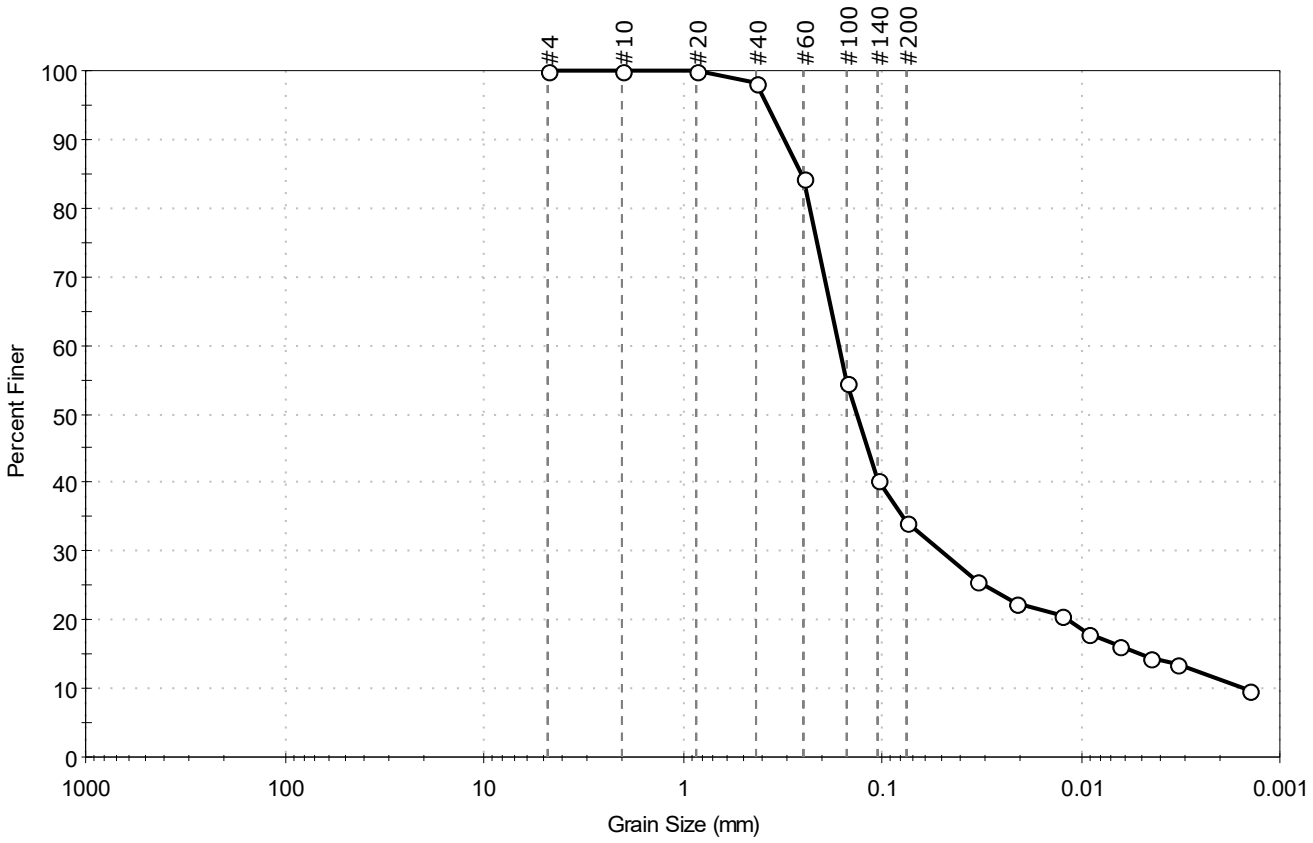
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/31/19	Checked By:	jsc
Depth :	83.20-83.89 ft	Test Id:	532862		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	65.8	34.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	98		
#60	0.25	84		
#100	0.15	55		
#140	0.11	40		
#200	0.075	34		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0335	26		
---	0.0211	23		
---	0.0126	21		
---	0.0091	18		
---	0.0065	16		
---	0.0045	14		
---	0.0033	13		
---	0.0014	10		

Coefficients

D_{85} =0.2569 mm	D_{30} =0.0503 mm
D_{60} =0.1643 mm	D_{15} =0.0051 mm
D_{50} =0.1338 mm	D_{10} =0.0015 mm
C_u =109.533	C_c =10.266

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

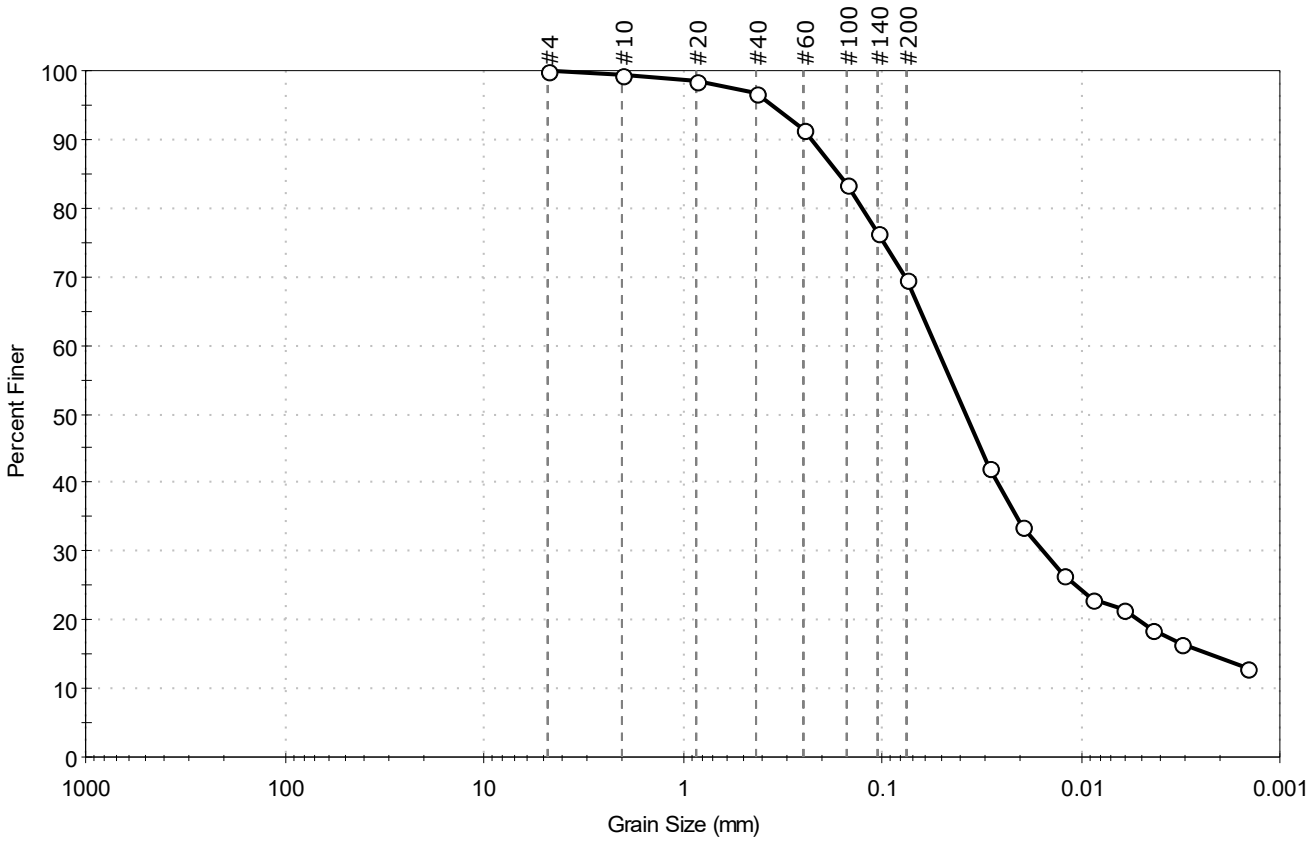
Dispersion Period : 1 minute

Est. Specific Gravity : 2.601

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/20/19	Checked By:	bfs
Depth :	110.56-111.12 ft	Test Id:	532863		
Test Comment:	---				
Visual Description:	Dry, pale brown sandy silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	30.4	69.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	99		
#40	0.42	97		
#60	0.25	91		
#100	0.15	84		
#140	0.11	77		
#200	0.075	70		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0292	42		
---	0.0199	34		
---	0.0121	27		
---	0.0087	23		
---	0.0062	22		
---	0.0044	19		
---	0.0031	17		
---	0.0015	13		

Coefficients

D_{85} = 0.1652 mm	D_{30} = 0.0155 mm
D_{60} = 0.0539 mm	D_{15} = 0.0022 mm
D_{50} = 0.0382 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy SILT (ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

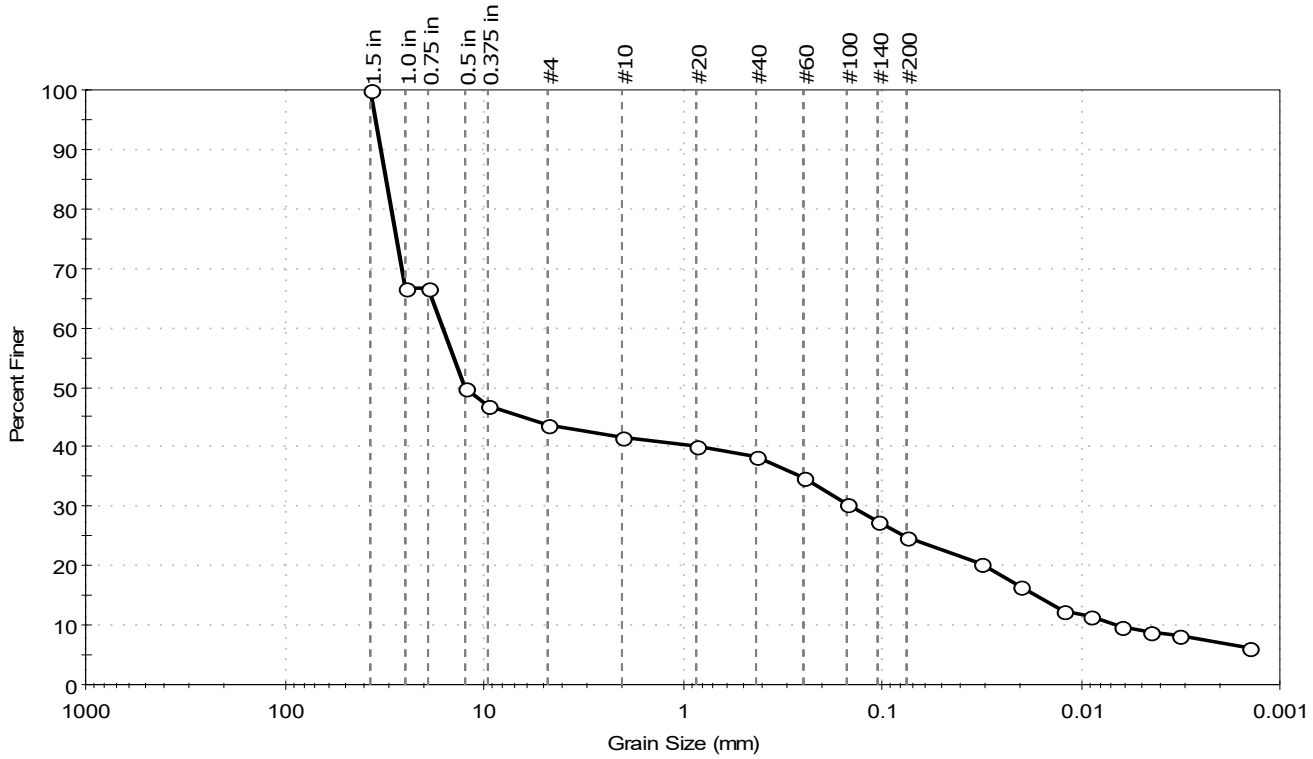
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/31/19	Checked By:	jsc
Depth :	130.51-131.07 ft	Test Id:	532864		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey gravel with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
--	56.2	19.0	24.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1.0 in	25.00	67		
0.75 in	19.00	67		
0.5 in	12.50	50		
0.375 in	9.50	47		
#4	4.75	44		
#10	2.00	42		
#20	0.85	40		
#40	0.42	38		
#60	0.25	35		
#100	0.15	31		
#140	0.11	27		
#200	0.075	25		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0314	20		
---	0.0202	17		
---	0.0123	12		
---	0.0089	11		
---	0.0063	10		
---	0.0045	9		
---	0.0032	8		
---	0.0014	6		

Coefficients

D_{85} = 31.2565 mm
D_{30} = 0.1416 mm
D_{60} = 16.1015 mm
D_{15} = 0.0166 mm
D_{50} = 12.5313 mm
D_{10} = 0.0066 mm
C_u = 2439.621
C_c = 0.189

Classification

ASTM: Silty, Clayey GRAVEL with Sand (GC-GM)

AASHTO: Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

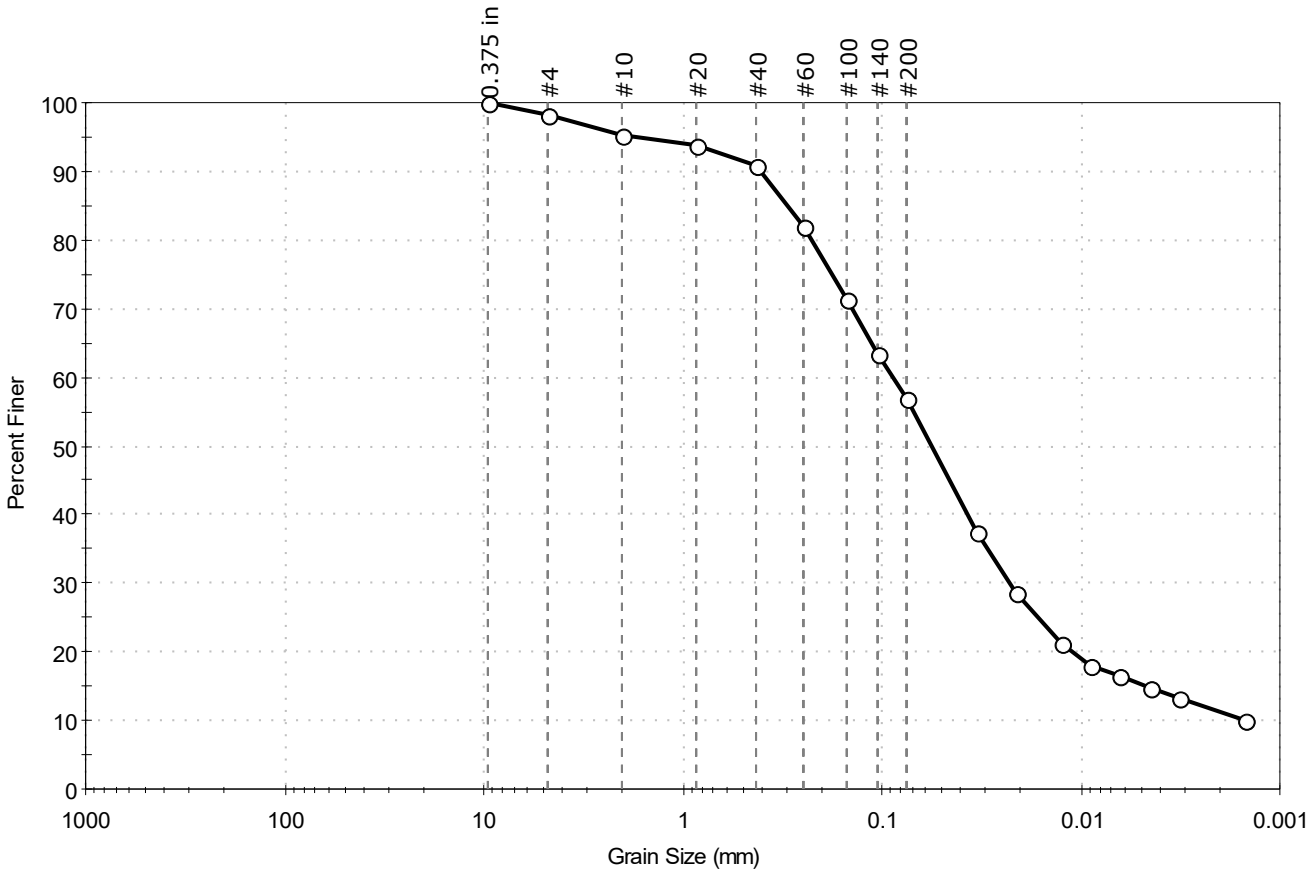
Dispersion Period : 1 minute

Est. Specific Gravity : 2.662

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/20/19	Checked By:	bfs
Depth :	141.50-142.16 ft	Test Id:	532865		
Test Comment:	---				
Visual Description:	Dry, pale brown sandy silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.9	41.1	57.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	95		
#20	0.85	94		
#40	0.42	91		
#60	0.25	82		
#100	0.15	71		
#140	0.11	64		
#200	0.075	57		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0333	38		
---	0.0213	29		
---	0.0126	21		
---	0.0090	18		
---	0.0064	16		
---	0.0045	15		
---	0.0032	13		
---	0.0015	10		

Coefficients

D_{85} =0.3005 mm	D_{30} =0.0228 mm
D_{60} =0.0879 mm	D_{15} =0.0047 mm
D_{50} =0.0559 mm	D_{10} =0.0015 mm
C_u =58.600	C_c =3.943

Classification

ASTM Sandy SILT (ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

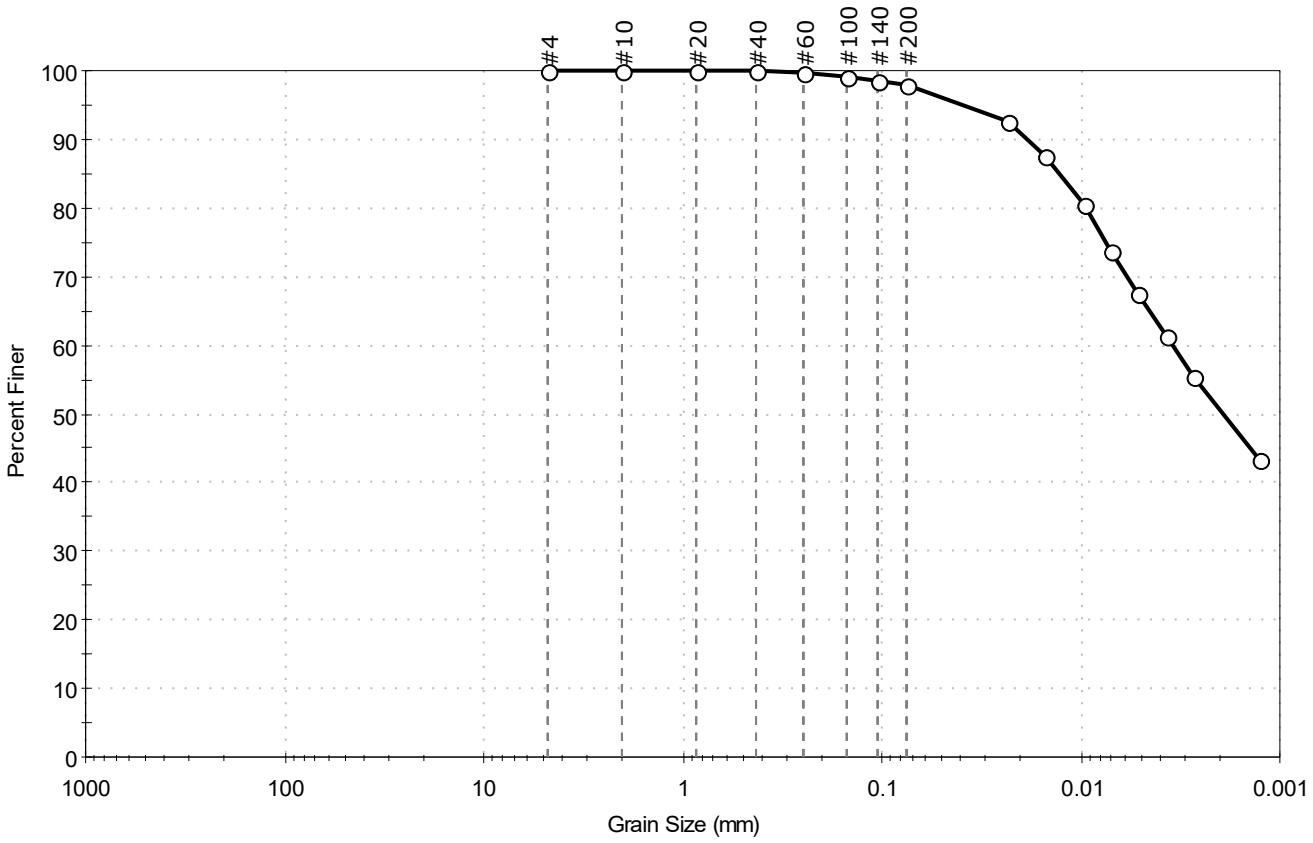
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	12/31/19	Checked By:	jsc
Depth :	148.06-148.62 ft	Test Id:	532866		
Test Comment:	---				
Visual Description:	Dry, pale brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.0	98.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	99		
#140	0.11	99		
#200	0.075	98		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0234	93		
---	0.0150	88		
---	0.0096	81		
---	0.0070	74		
---	0.0052	68		
---	0.0038	61		
---	0.0027	55		
---	0.0013	43		

Coefficients

D_{85} = 0.0128 mm	D_{30} = N/A
D_{60} = 0.0035 mm	D_{15} = N/A
D_{50} = 0.0019 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-7-6 (25))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

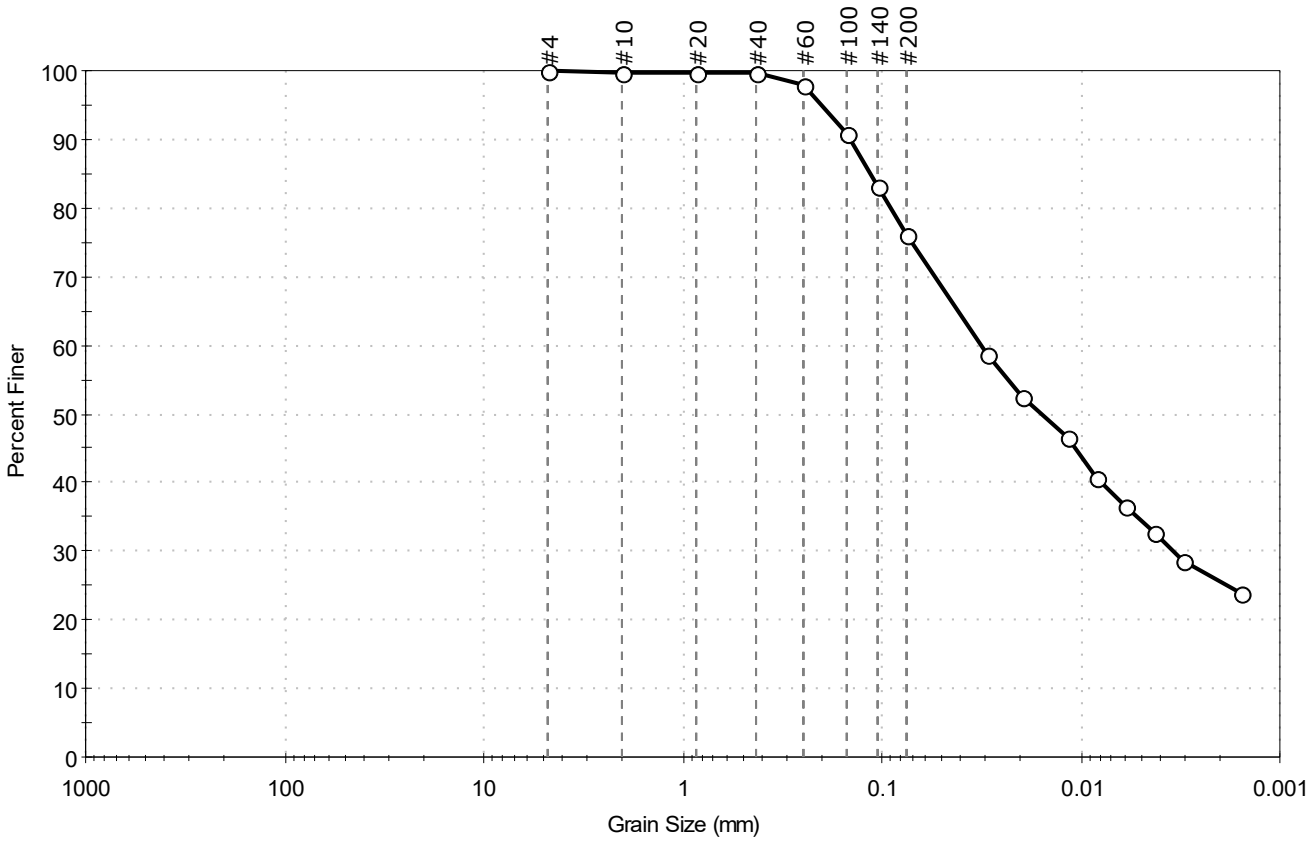
Dispersion Period : 1 minute

Est. Specific Gravity : 2.652

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	01/09/20	Checked By:	jsc
Depth :	86.84-87.40 ft	Test Id:	537459		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	23.9	76.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	98		
#100	0.15	91		
#140	0.11	83		
#200	0.075	76		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0296	59		
---	0.0197	53		
---	0.0117	47		
---	0.0084	41		
---	0.0060	37		
---	0.0043	33		
---	0.0031	29		
---	0.0016	24		

Coefficients

D_{85} = 0.1153 mm	D_{30} = 0.0035 mm
D_{60} = 0.0319 mm	D_{15} = N/A
D_{50} = 0.0157 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (7))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

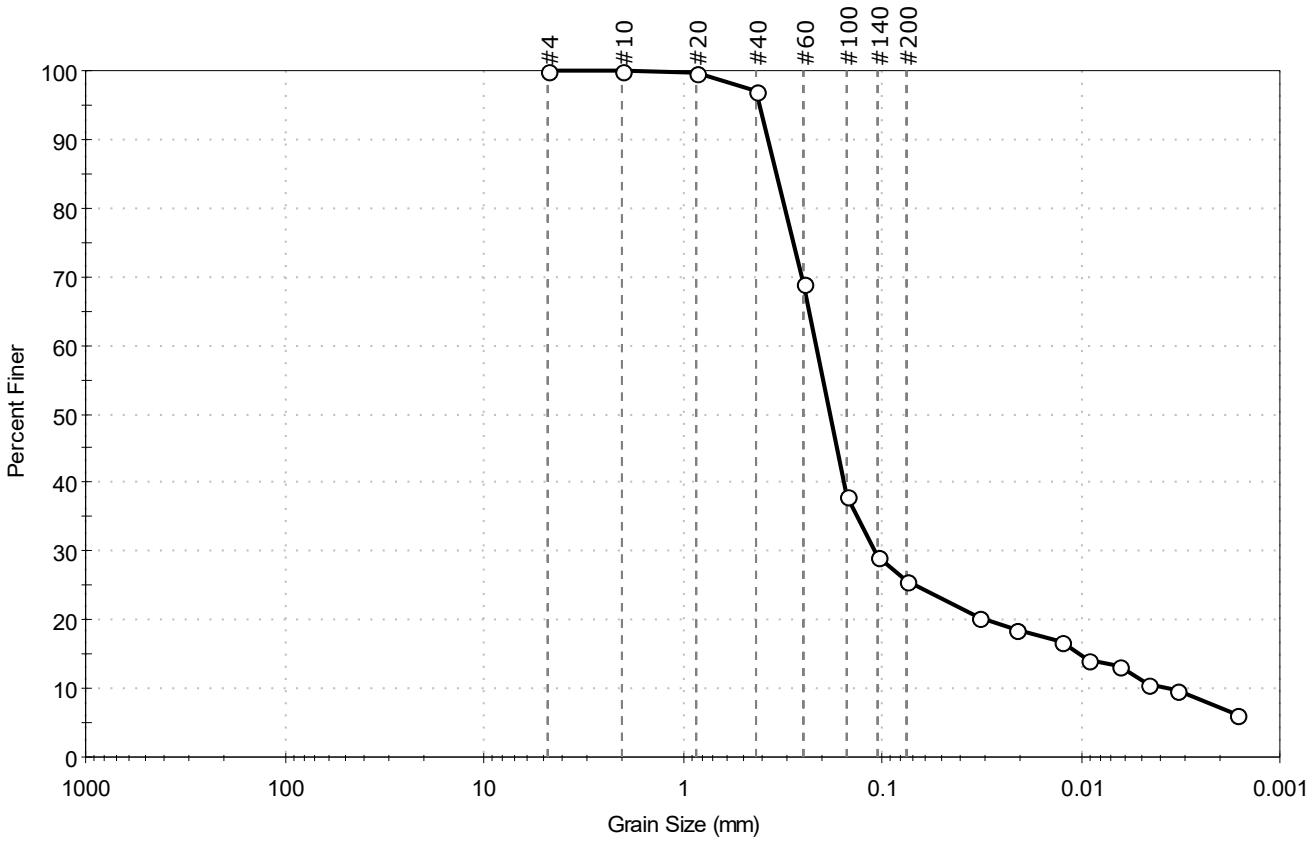
Dispersion Period : 1 minute

Est. Specific Gravity : 2.649

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	01/09/20	Checked By:	jsc
Depth :	102.69-103.28 ft	Test Id:	537460		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	74.4	25.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	97		
#60	0.25	69		
#100	0.15	38		
#140	0.11	29		
#200	0.075	26		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0328	20		
---	0.0212	19		
---	0.0127	17		
---	0.0091	14		
---	0.0065	13		
---	0.0046	11		
---	0.0033	10		
---	0.0016	6		

Coefficients

D_{85} =0.3383 mm	D_{30} =0.1093 mm
D_{60} =0.2156 mm	D_{15} =0.0101 mm
D_{50} =0.1830 mm	D_{10} =0.0037 mm
C_u =58.270	C_c =14.976

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

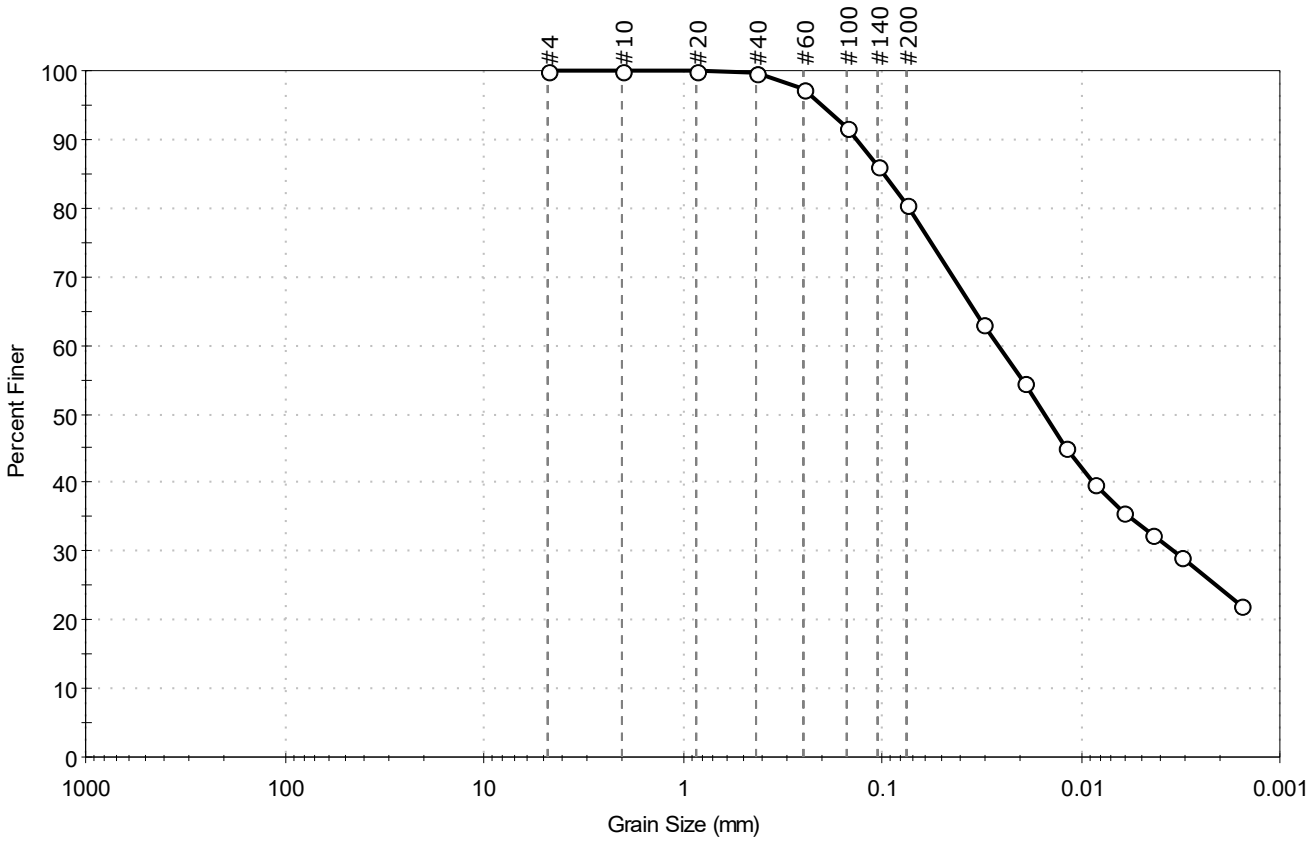
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	01/09/20	Checked By:	jsc
Depth :	111.35-111.94 ft	Test Id:	537461		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	19.6	80.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	97		
#100	0.15	92		
#140	0.11	86		
#200	0.075	80		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0309	63		
---	0.0194	55		
---	0.0118	45		
---	0.0086	40		
---	0.0062	36		
---	0.0044	32		
---	0.0031	29		
---	0.0016	22		

Coefficients

D_{85} = 0.0994 mm	D_{30} = 0.0034 mm
D_{60} = 0.0261 mm	D_{15} = N/A
D_{50} = 0.0152 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (6))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

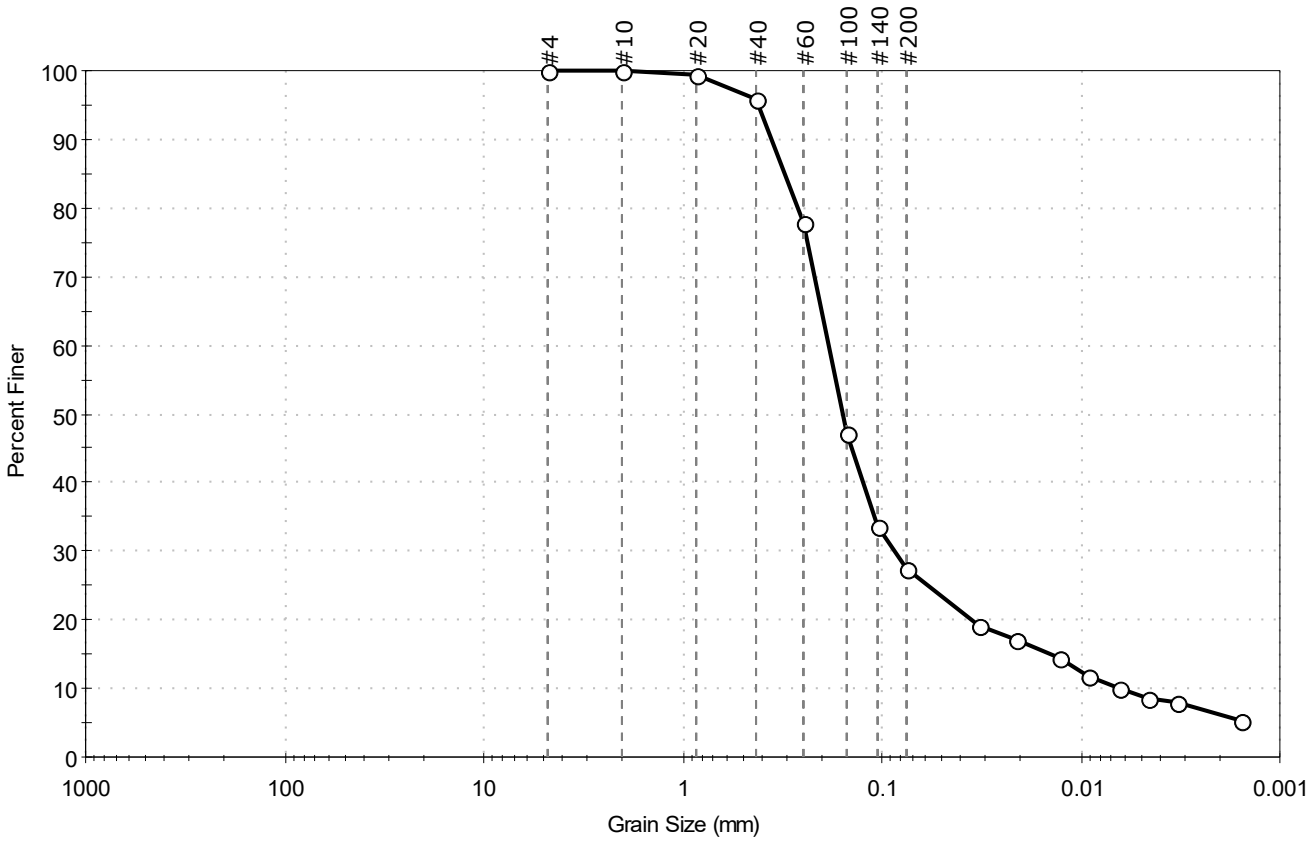
Dispersion Period : 1 minute

Est. Specific Gravity : 2.621

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	01/10/20	Checked By:	jsc
Depth :	116.80-117.39 ft	Test Id:	537462		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	72.6	27.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	96		
#60	0.25	78		
#100	0.15	47		
#140	0.11	34		
#200	0.075	27		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0323	19		
---	0.0210	17		
---	0.0127	15		
---	0.0091	12		
---	0.0065	10		
---	0.0046	9		
---	0.0033	8		
---	0.0016	5		

Coefficients

D_{85} =0.3088 mm	D_{30} =0.0864 mm
D_{60} =0.1856 mm	D_{15} =0.0139 mm
D_{50} =0.1569 mm	D_{10} =0.0065 mm
C_u =28.554	C_c =6.188

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

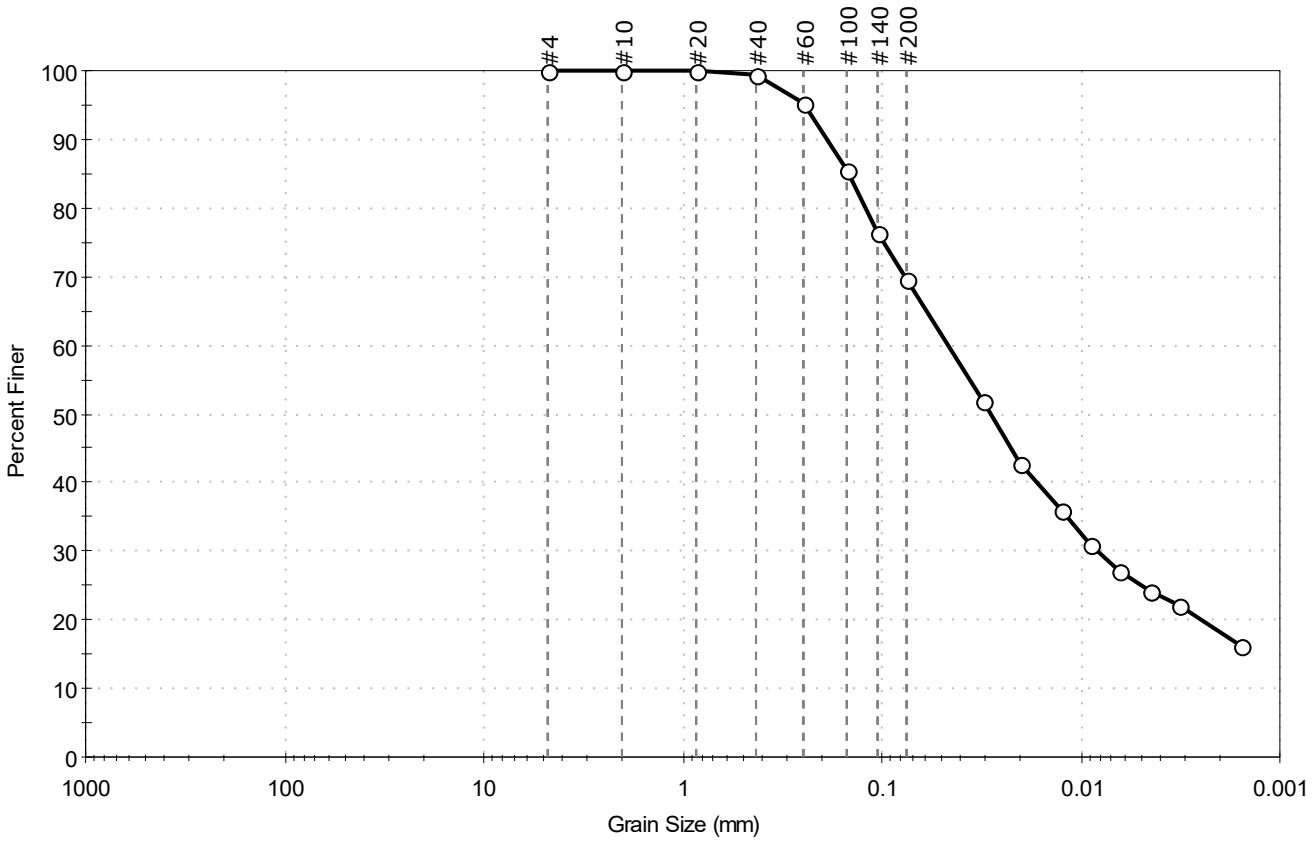
Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:07 PM

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	01/10/20	Checked By:	jsc
Depth :	126.44-127.03 ft	Test Id:	537463		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	30.4	69.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	95		
#100	0.15	86		
#140	0.11	77		
#200	0.075	70		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0311	52		
---	0.0201	43		
---	0.0125	36		
---	0.0089	31		
---	0.0064	27		
---	0.0045	24		
---	0.0032	22		
---	0.0016	16		

Coefficients

D_{85} = 0.1469 mm	D_{30} = 0.0082 mm
D_{60} = 0.0466 mm	D_{15} = N/A
D_{50} = 0.0285 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (2))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

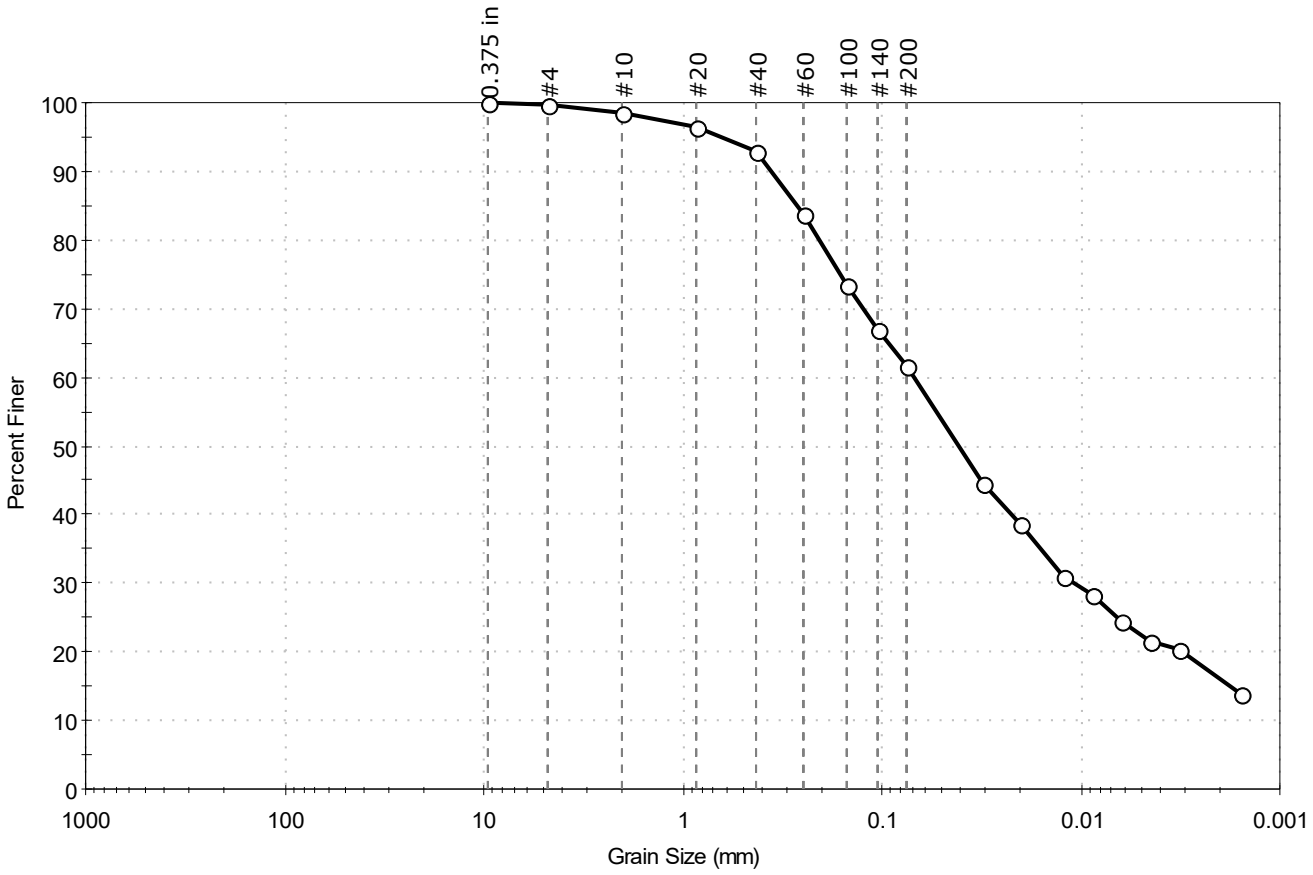
Dispersion Period : 1 minute

Est. Specific Gravity : 2.57

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	01/10/20	Checked By:	jsc
Depth :	136.98-137.43 ft	Test Id:	537464		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.4	37.8	61.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	100		
#10	2.00	98		
#20	0.85	97		
#40	0.42	93		
#60	0.25	84		
#100	0.15	73		
#140	0.11	67		
#200	0.075	62		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	45		
---	0.0201	39		
---	0.0123	31		
---	0.0088	28		
---	0.0063	24		
---	0.0045	21		
---	0.0032	21		
---	0.0016	14		

Coefficients

D_{85} =0.2663 mm	D_{30} =0.0109 mm
D_{60} =0.0685 mm	D_{15} =0.0018 mm
D_{50} =0.0410 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

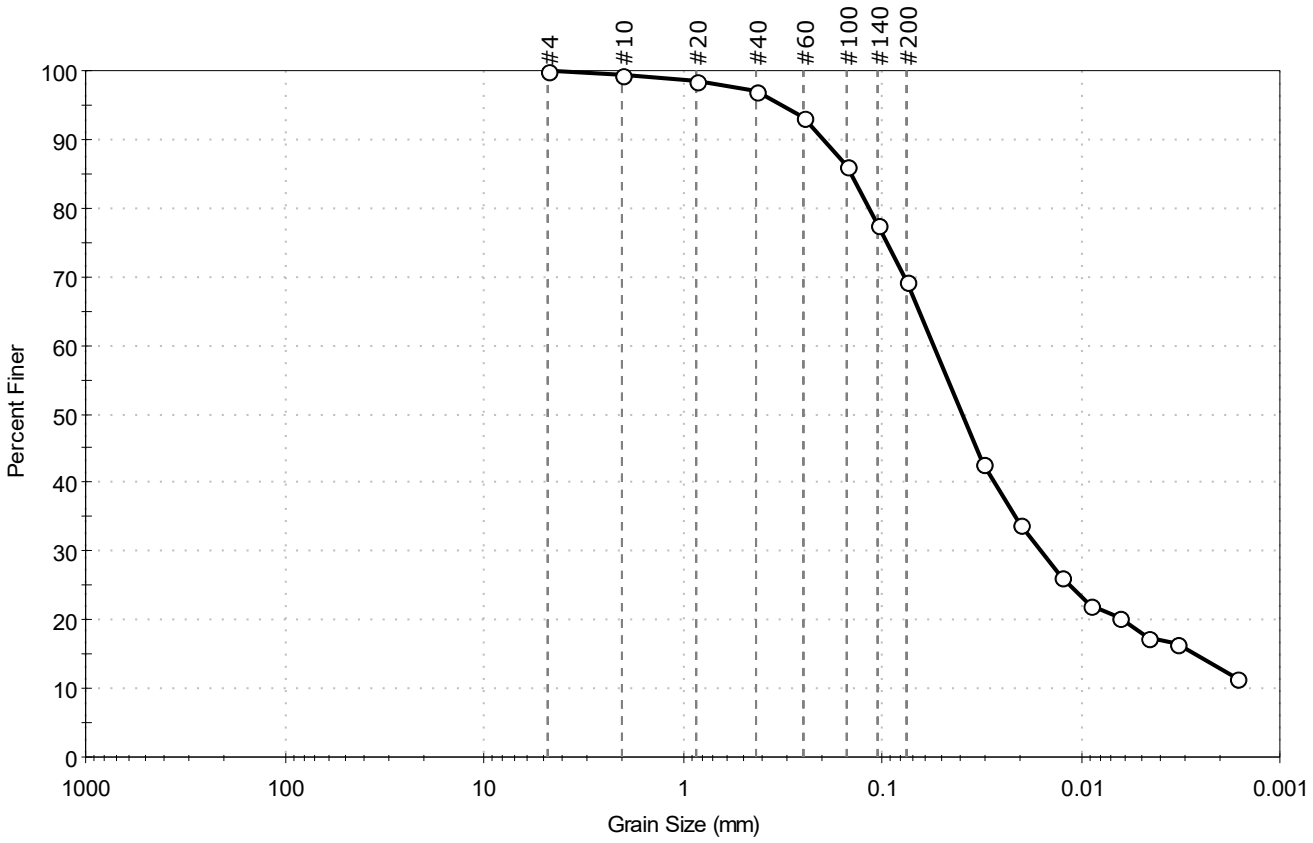
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	01/09/20	Checked By:	jsc
Depth :	145.83-146.46 ft	Test Id:	537479		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	30.6	69.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	99		
#40	0.42	97		
#60	0.25	93		
#100	0.15	86		
#140	0.11	78		
#200	0.075	69		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0313	43		
---	0.0203	34		
---	0.0127	26		
---	0.0090	22		
---	0.0064	20		
---	0.0046	17		
---	0.0033	16		
---	0.0016	12		

Coefficients

D_{85} = 0.1435 mm	D_{30} = 0.0160 mm
D_{60} = 0.0551 mm	D_{15} = 0.0027 mm
D_{50} = 0.0398 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

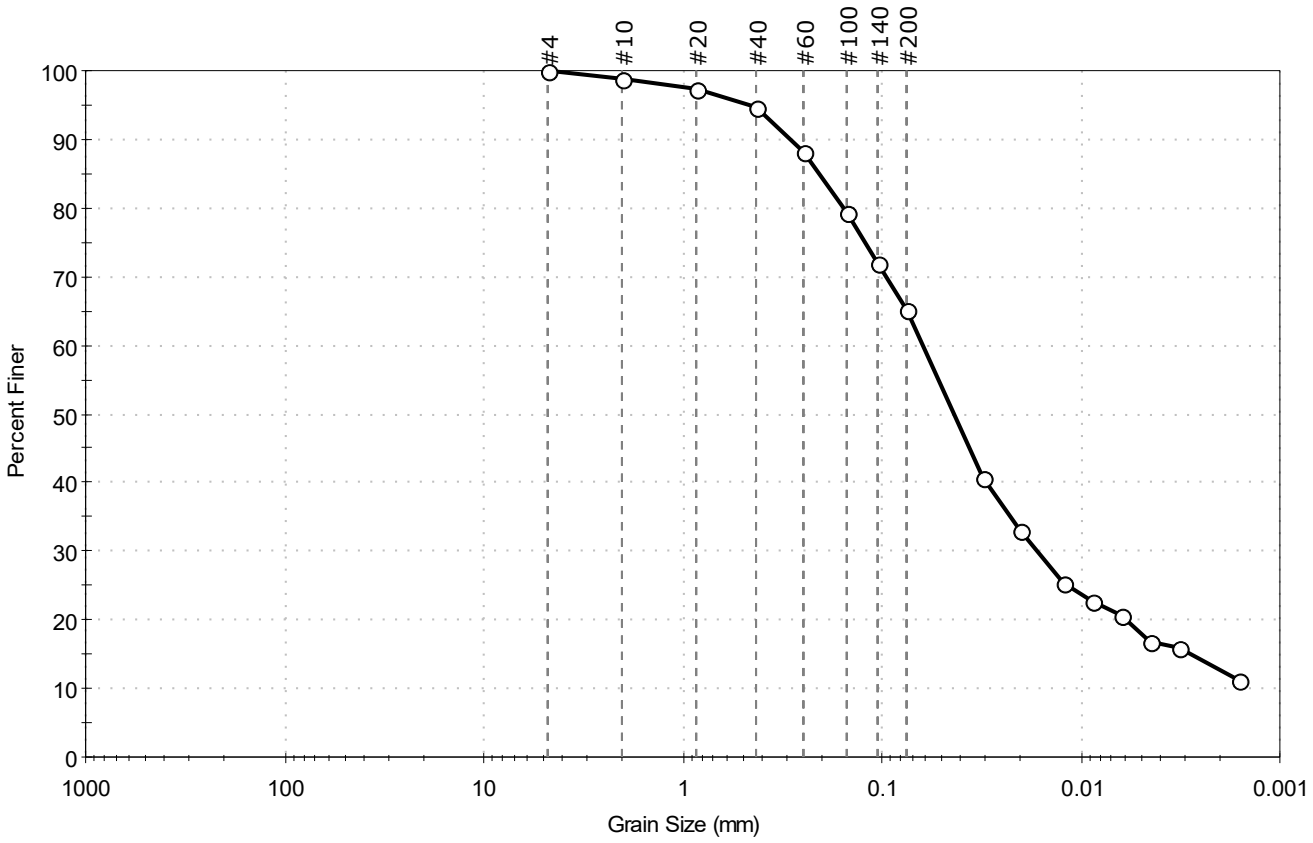
Dispersion Period : 1 minute

Est. Specific Gravity : 2.608

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	01/09/20	Checked By:	jsc
Depth :	155.94-156.56 ft	Test Id:	537480		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	34.8	65.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	97		
#40	0.42	95		
#60	0.25	88		
#100	0.15	79		
#140	0.11	72		
#200	0.075	65		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0314	41		
---	0.0200	33		
---	0.0123	25		
---	0.0089	23		
---	0.0063	21		
---	0.0045	17		
---	0.0032	16		
---	0.0016	11		

Coefficients

D_{85} = 0.2074 mm	D_{30} = 0.0164 mm
D_{60} = 0.0624 mm	D_{15} = 0.0028 mm
D_{50} = 0.0437 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

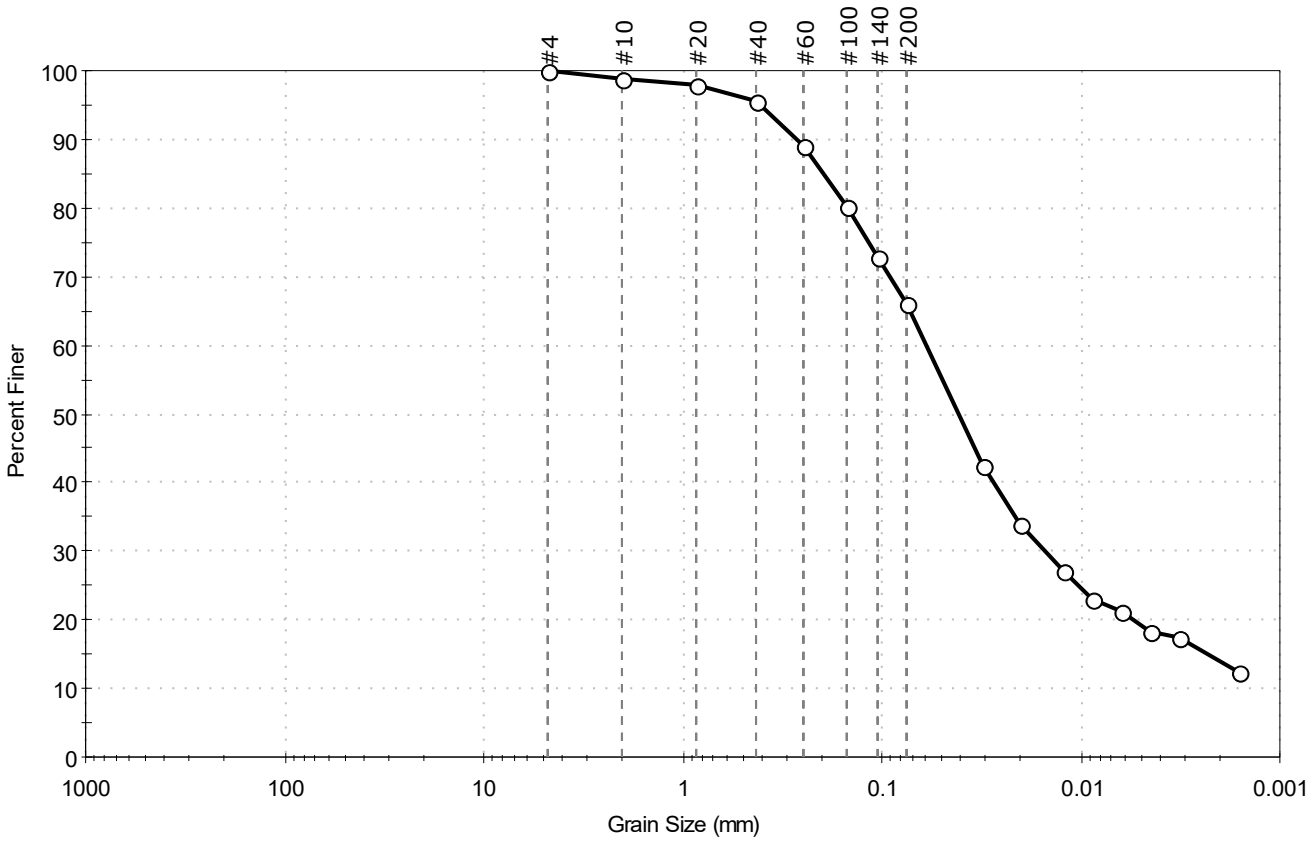
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	01/09/20	Checked By:	jsc
Depth :	167.49-168.11 ft	Test Id:	537481		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	34.0	66.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	98		
#40	0.42	96		
#60	0.25	89		
#100	0.15	80		
#140	0.11	73		
#200	0.075	66		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	43		
---	0.0204	34		
---	0.0123	27		
---	0.0089	23		
---	0.0063	21		
---	0.0045	18		
---	0.0032	17		
---	0.0016	12		

Coefficients

D_{85} = 0.1972 mm	D_{30} = 0.0153 mm
D_{60} = 0.0598 mm	D_{15} = 0.0023 mm
D_{50} = 0.0410 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

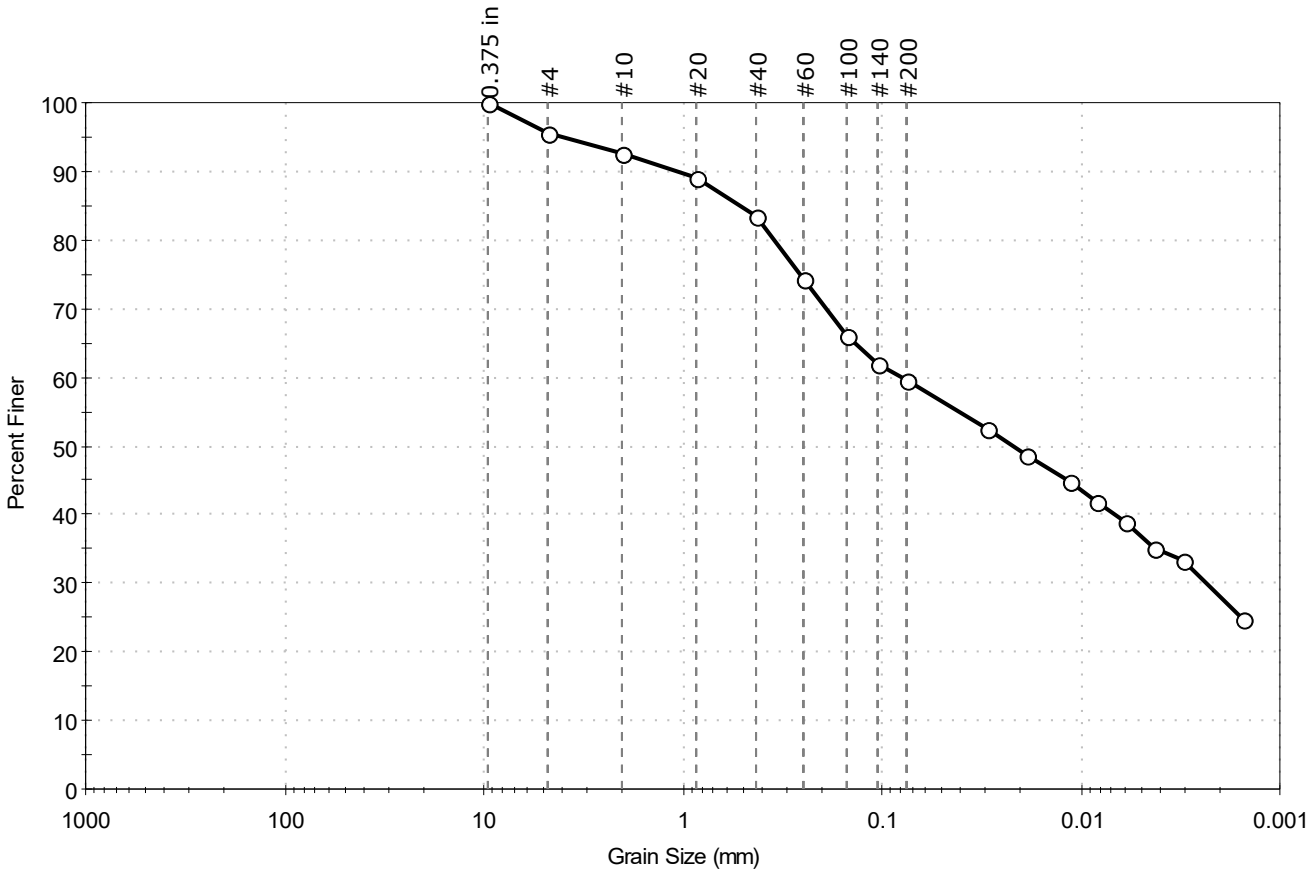
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-010	Test Date:	01/09/20	Checked By:	jsc
Depth :	192.32-192.88 ft	Test Id:	537482		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	4.3	36.0	59.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	96		
#10	2.00	92		
#20	0.85	89		
#40	0.42	84		
#60	0.25	74		
#100	0.15	66		
#140	0.11	62		
#200	0.075	60		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0297	52		
---	0.0189	49		
---	0.0114	45		
---	0.0084	42		
---	0.0060	39		
---	0.0043	35		
---	0.0030	33		
---	0.0015	25		

Coefficients

D_{85} =0.5052 mm	D_{30} =0.0023 mm
D_{60} =0.0789 mm	D_{15} =N/A
D_{50} =0.0223 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (4))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

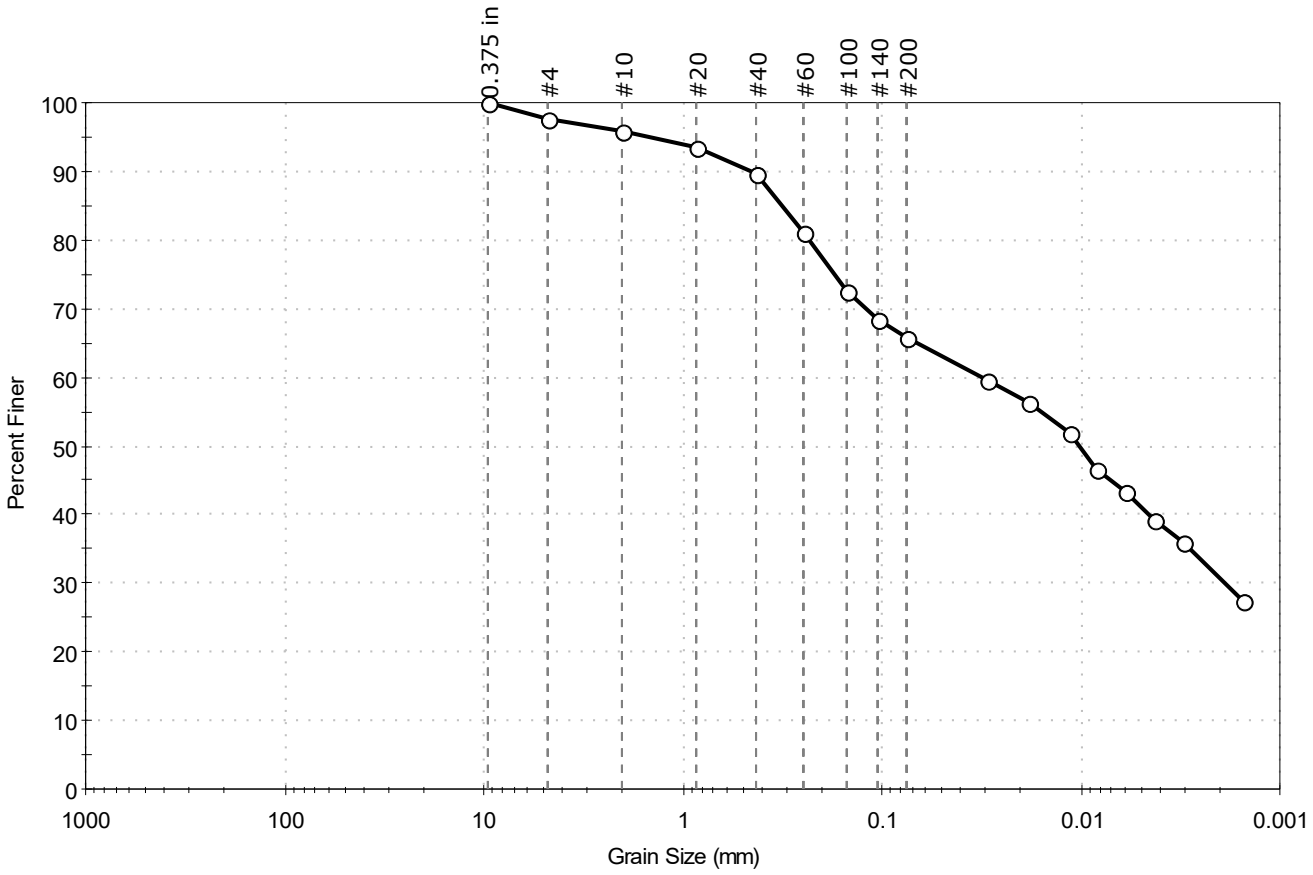
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	01/09/20	Checked By:	jsc
Depth :	201.44-202.00 ft	Test Id:	537483		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	2.4	31.8	65.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	96		
#20	0.85	94		
#40	0.42	90		
#60	0.25	81		
#100	0.15	73		
#140	0.11	68		
#200	0.075	66		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0296	59		
---	0.0185	56		
---	0.0115	52		
---	0.0083	47		
---	0.0059	43		
---	0.0043	39		
---	0.0031	36		
---	0.0016	28		

Coefficients

D_{85} = 0.3161 mm D_{30} = 0.0019 mm

D_{60} = 0.0321 mm D_{15} = N/A

D_{50} = 0.0102 mm D_{10} = N/A

C_u = N/A C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (8))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

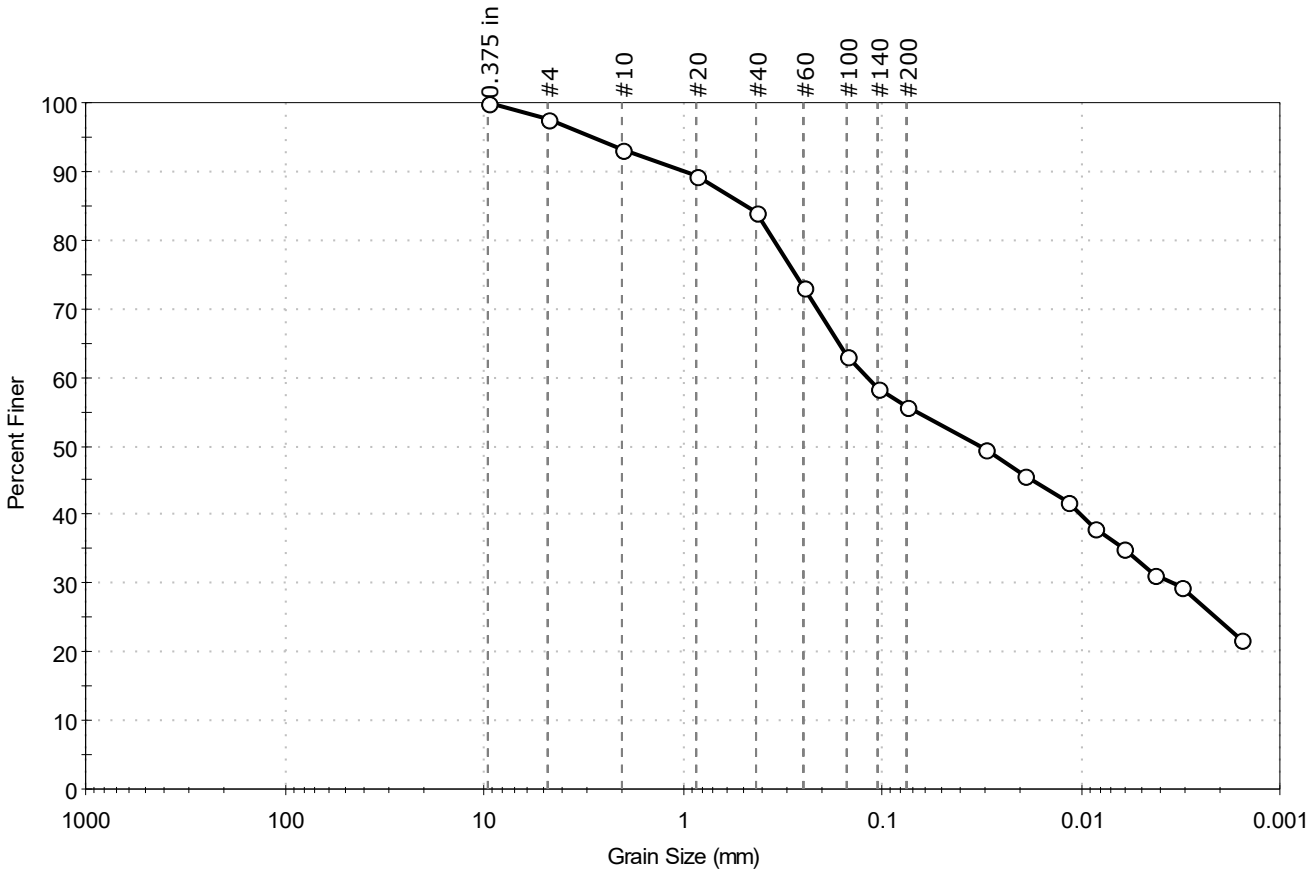
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-012	Test Date:	01/09/20	Checked By:	jsc
Depth :	210.20-210.73 ft	Test Id:	537484		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	2.4	41.9	55.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	93		
#20	0.85	90		
#40	0.42	84		
#60	0.25	73		
#100	0.15	63		
#140	0.11	58		
#200	0.075	56		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0306	49		
---	0.0194	46		
---	0.0116	42		
---	0.0085	38		
---	0.0061	35		
---	0.0043	31		
---	0.0031	29		
---	0.0016	22		

Coefficients

D_{85} =0.4728 mm	D_{30} =0.0035 mm
D_{60} =0.1190 mm	D_{15} =N/A
D_{50} =0.0332 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Silty Soils (A-4 (2))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

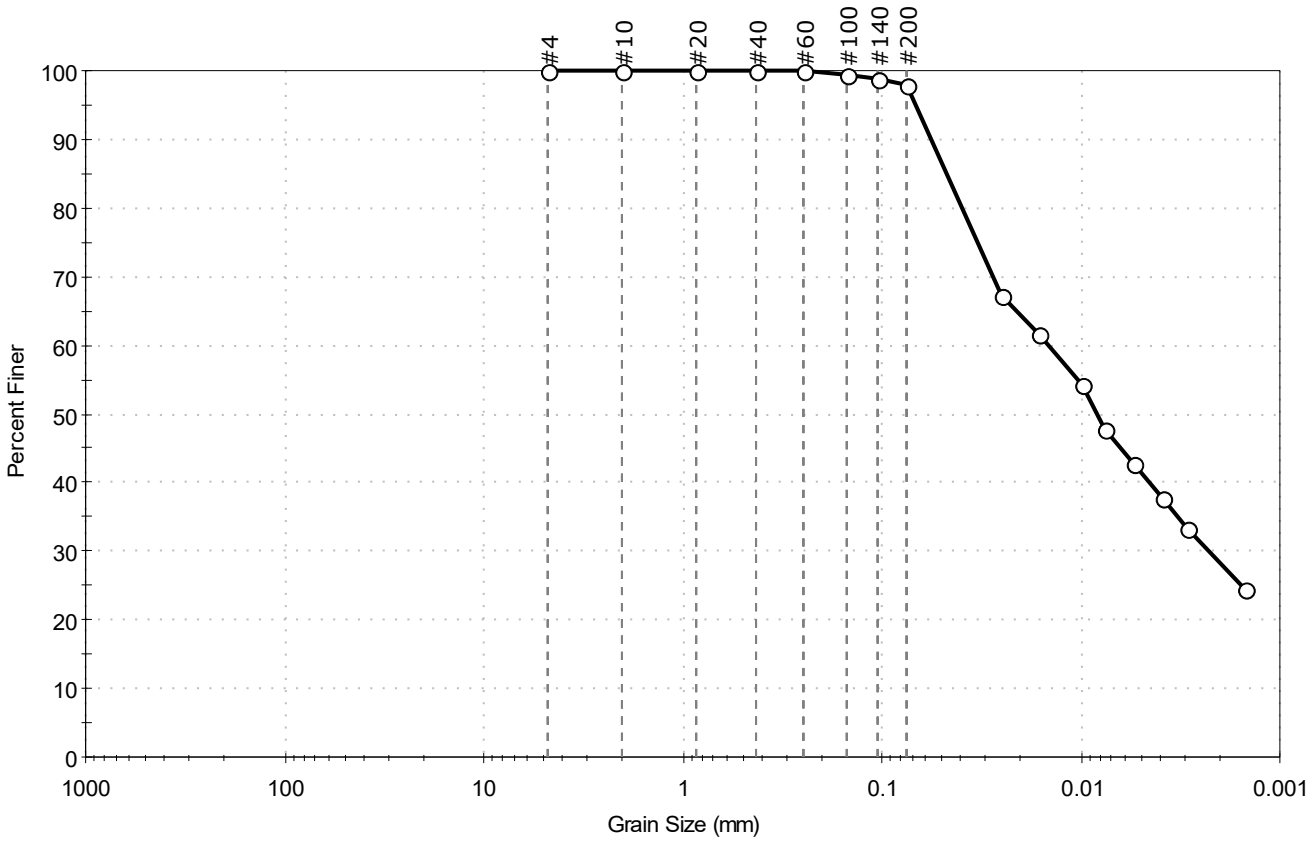
Dispersion Period : 1 minute

Est. Specific Gravity : 2.614

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	01/09/20	Checked By:	jsc
Depth :	220.37-220.93 ft	Test Id:	537495		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.0	98.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	99		
#200	0.075	98		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0248	67		
---	0.0162	62		
---	0.0100	54		
---	0.0076	48		
---	0.0055	43		
---	0.0039	38		
---	0.0029	33		
---	0.0015	25		

Coefficients

D_{85} = 0.0469 mm	D_{30} = 0.0023 mm
D_{60} = 0.0146 mm	D_{15} = N/A
D_{50} = 0.0083 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (16))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

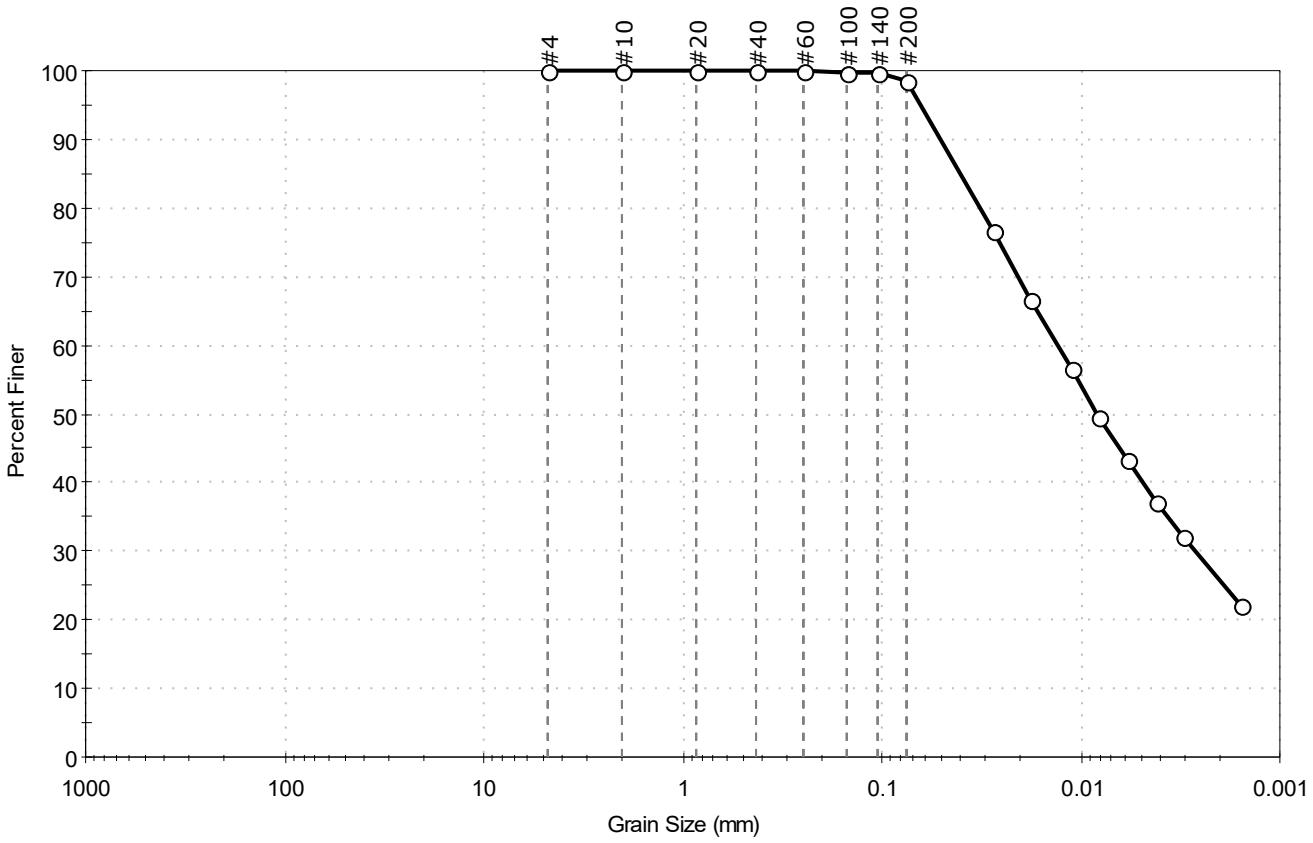
Dispersion Period : 1 minute

Est. Specific Gravity : 2.688

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	01/09/20	Checked By:	jsc
Depth :	240.55-241.08 ft	Test Id:	537496		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.3	98.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	99		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0274	77		
---	0.0178	67		
---	0.0110	57		
---	0.0081	49		
---	0.0059	43		
---	0.0042	37		
---	0.0031	32		
---	0.0016	22		

Coefficients

D_{85} = 0.0399 mm	D_{30} = 0.0026 mm
D_{60} = 0.0130 mm	D_{15} = N/A
D_{50} = 0.0083 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Silty Soils (A-4 (8))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

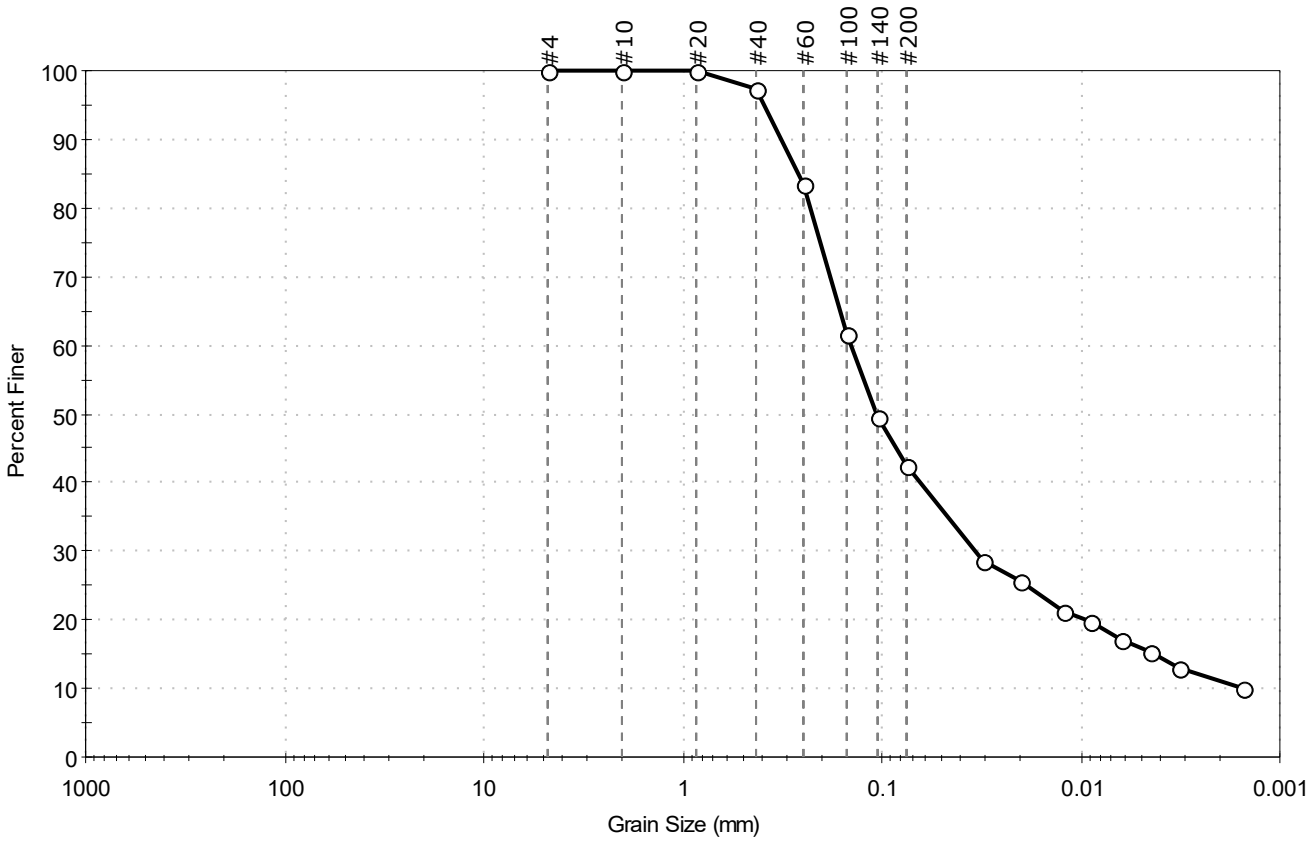
Dispersion Period : 1 minute

Est. Specific Gravity : 2.657

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/20/19	Checked By:	bfs
Depth :	100.62-101.12 ft	Test Id:	533666		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	57.4	42.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	97		
#60	0.25	83		
#100	0.15	62		
#140	0.11	50		
#200	0.075	43		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0314	29		
---	0.0204	26		
---	0.0124	21		
---	0.0089	20		
---	0.0063	17		
---	0.0045	15		
---	0.0032	13		
---	0.0015	10		

Coefficients

D_{85} = 0.2647 mm	D_{30} = 0.0343 mm
D_{60} = 0.1428 mm	D_{15} = 0.0043 mm
D_{50} = 0.1070 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty SAND (SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

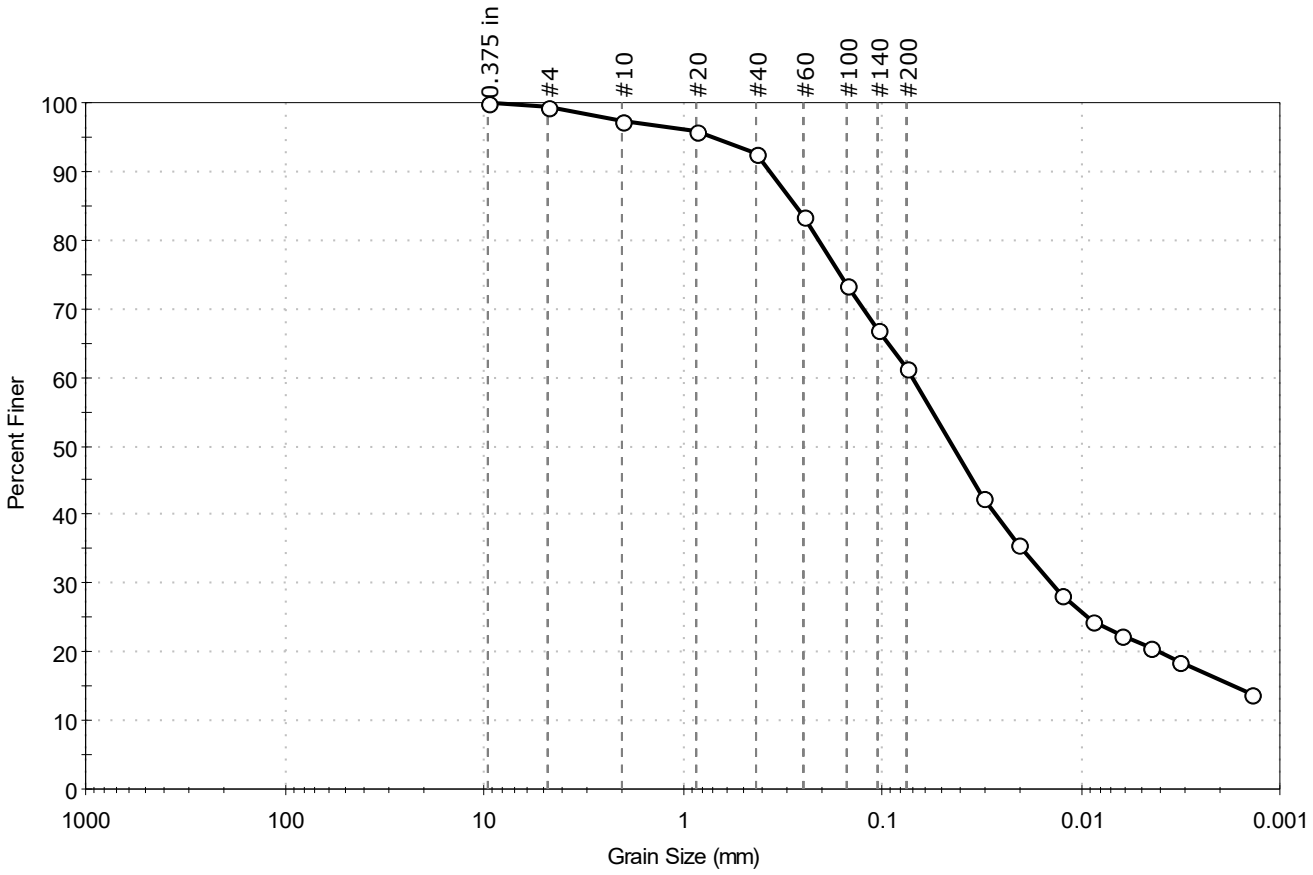
Dispersion Period : 1 minute

Est. Specific Gravity : 2.626

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/31/19	Checked By:	jsc
Depth :	116.17-116.67 ft	Test Id:	533667		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.6	38.0	61.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	97		
#20	0.85	96		
#40	0.42	93		
#60	0.25	84		
#100	0.15	74		
#140	0.11	67		
#200	0.075	61		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0307	42		
---	0.0209	36		
---	0.0124	28		
---	0.0088	24		
---	0.0063	23		
---	0.0045	21		
---	0.0032	19		
---	0.0014	14		

Coefficients

D_{85} =0.2723 mm	D_{30} =0.0141 mm
D_{60} =0.0701 mm	D_{15} =0.0017 mm
D_{50} =0.0439 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

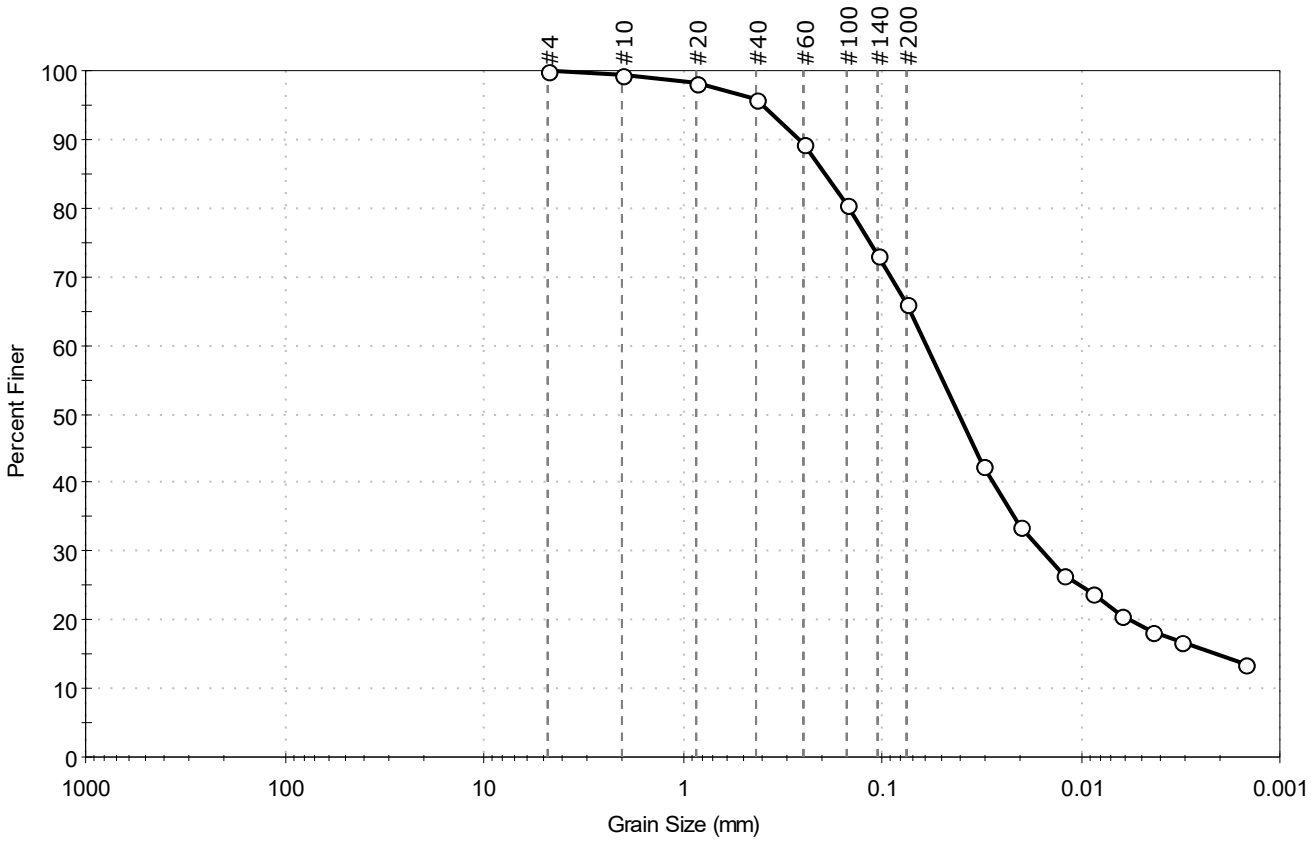
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/20/19	Checked By:	bfs
Depth :	126.02-126.58 ft	Test Id:	533668		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	33.9	66.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	98		
#40	0.42	96		
#60	0.25	89		
#100	0.15	80		
#140	0.11	73		
#200	0.075	66		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0309	43		
---	0.0203	34		
---	0.0121	26		
---	0.0087	24		
---	0.0062	21		
---	0.0044	18		
---	0.0032	17		
---	0.0015	14		

Coefficients

D_{85} = 0.1943 mm	D_{30} = 0.0156 mm
D_{60} = 0.0596 mm	D_{15} = 0.0021 mm
D_{50} = 0.0409 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

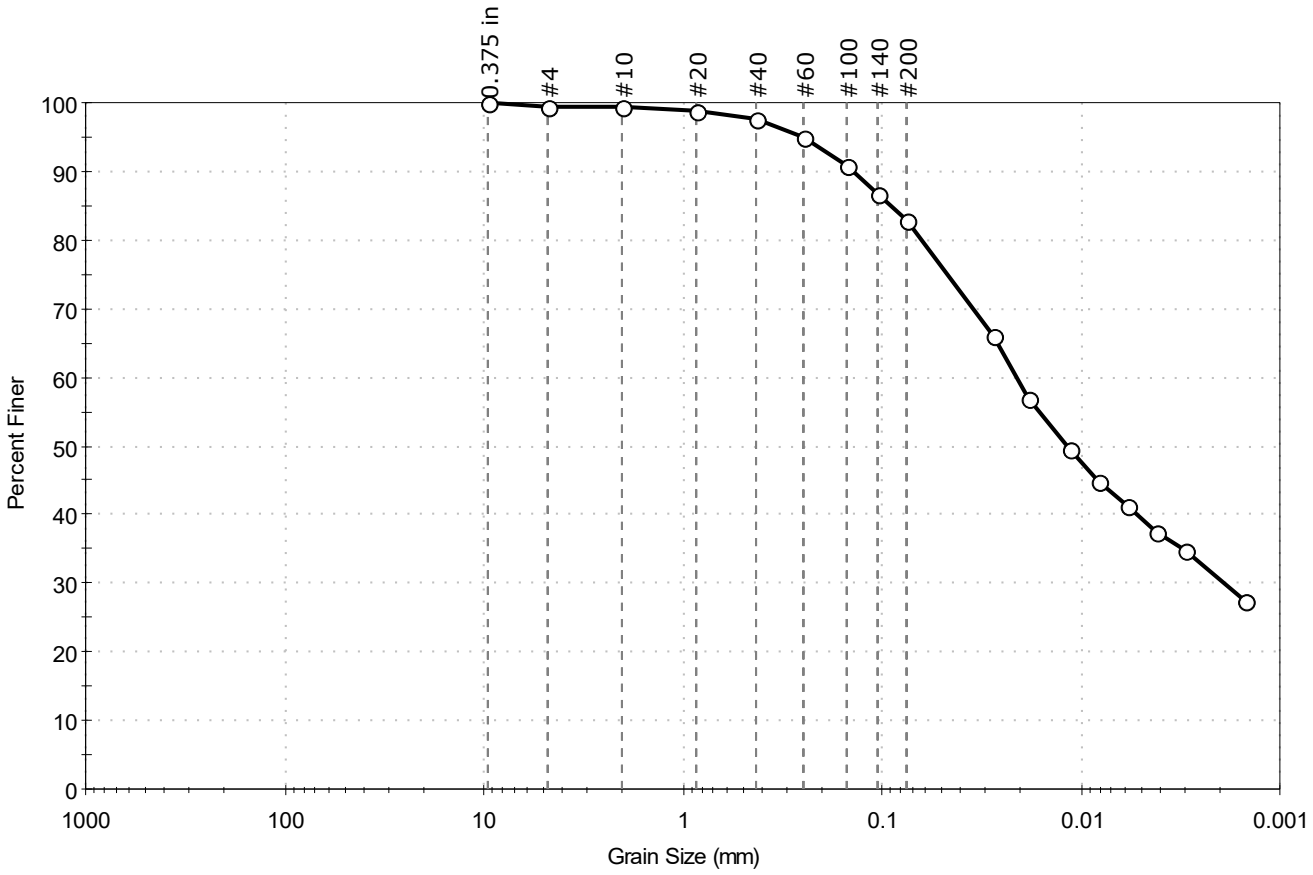
Dispersion Period : 1 minute

Est. Specific Gravity : 2.678

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/27/19	Checked By:	jsc
Depth :	141.83-142.45 ft	Test Id:	533669		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.5	16.7	82.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	100		
#10	2.00	99		
#20	0.85	99		
#40	0.42	98		
#60	0.25	95		
#100	0.15	91		
#140	0.11	87		
#200	0.075	83		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0278	66		
---	0.0182	57		
---	0.0113	50		
---	0.0082	45		
---	0.0059	41		
---	0.0042	38		
---	0.0030	35		
---	0.0015	27		

Coefficients

D_{85} = 0.0909 mm	D_{30} = 0.0019 mm
D_{60} = 0.0210 mm	D_{15} = N/A
D_{50} = 0.0117 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (8))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

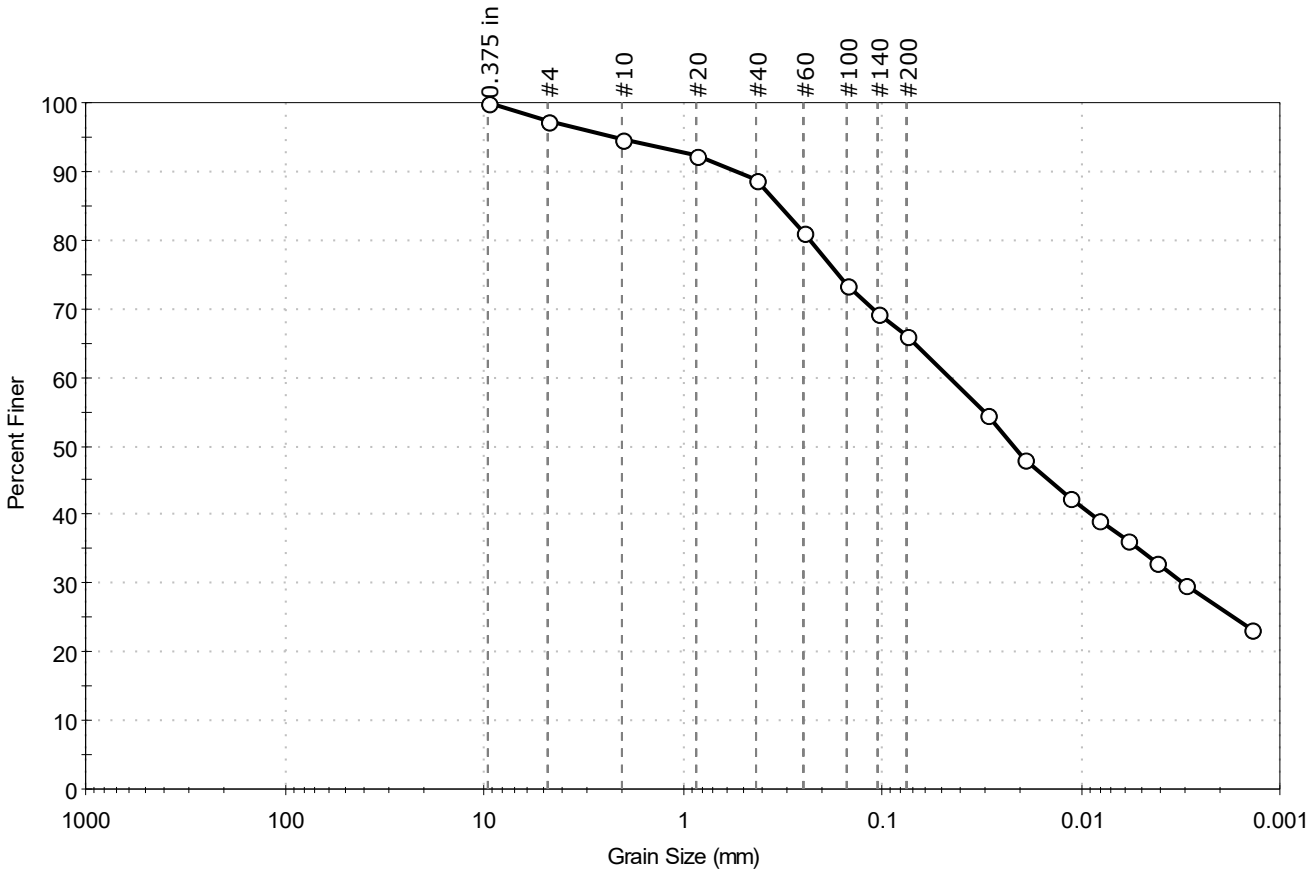
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:23 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/20/19	Checked By:	bfs
Depth :	152.56-153.22 ft	Test Id:	533670		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	2.7	31.2	66.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	97		
#10	2.00	95		
#20	0.85	92		
#40	0.42	89		
#60	0.25	81		
#100	0.15	73		
#140	0.11	69		
#200	0.075	66		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0294	55		
---	0.0192	48		
---	0.0114	43		
---	0.0082	39		
---	0.0059	36		
---	0.0042	33		
---	0.0030	30		
---	0.0014	23		

Coefficients

D_{85} = 0.3283 mm	D_{30} = 0.0031 mm
D_{60} = 0.0457 mm	D_{15} = N/A
D_{50} = 0.0218 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Silty Soils (A-4 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

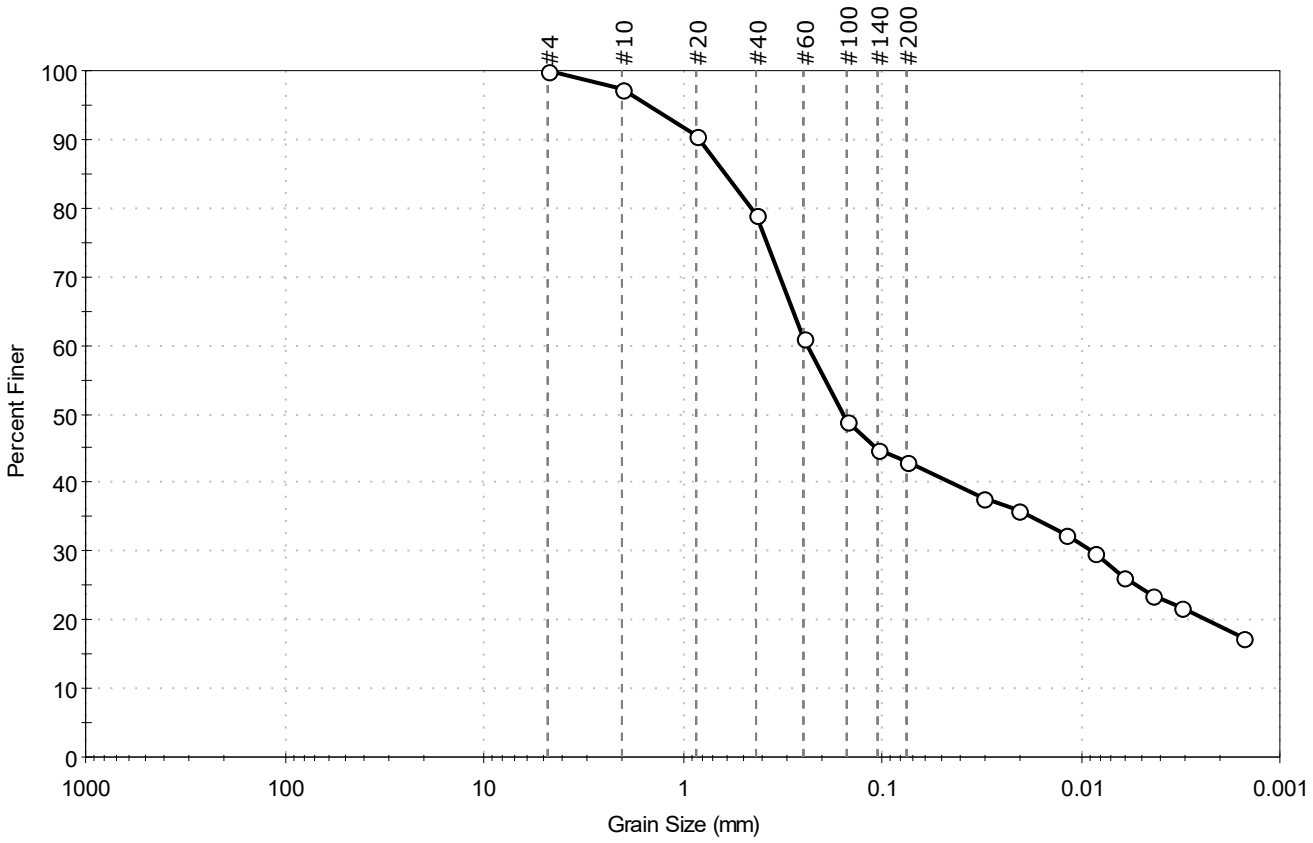
Dispersion Period : 1 minute

Est. Specific Gravity : 2.661

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	12/27/19	Checked By:	jsc
Depth :	189.12-159.68 ft	Test Id:	533671		
Test Comment:	---				
Visual Description:	Moist, brown clayey sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	57.1	42.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	97		
#20	0.85	91		
#40	0.42	79		
#60	0.25	61		
#100	0.15	49		
#140	0.11	45		
#200	0.075	43		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0308	38		
---	0.0206	36		
---	0.0120	32		
---	0.0086	30		
---	0.0062	26		
---	0.0044	24		
---	0.0031	22		
---	0.0015	17		

Coefficients

D_{85} = 0.6077 mm	D_{30} = 0.0088 mm
D_{60} = 0.2403 mm	D_{15} = N/A
D_{50} = 0.1574 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Clayey SAND (SC)

AASHTO Clayey Soils (A-6 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

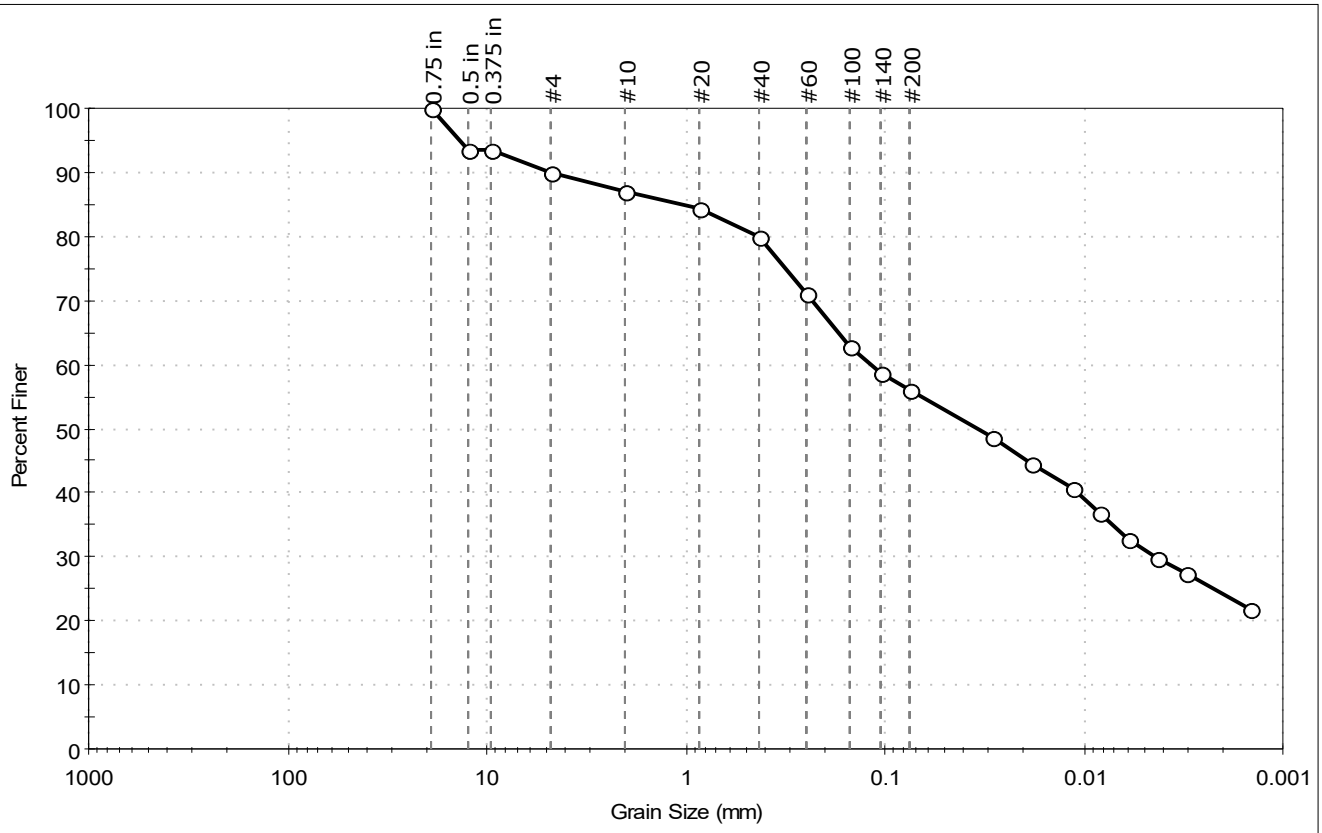
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:25 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	12/20/19	Checked By:	bfs
Depth :	172.28-172.83 ft	Test Id:	533988		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	9.9	34.1	56.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	94		
0.375 in	9.50	94		
#4	4.75	90		
#10	2.00	87		
#20	0.85	84		
#40	0.42	80		
#60	0.25	71		
#100	0.15	63		
#140	0.11	59		
#200	0.075	56		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0292	49		
---	0.0186	45		
---	0.0115	41		
---	0.0083	37		
---	0.0060	33		
---	0.0043	30		
---	0.0031	27		
---	0.0015	22		

Coefficients

D_{85} = 1.0695 mm D_{30} = 0.0044 mm
D_{60} = 0.1194 mm D_{15} = N/A
D_{50} = 0.0350 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Silty Soils (A-4 (2))

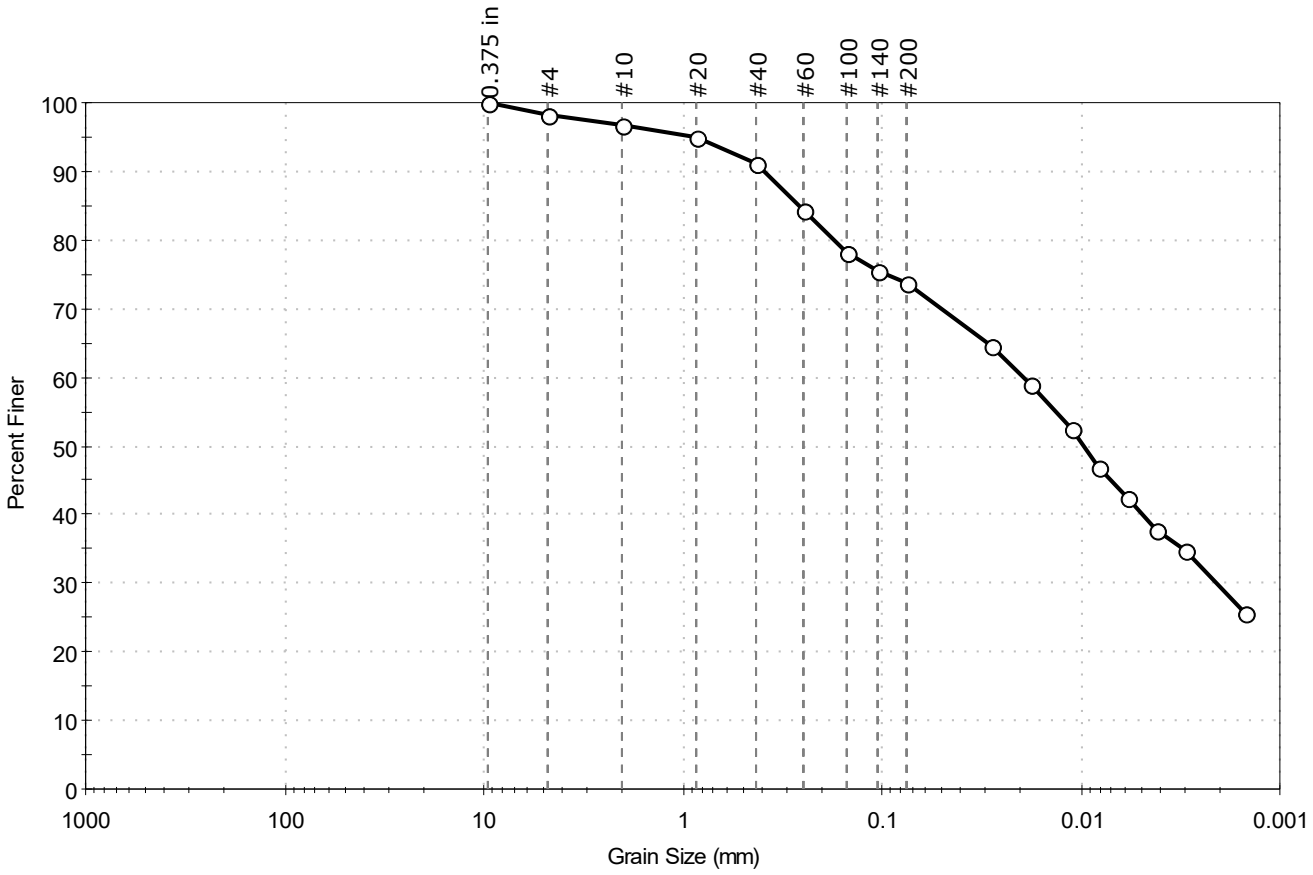
Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.624
Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	12/27/19	Checked By:	jsc
Depth :	180.48-181.07 ft	Test Id:	533989		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.7	24.6	73.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	97		
#20	0.85	95		
#40	0.42	91		
#60	0.25	84		
#100	0.15	78		
#140	0.11	75		
#200	0.075	74		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0280	65		
---	0.0180	59		
---	0.0111	53		
---	0.0081	47		
---	0.0058	42		
---	0.0042	38		
---	0.0030	35		
---	0.0015	26		

Coefficients

D_{85} =0.2643 mm	D_{30} =0.0021 mm
D_{60} =0.0196 mm	D_{15} =N/A
D_{50} =0.0096 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (5))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

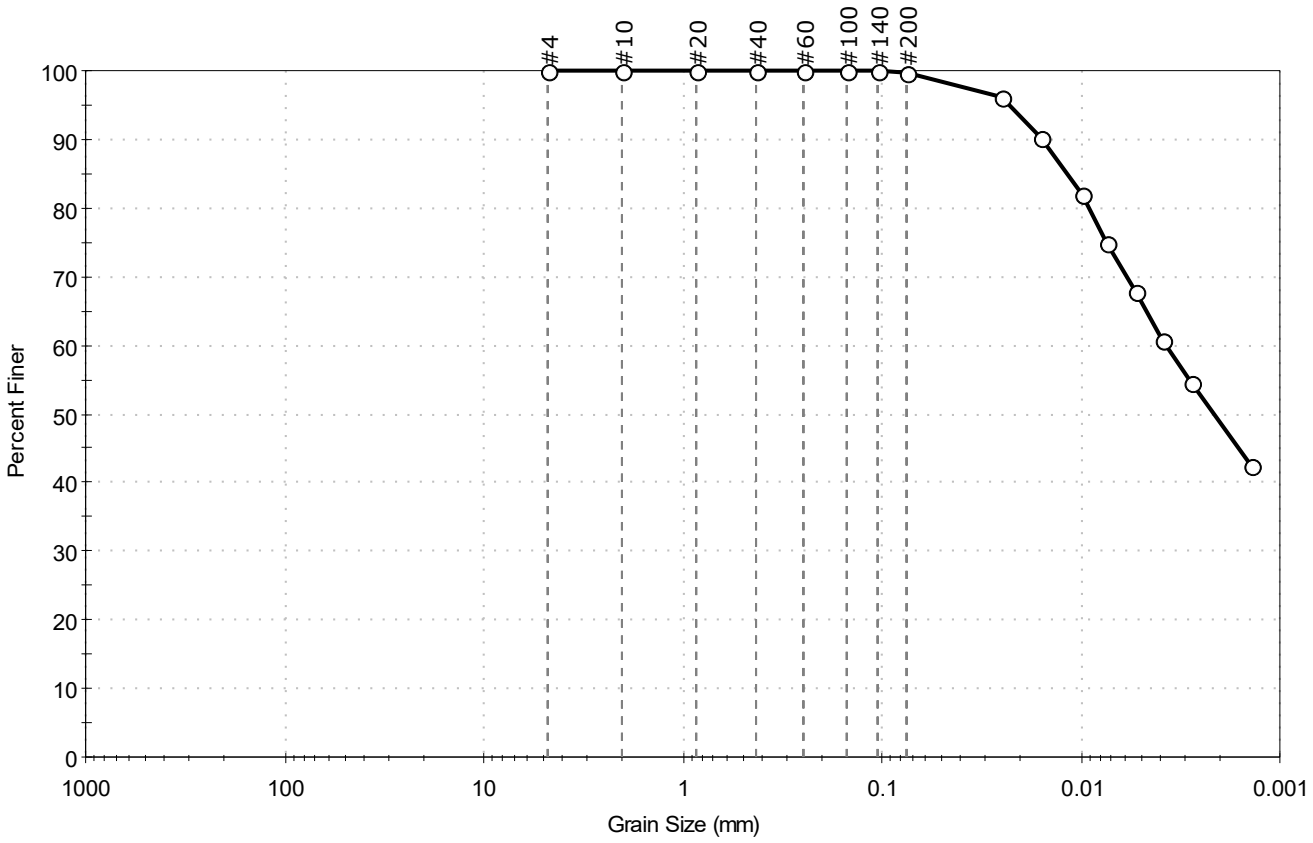
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:28 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	12/19/19	Checked By:	bfs
Depth :	191.37-191.96 ft	Test Id:	533990		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.2	99.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0249	96		
---	0.0161	90		
---	0.0099	82		
---	0.0074	75		
---	0.0054	68		
---	0.0039	61		
---	0.0028	55		
---	0.0014	42		

Coefficients

D_{85} =0.0118 mm	D_{30} =N/A
D_{60} =0.0038 mm	D_{15} =N/A
D_{50} =0.0022 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (20))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

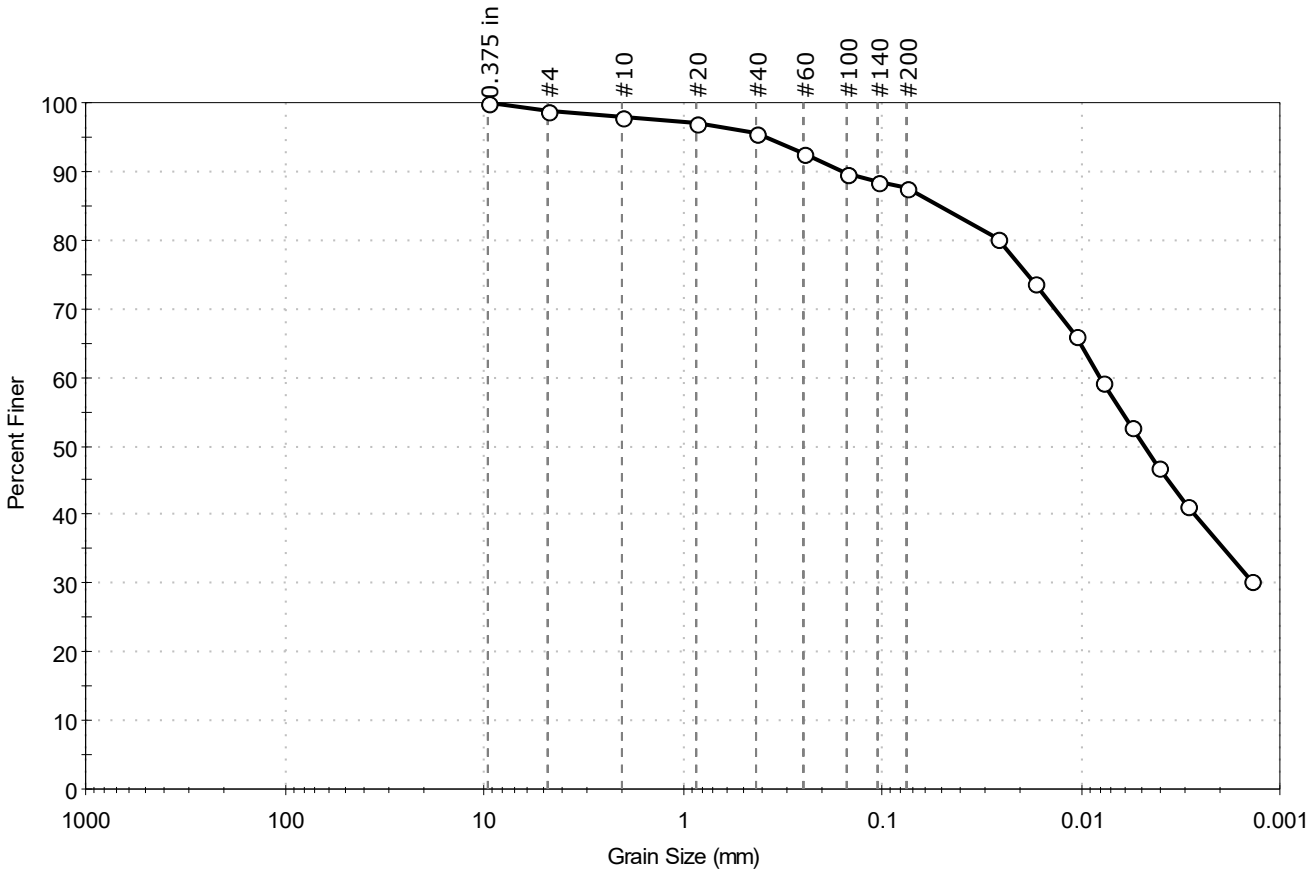
Est. Specific Gravity : 2.662

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-010	Test Date:	12/19/19	Checked By:	bfs
Depth :	198.92-199.44 ft	Test Id:	533991		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.3	11.2	87.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	98		
#20	0.85	97		
#40	0.42	96		
#60	0.25	93		
#100	0.15	90		
#140	0.11	88		
#200	0.075	87		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0263	80		
---	0.0170	74		
---	0.0106	66		
---	0.0078	59		
---	0.0056	53		
---	0.0041	47		
---	0.0029	41		
---	0.0014	30		

Coefficients

D_{85} = 0.0520 mm	D_{30} = N/A
D_{60} = 0.0080 mm	D_{15} = N/A
D_{50} = 0.0048 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (11))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

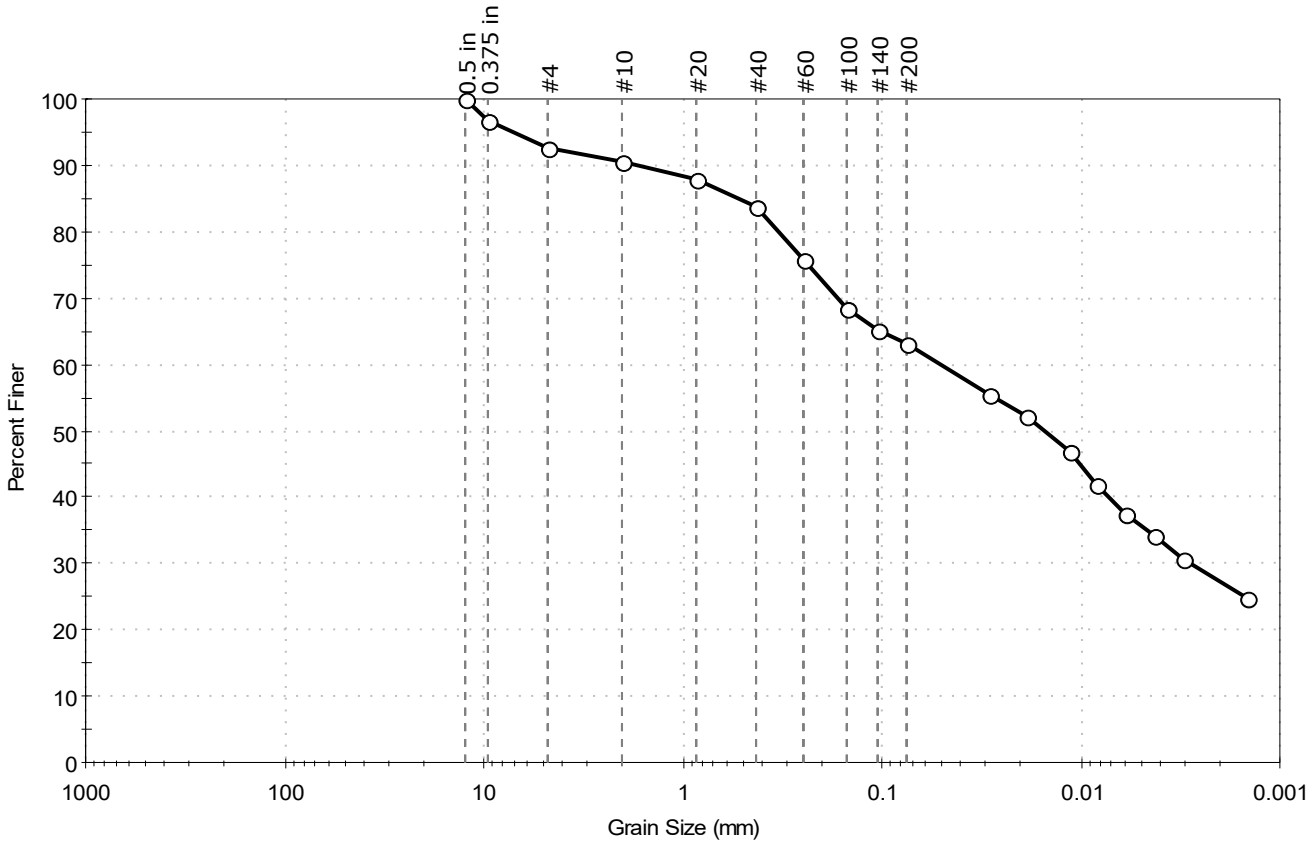
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	12/20/19	Checked By:	bfs
Depth :	209.94-210.50 ft	Test Id:	533992		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	7.5	29.4	63.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	93		
#10	2.00	91		
#20	0.85	88		
#40	0.42	84		
#60	0.25	76		
#100	0.15	69		
#140	0.11	65		
#200	0.075	63		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0287	56		
---	0.0190	52		
---	0.0115	47		
---	0.0083	42		
---	0.0060	38		
---	0.0043	34		
---	0.0031	31		
---	0.0015	25		

Coefficients

D_{85} = 0.5189 mm	D_{30} = 0.0028 mm
D_{60} = 0.0508 mm	D_{15} = N/A
D_{50} = 0.0155 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Silty Soils (A-4 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

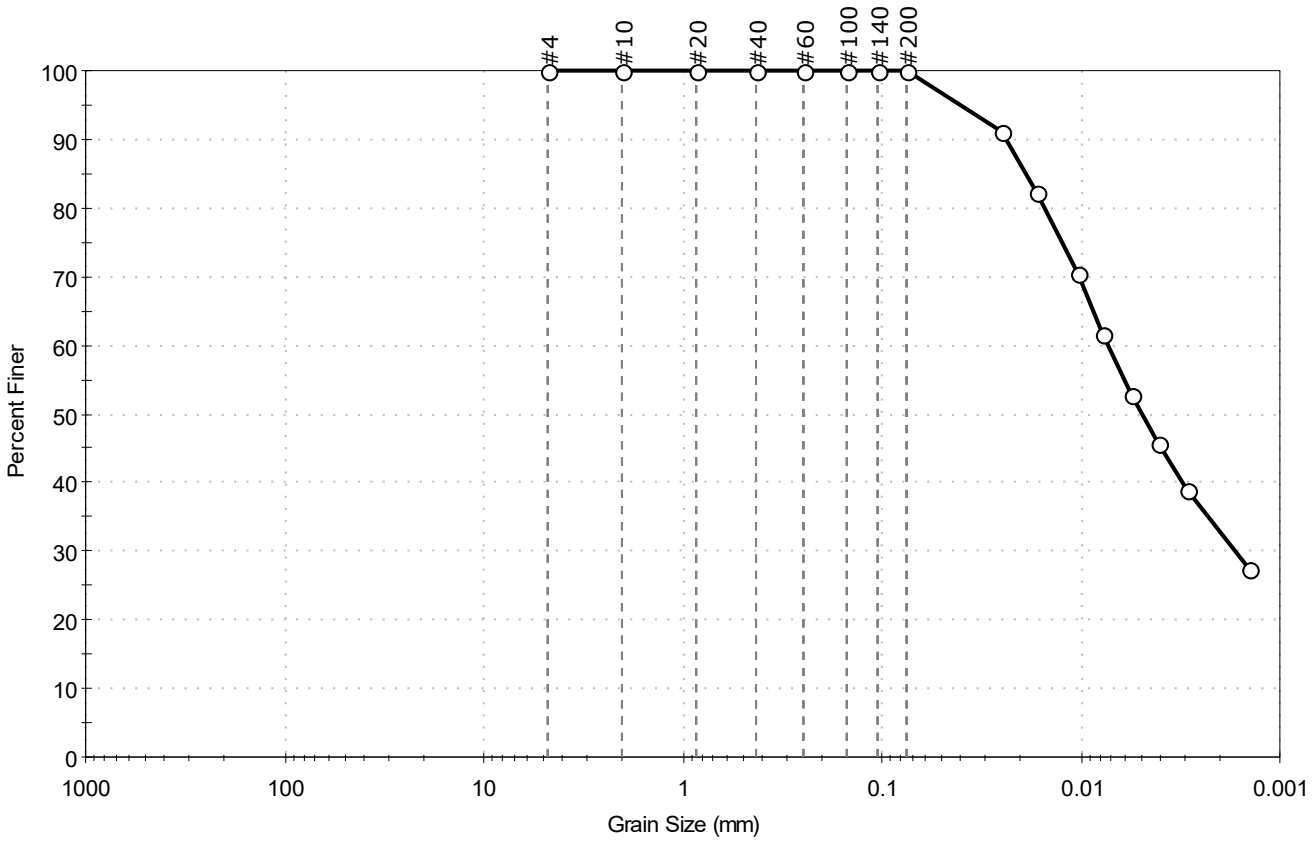
Dispersion Period : 1 minute

Est. Specific Gravity : 2.603

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-012	Test Date:	12/19/19	Checked By:	bfs
Depth :	219.03-219.55 ft	Test Id:	533993		
Test Comment:	---				
Visual Description:	Moist, dark grayish brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.1	99.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0253	91		
---	0.0166	82		
---	0.0105	71		
---	0.0078	62		
---	0.0056	53		
---	0.0041	46		
---	0.0029	39		
---	0.0014	28		

Coefficients

D_{85} = 0.0188 mm	D_{30} = 0.0017 mm
D_{60} = 0.0074 mm	D_{15} = N/A
D_{50} = 0.0050 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (10))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

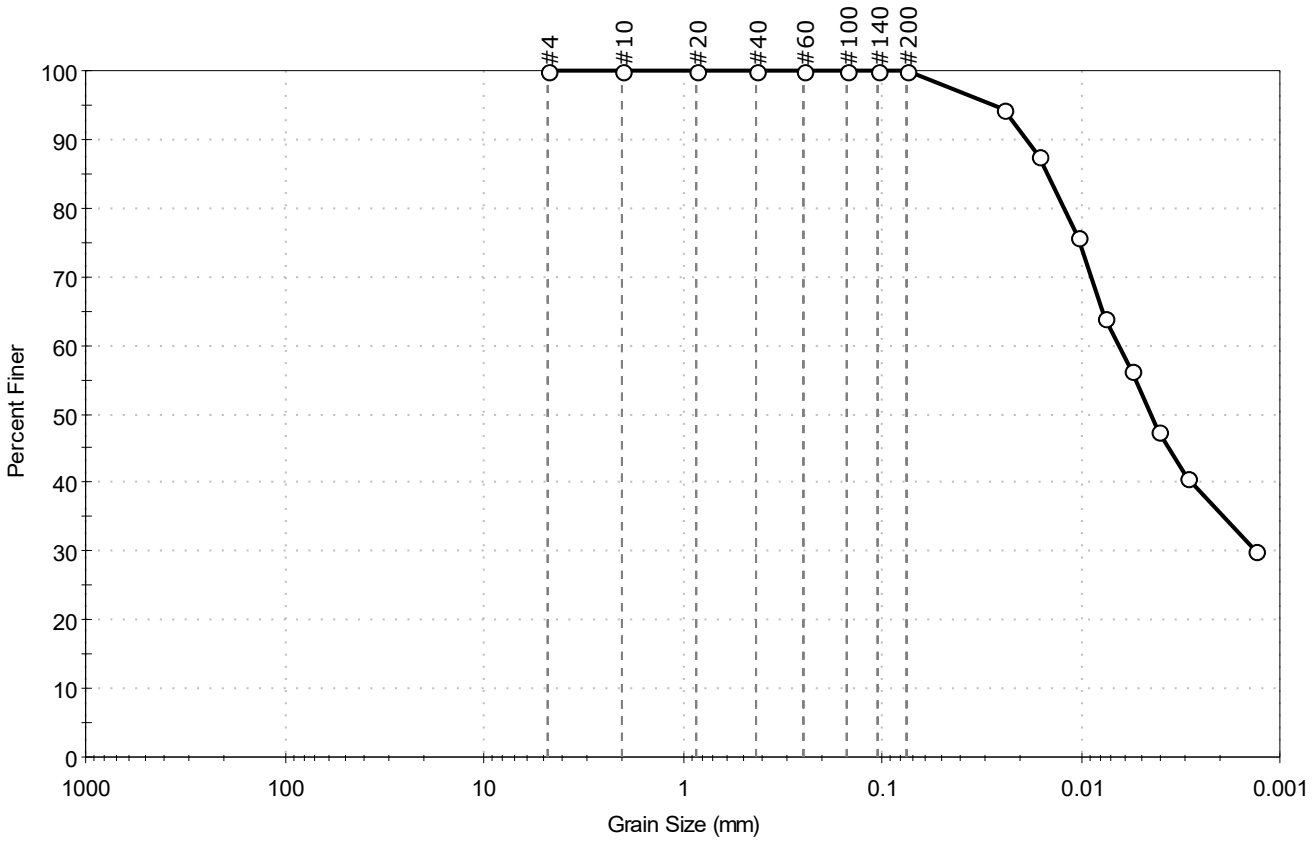
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	12/31/19	Checked By:	jsc
Depth :	228.02-228.54 ft	Test Id:	532686		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.1	99.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0242	94		
---	0.0163	88		
---	0.0102	76		
---	0.0076	64		
---	0.0056	56		
---	0.0041	48		
---	0.0029	41		
---	0.0013	30		

Coefficients

D_{85} = 0.0148 mm	D_{30} = N/A
D_{60} = 0.0064 mm	D_{15} = N/A
D_{50} = 0.0044 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (12))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

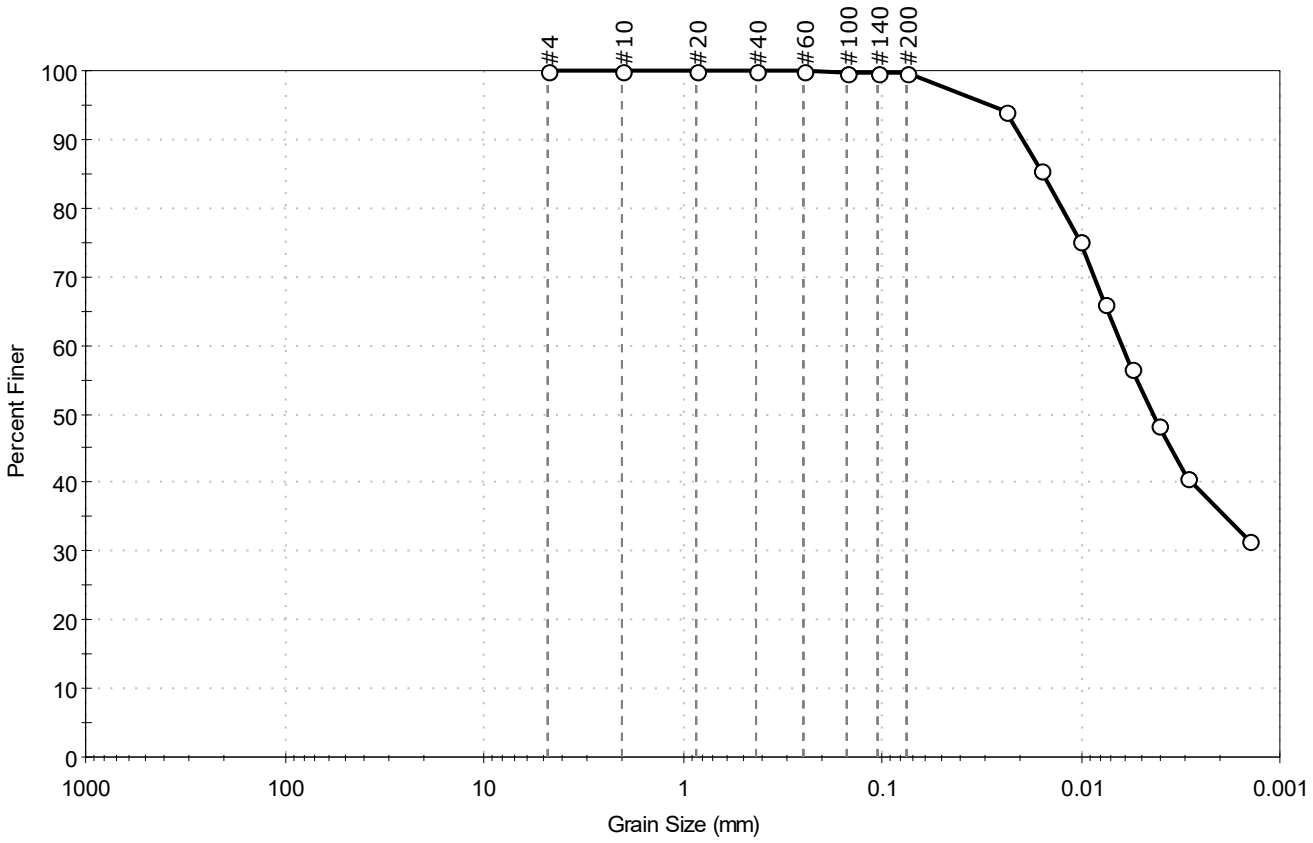
Dispersion Period : 1 minute

Est. Specific Gravity : 2.68

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	12/20/19	Checked By:	bfs
Depth :	237.30-237.83 ft	Test Id:	532687		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.4	99.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0239	94		
---	0.0158	86		
---	0.0102	75		
---	0.0075	66		
---	0.0055	57		
---	0.0041	48		
---	0.0029	41		
---	0.0014	32		

Coefficients

D_{85} = 0.0154 mm D_{30} = N/A

D_{60} = 0.0062 mm D_{15} = N/A

D_{50} = 0.0043 mm D_{10} = N/A

C_u = N/A C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (10))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

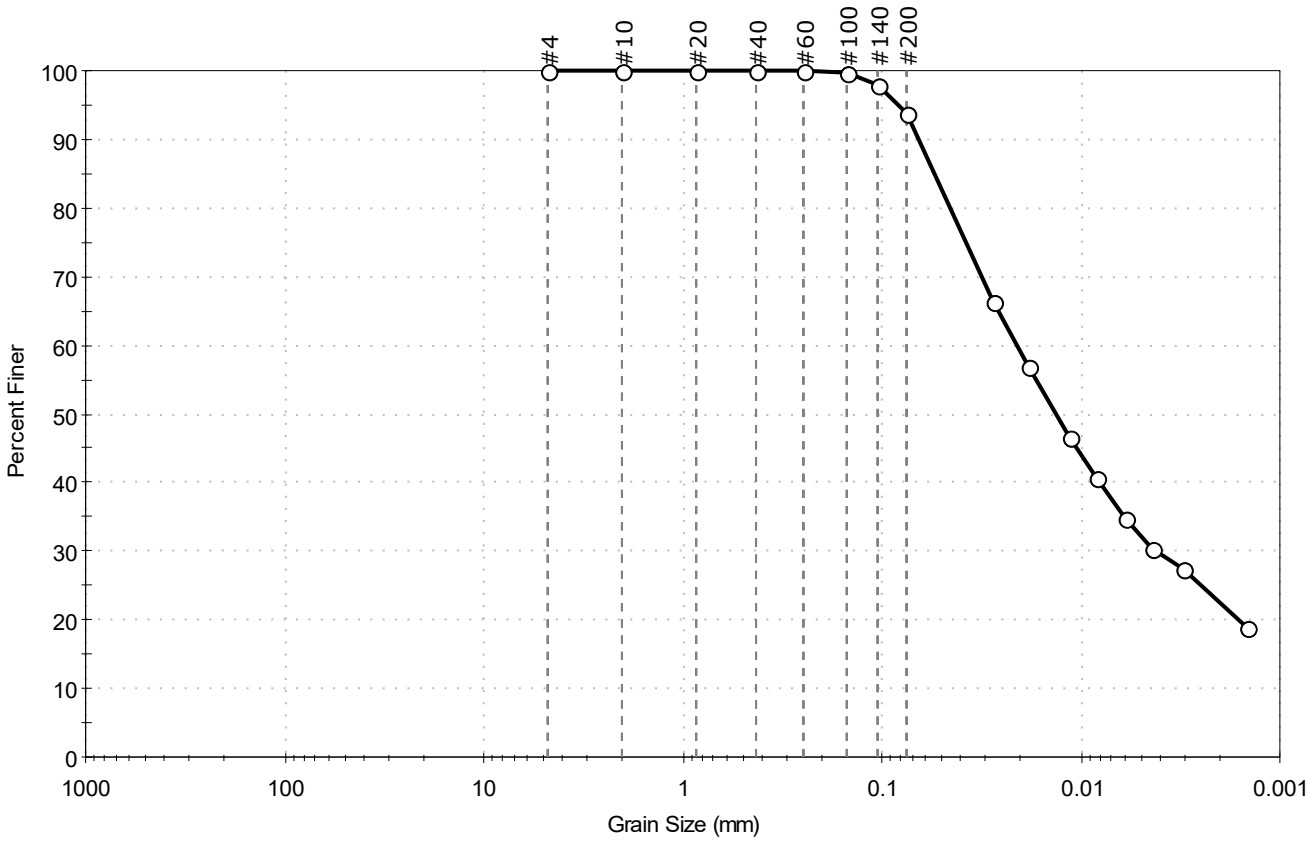
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	01/03/20	Checked By:	jsc
Depth :	250.85-251.38 ft	Test Id:	532688		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	6.1	93.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	98		
#200	0.075	94		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0276	66		
---	0.0184	57		
---	0.0115	47		
---	0.0084	41		
---	0.0060	35		
---	0.0044	30		
---	0.0031	27		
---	0.0015	19		

Coefficients

D_{85} = 0.0543 mm	D_{30} = 0.0042 mm
D_{60} = 0.0210 mm	D_{15} = N/A
D_{50} = 0.0134 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Silty Soils (A-4 (7))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

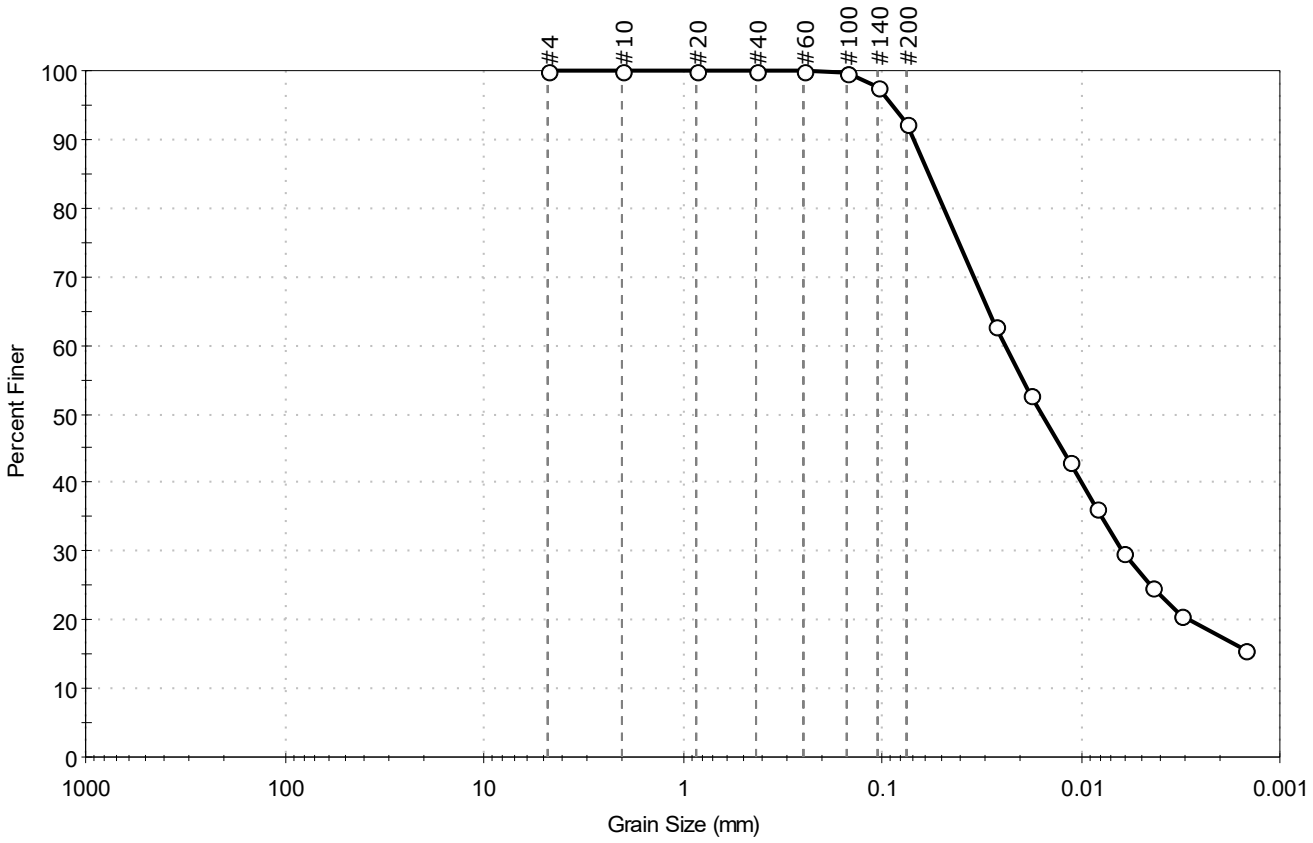
Est. Specific Gravity : 2.647

Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:36 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-016	Test Date:	12/19/19	Checked By:	bfs
Depth :	257.64-258.20 ft	Test Id:	532689		
Test Comment:	---				
Visual Description:	Moist, brown silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	7.5	92.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	98		
#200	0.075	92		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0271	63		
---	0.0180	53		
---	0.0114	43		
---	0.0083	36		
---	0.0061	30		
---	0.0044	25		
---	0.0031	21		
---	0.0015	16		

Coefficients

D_{85} = 0.0580 mm	D_{30} = 0.0061 mm
D_{60} = 0.0241 mm	D_{15} = N/A
D_{50} = 0.0157 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM SILT (ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

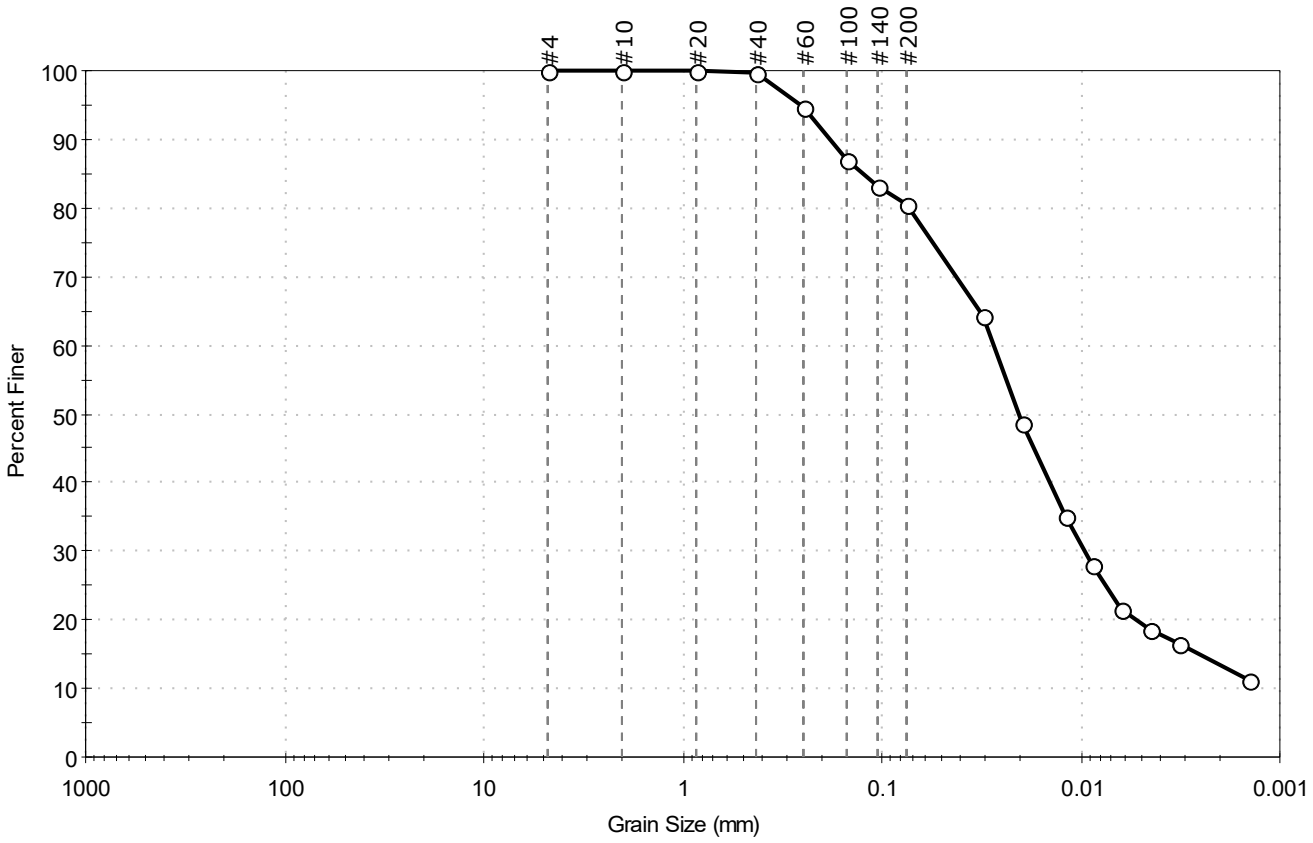
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-017	Test Date:	12/31/19	Checked By:	jsc
Depth :	267.82-268.44 ft	Test Id:	532690		
Test Comment:	---				
Visual Description:	Moist, pale brown silt with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	19.4	80.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	95		
#100	0.15	87		
#140	0.11	83		
#200	0.075	81		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	64		
---	0.0197	49		
---	0.0121	35		
---	0.0088	28		
---	0.0063	22		
---	0.0045	19		
---	0.0032	16		
---	0.0014	11		

Coefficients

D_{85} = 0.1248 mm	D_{30} = 0.0096 mm
D_{60} = 0.0274 mm	D_{15} = 0.0026 mm
D_{50} = 0.0204 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM SILT with Sand (ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

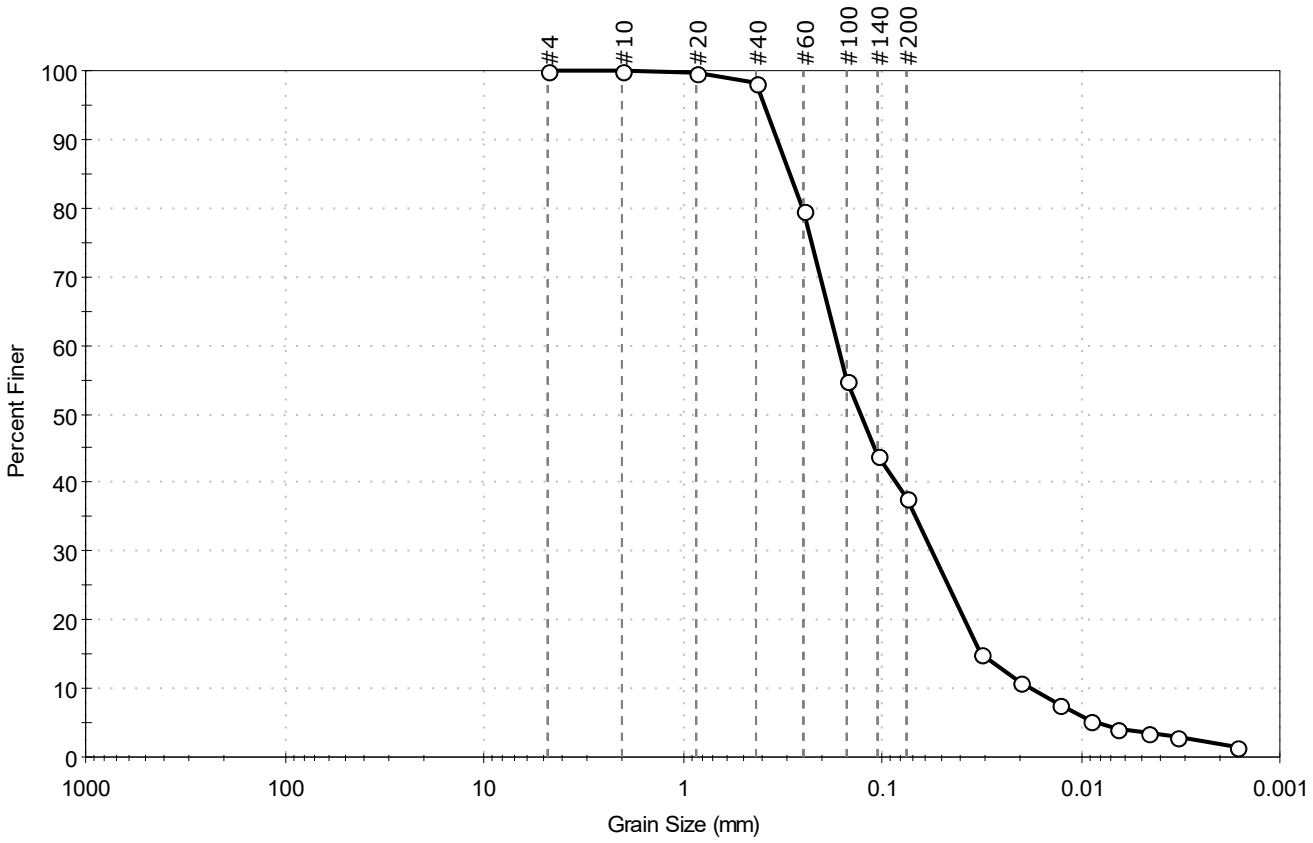
Dispersion Period : 1 minute

Est. Specific Gravity : 2.663

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-018	Test Date:	01/09/20	Checked By:	jsc
Depth :	279.53-280.09 ft	Test Id:	537528		
Test Comment:	---				
Visual Description:	Moist, light grayish brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	62.2	37.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	98		
#60	0.25	80		
#100	0.15	55		
#140	0.11	44		
#200	0.075	38		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0315	15		
---	0.0204	11		
---	0.0128	8		
---	0.0091	5		
---	0.0065	4		
---	0.0046	3		
---	0.0033	3		
---	0.0017	1		

Coefficients

D_{85} =0.2916 mm	D_{30} =0.0556 mm
D_{60} =0.1668 mm	D_{15} =0.0312 mm
D_{50} =0.1287 mm	D_{10} =0.0181 mm
C_u =9.215	C_c =1.024

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

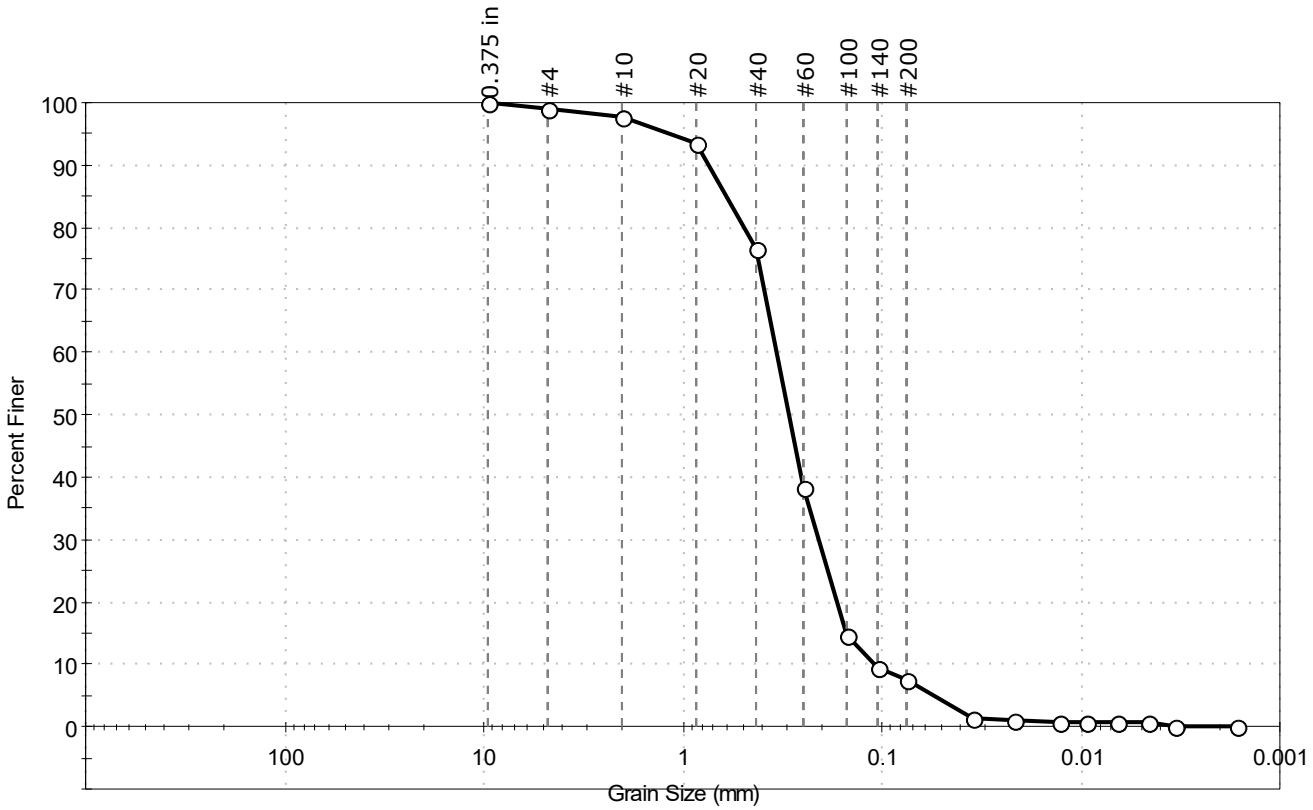
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-019	Test Date:	01/09/20	Checked By:	jsc
Depth :	288.38-288.94 ft	Test Id:	537529		
Test Comment:	---				
Visual Description:	Moist, grayish brown sand with silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.0	91.4	7.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	98		
#20	0.85	93		
#40	0.42	77		
#60	0.25	38		
#100	0.15	15		
#140	0.11	9		
#200	0.075	7.6		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0347	1		
---	0.0220	1		
---	0.0130	1		
---	0.0094	1		
---	0.0066	1		
---	0.0046	1		
---	0.0034	0		
---	0.0017	0		

Coefficients

D_{85} =0.6025 mm	D_{30} =0.2091 mm
D_{60} =0.3381 mm	D_{15} =0.1510 mm
D_{50} =0.2943 mm	D_{10} =0.1096 mm
C_u =3.085	C_c =1.180

Classification

ASTM N/A

AASHTO Fine Sand (A-3 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

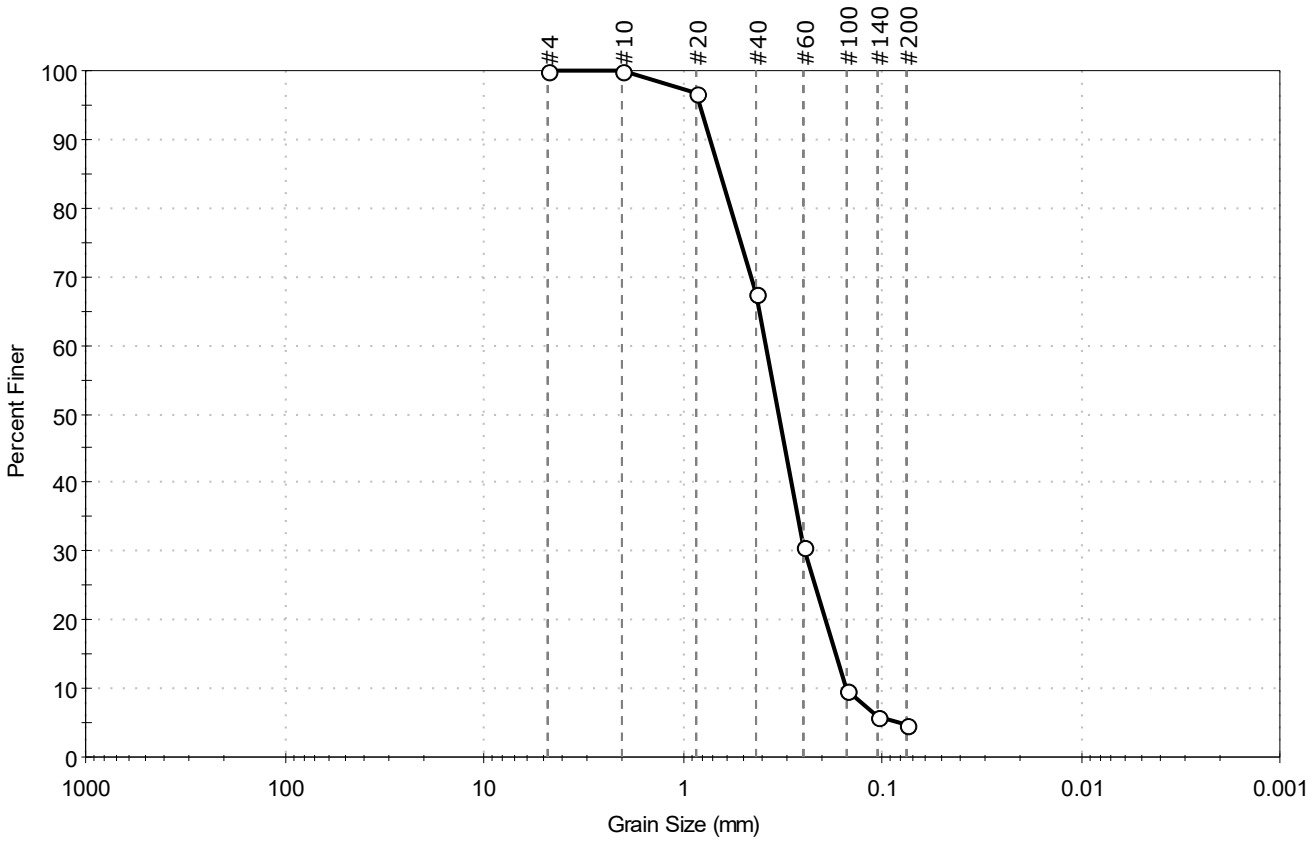
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-020	Test Date:	01/09/20	Checked By:	jsc
Depth :	297.57-298.13 ft	Test Id:	537530		
Test Comment:	---				
Visual Description:	Moist, light grayish brown sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	95.3	4.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	97		
#40	0.42	67		
#60	0.25	31		
#100	0.15	10		
#140	0.11	6		
#200	0.075	4.7		

Coefficients

D_{85} = 0.6447 mm	D_{30} = 0.2465 mm
D_{60} = 0.3817 mm	D_{15} = 0.1709 mm
D_{50} = 0.3306 mm	D_{10} = 0.1512 mm
C_u = 2.524	C_c = 1.053

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

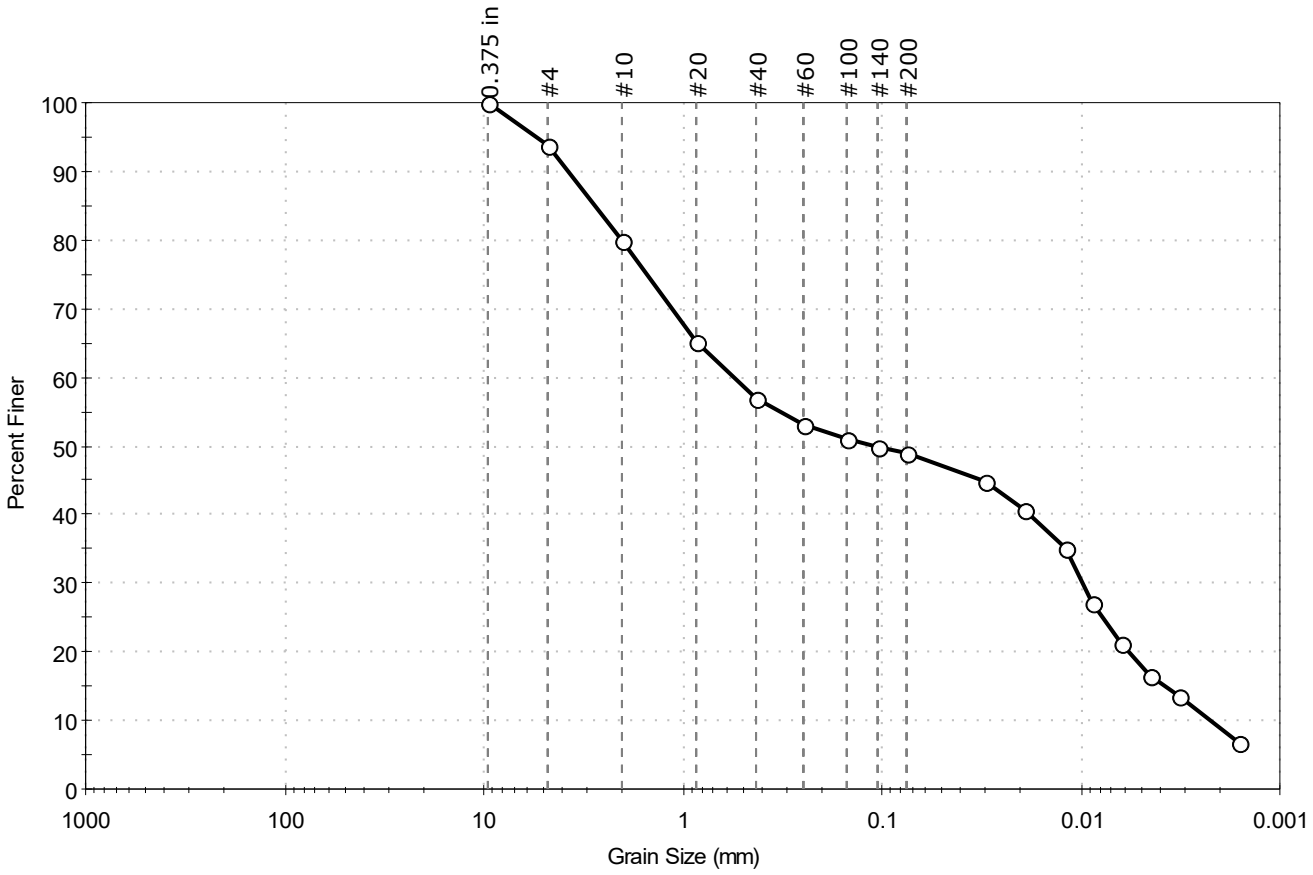
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-022	Test Date:	01/09/20	Checked By:	jsc
Depth :	321.75-322.18 ft	Test Id:	537531		
Test Comment:	---				
Visual Description:	Moist, gray silty clayey sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	6.1	44.8	49.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	94		
#10	2.00	80		
#20	0.85	65		
#40	0.42	57		
#60	0.25	53		
#100	0.15	51		
#140	0.11	50		
#200	0.075	49		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0305	45		
---	0.0194	41		
---	0.0120	35		
---	0.0087	27		
---	0.0063	21		
---	0.0045	16		
---	0.0032	13		
---	0.0016	7		

Coefficients

D_{85} =2.7402 mm	D_{30} =0.0098 mm
D_{60} =0.5435 mm	D_{15} =0.0038 mm
D_{50} =0.1101 mm	D_{10} =0.0023 mm
C_u =236.304	C_c =0.077

Classification

ASTM Silty, Clayey SAND (SC-SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

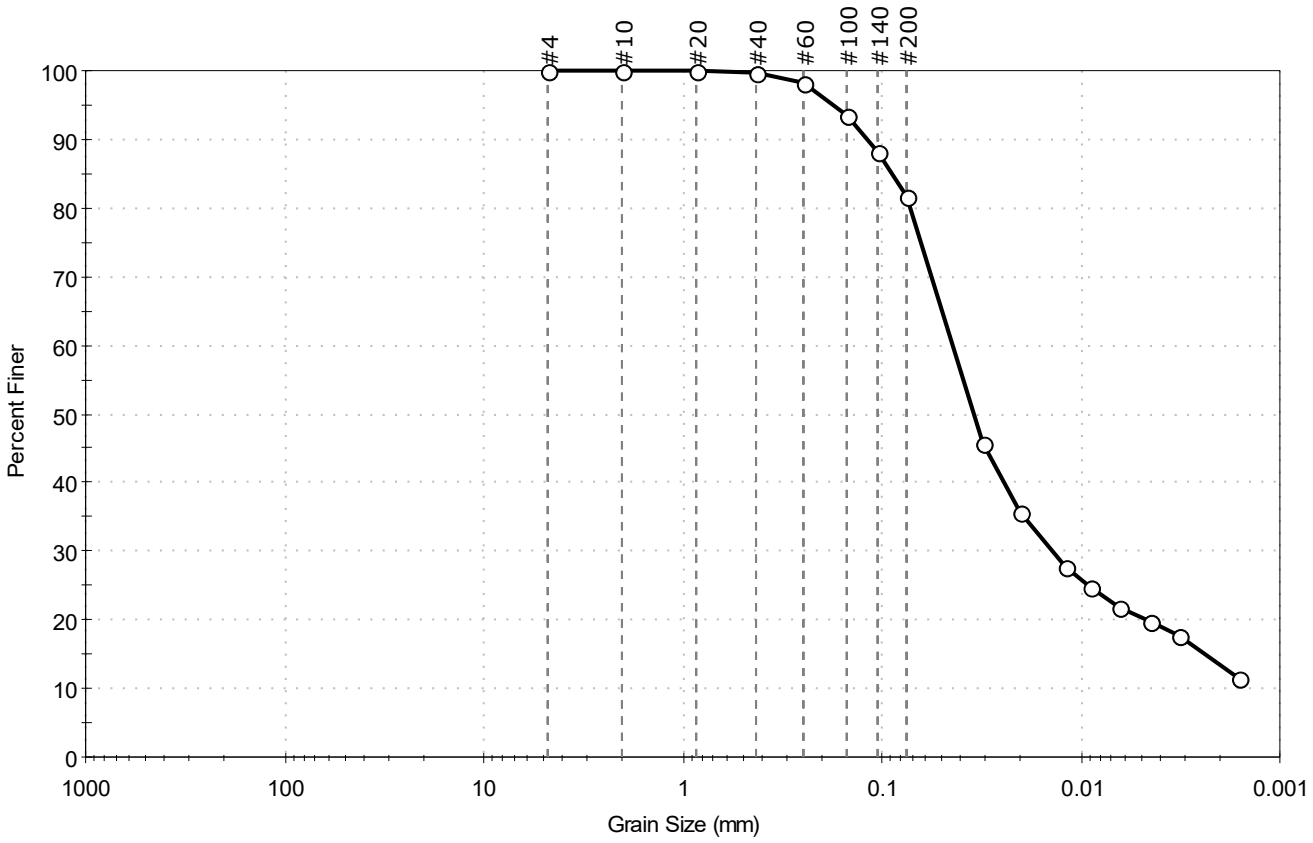
Dispersion Period : 1 minute

Est. Specific Gravity : 2.673

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	tube	Tested By:	GA
Sample ID:	BH19-26-ST-001	Test Date:	01/23/20	Checked By:	n/a
Depth :	104.99-107.35 ft	Test Id:	540889		
Test Comment:	---				
Visual Description:	Moist, brown silty clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	18.4	81.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	98		
#100	0.15	93		
#140	0.11	88		
#200	0.075	82		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0311	46		
---	0.0201	36		
---	0.0120	28		
---	0.0089	25		
---	0.0064	22		
---	0.0045	20		
---	0.0032	18		
---	0.0016	11		

Coefficients

D_{85} = 0.0895 mm	D_{30} = 0.0138 mm
D_{60} = 0.0441 mm	D_{15} = 0.0024 mm
D_{50} = 0.0345 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty CLAY with Sand (CL-ML)

AASHTO Silty Soils (A-4 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

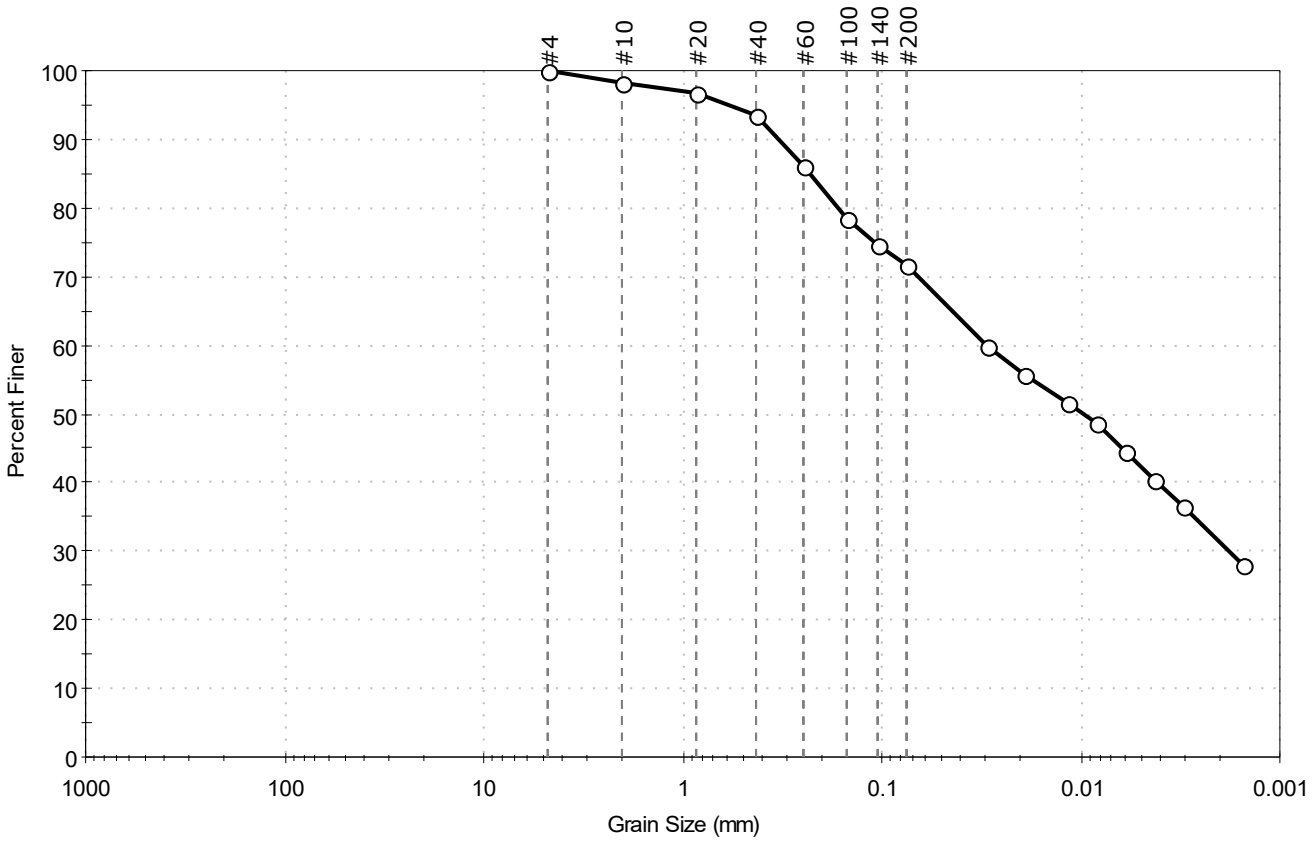
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	tube	Tested By:	GA
Sample ID:	BH19-26-ST-002	Test Date:	01/23/20	Checked By:	n/a
Depth :	134.51-135.47 ft	Test Id:	540890		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	28.4	71.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	98		
#20	0.85	97		
#40	0.42	93		
#60	0.25	86		
#100	0.15	79		
#140	0.11	74		
#200	0.075	72		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0297	60		
---	0.0195	56		
---	0.0116	52		
---	0.0083	49		
---	0.0060	45		
---	0.0043	41		
---	0.0031	36		
---	0.0016	28		

Coefficients

D_{85} = 0.2329 mm	D_{30} = 0.0018 mm
D_{60} = 0.0302 mm	D_{15} = N/A
D_{50} = 0.0097 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (7))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

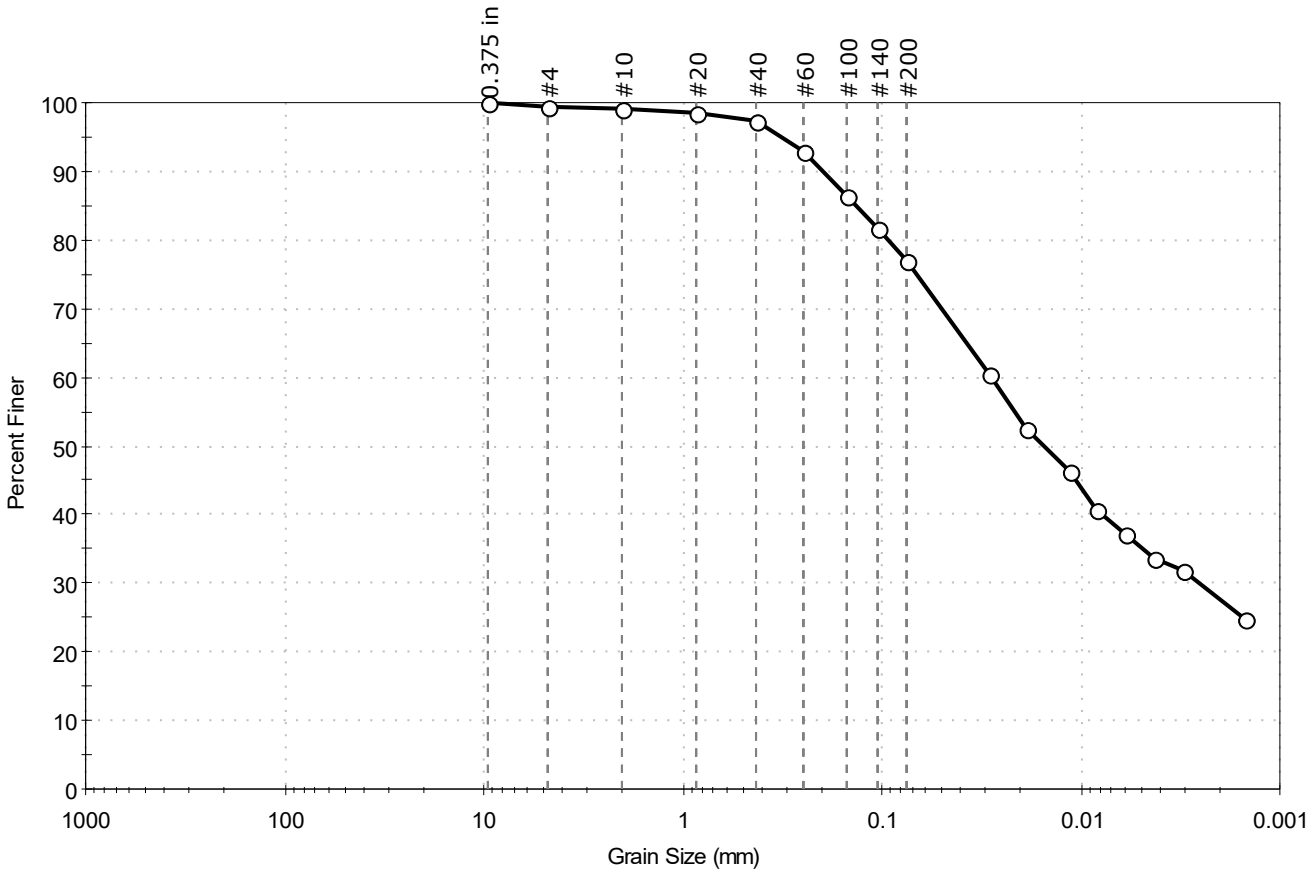
Est. Specific Gravity : 2.634

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/27/19	Checked By:	jsc
Depth :	120.31-120.90 ft	Test Id:	532899		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.7	22.2	77.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	99		
#20	0.85	99		
#40	0.42	97		
#60	0.25	93		
#100	0.15	87		
#140	0.11	82		
#200	0.075	77		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0287	60		
---	0.0187	52		
---	0.0115	46		
---	0.0084	41		
---	0.0060	37		
---	0.0043	34		
---	0.0031	32		
---	0.0015	25		

Coefficients

D_{85} = 0.1348 mm	D_{30} = 0.0025 mm
D_{60} = 0.0280 mm	D_{15} = N/A
D_{50} = 0.0155 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY with Sand (CL)

AASHTO Clayey Soils (A-6 (5))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.598

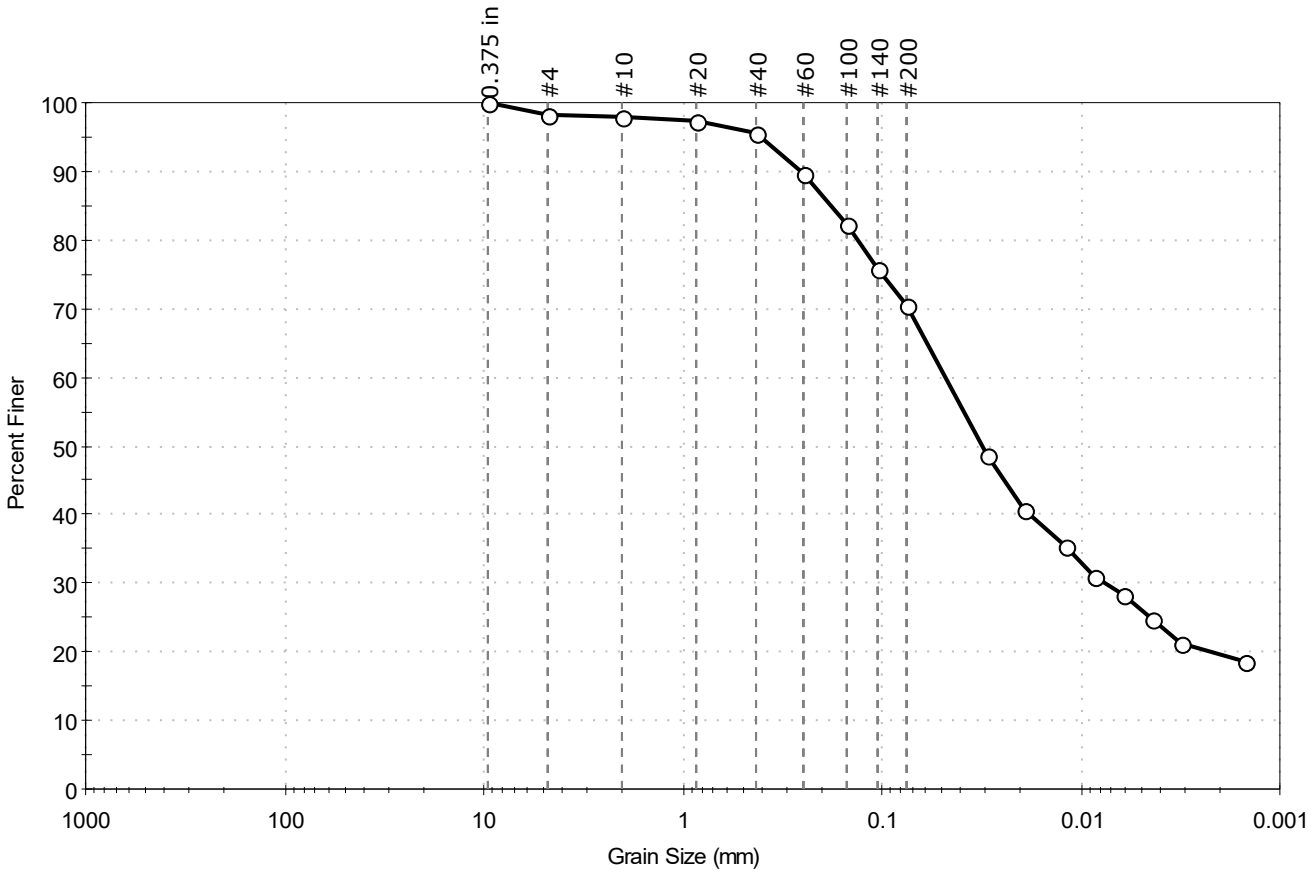
Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:46 PM

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/19/19	Checked By:	bfs
Depth :	133.20-133.69 ft	Test Id:	532900		
Test Comment:	---				
Visual Description:	Moist, brown silty clay with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.8	27.8	70.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	98		
#20	0.85	97		
#40	0.42	96		
#60	0.25	90		
#100	0.15	82		
#140	0.11	76		
#200	0.075	70		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0296	49		
---	0.0192	41		
---	0.0118	35		
---	0.0086	31		
---	0.0061	28		
---	0.0044	25		
---	0.0031	21		
---	0.0015	18		

Coefficients

D_{85} = 0.1813 mm	D_{30} = 0.0077 mm
D_{60} = 0.0481 mm	D_{15} = N/A
D_{50} = 0.0313 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty CLAY with Sand (CL-ML)

AASHTO Silty Soils (A-4 (2))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

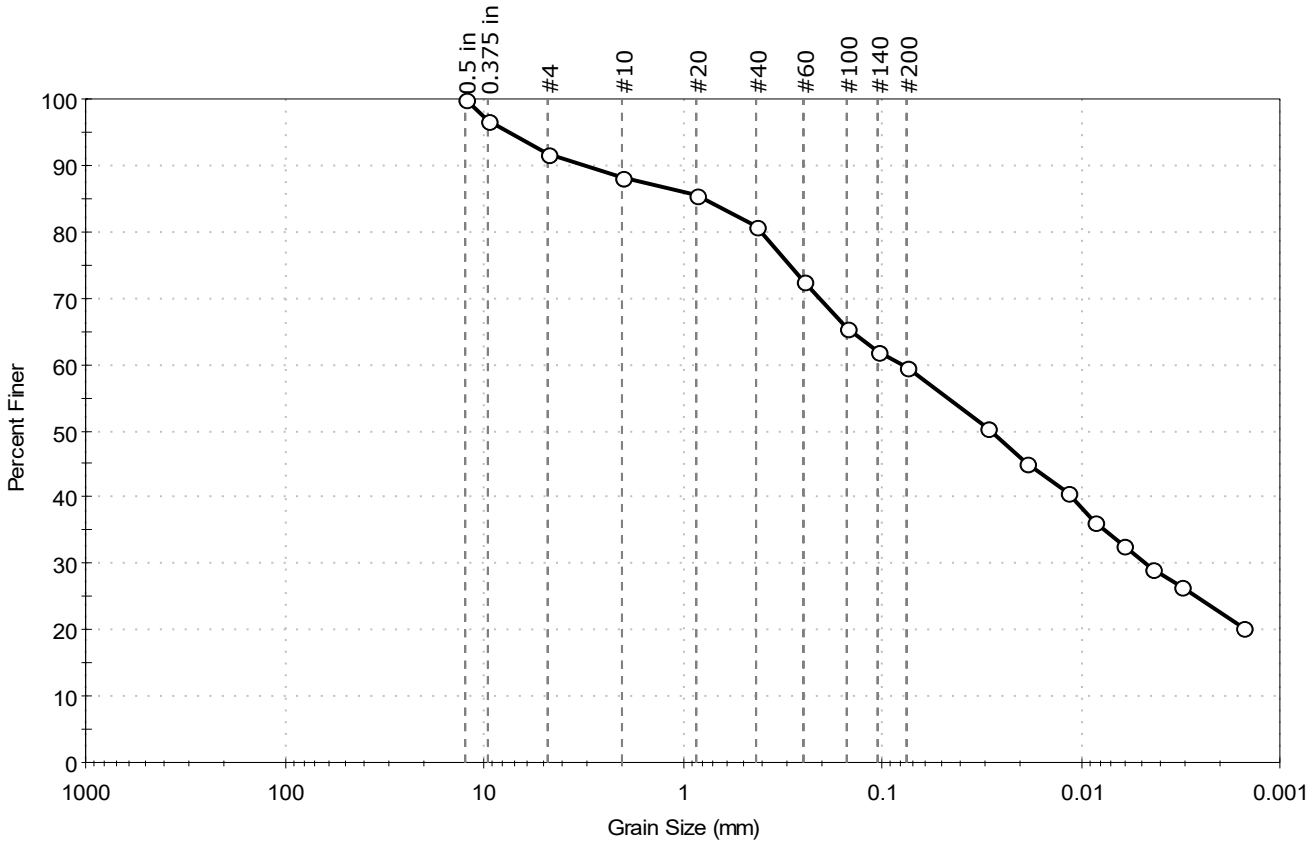
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:48 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	144.26-144.75 ft	Test Id:	532901		
Test Comment:	---				
Visual Description:	Dry, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	8.3	32.0	59.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	92		
#10	2.00	88		
#20	0.85	86		
#40	0.42	81		
#60	0.25	73		
#100	0.15	65		
#140	0.11	62		
#200	0.075	60		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0296	50		
---	0.0190	45		
---	0.0116	41		
---	0.0085	36		
---	0.0061	33		
---	0.0044	29		
---	0.0031	26		
---	0.0015	20		

Coefficients

D_{85} =0.7777 mm	D_{30} =0.0047 mm
D_{60} =0.0795 mm	D_{15} =N/A
D_{50} =0.0285 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (3))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

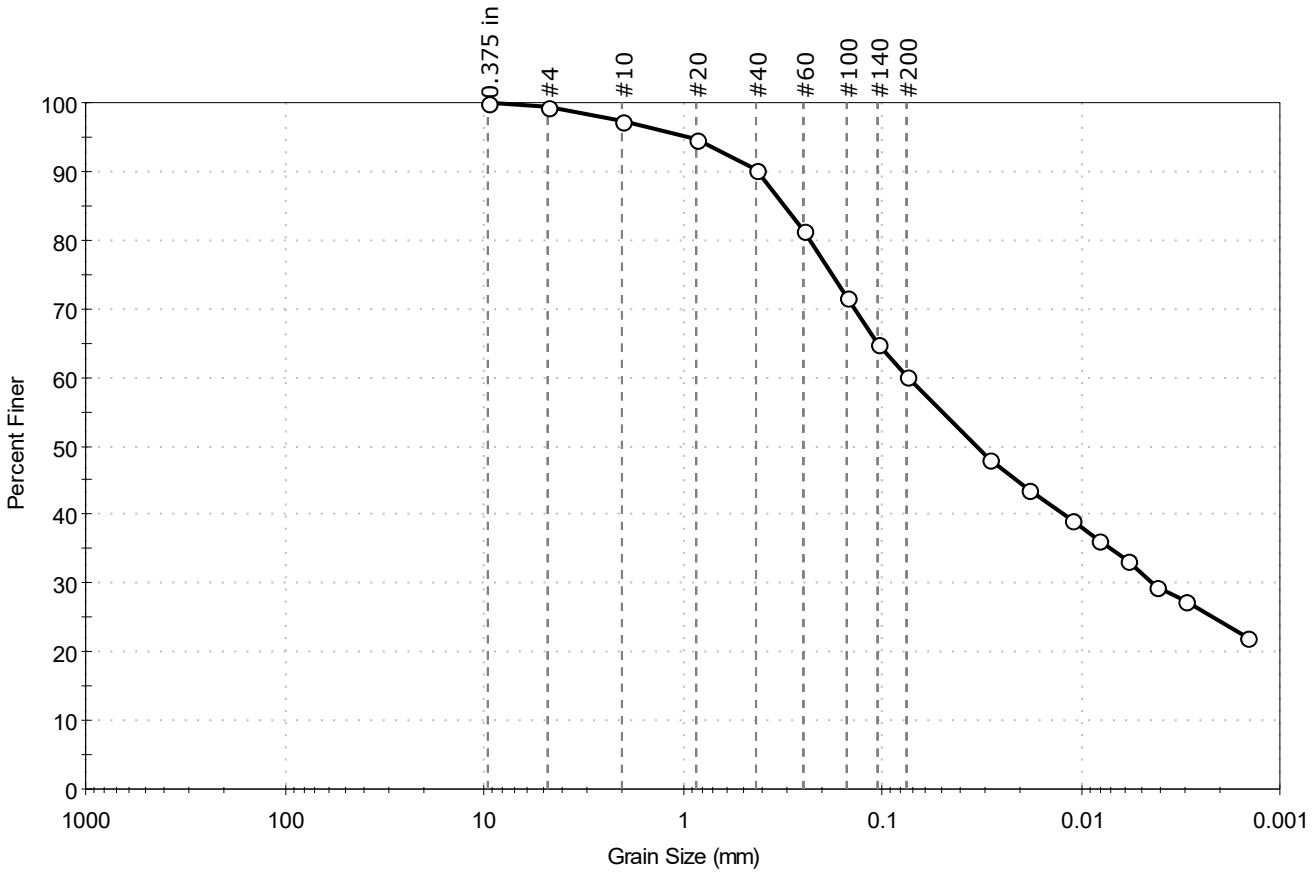
Dispersion Period : 1 minute

Est. Specific Gravity : 2.628

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/20/19	Checked By:	bfs
Depth :	153.35-153.94 ft	Test Id:	532902		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.7	39.2	60.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	97		
#20	0.85	95		
#40	0.42	90		
#60	0.25	81		
#100	0.15	72		
#140	0.11	65		
#200	0.075	60		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0286	48		
---	0.0184	44		
---	0.0113	39		
---	0.0082	36		
---	0.0059	33		
---	0.0042	30		
---	0.0030	27		
---	0.0015	22		

Coefficients

D_{85} = 0.3102 mm	D_{30} = 0.0044 mm
D_{60} = 0.0747 mm	D_{15} = N/A
D_{50} = 0.0333 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Silty Soils (A-4 (2))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

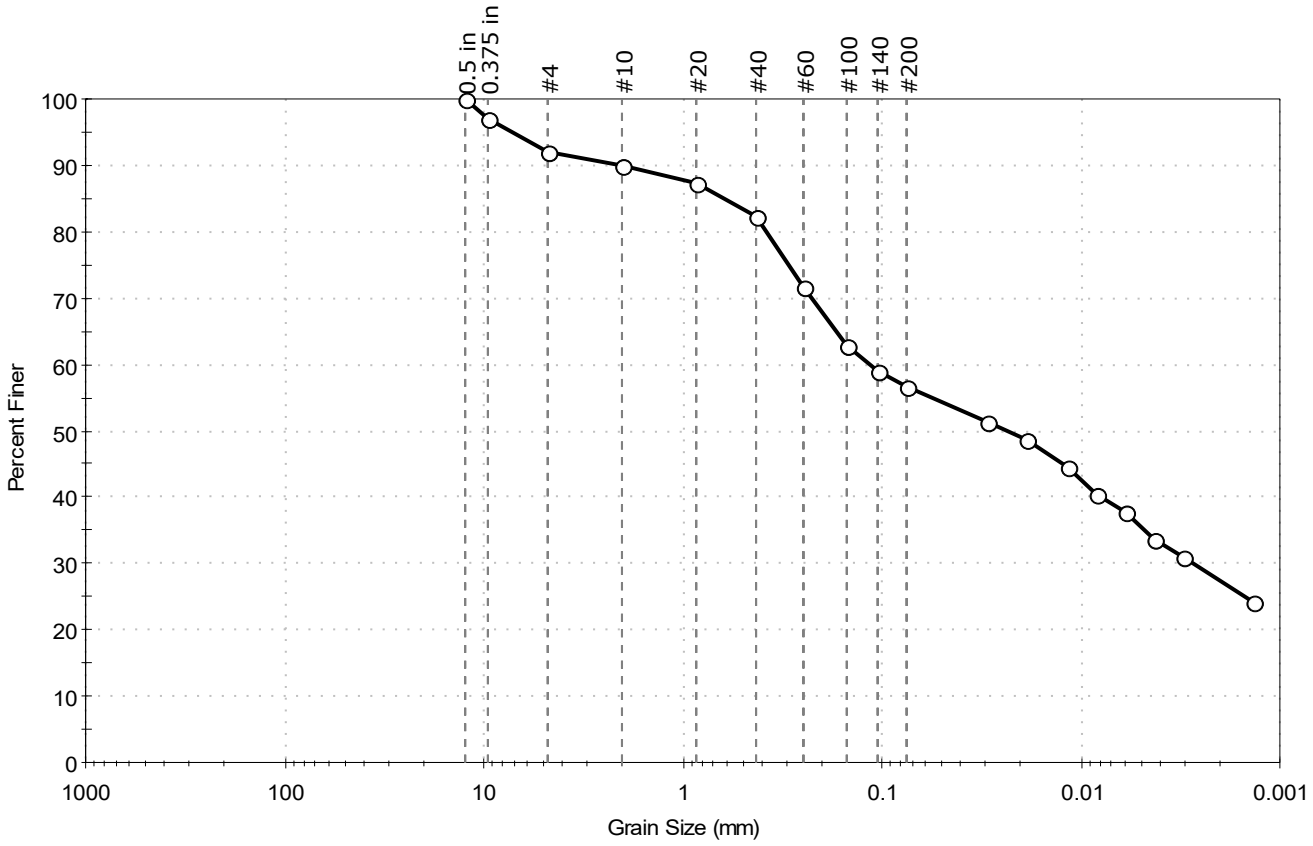
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/31/19	Checked By:	jsc
Depth :	162.40-162.86 ft	Test Id:	532903		
Test Comment:	---				
Visual Description:	Dry, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	7.8	35.7	56.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	92		
#10	2.00	90		
#20	0.85	87		
#40	0.42	82		
#60	0.25	72		
#100	0.15	63		
#140	0.11	59		
#200	0.075	57		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0296	51		
---	0.0189	49		
---	0.0116	45		
---	0.0083	40		
---	0.0059	38		
---	0.0043	34		
---	0.0031	31		
---	0.0014	24		

Coefficients

D_{85} = 0.6219 mm
D_{30} = 0.0027 mm
D_{60} = 0.1168 mm
D_{15} = N/A
D_{50} = 0.0234 mm
D_{10} = N/A
C_u = N/A
C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (4))

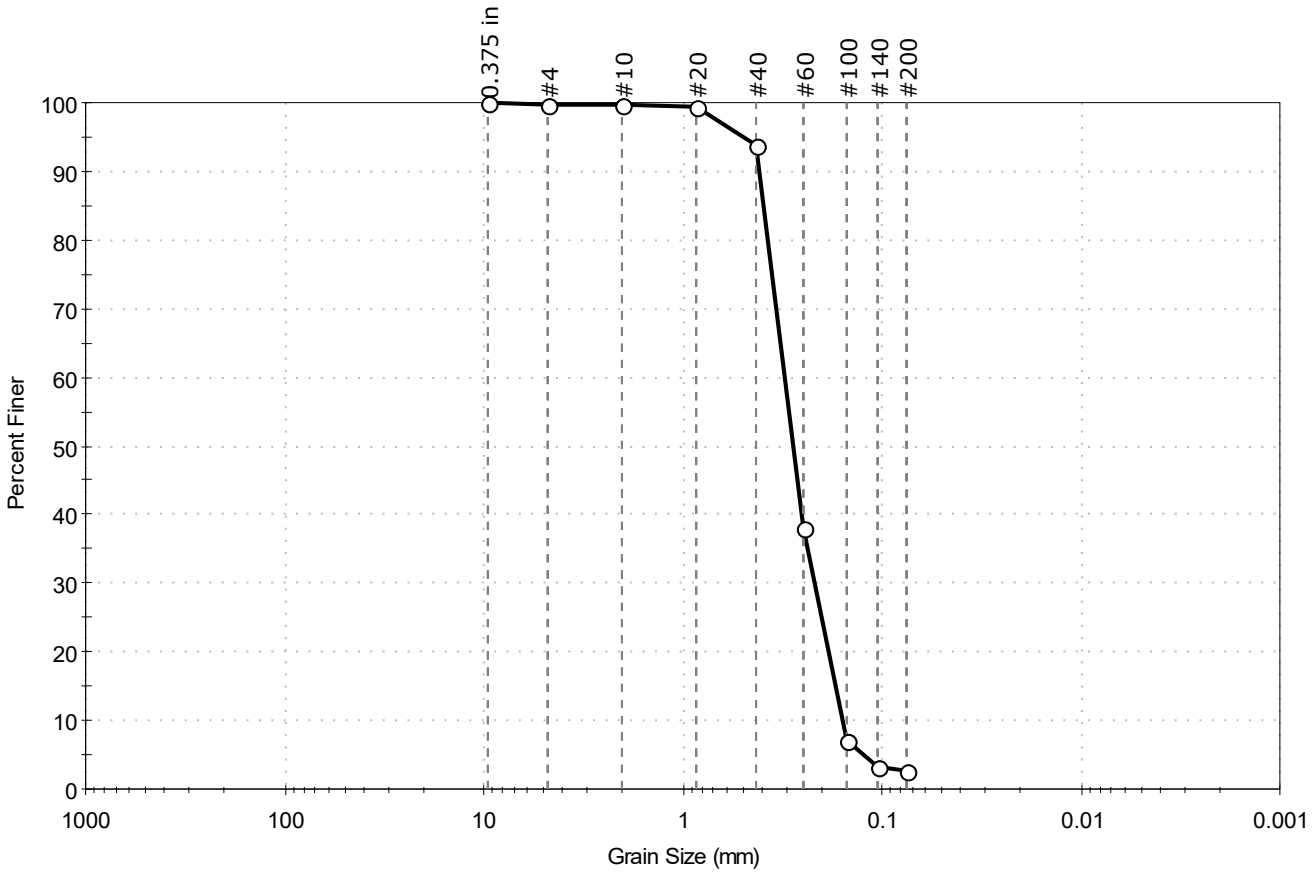
Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.609
Separation of Sample: #200 Sieve

printed 2/20/2020 4:15:51 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	12/20/19	Checked By:	jsc
Depth :	176.51-176.84 ft	Test Id:	532904		
Test Comment:	---				
Visual Description:	Moist, brown sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.2	97.3	2.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	94		
#60	0.25	38		
#100	0.15	7		
#140	0.11	3		
#200	0.075	2.5		

Coefficients

D_{85} = 0.3908 mm	D_{30} = 0.2188 mm
D_{60} = 0.3079 mm	D_{15} = 0.1711 mm
D_{50} = 0.2799 mm	D_{10} = 0.1577 mm
C_u = 1.952	C_c = 0.986

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

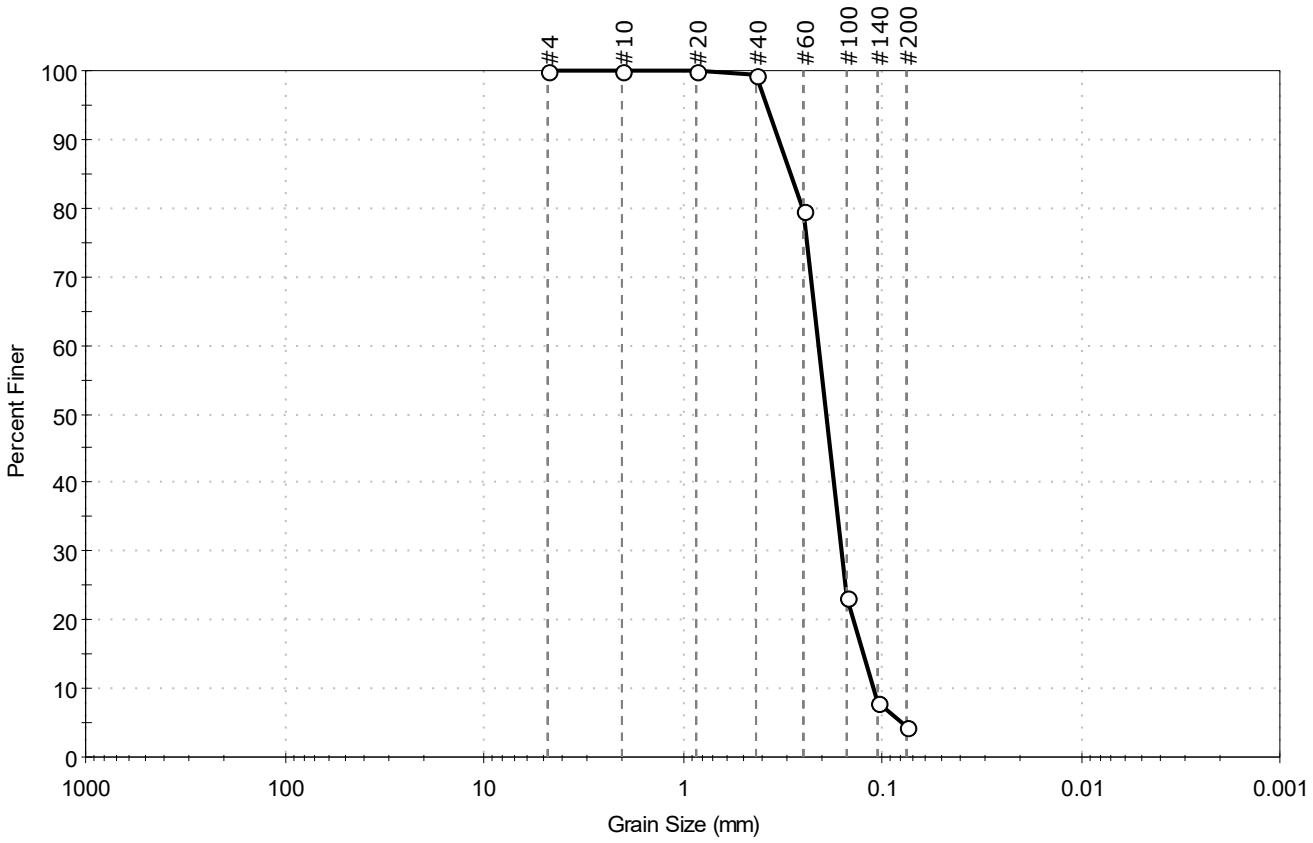
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	12/31/19	Checked By:	jsc
Depth :	182.09-182.58 ft	Test Id:	535557		
Test Comment:	---				
Visual Description:	Moist, brown sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	95.6	4.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	80		
#100	0.15	23		
#140	0.11	8		
#200	0.075	4.4		

Coefficients

D_{85} = 0.2879 mm	D_{30} = 0.1596 mm
D_{60} = 0.2092 mm	D_{15} = 0.1246 mm
D_{50} = 0.1911 mm	D_{10} = 0.1112 mm
C_u = 1.881	C_c = 1.095

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

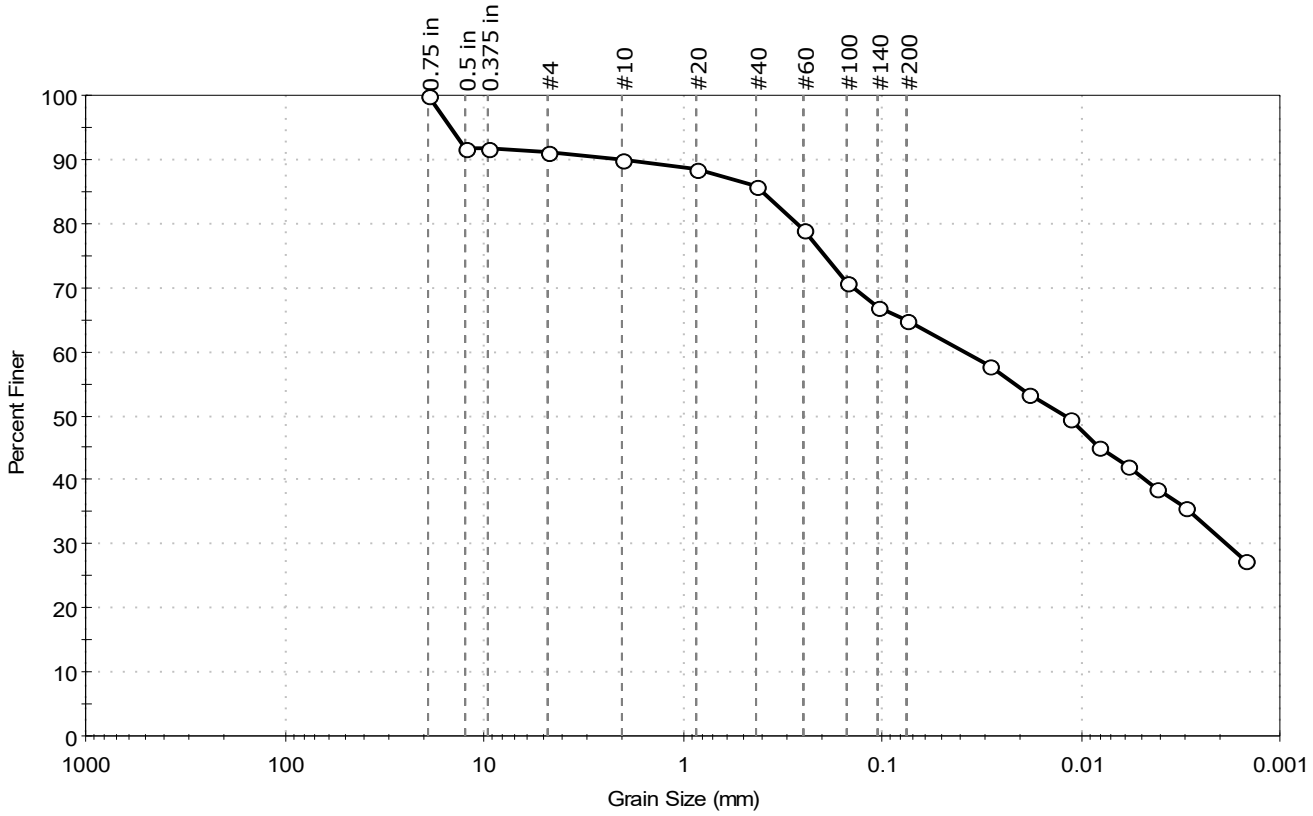
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	12/27/19	Checked By:	jsc
Depth :	195.37-195.87 ft	Test Id:	534720		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	8.8	26.4	64.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	92		
0.375 in	9.50	92		
#4	4.75	91		
#10	2.00	90		
#20	0.85	89		
#40	0.42	86		
#60	0.25	79		
#100	0.15	71		
#140	0.11	67		
#200	0.075	65		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0292	58		
---	0.0186	53		
---	0.0114	50		
---	0.0082	45		
---	0.0059	42		
---	0.0042	39		
---	0.0030	36		
---	0.0015	27		

Coefficients

D_{85} = 0.3949 mm D_{30} = 0.0019 mm
D_{60} = 0.0390 mm D_{15} = N/A
D_{50} = 0.0121 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

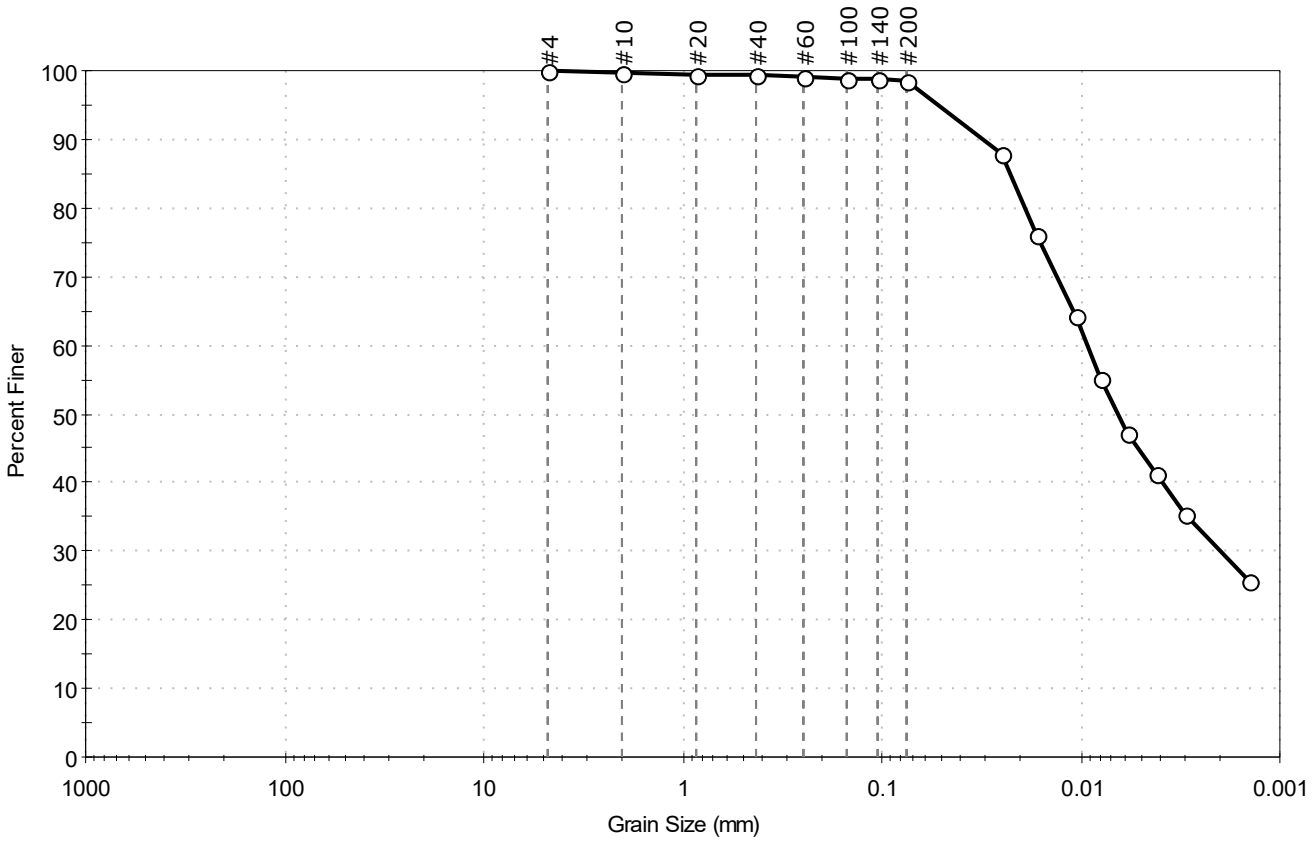
AASHTO Clayey Soils (A-6 (7))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.628
Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	01/03/20	Checked By:	jsc
Depth :	198.33-198.82 ft	Test Id:	534721		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.4	98.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#140	0.11	99		
#200	0.075	99		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0252	88		
---	0.0168	76		
---	0.0107	64		
---	0.0079	55		
---	0.0058	47		
---	0.0042	41		
---	0.0030	35		
---	0.0014	26		

Coefficients

D_{85} = 0.0229 mm	D_{30} = 0.0020 mm
D_{60} = 0.0093 mm	D_{15} = N/A
D_{50} = 0.0065 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Silty Soils (A-4 (8))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

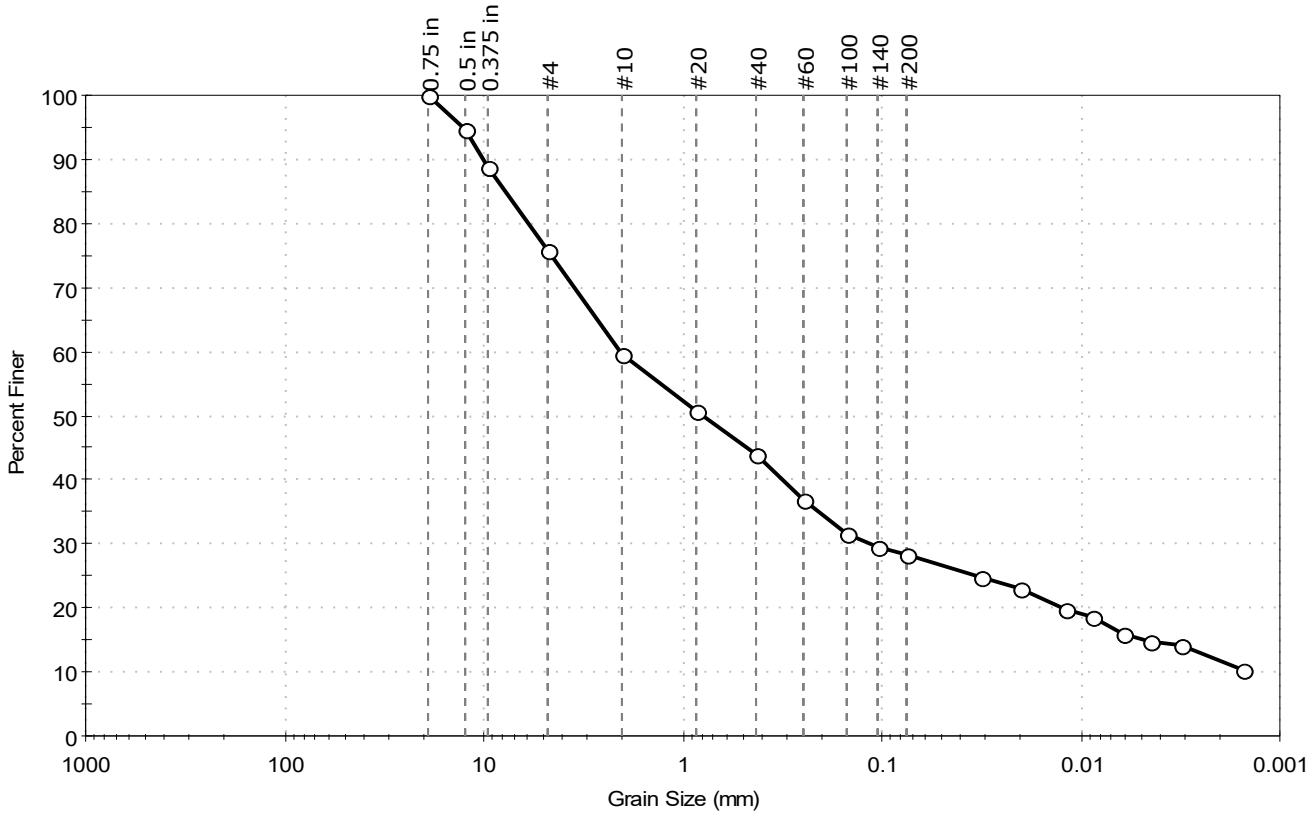
Est. Specific Gravity : 2.672

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	12/27/19	Checked By:	jsc
Depth :	217.06-217.49 ft	Test Id:	533979		
Test Comment:	---				
Visual Description:	Moist, brown clayey sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
–	24.1	47.7	28.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	95		
0.375 in	9.50	89		
#4	4.75	76		
#10	2.00	60		
#20	0.85	51		
#40	0.42	44		
#60	0.25	37		
#100	0.15	32		
#140	0.11	30		
#200	0.075	28		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0320	25		
---	0.0201	23		
---	0.0120	20		
---	0.0088	19		
---	0.0061	16		
---	0.0045	15		
---	0.0032	14		
---	0.0016	10		

Coefficients

D_{85} = 7.7912 mm	D_{30} = 0.1147 mm
D_{60} = 2.0506 mm	D_{15} = 0.0047 mm
D_{50} = 0.7970 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Clayey SAND with Gravel (SC)

AASHTO Clayey Gravel and Sand (A-2-6 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

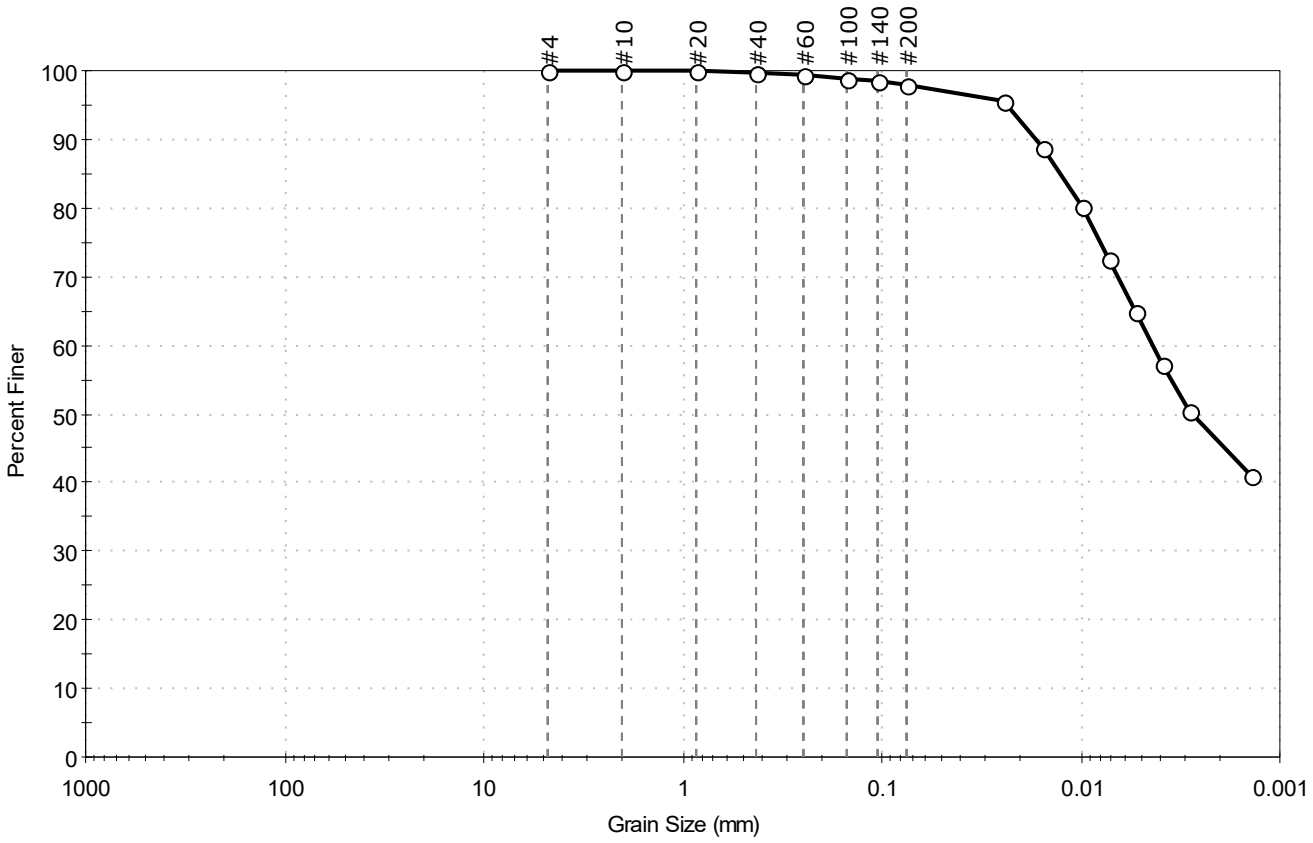
Dispersion Period : 1 minute

Est. Specific Gravity : 2.628

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	12/19/19	Checked By:	bfs
Depth :	242.55-243.11 ft	Test Id:	532783		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.0	98.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#140	0.11	98		
#200	0.075	98		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0243	95		
---	0.0157	89		
---	0.0098	80		
---	0.0073	72		
---	0.0054	65		
---	0.0039	57		
---	0.0028	50		
---	0.0014	41		

Coefficients

D_{85} = 0.0128 mm	D_{30} = N/A
D_{60} = 0.0044 mm	D_{15} = N/A
D_{50} = 0.0027 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (16))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

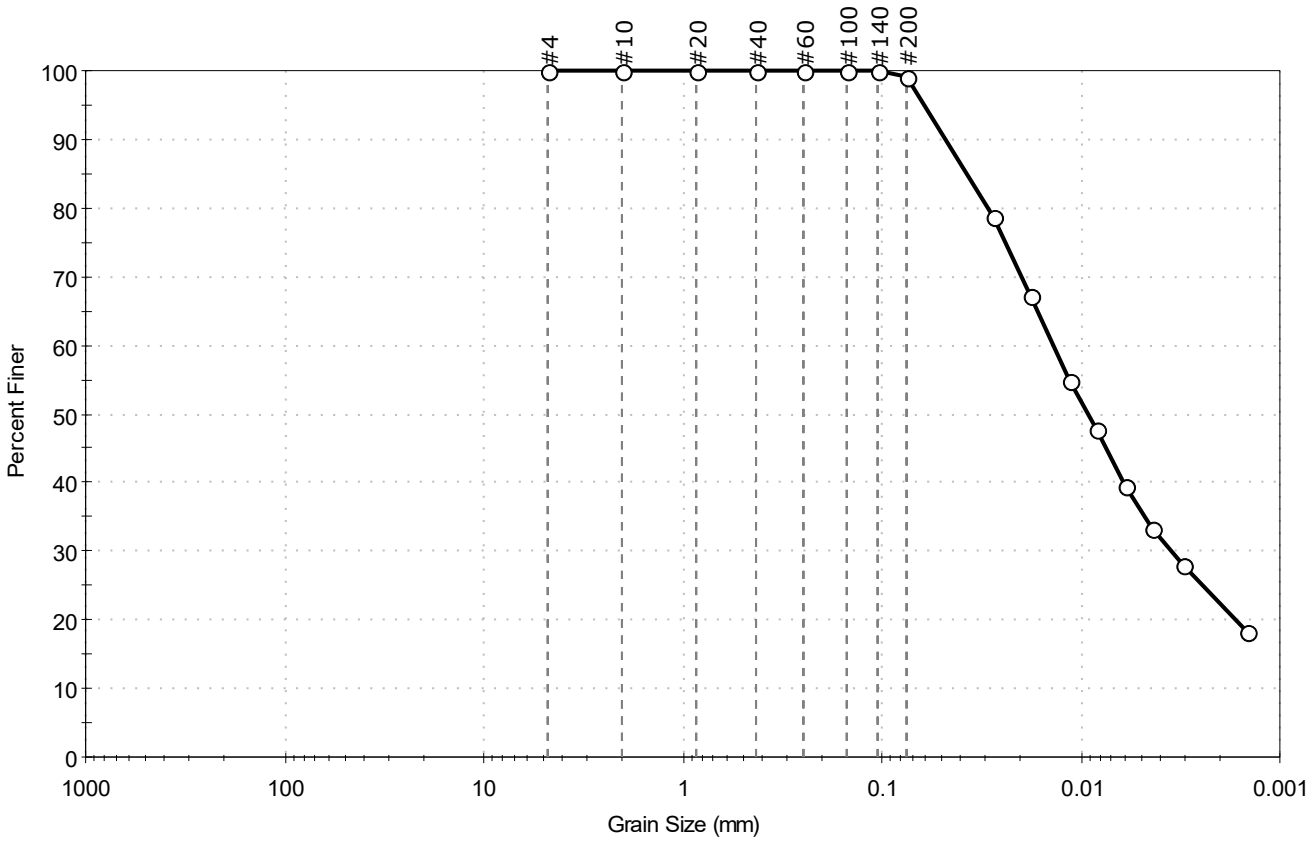
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-016	Test Date:	12/19/19	Checked By:	bfs
Depth :	262.80-263.32 ft	Test Id:	532784		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.9	99.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	99		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0275	79		
---	0.0179	67		
---	0.0113	55		
---	0.0083	48		
---	0.0060	39		
---	0.0044	33		
---	0.0031	28		
---	0.0015	18		

Coefficients

D_{85} = 0.0375 mm	D_{30} = 0.0035 mm
D_{60} = 0.0136 mm	D_{15} = N/A
D_{50} = 0.0091 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Silty Soils (A-4 (5))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

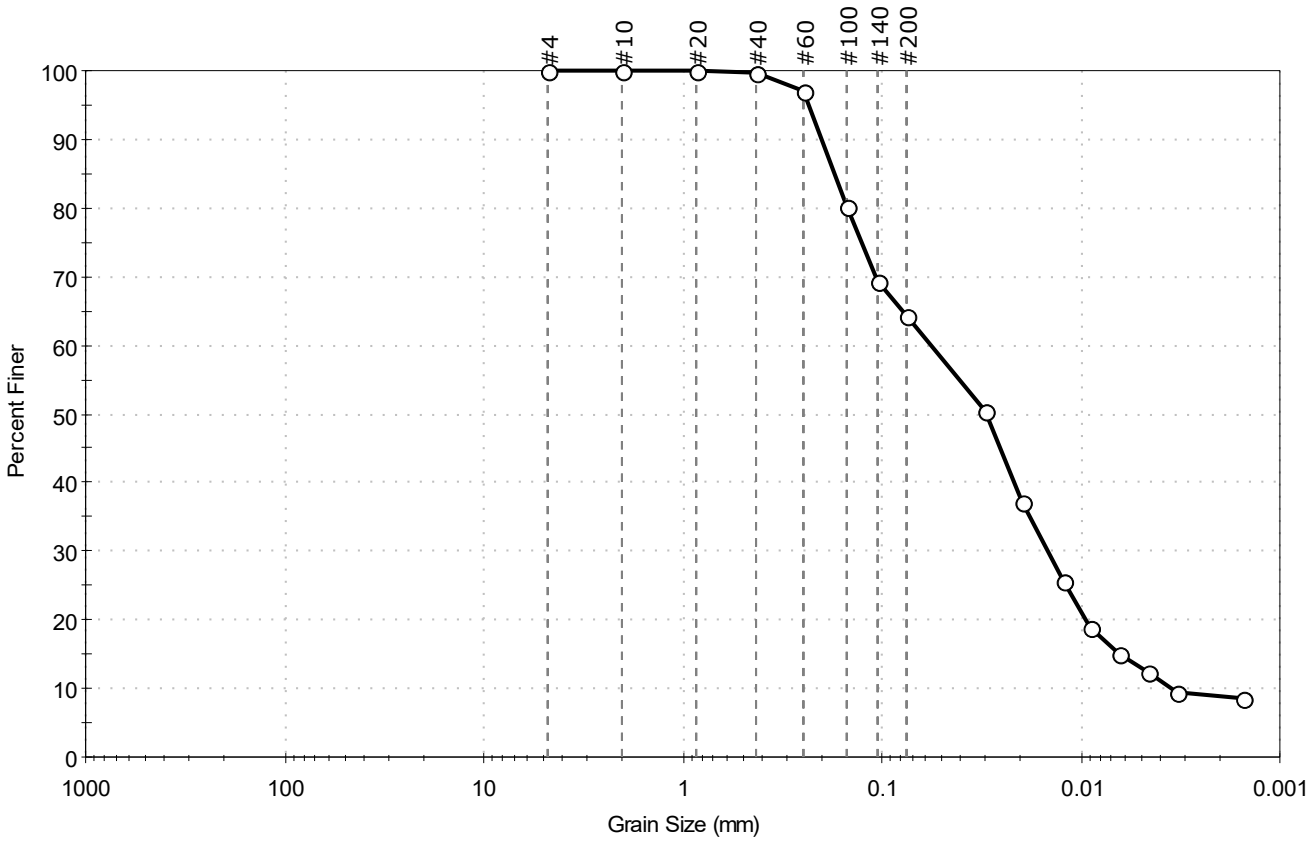
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-018	Test Date:	12/19/19	Checked By:	bfs
Depth :	281.17-280.68 ft	Test Id:	532785		
Test Comment:	---				
Visual Description:	Moist, light grayish brown sandy silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	35.7	64.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	97		
#100	0.15	80		
#140	0.11	69		
#200	0.075	64		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0300	51		
---	0.0197	37		
---	0.0123	26		
---	0.0090	19		
---	0.0065	15		
---	0.0046	12		
---	0.0033	9		
---	0.0015	8		

Coefficients

D_{85} =0.1740 mm	D_{30} =0.0147 mm
D_{60} =0.0562 mm	D_{15} =0.0064 mm
D_{50} =0.0295 mm	D_{10} =0.0035 mm
C_u =16.057	C_c =1.099

Classification

ASTM Sandy SILT (ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

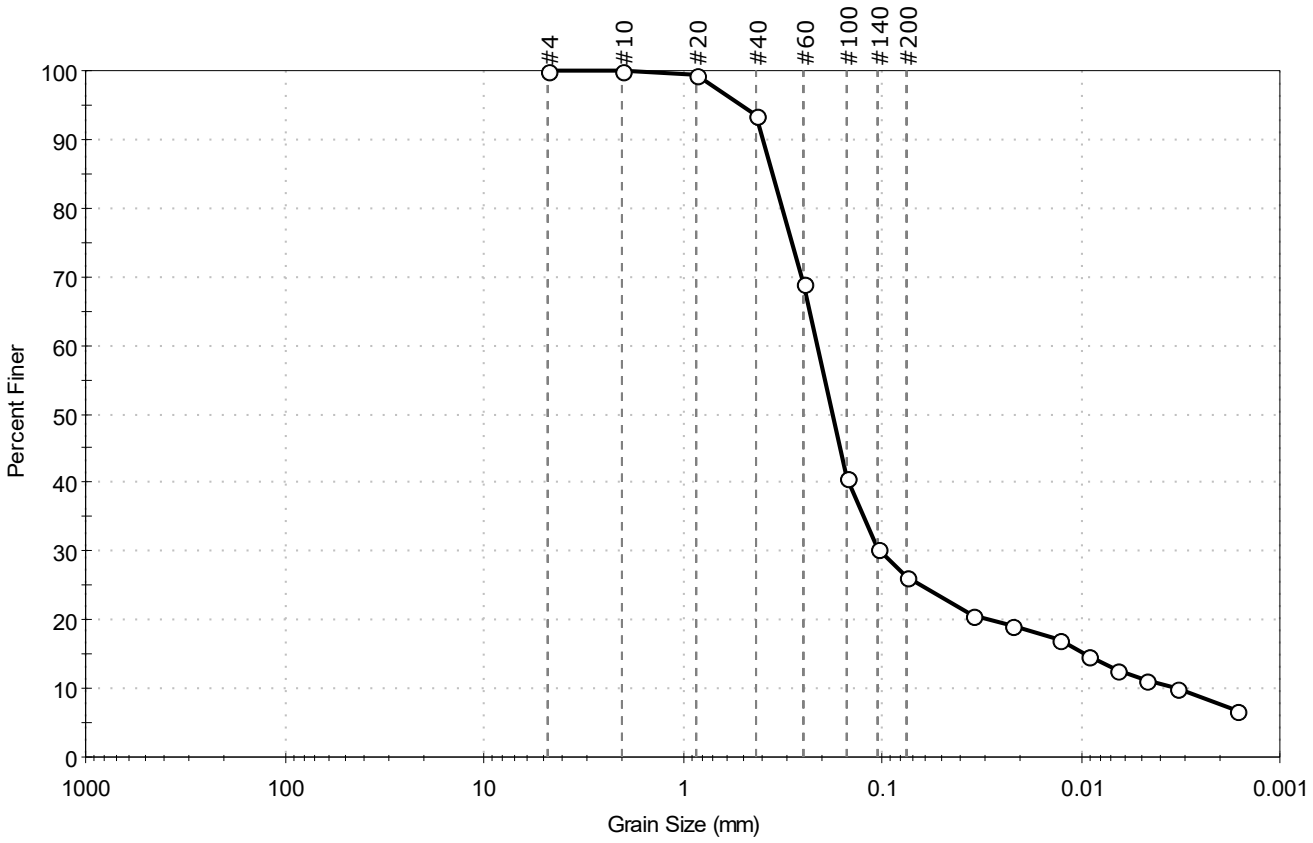
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	tube	Tested By:	GA
Sample ID:	BH19-27-ST-002	Test Date:	01/23/20	Checked By:	n/a
Depth :	127.95-129.92 ft	Test Id:	540891		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	73.7	26.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	93		
#60	0.25	69		
#100	0.15	41		
#140	0.11	30		
#200	0.075	26		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0350	21		
---	0.0225	19		
---	0.0128	17		
---	0.0092	15		
---	0.0066	13		
---	0.0047	11		
---	0.0033	10		
---	0.0017	7		

Coefficients

D_{85} =0.3538 mm	D_{30} =0.1018 mm
D_{60} =0.2126 mm	D_{15} =0.0094 mm
D_{50} =0.1776 mm	D_{10} =0.0034 mm
C_u =62.529	C_c =14.337

Classification

ASTM Silty SAND (SM)

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

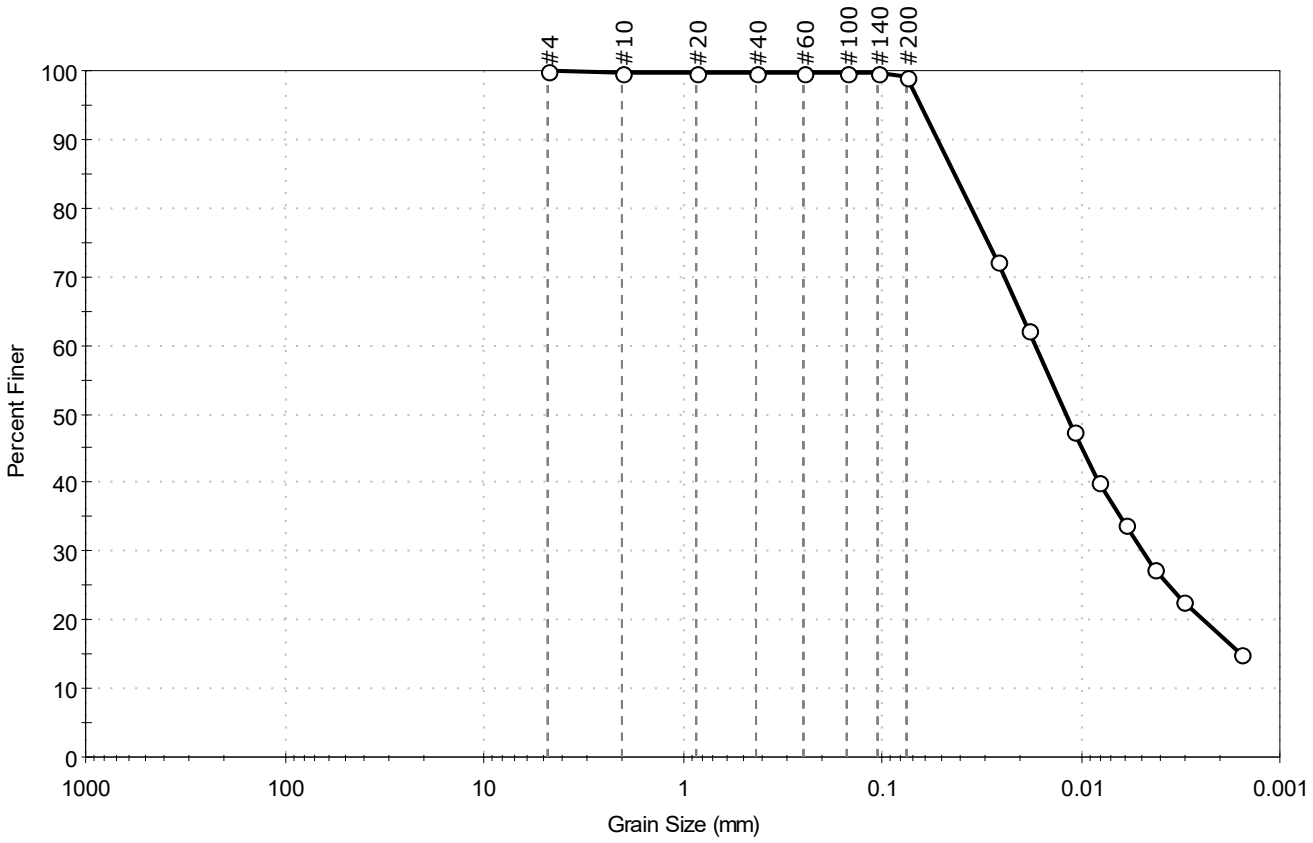
Dispersion Period : 1 minute

Est. Specific Gravity : 2.596

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	tube	Tested By:	GA
Sample ID:	BH19-27-ST-003	Test Date:	01/23/20	Checked By:	n/a
Depth :	260.83-263.45 ft	Test Id:	540892		
Test Comment:	---				
Visual Description:	Moist, grayish brown silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.8	99.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	99		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0263	72		
---	0.0184	62		
---	0.0110	48		
---	0.0082	40		
---	0.0059	34		
---	0.0043	27		
---	0.0031	23		
---	0.0016	15		

Coefficients

D_{85} =0.0432 mm	D_{30} =0.0049 mm
D_{60} =0.0170 mm	D_{15} =N/A
D_{50} =0.0120 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (2))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

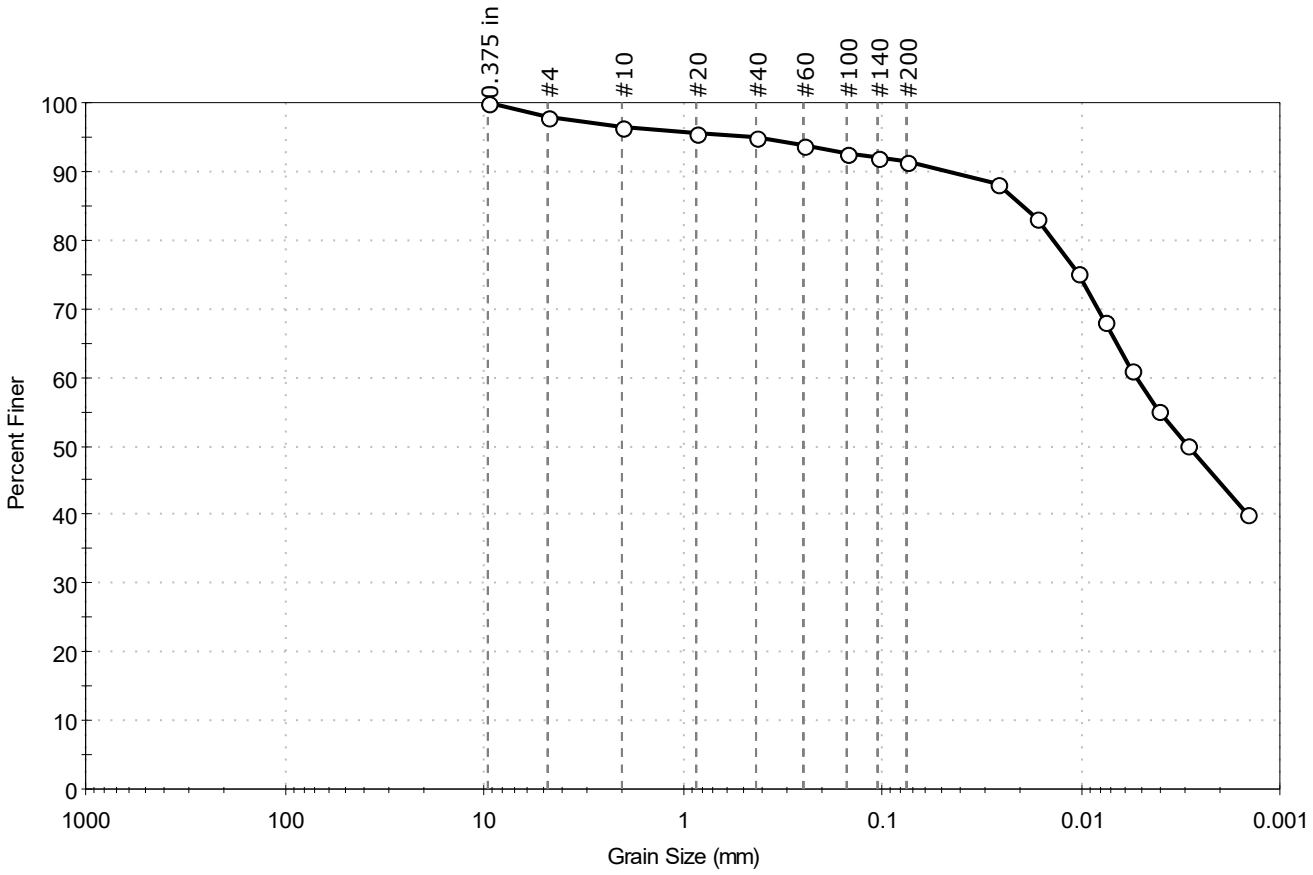
Dispersion Period : 1 minute

Est. Specific Gravity : 2.728

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/27/19	Checked By:	jsc
Depth :	87.5-88.12 ft	Test Id:	532734		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.9	6.5	91.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	96		
#20	0.85	96		
#40	0.42	95		
#60	0.25	94		
#100	0.15	93		
#140	0.11	92		
#200	0.075	92		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0260	88		
---	0.0166	83		
---	0.0104	75		
---	0.0077	68		
---	0.0056	61		
---	0.0040	55		
---	0.0029	50		
---	0.0014	40		

Coefficients

D_{85} = 0.0193 mm	D_{30} = N/A
D_{60} = 0.0052 mm	D_{15} = N/A
D_{50} = 0.0029 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (16))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

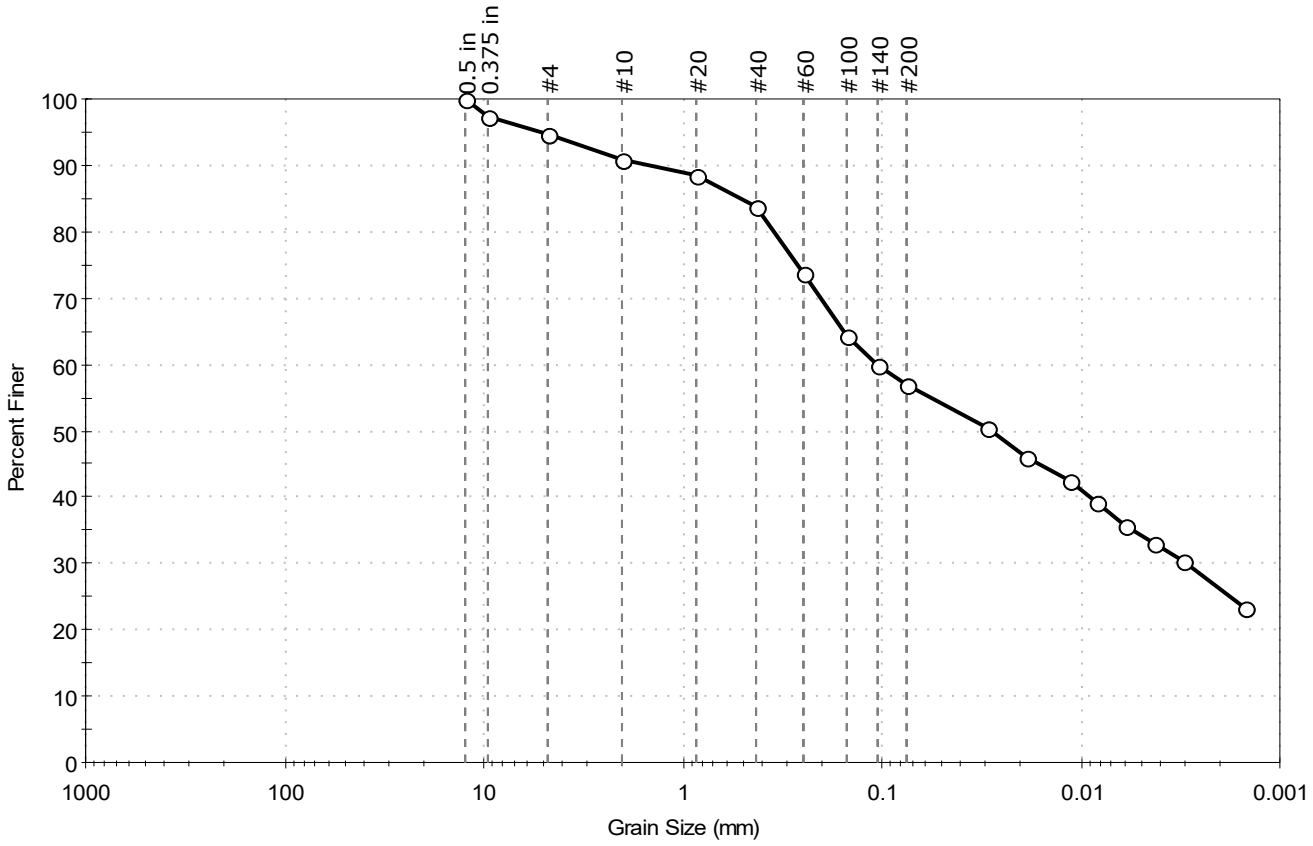
Est. Specific Gravity : 2.621

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/27/19	Checked By:	jsc
Depth :	102.79-103.35 ft	Test Id:	532735		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	5.3	37.8	56.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	97		
#4	4.75	95		
#10	2.00	91		
#20	0.85	88		
#40	0.42	84		
#60	0.25	74		
#100	0.15	64		
#140	0.11	60		
#200	0.075	57		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0295	50		
---	0.0188	46		
---	0.0114	43		
---	0.0083	39		
---	0.0060	36		
---	0.0043	33		
---	0.0030	30		
---	0.0015	23		

Coefficients

D_{85} = 0.5156 mm	D_{30} = 0.0029 mm
D_{60} = 0.1078 mm	D_{15} = N/A
D_{50} = 0.0280 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

AASHTO Silty Soils (A-4 (2))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

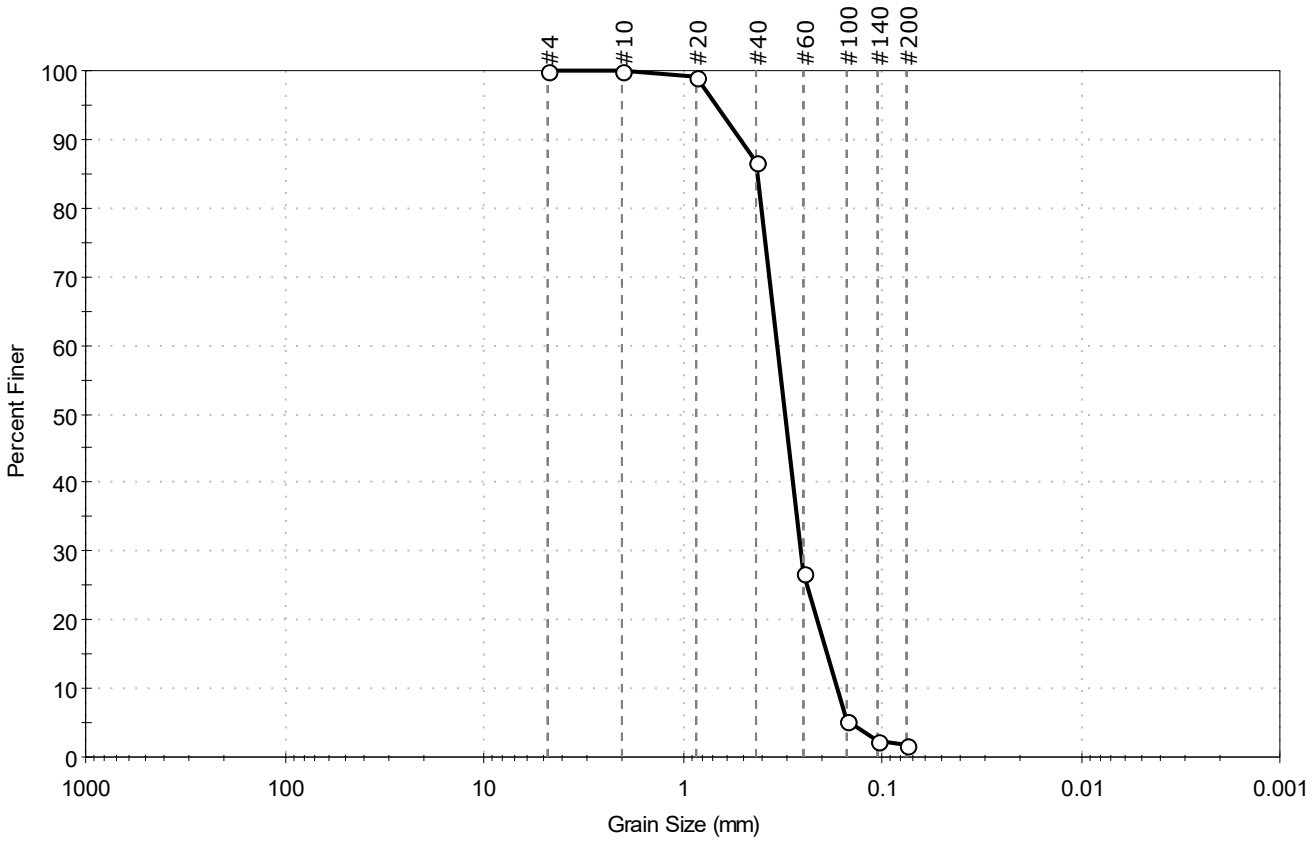
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/20/19	Checked By:	bfs
Depth :	142.82-143.27 ft	Test Id:	532736		
Test Comment:	---				
Visual Description:	Moist, brown sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	98.2	1.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	87		
#60	0.25	27		
#100	0.15	5		
#140	0.11	2		
#200	0.075	1.8		

Coefficients

D_{85} = 0.4183 mm	D_{30} = 0.2574 mm
D_{60} = 0.3355 mm	D_{15} = 0.1890 mm
D_{50} = 0.3071 mm	D_{10} = 0.1677 mm
C_u = 2.001	C_c = 1.178

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

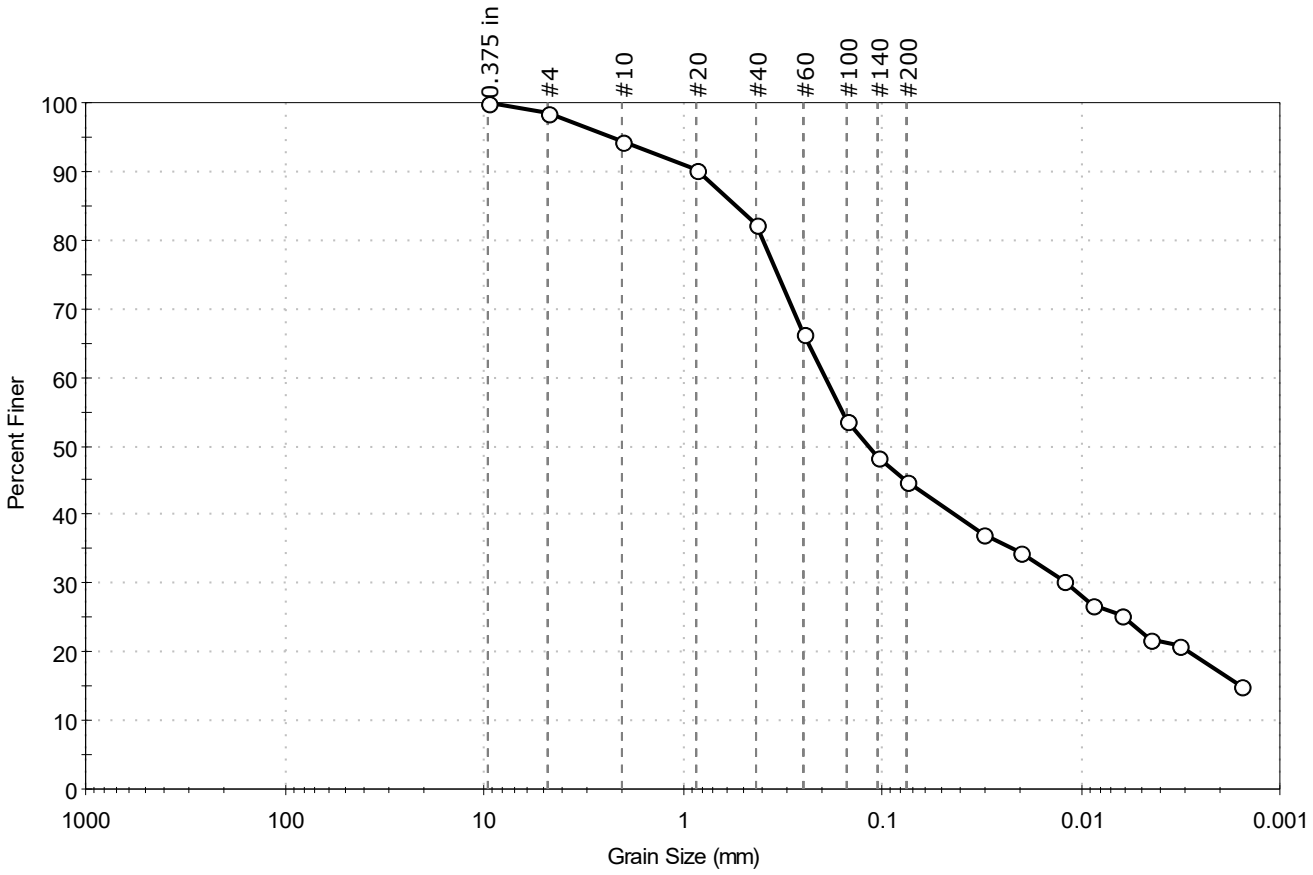
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/27/19	Checked By:	jsc
Depth :	152.72-153.31 ft	Test Id:	532737		
Test Comment:	---				
Visual Description:	Dry, silty clayey sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.6	53.5	44.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	94		
#20	0.85	90		
#40	0.42	82		
#60	0.25	66		
#100	0.15	54		
#140	0.11	48		
#200	0.075	45		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0313	37		
---	0.0204	35		
---	0.0122	30		
---	0.0088	27		
---	0.0063	25		
---	0.0045	22		
---	0.0032	21		
---	0.0016	15		

Coefficients

D_{85} = 0.5336 mm	D_{30} = 0.0118 mm
D_{60} = 0.1927 mm	D_{15} = N/A
D_{50} = 0.1182 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM Silty, Clayey SAND (SC-SM)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

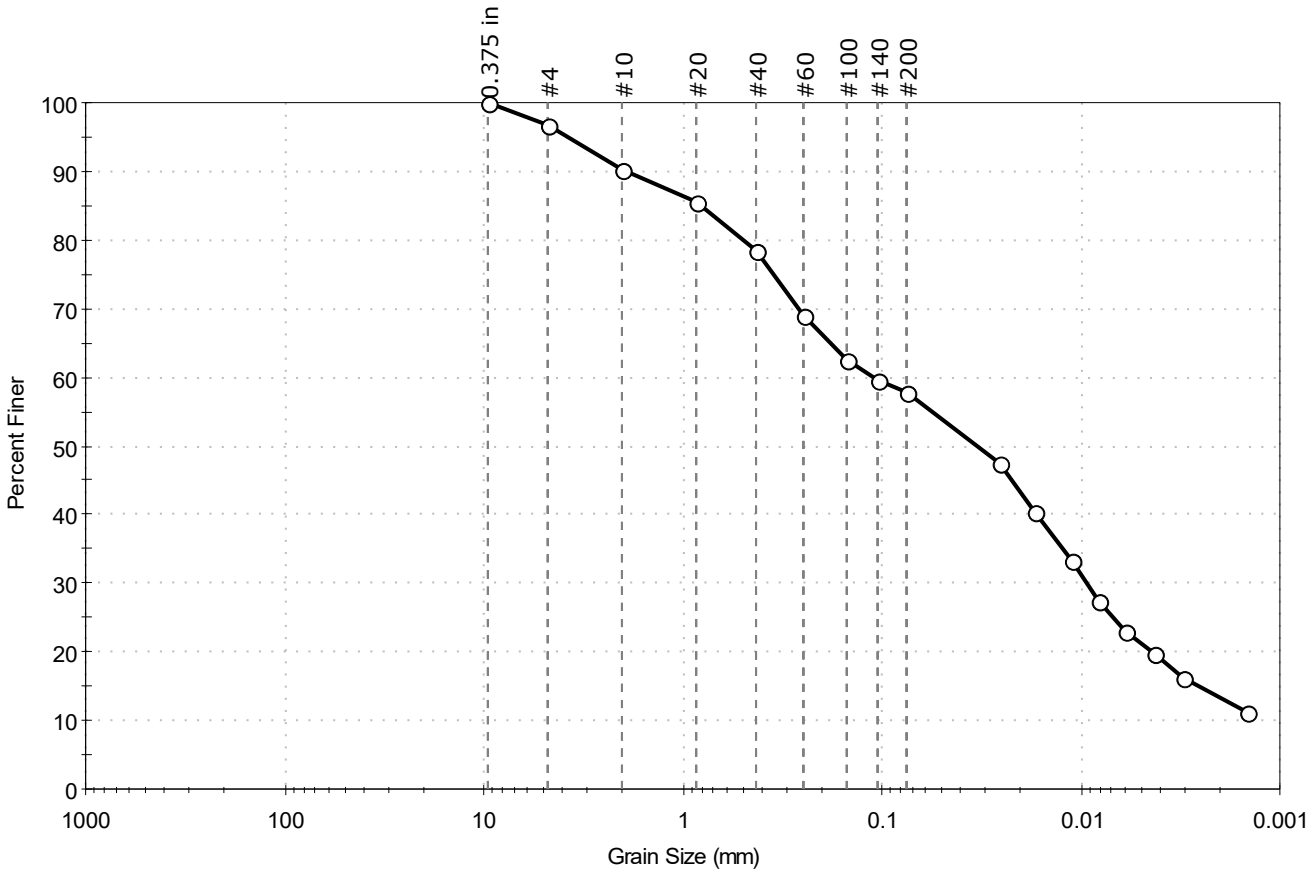
Dispersion Period : 1 minute

Est. Specific Gravity : 2.6

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/20/19	Checked By:	bfs
Depth :	156.46-156.92 ft	Test Id:	532738		
Test Comment:	---				
Visual Description:	Dry, pale brown sandy silty clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	3.3	38.8	57.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	97		
#10	2.00	90		
#20	0.85	85		
#40	0.42	78		
#60	0.25	69		
#100	0.15	63		
#140	0.11	60		
#200	0.075	58		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0255	48		
---	0.0170	40		
---	0.0110	33		
---	0.0081	28		
---	0.0059	23		
---	0.0043	20		
---	0.0031	16		
---	0.0015	11		

Coefficients

D_{85} =0.8163 mm	D_{30} =0.0093 mm
D_{60} =0.1120 mm	D_{15} =0.0026 mm
D_{50} =0.0327 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM Sandy Silty CLAY (CL-ML)

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

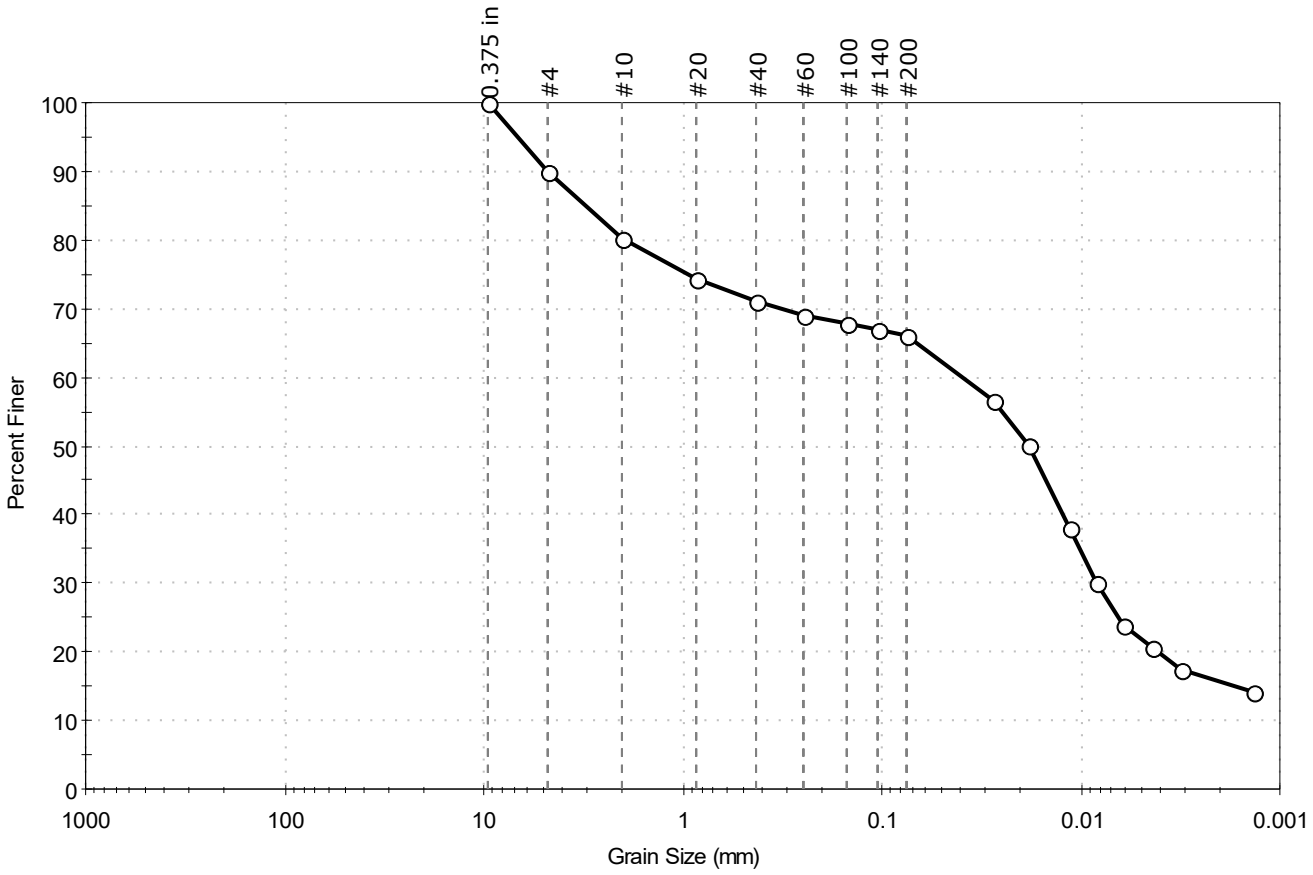
Dispersion Period : 1 minute

Est. Specific Gravity : 2.637

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/31/19	Checked By:	jsc
Depth :	131.23-131.56 ft	Test Id:	532747		
Test Comment:	---				
Visual Description:	Moist, light brownish gray sandy clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	10.1	23.8	66.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	90		
#10	2.00	80		
#20	0.85	74		
#40	0.42	71		
#60	0.25	69		
#100	0.15	68		
#140	0.11	67		
#200	0.075	66		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0274	57		
---	0.0182	50		
---	0.0114	38		
---	0.0084	30		
---	0.0061	24		
---	0.0043	21		
---	0.0031	17		
---	0.0014	14		

Coefficients

D_{85} = 3.0555 mm
D_{30} = 0.0083 mm
D_{60} = 0.0394 mm
D_{15} = 0.0017 mm
D_{50} = 0.0181 mm
D_{10} = N/A
C_u = N/A
C_c = N/A

Classification

ASTM Sandy Lean CLAY (CL)

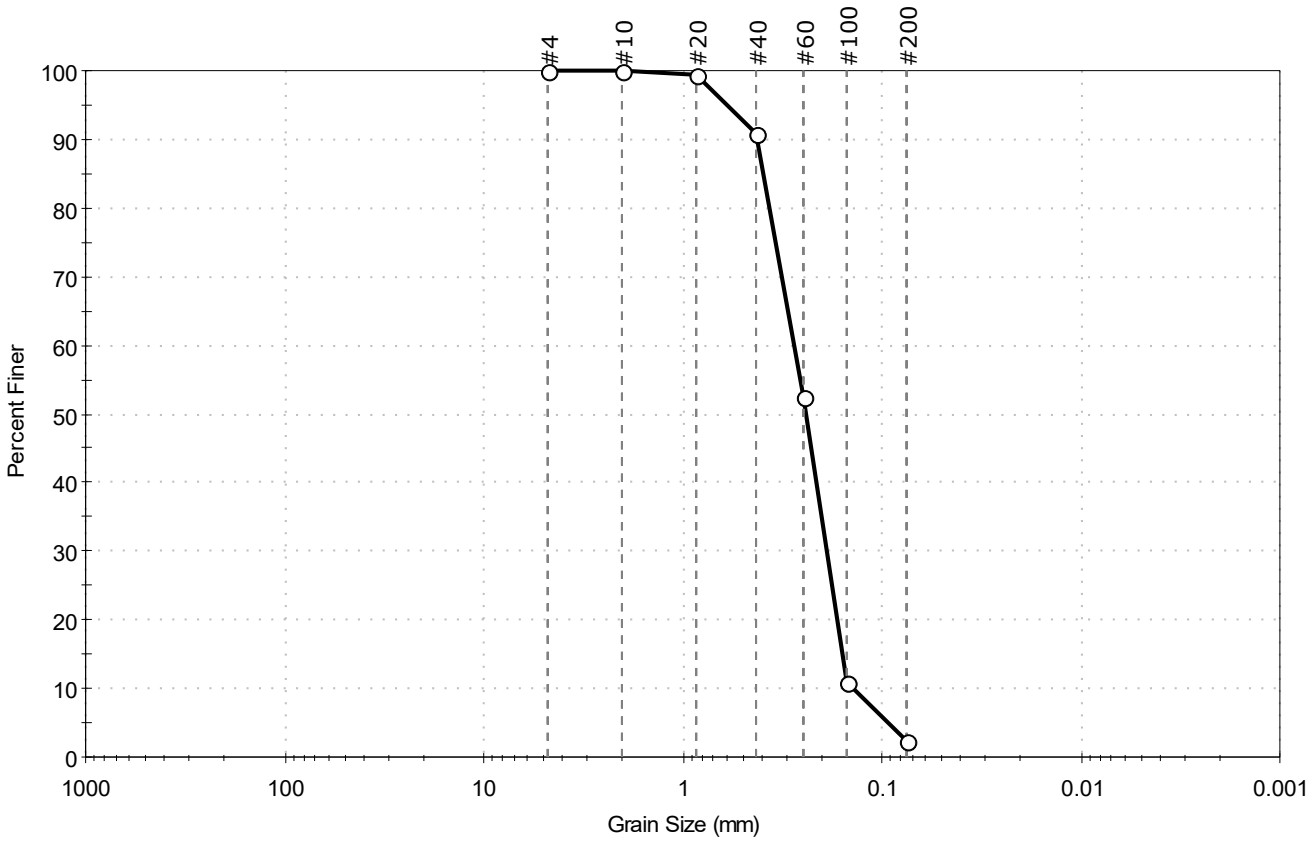
AASHTO Clayey Soils (A-6 (6))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.712
Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-002	Test Date:	08/14/19	Checked By:	jsc
Depth :	75-80 ft	Test Id:	516903		
Test Comment:	---				
Visual Description:	Moist, light brown sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	97.7	2.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	91		
#60	0.25	52		
#100	0.15	11		
#200	0.075	2.3		

Coefficients

D_{85} = 0.3918 mm	D_{30} = 0.1895 mm
D_{60} = 0.2773 mm	D_{15} = 0.1575 mm
D_{50} = 0.2425 mm	D_{10} = 0.1381 mm
C_u = 2.008	C_c = 0.938

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

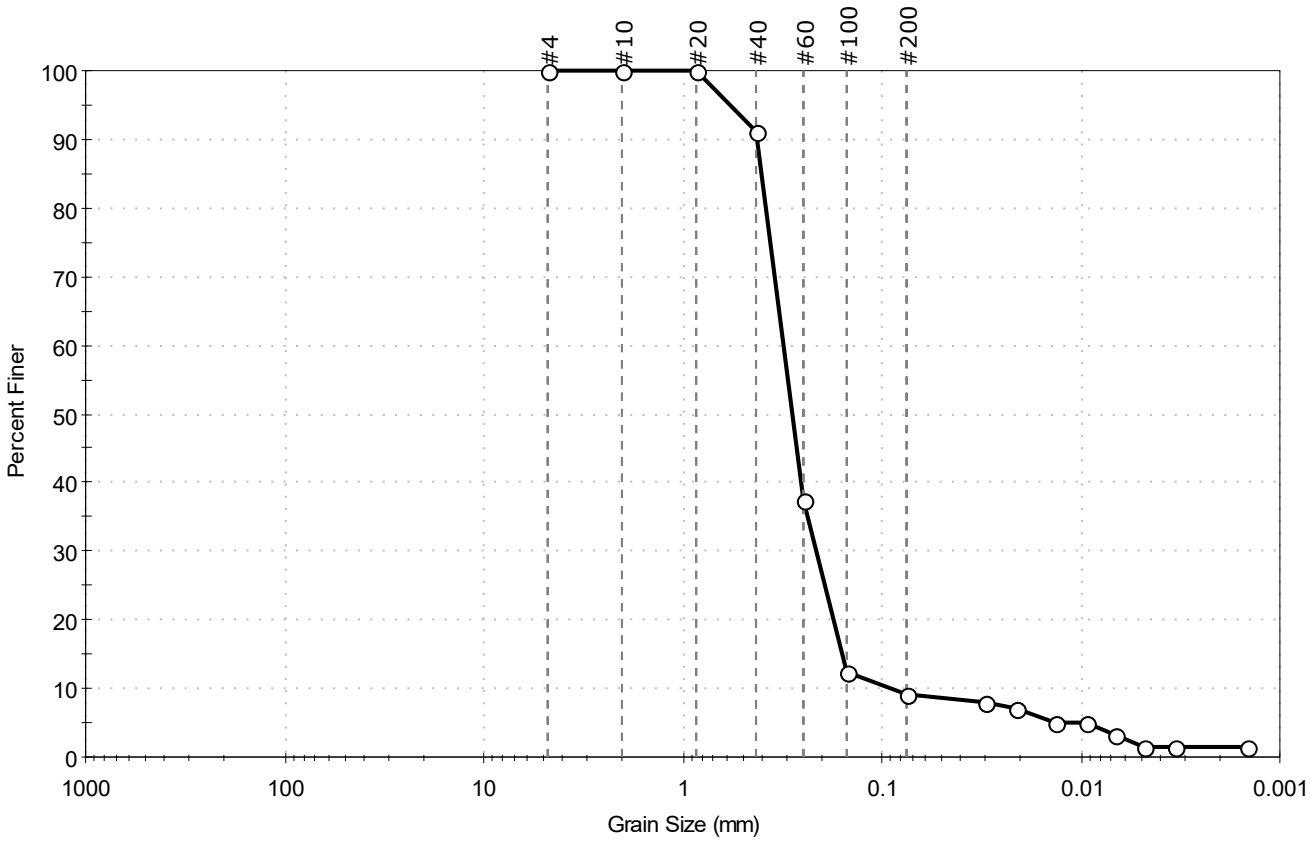
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-003	Test Date:	08/14/19	Checked By:	jsc
Depth :	100-110 ft	Test Id:	516904		
Test Comment:	---				
Visual Description:	Moist, light pale brown silty sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	90.9	9.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	91		
#60	0.25	38		
#100	0.15	12		
#200	0.075	9.1		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0303	8		
---	0.0214	7		
---	0.0135	5		
---	0.0094	5		
---	0.0068	3		
---	0.0048	1		
---	0.0034	1		
---	0.0015	1		

Coefficients

D_{85} = 0.4002 mm	D_{30} = 0.2144 mm
D_{60} = 0.3124 mm	D_{15} = 0.1579 mm
D_{50} = 0.2829 mm	D_{10} = 0.0900 mm
C_u = 3.471	C_c = 1.635

Classification

ASTM N/A

AASHTO Fine Sand (A-3 (1))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

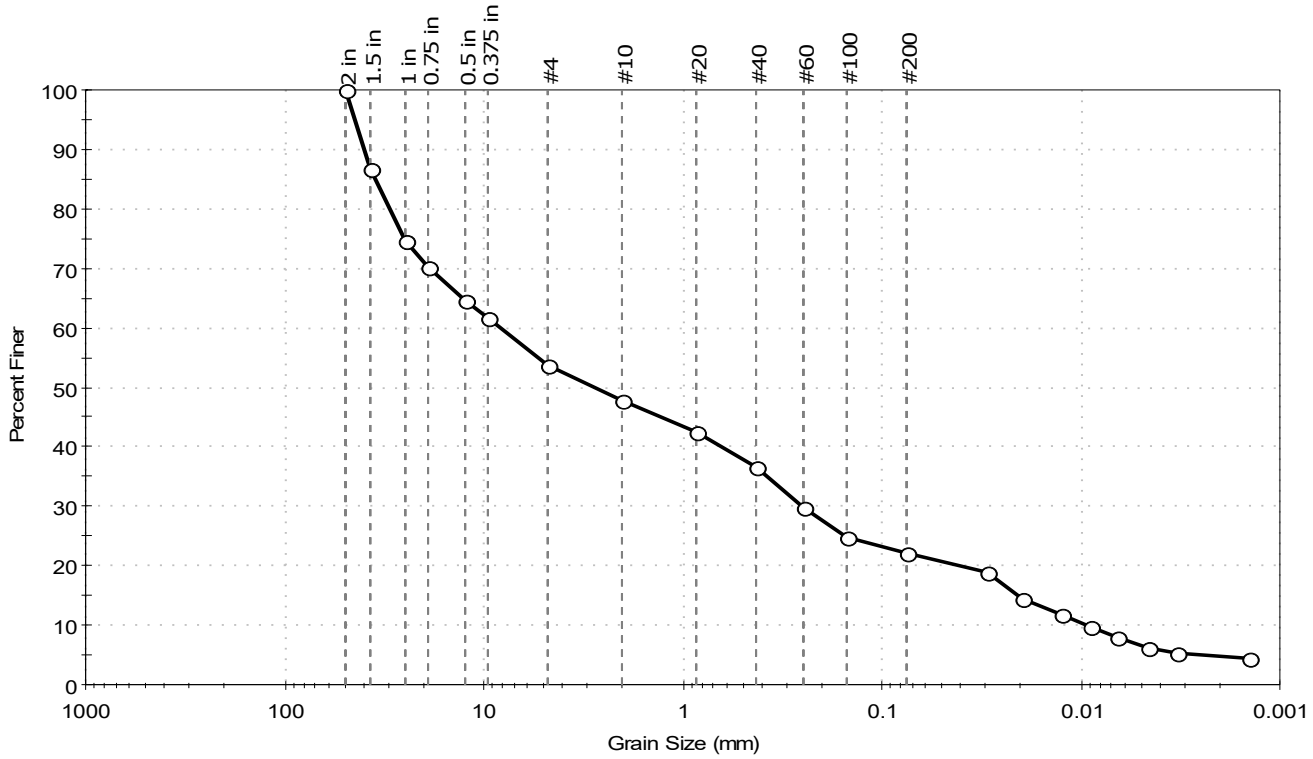
Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-004	Test Date:	08/14/19	Checked By:	jsc
Depth :	130-135 ft	Test Id:	516905		
Test Comment:	---				
Visual Description:	Moist, pale brown silty gravel with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
--	46.4	31.6	22.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
2 in	50.00	100		
1.5 in	37.50	87		
1 in	25.00	75		
0.75 in	19.00	70		
0.5 in	12.50	65		
0.375 in	9.50	62		
#4	4.75	54		
#10	2.00	48		
#20	0.85	42		
#40	0.42	36		
#60	0.25	30		
#100	0.15	25		
#200	0.075	22		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0296	19		
---	0.0199	14		
---	0.0126	12		
---	0.0090	10		
---	0.0065	8		
---	0.0046	6		
---	0.0033	5		
---	0.0014	4		

Coefficients

D_{85} = 35.4894 mm	D_{30} = 0.2553 mm
D_{60} = 8.3081 mm	D_{15} = 0.0209 mm
D_{50} = 2.7969 mm	D_{10} = 0.0093 mm
C_u = 893.344	C_c = 0.844

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

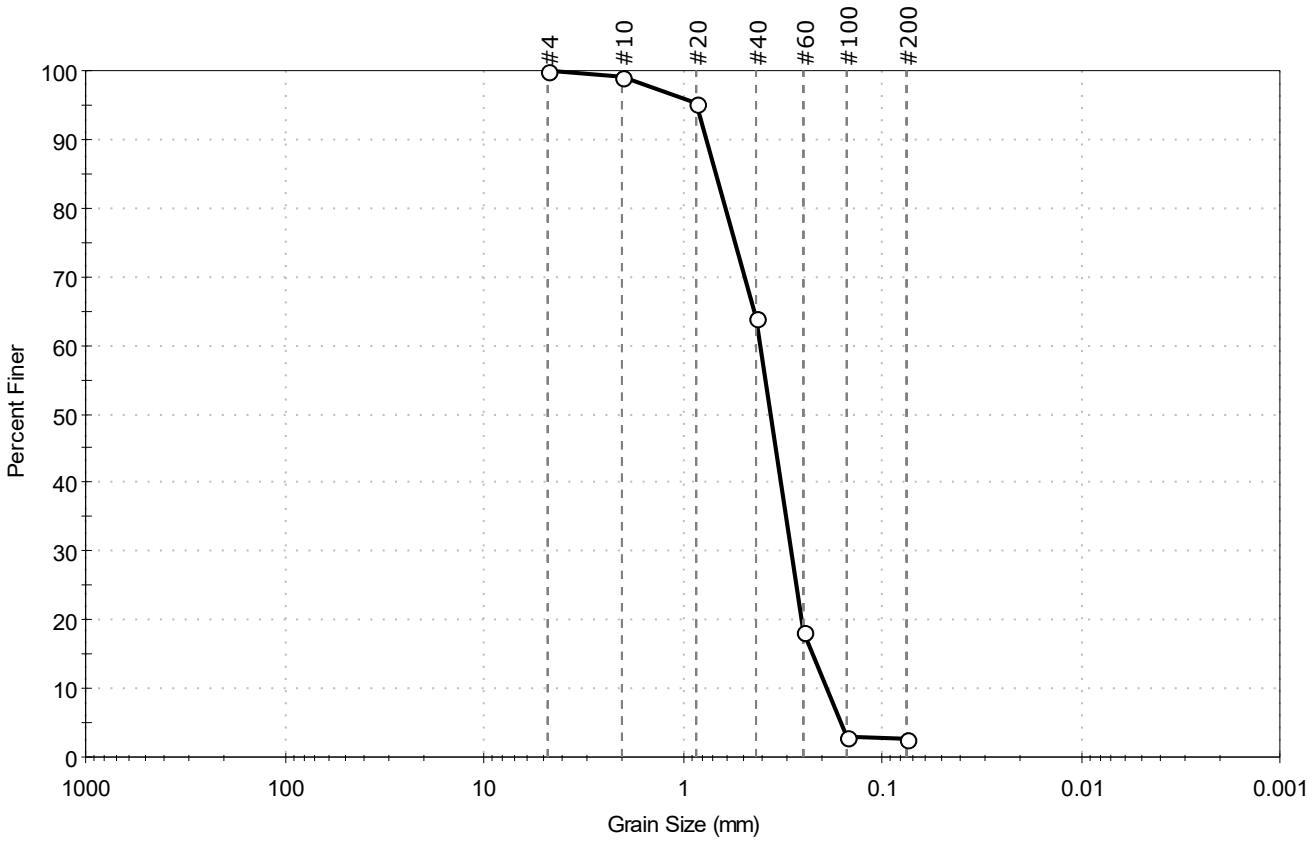
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	bag	Tested By:	ckg
Sample ID:	LSB-002	Test Date:	08/10/19	Checked By:	jsc
Depth :	69-70 ft	Test Id:	516900		
Test Comment:	---				
Visual Description:	Moist, light brown sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	97.3	2.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.85	95		
#40	0.42	64		
#60	0.25	18		
#100	0.15	3		
#200	0.075	2.7		

Coefficients

D_{85} = 0.6763 mm	D_{30} = 0.2864 mm
D_{60} = 0.4057 mm	D_{15} = 0.2240 mm
D_{50} = 0.3613 mm	D_{10} = 0.1896 mm
C_u = 2.140	C_c = 1.066

Classification

ASTM Poorly graded SAND (SP)

AASHTO Fine Sand (A-3 (1))

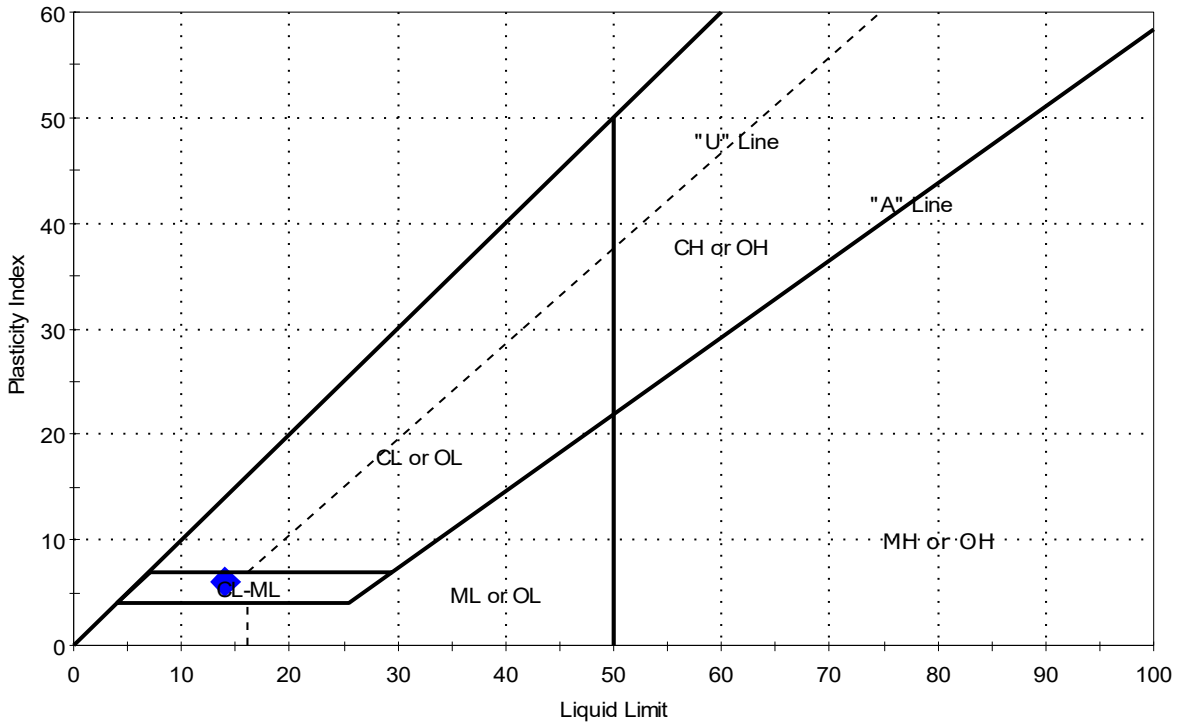
Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	bag	Tested By:	cam
Sample ID:	LSB-001	Test Date:	08/08/19	Checked By:	bfs
Depth :	55-60 ft	Test Id:	516899		
Test Comment:	---				
Visual Description:	Moist, red silty, clayey sand with gravel				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

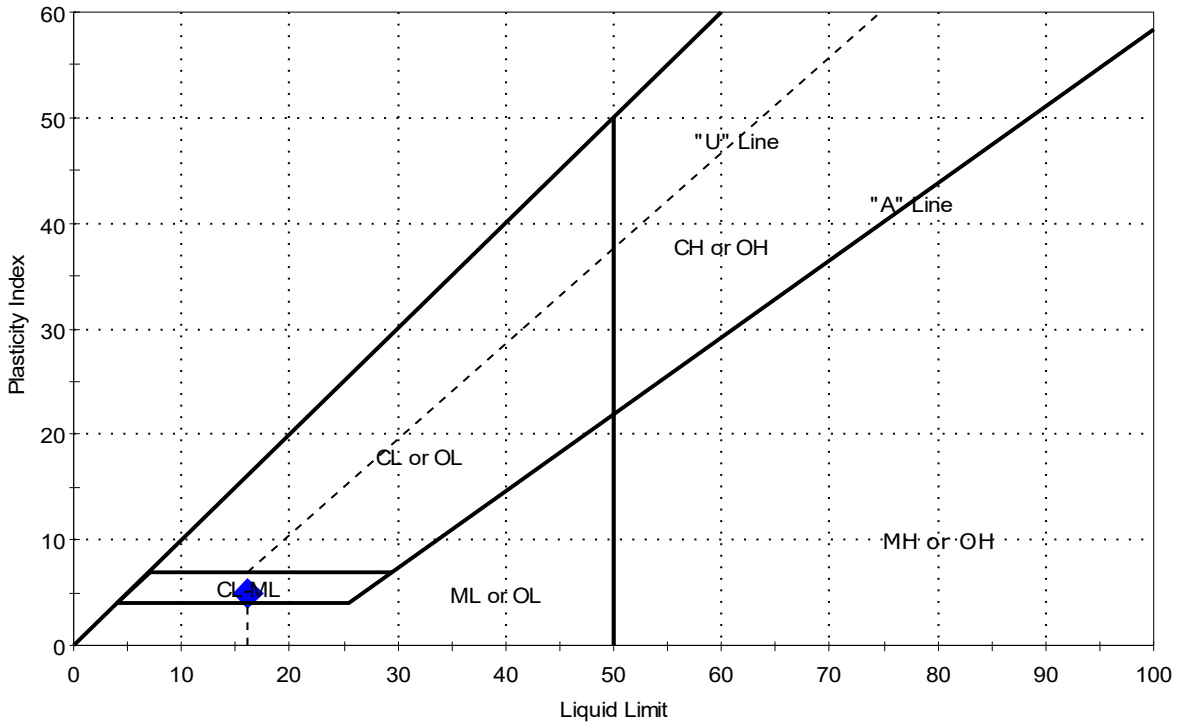


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-07	55-60 ft	1	14	8	6	-1.2	Silty, Clayey SAND with Gravel (SC-SM)

Sample Prepared using the WET method
40% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/30/19	Checked By:	jsc
Depth :	47.90-48.56 ft	Test Id:	532656		
Test Comment:	---				
Visual Description:	Moist, pale brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-024	47.90-48.5 ft	3	16	11	5	-1.7	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
1% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	01/03/20	Checked By:	jsc
Depth :	68.24-68.73 ft	Test Id:	532657		
Test Comment:	---				
Visual Description:	Moist, pale brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

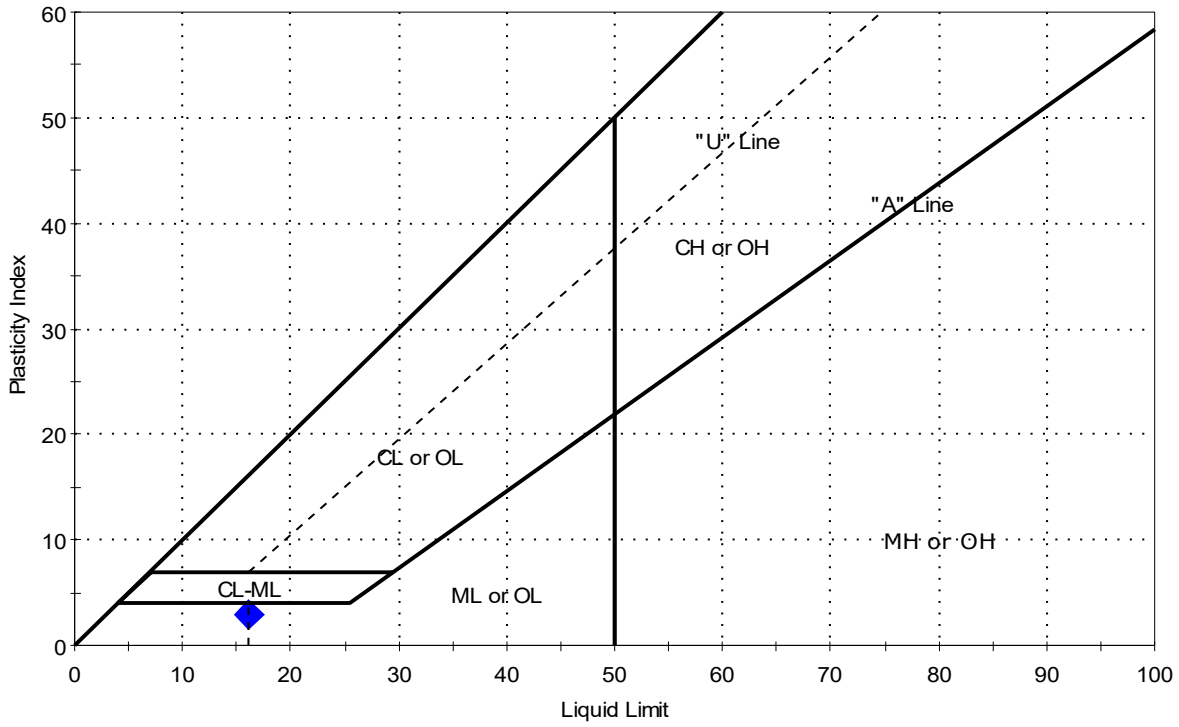
Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-024A	68.24-68.73 ft	2	n/a	n/a	n/a	n/a	Silty SAND (SM)

1% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

printed 2/20/2020 4:26:14 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	93.01-93.50 ft	Test Id:	532658		
Test Comment:	---				
Visual Description:	Moist, pale brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

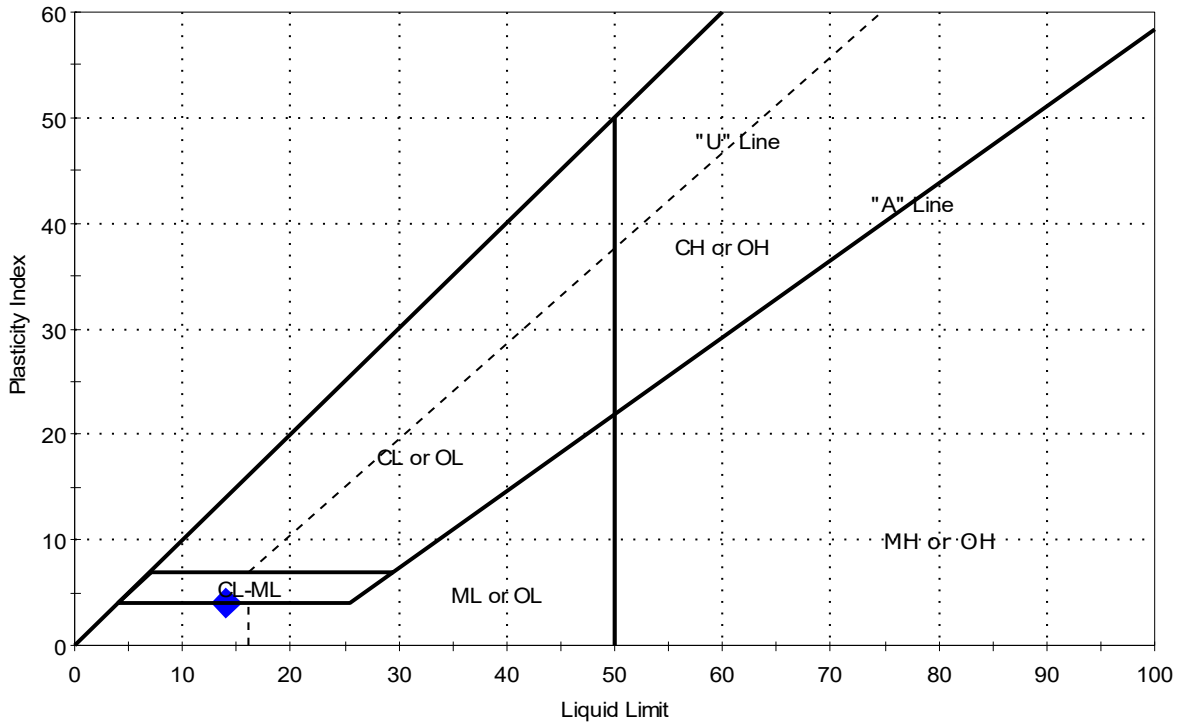


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-024A	93.01-93.50 ft	3	16	13	3	-3.4	Silty SAND (SM)

Sample Prepared using the WET method
7% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	01/06/20	Checked By:	jsc
Depth :	120.08-120.57 ft	Test Id:	532659		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

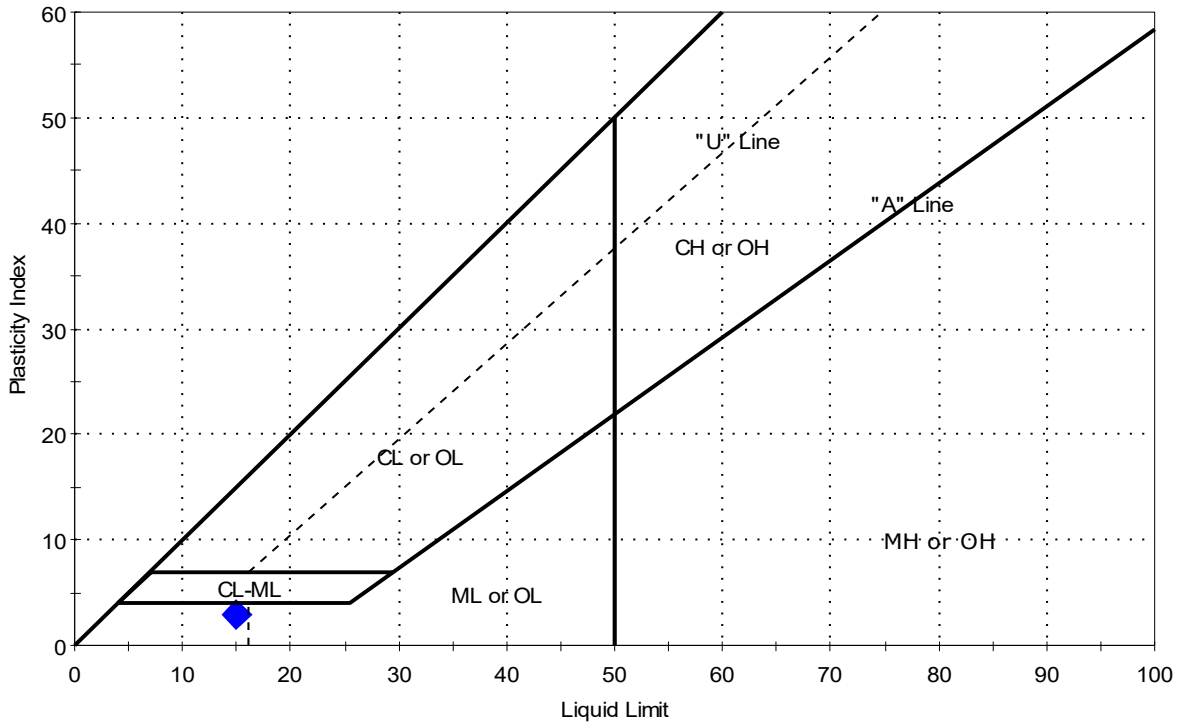


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-024A	120.08-120.57 ft	0	14	10	4	-2.4	Silty, Clayey SAND (SC-SM)

Sample Prepared using the WET method
9% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: LOW

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/27/19	Checked By:	jsc
Depth :	141.90-152.55 ft	Test Id:	532660		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

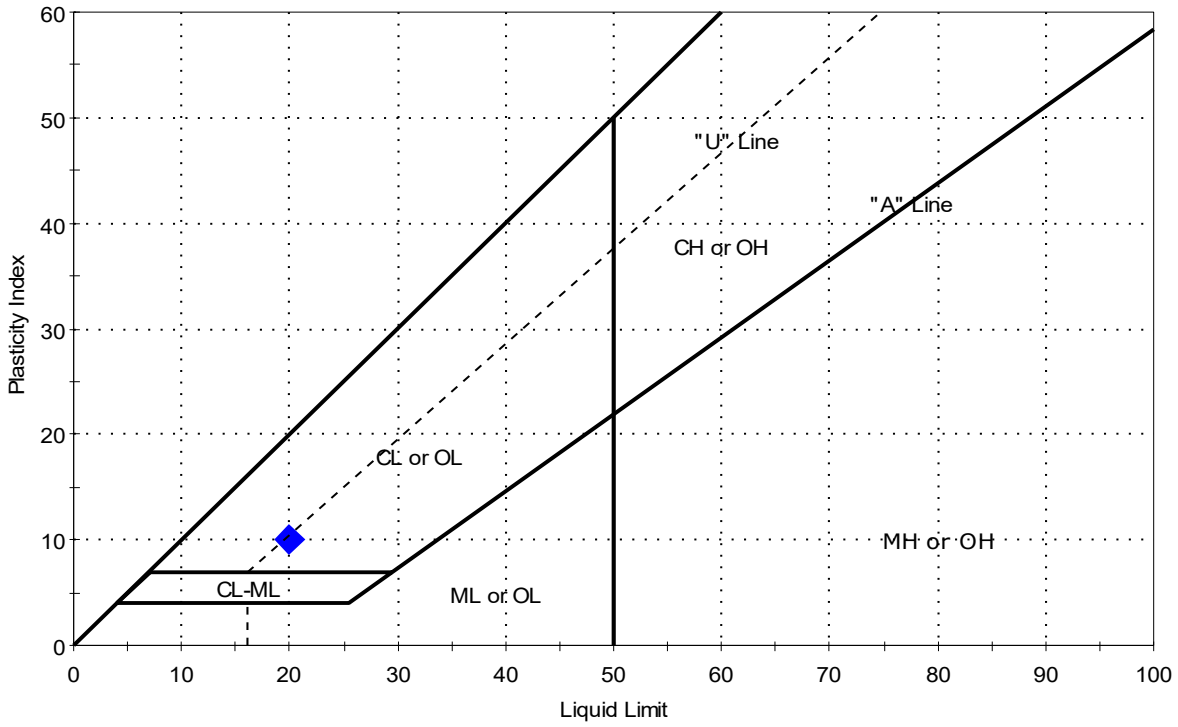


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-005	BH19-024A	141.90-152.55 ft	1	15	12	3	-3.7	Silty SAND (SM)

Sample Prepared using the WET method
12% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	12/30/19	Checked By:	jsc
Depth :	156.66-157.32 ft	Test Id:	532661		
Test Comment:	---				
Visual Description:	Dry, pale brown clayey sand with gravel				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

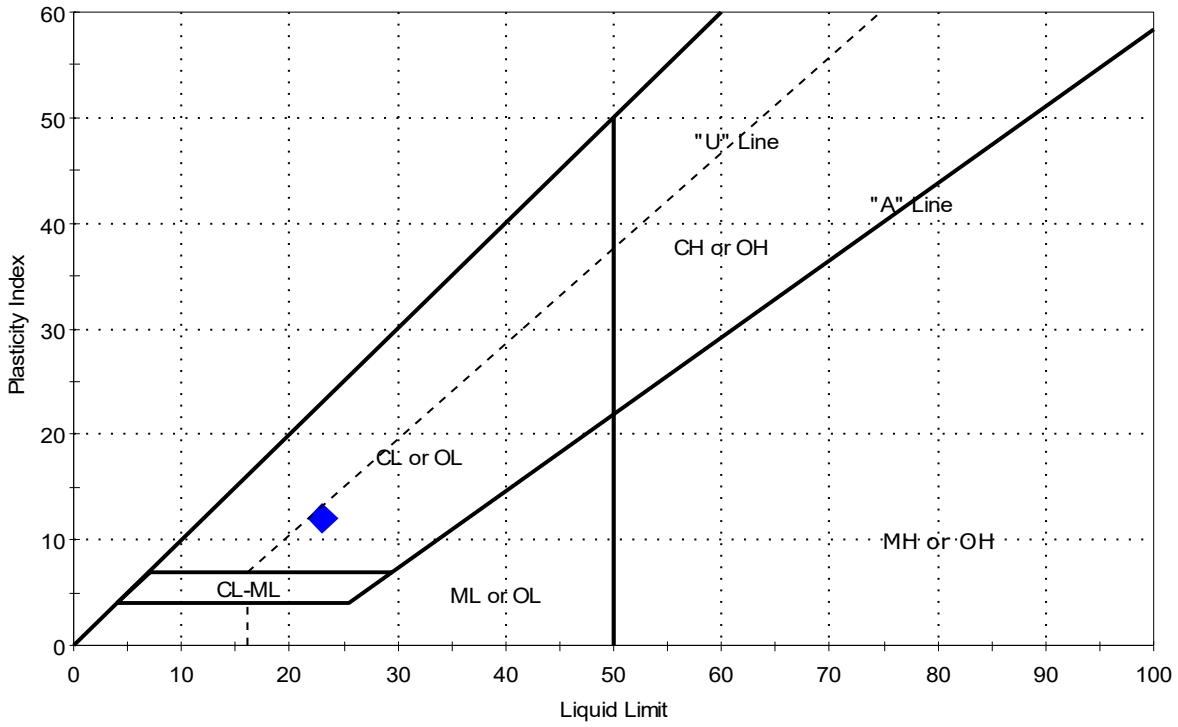


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-006	BH19-024A	156.66-157.32 ft	3	20	10	10	-0.7	Clayey SAND with Gravel (SC)

Sample Prepared using the WET method
31% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	12/27/19	Checked By:	jsc
Depth :	174.54-175.03 ft	Test Id:	532624		
Test Comment:	---				
Visual Description:	Dry, pale brown clayey sand with gravel				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

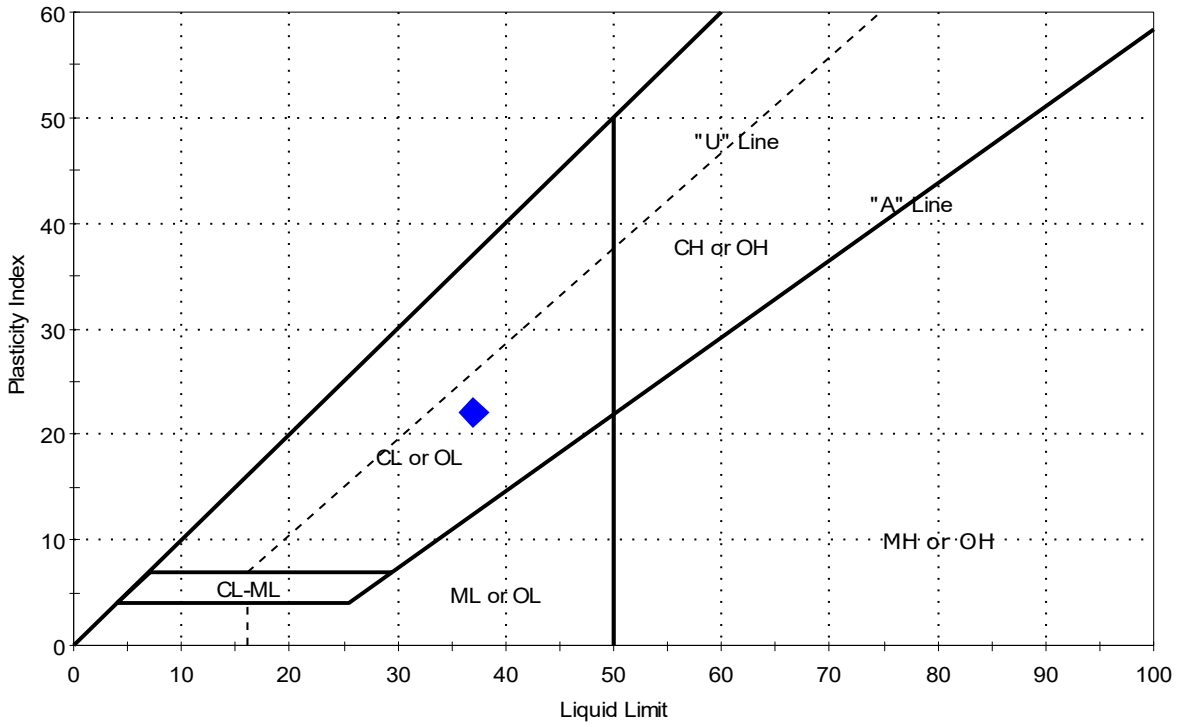


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-007	BH19-024A	174.54-175.03 ft	1	23	11	12	-0.8	Clayey SAND with Gravel (SC)

Sample Prepared using the WET method
31% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	12/27/19	Checked By:	jsc
Depth :	180.94-181.43 ft	Test Id:	532625		
Test Comment:	---				
Visual Description:	Moist, pale brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

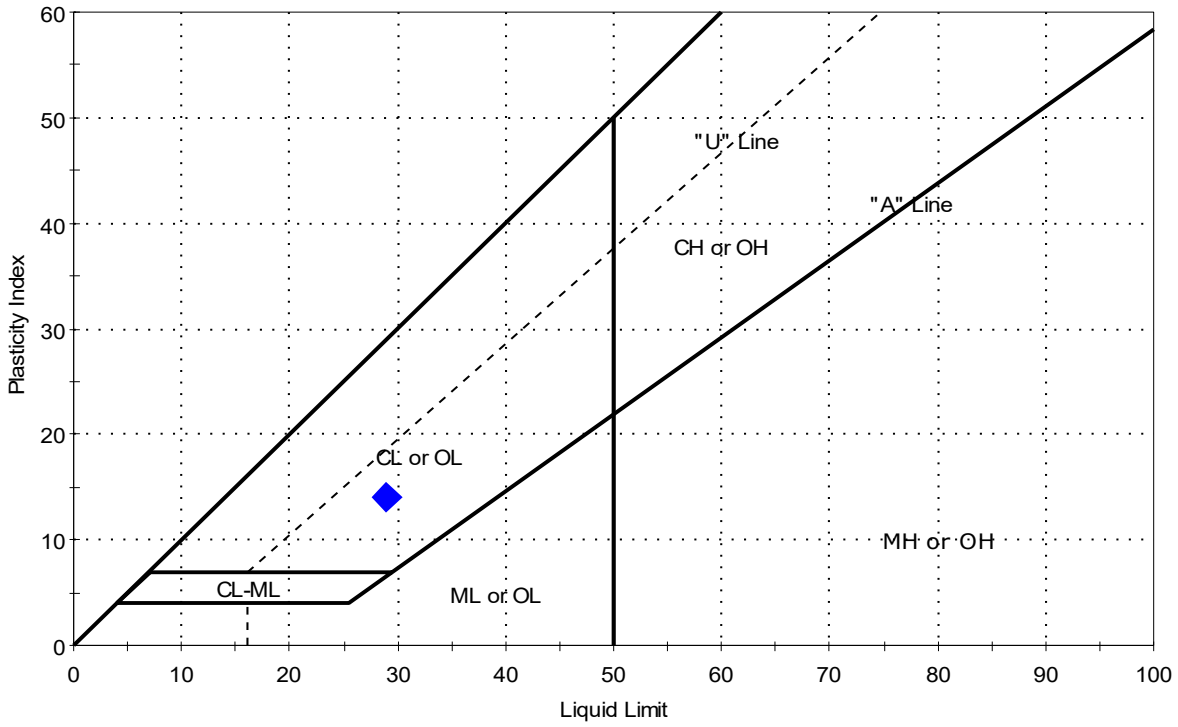


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-008	BH19-024A	180.94-181.43 ft	10	37	15	22	-0.2	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
12% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	12/27/19	Checked By:	jsc
Depth :	185.20-185.70 ft	Test Id:	532626		
Test Comment:	---				
Visual Description:	Moist, pale brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

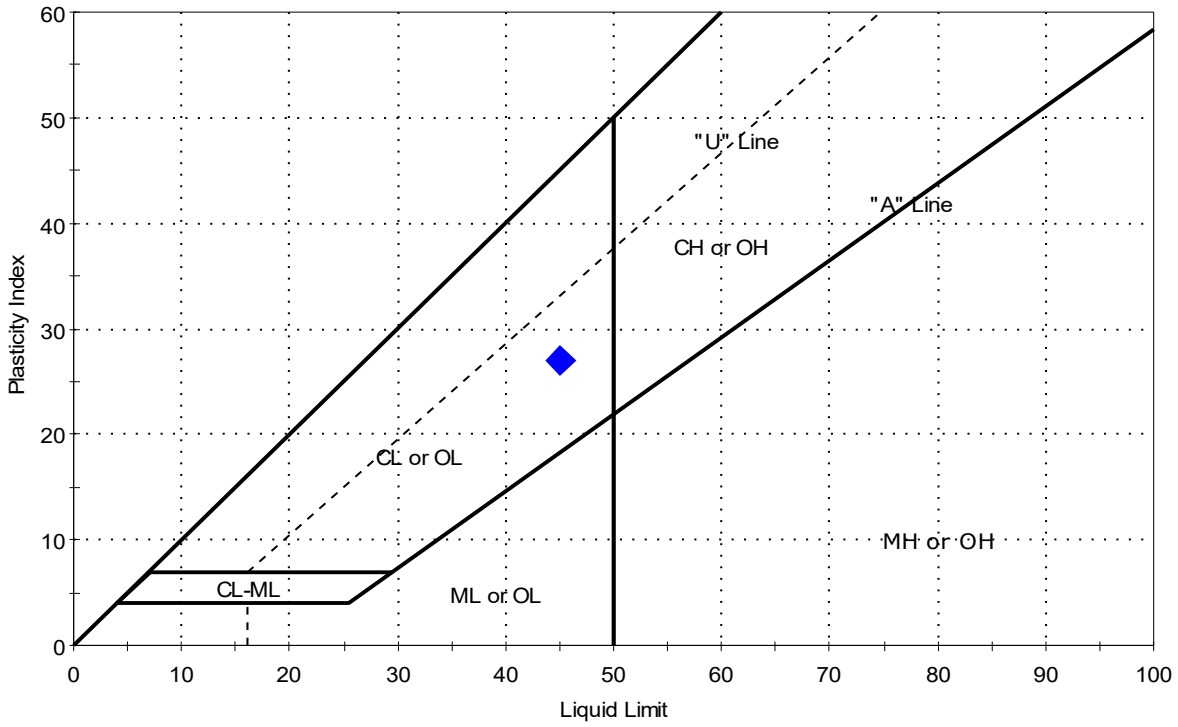


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-009	BH19-024A	185.20-185.70 ft	11	29	15	14	-0.3	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-010	Test Date:	01/03/20	Checked By:	jsc
Depth :	189.57-190.22 ft	Test Id:	532627		
Test Comment:	---				
Visual Description:	Moist, pale brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

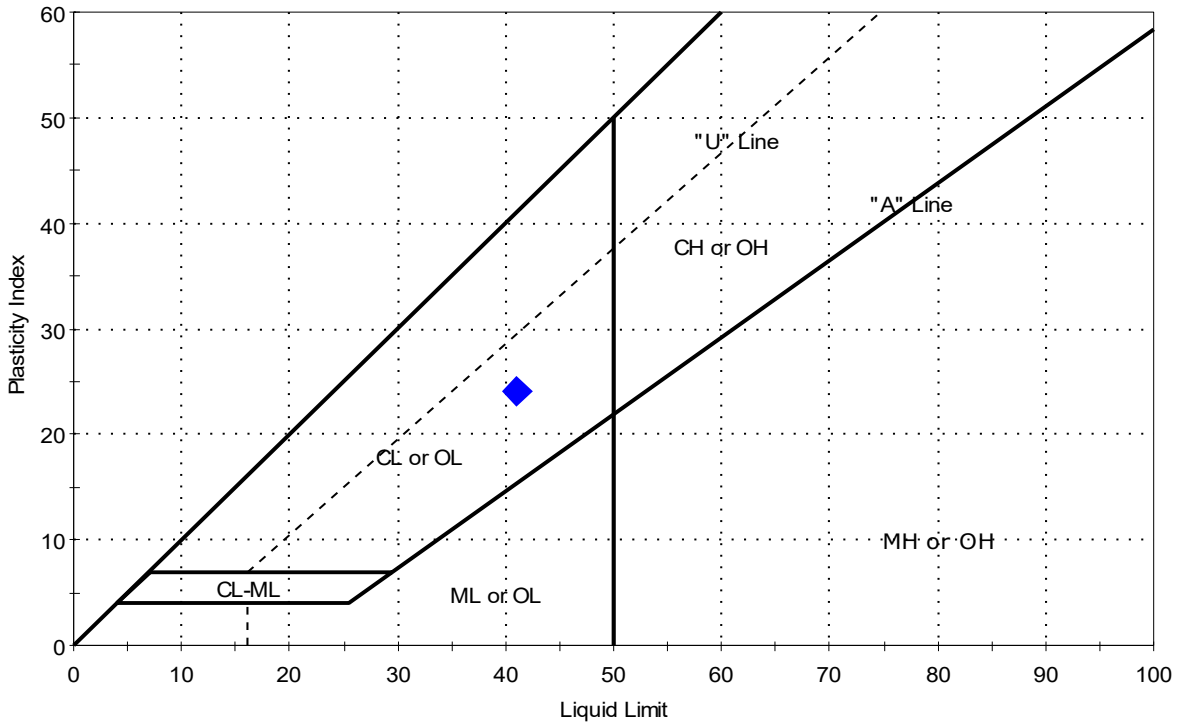


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-010	BH19-024A	189.57-190.22 ft	13	45	18	27	-0.2	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	12/23/19	Checked By:	bfs
Depth :	193.96-194.42 ft	Test Id:	532628		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

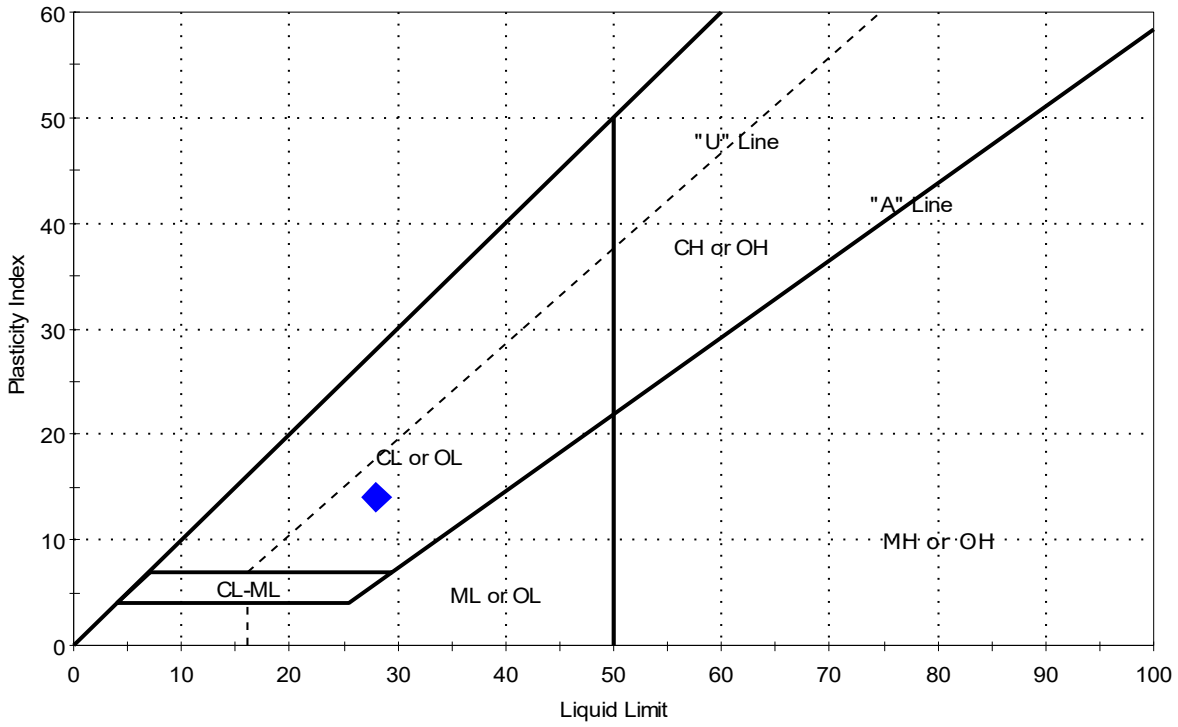


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-011	BH19-024A	193.96-194.42 ft	16	41	17	24	0	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-012	Test Date:	01/06/20	Checked By:	jsc
Depth :	200.85-201.41 ft	Test Id:	532629		
Test Comment:	---				
Visual Description:	Moist, pale brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

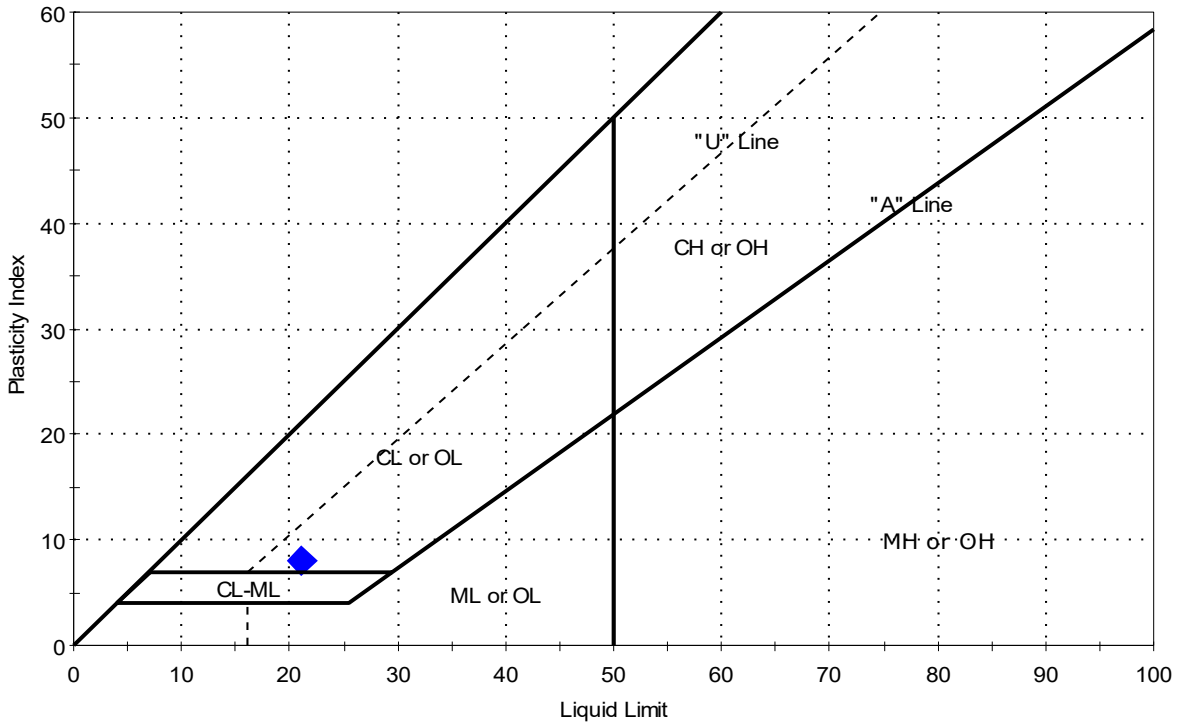


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-012	BH19-024A	200.85-201.41 ft	10	28	14	14	-0.3	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	12/27/19	Checked By:	jsc
Depth :	204.33-204.92 ft	Test Id:	533650		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

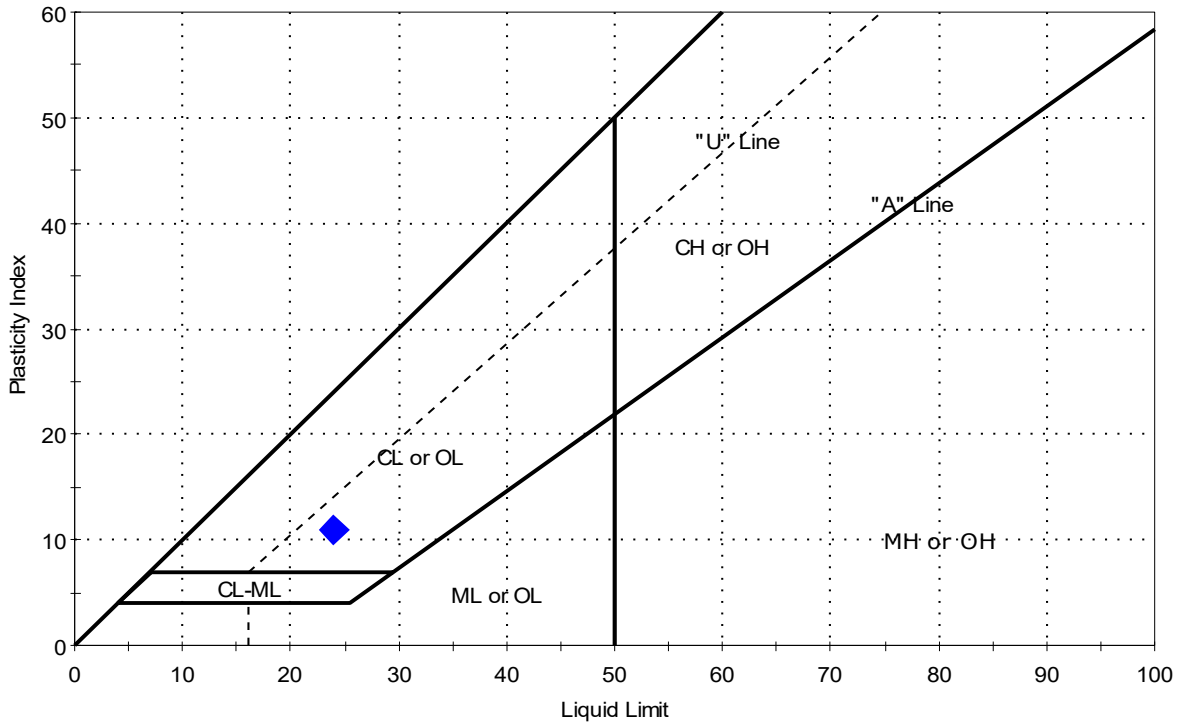


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-013	BH19-024A	204.33-204.92 ft	10	21	13	8	-0.4	Lean CLAY (CL)

Sample Prepared using the WET method
1% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	12/23/19	Checked By:	jsc
Depth :	208.75-209.42 ft	Test Id:	533651		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

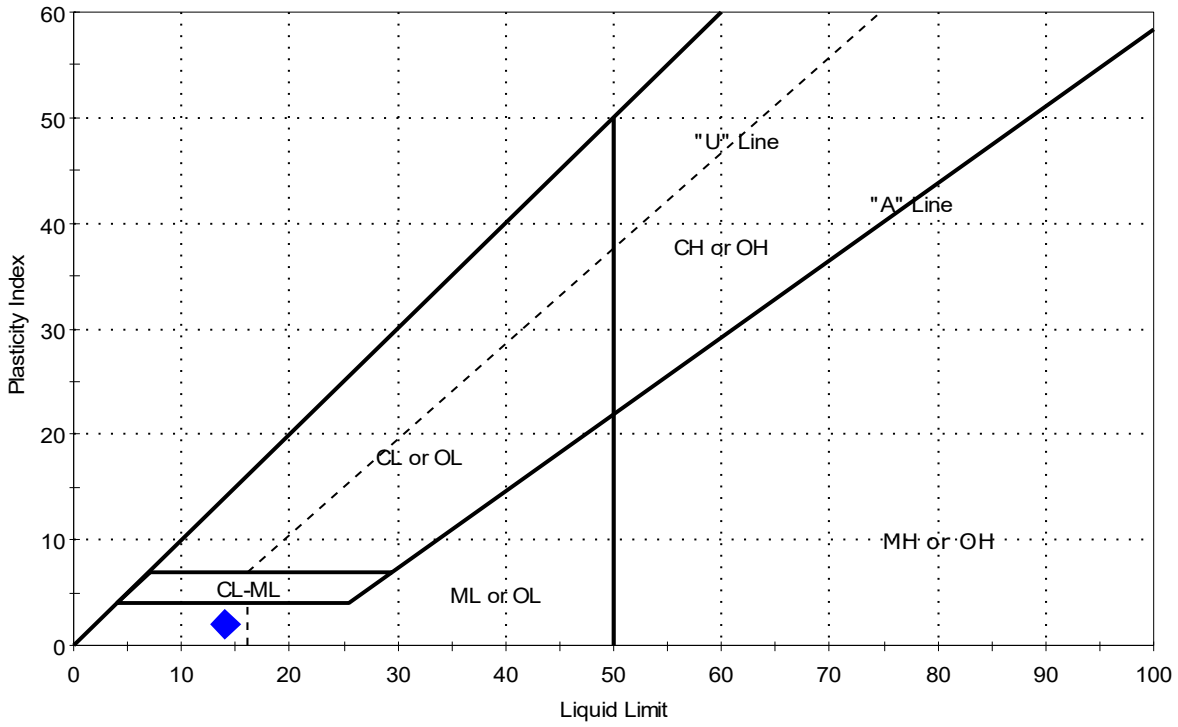


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-014	BH19-024A	208.75-209.42 ft	10	24	13	11	-0.3	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-024A	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	01/03/20	Checked By:	jsc
Depth :	218.50-219.00 ft	Test Id:	533652		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

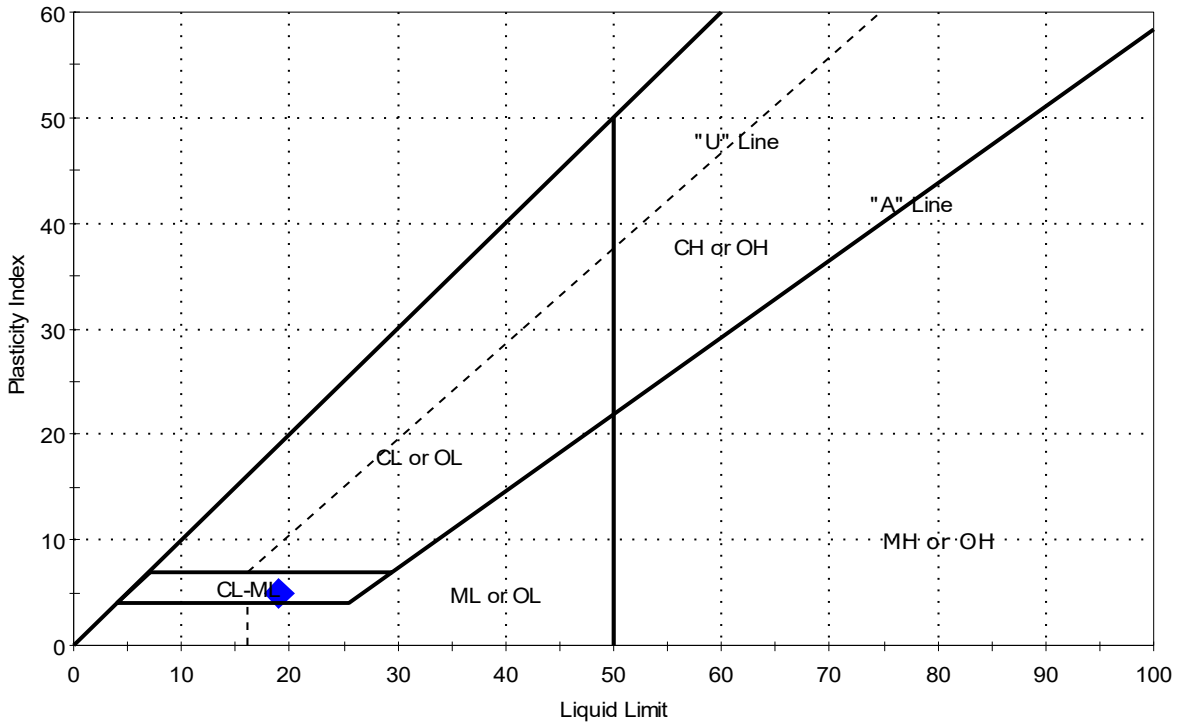


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-015	BH19-024A	218.50-219.00 ft	1	14	12	2	-5.4	Silty SAND (SM)

Sample Prepared using the WET method
23% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: LOW

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	jar	Tested By:	GA
Sample ID:	SS-005	Test Date:	07/26/19	Checked By:	bfs
Depth :	100-102	Test Id:	514355		
Test Comment:	---				
Visual Description:	Moist, gray silty clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	SS-005	BH19-15	100-102	13	19	14	5	-0.1	Silty CLAY with Sand (CL-ML)

Sample Prepared using the WET method
21% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	bag	Tested By:	cam
Sample ID:	LSB-001	Test Date:	07/26/19	Checked By:	bfs
Depth :	69-70 ft	Test Id:	514184		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

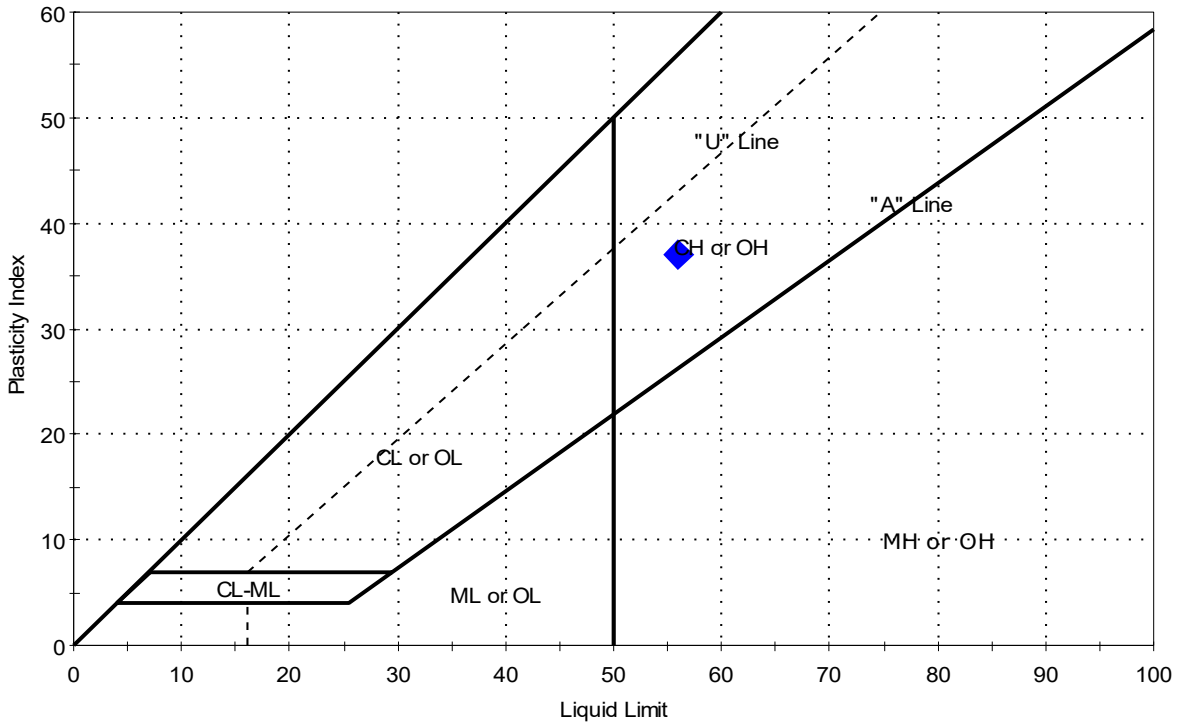
Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-16	69-70 ft	16	n/a	n/a	n/a	n/a	Silty SAND (SM)

9% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/23/19	Checked By:	bfs
Depth :	34.91-35.30 ft	Test Id:	532750		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

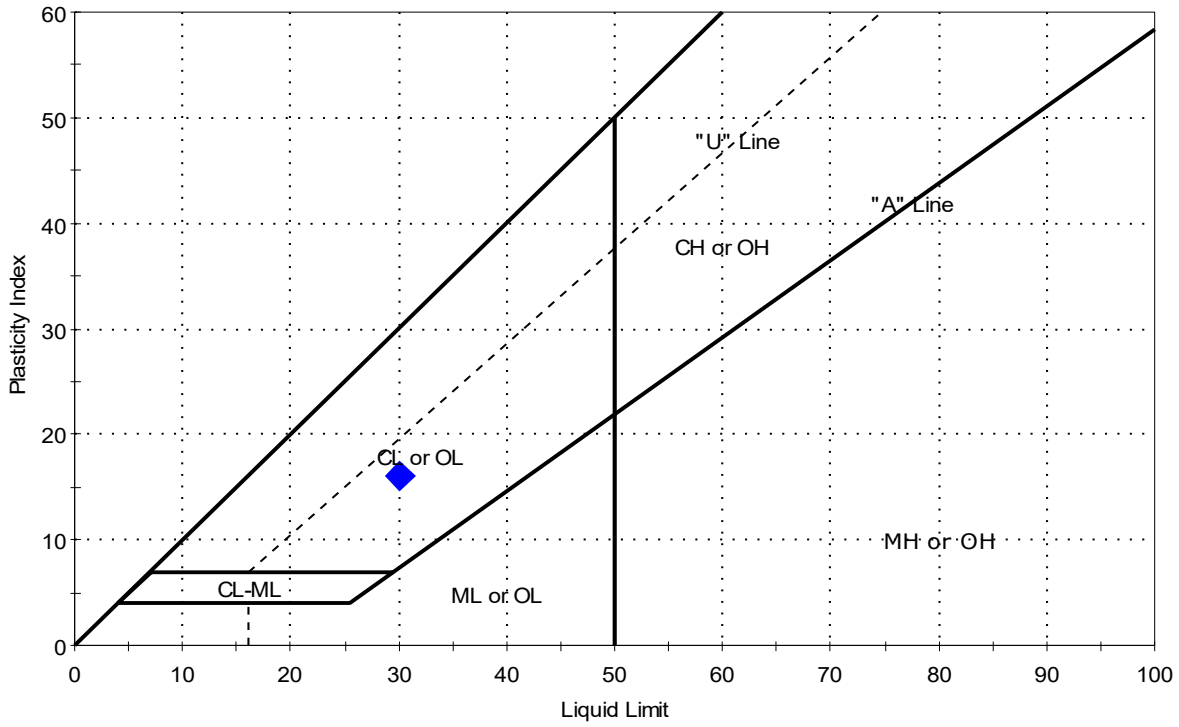


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-21	4.91-35.3 ft	19	56	19	37	0	Fat CLAY (CH)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	01/06/20	Checked By:	jsc
Depth :	39.24-39.70 ft	Test Id:	532751		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

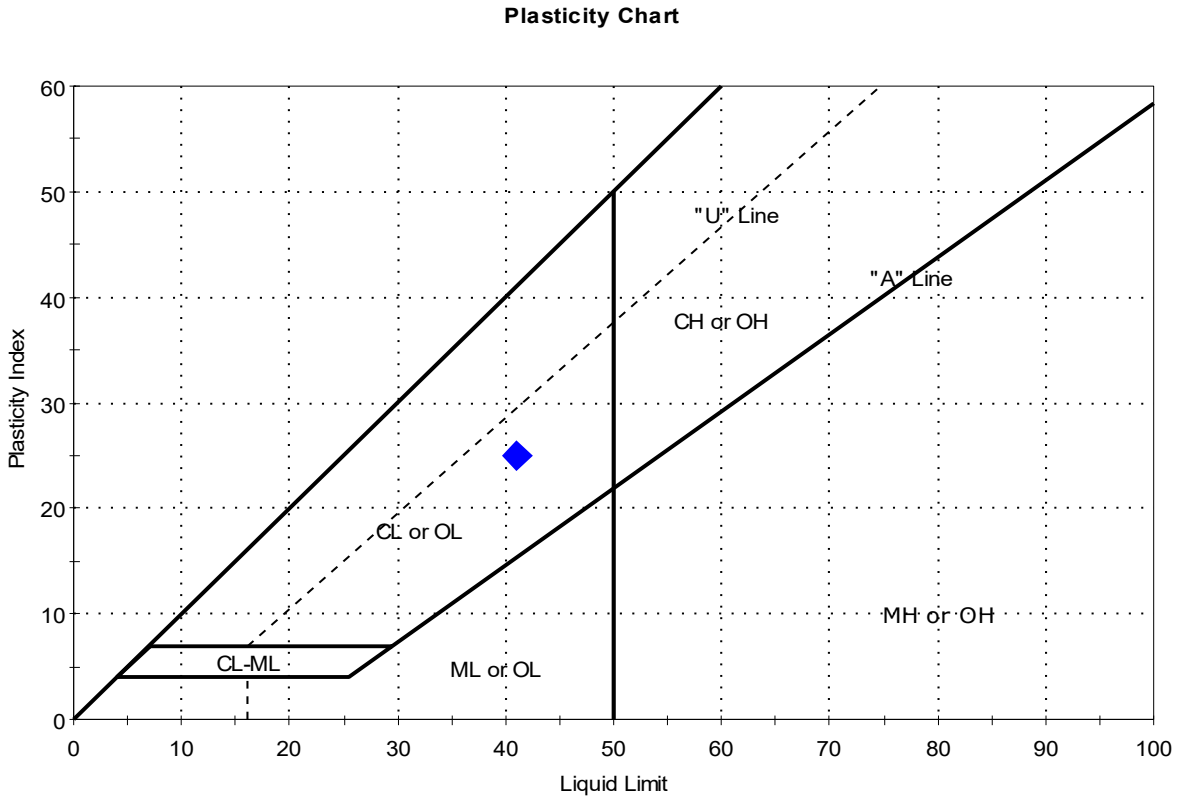


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-21	9.24-39.7 ft	18	30	14	16	0.3	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
5% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/23/19	Checked By:	bfs
Depth :	44.55-44.94 ft	Test Id:	532752		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

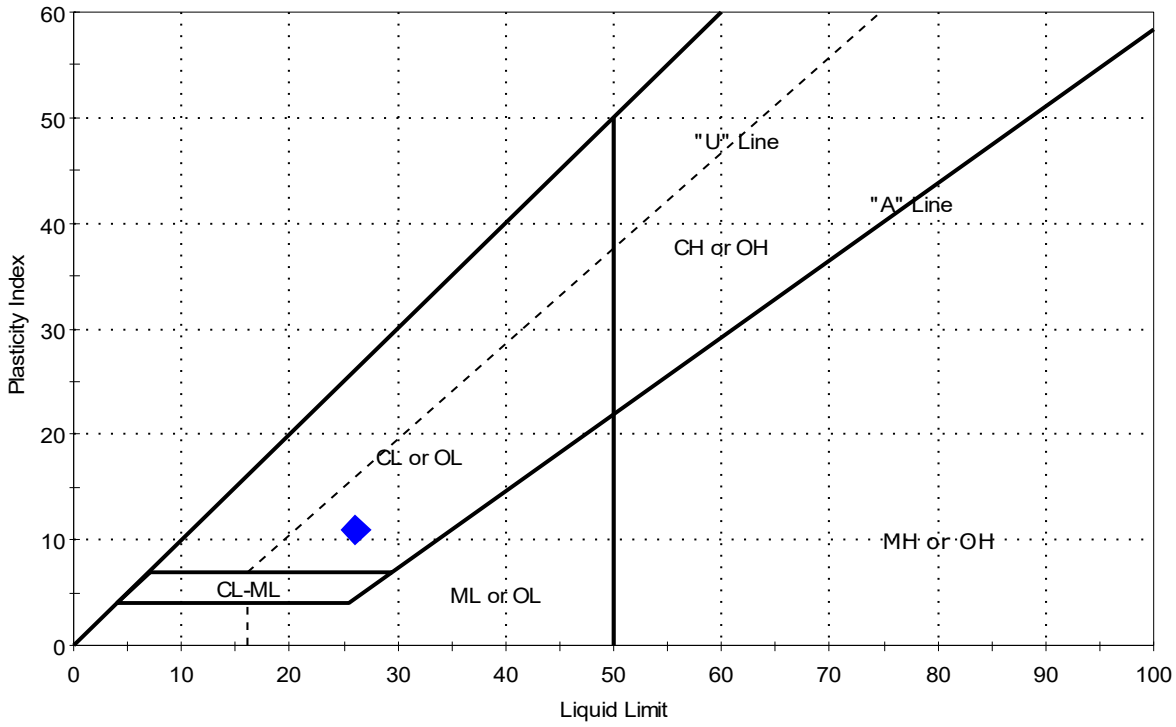


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-21	4.55-44.9 ft	25	41	16	25	0.4	Lean CLAY (CL)

Sample Prepared using the WET method
3% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	01/03/20	Checked By:	jsc
Depth :	48.10-48.56 ft	Test Id:	532753		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

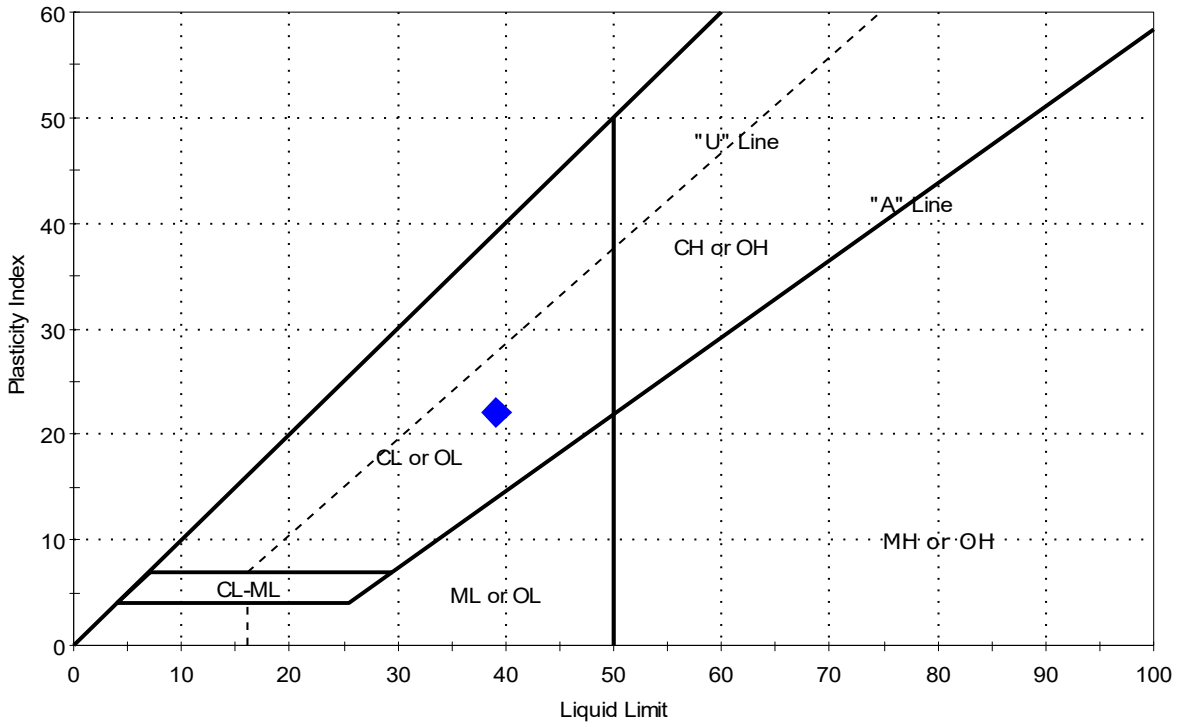


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-21	8.10-48.5 ft	12	26	15	11	-0.3	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
39% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/30/19	Checked By:	jsc
Depth :	29.40-29.95 ft	Test Id:	534002		
Test Comment:	---				
Visual Description:	Dry, pale brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-23	9.40-29.9 ft	2	39	17	22	-0.7	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/27/19	Checked By:	jsc
Depth :	68.01-68.64 ft	Test Id:	534003		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

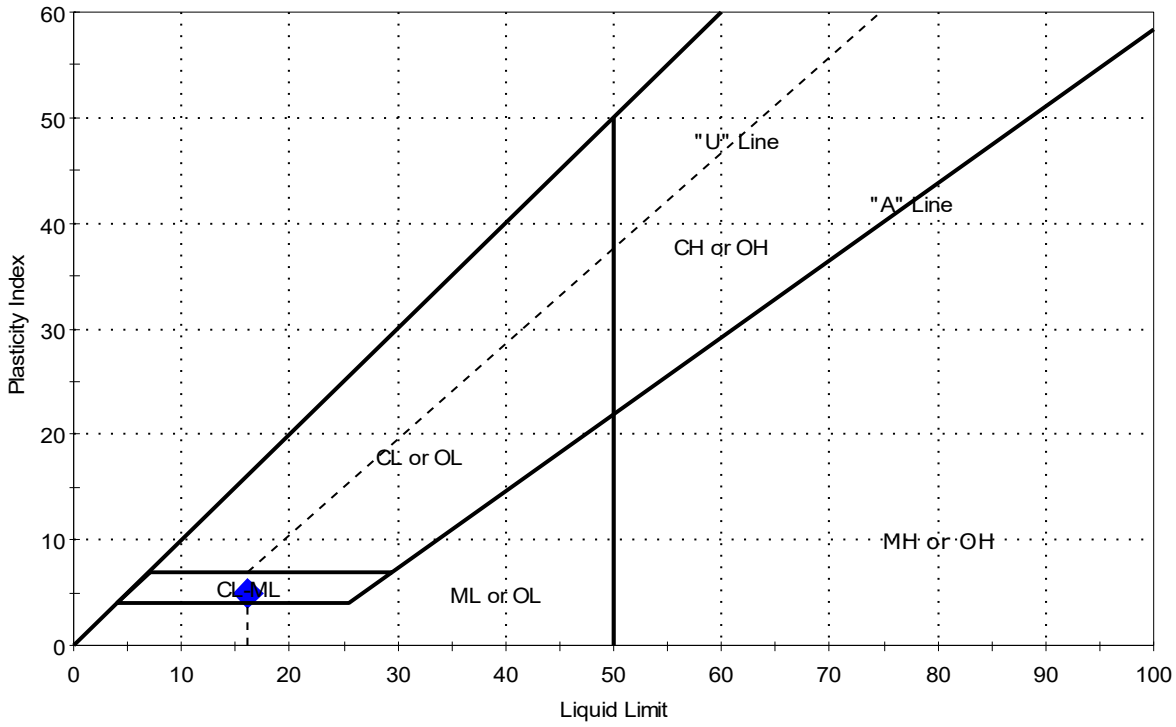
Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-23	8.01-68.6 ft	0	n/a	n/a	n/a	n/a	Silty SAND (SM)

3% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	94.26-94.78 ft	Test Id:	534004		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

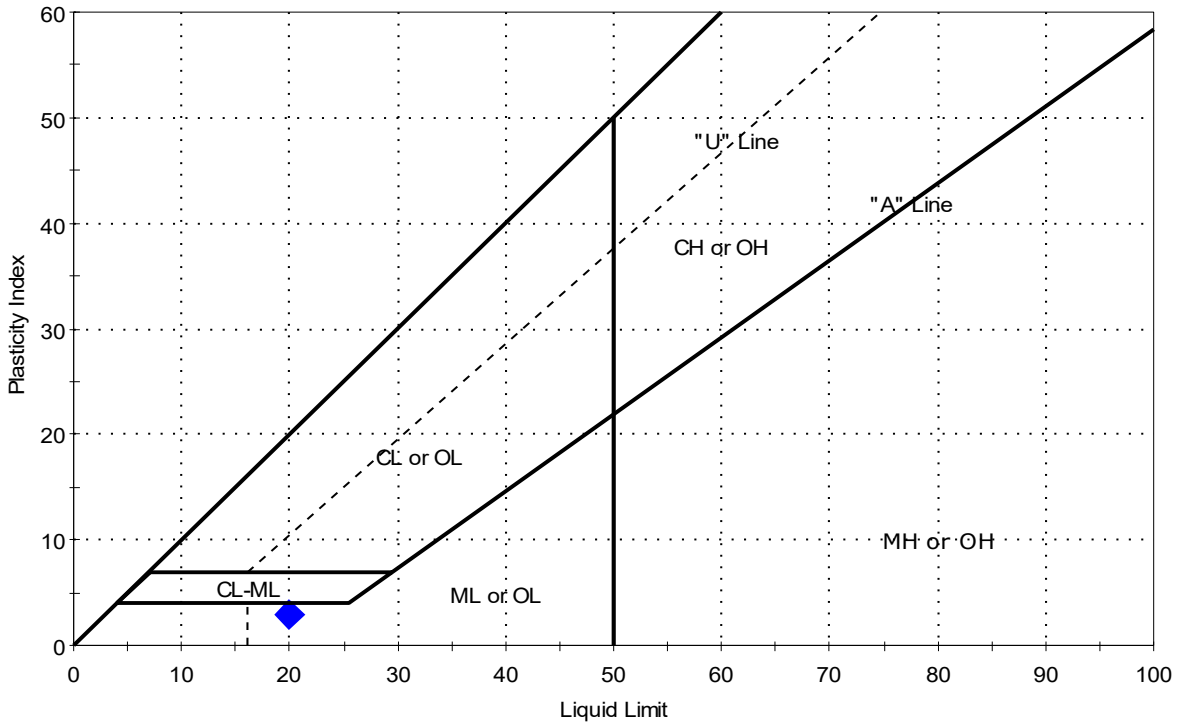


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-23	4.26-94.7 ft	1	16	11	5	-2.1	Silty, Clayey SAND (SC-SM)

Sample Prepared using the WET method
23% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	cam
Sample ID:	LRB-005	Test Date:	02/07/20	Checked By:	jsc
Depth :	180.12-180.45 ft	Test Id:	543127		
Test Comment:	---				
Visual Description:	Dry, light gray silt				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LRB-005	BH19-23	0.12-180. ft	1	20	17	3	-5.3	

Sample Prepared using the WET method

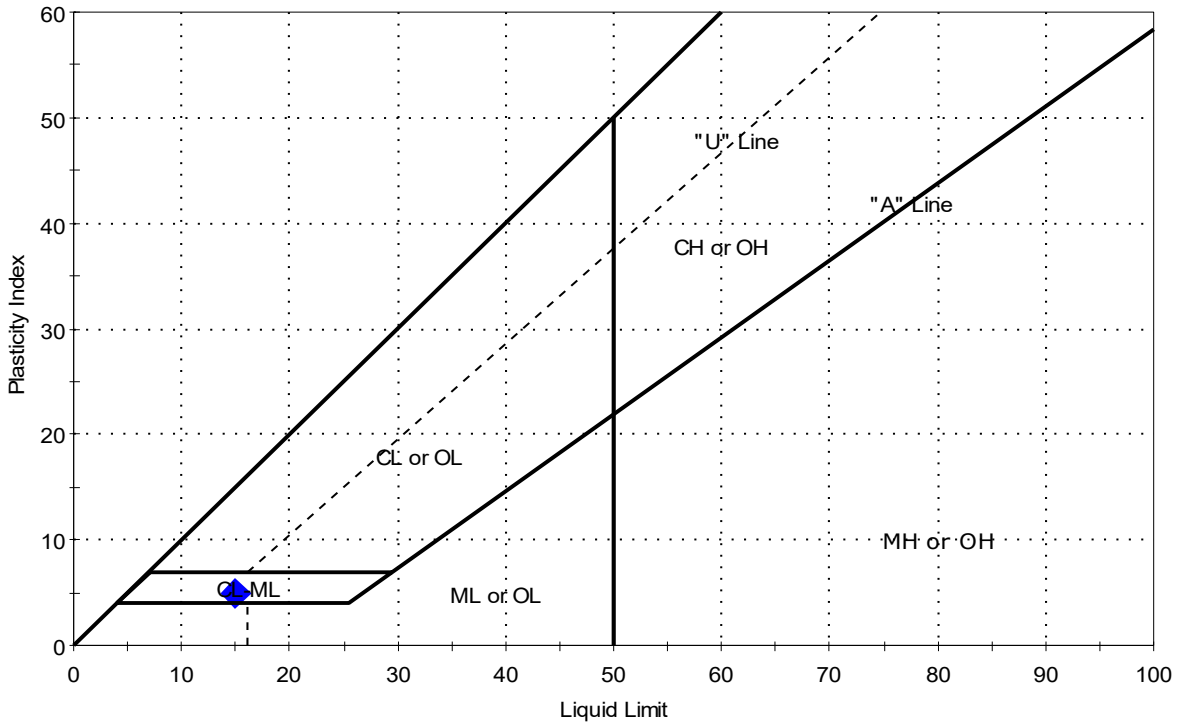
Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/30/19	Checked By:	jsc
Depth :	66.89-67.42 ft	Test Id:	532830		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-24	6.89-67.4 ft	2	15	10	5	-1.5	Silty, Clayey SAND (SC-SM)

Sample Prepared using the WET method
2% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	01/03/20	Checked By:	jsc
Depth :	83.20-83.89 ft	Test Id:	532831		
Test Comment:	---				
Visual Description:	Dry, pale brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-24	3.20-83.8 ft	1	n/a	n/a	n/a	n/a	Silty SAND (SM)

2% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	110.56-111.12 ft	Test Id:	532832		
Test Comment:	---				
Visual Description:	Dry, pale brown sandy silt				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

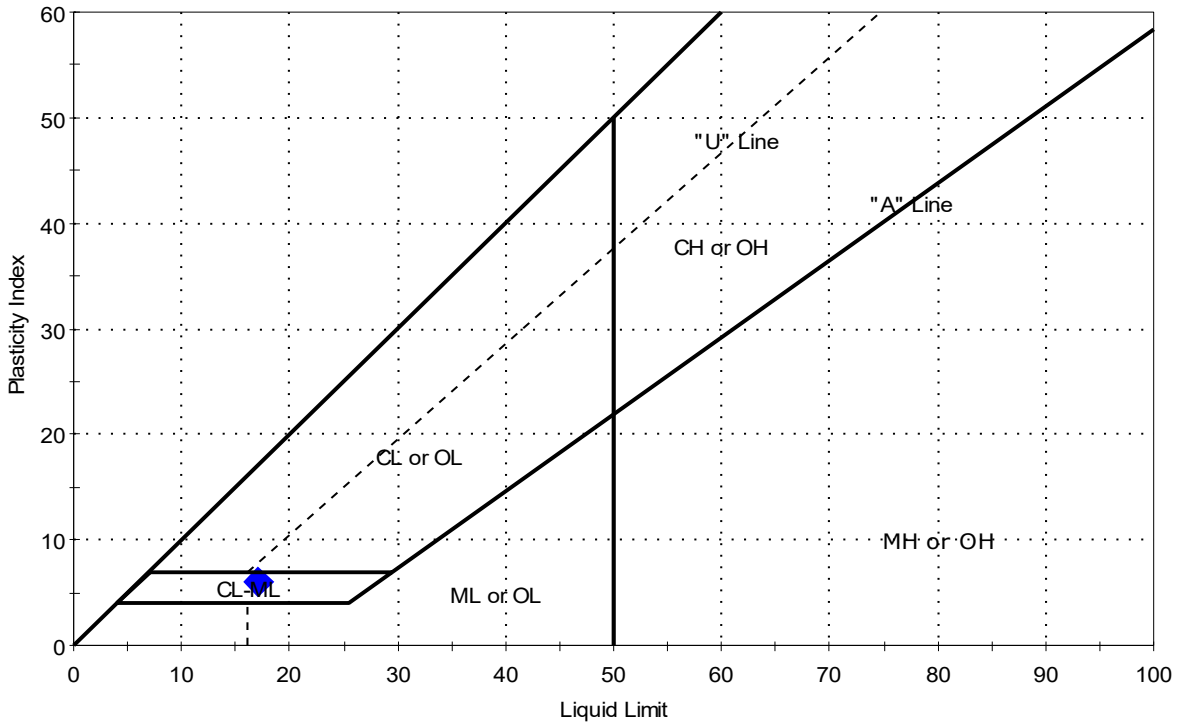
Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-24	0.56-111. ft	1	n/a	n/a	n/a	n/a	Sandy SILT (ML)

3% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	01/03/20	Checked By:	jsc
Depth :	130.51-131.07 ft	Test Id:	532833		
Test Comment:	---				
Visual Description:	Dry, pale brown silty clayey gravel with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

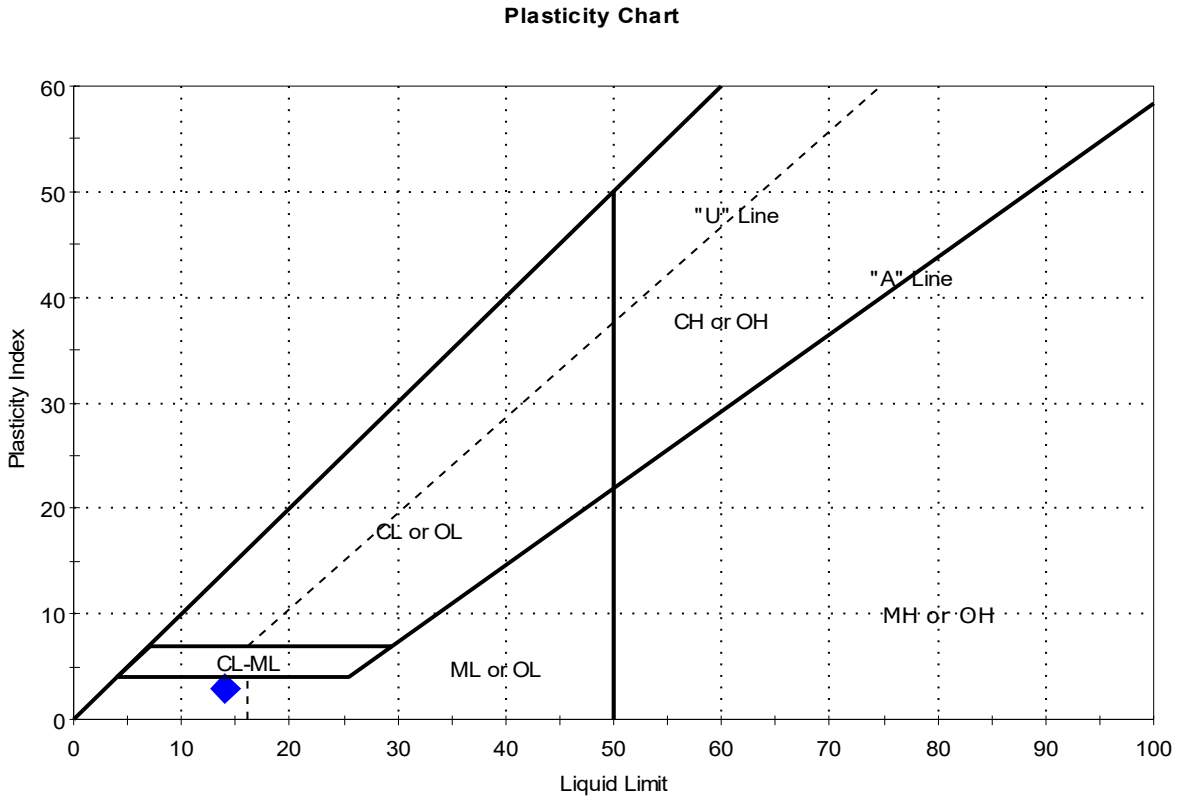


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-24	0.51-131. ft	1	17	11	6	-1.7	Silty, Clayey GRAVEL with Sand (GC-GM)

Sample Prepared using the WET method
62% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	01/06/20	Checked By:	jsc
Depth :	141.50-142.16 ft	Test Id:	532834		
Test Comment:	---				
Visual Description:	Dry, pale brown sandy silt				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

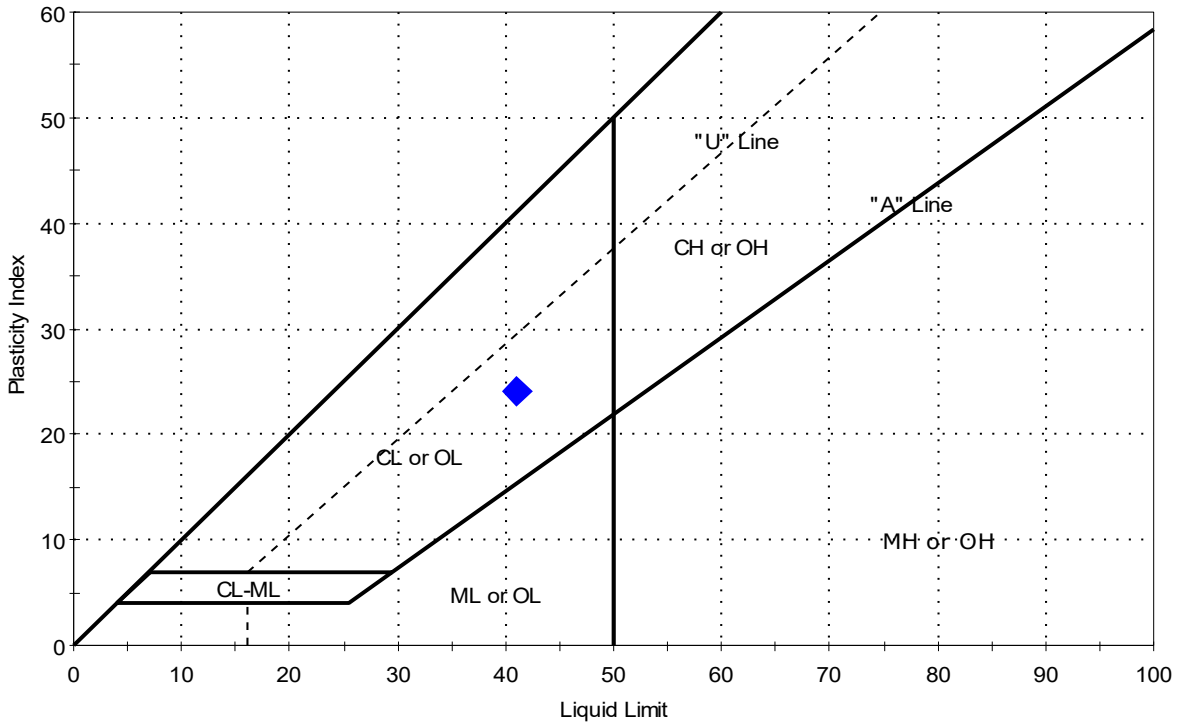


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-005	BH19-24	141.50-142.16 ft	2	14	11	3	-3	Sandy SILT (ML)

Sample Prepared using the WET method
9% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: LOW

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	01/06/20	Checked By:	jsc
Depth :	148.06-148.62 ft	Test Id:	532835		
Test Comment:	---				
Visual Description:	Dry, pale brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

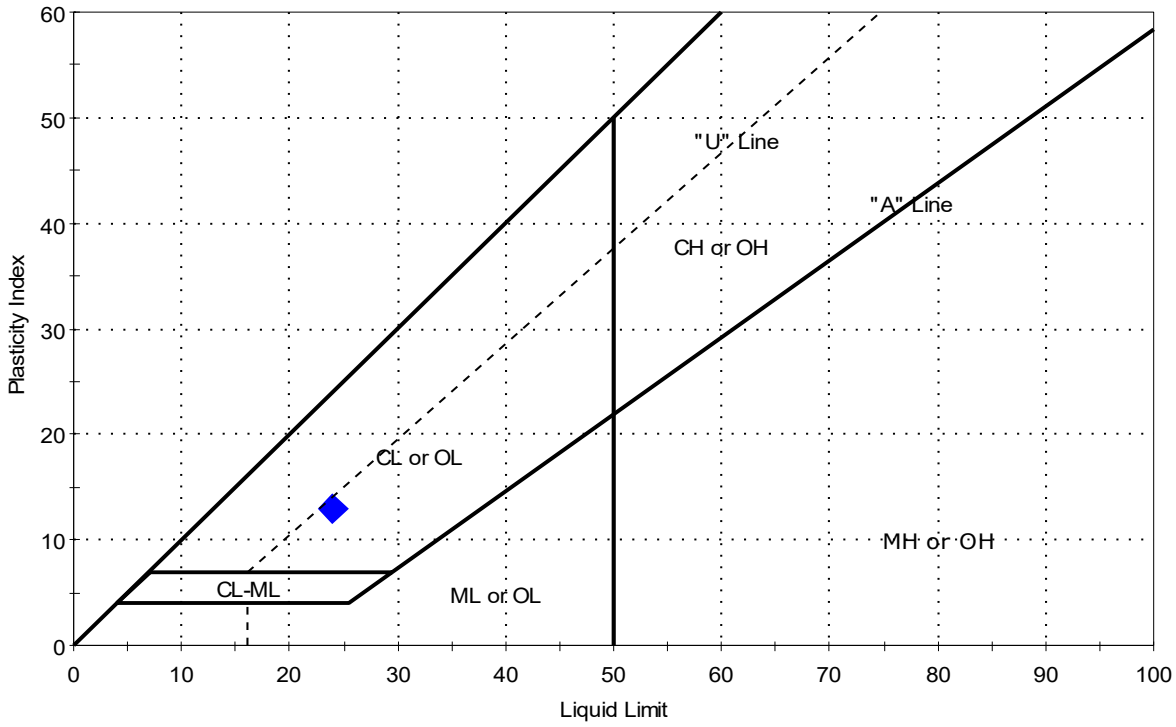


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-006	BH19-24	148.06-148.62 ft	3	41	17	24	-0.6	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	01/08/20	Checked By:	jsc
Depth :	86.84-87.40 ft	Test Id:	537453		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-25	6.84-87.4 ft	18	24	11	13	0.6	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	01/08/20	Checked By:	jsc
Depth :	102.69-103.28 ft	Test Id:	537454		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

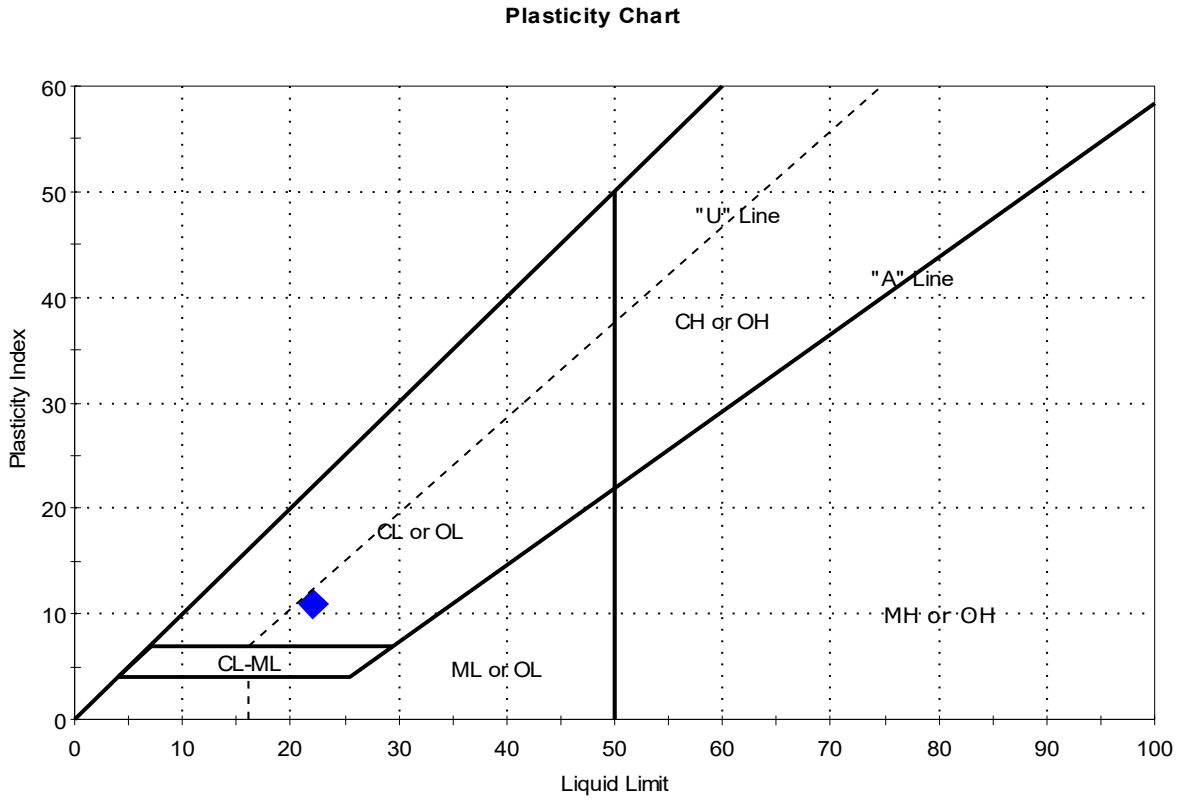
Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-25	2.69-103. ft	14	n/a	n/a	n/a	n/a	Silty SAND (SM)

3% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	01/08/20	Checked By:	jsc
Depth :	111.35-111.94 ft	Test Id:	537455		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-25	1.35-111. ft	22	22	11	11	1	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	01/08/20	Checked By:	jsc
Depth :	116.80-117.39 ft	Test Id:	537456		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

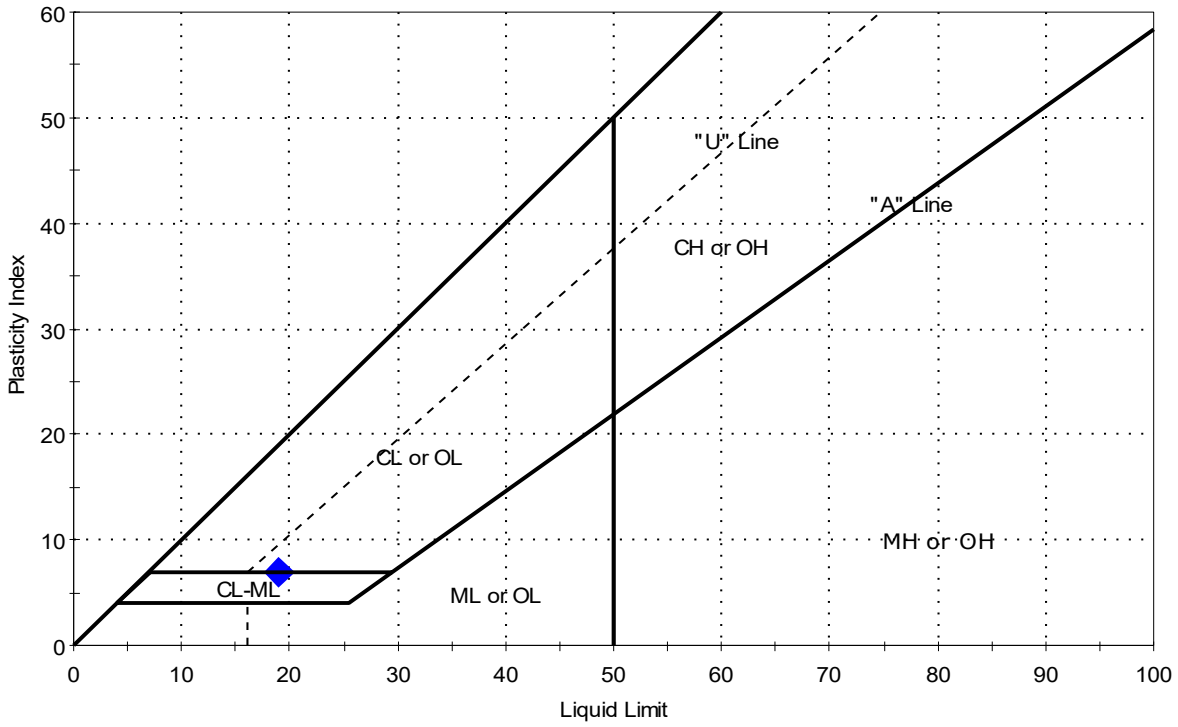
Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-25	6.80-117. ft	14	n/a	n/a	n/a	n/a	Silty SAND (SM)

4% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

printed 2/20/2020 4:26:43 PM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	01/08/20	Checked By:	jsc
Depth :	126.44-127.03 ft	Test Id:	537457		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

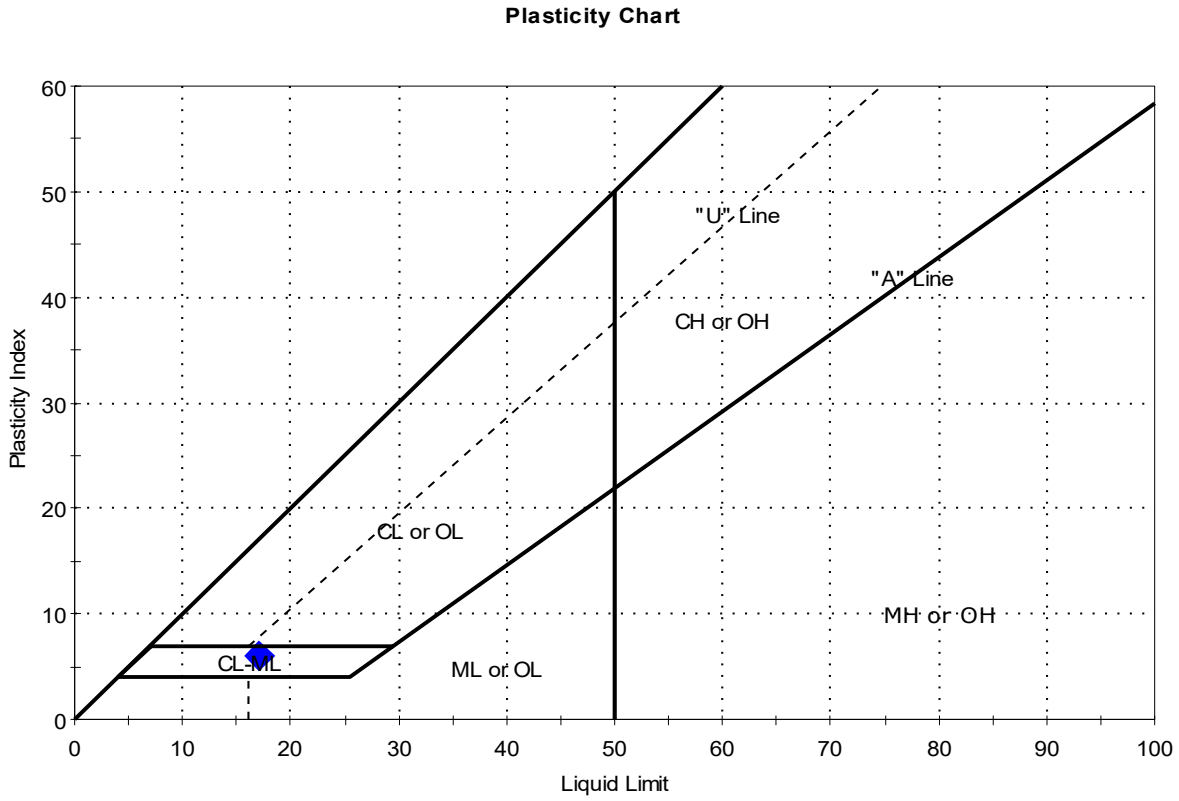


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-005	BH19-25	6.44-127. ft	14	19	12	7	0.3	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
1% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	01/08/20	Checked By:	jsc
Depth :	136.98-137.43 ft	Test Id:	537458		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

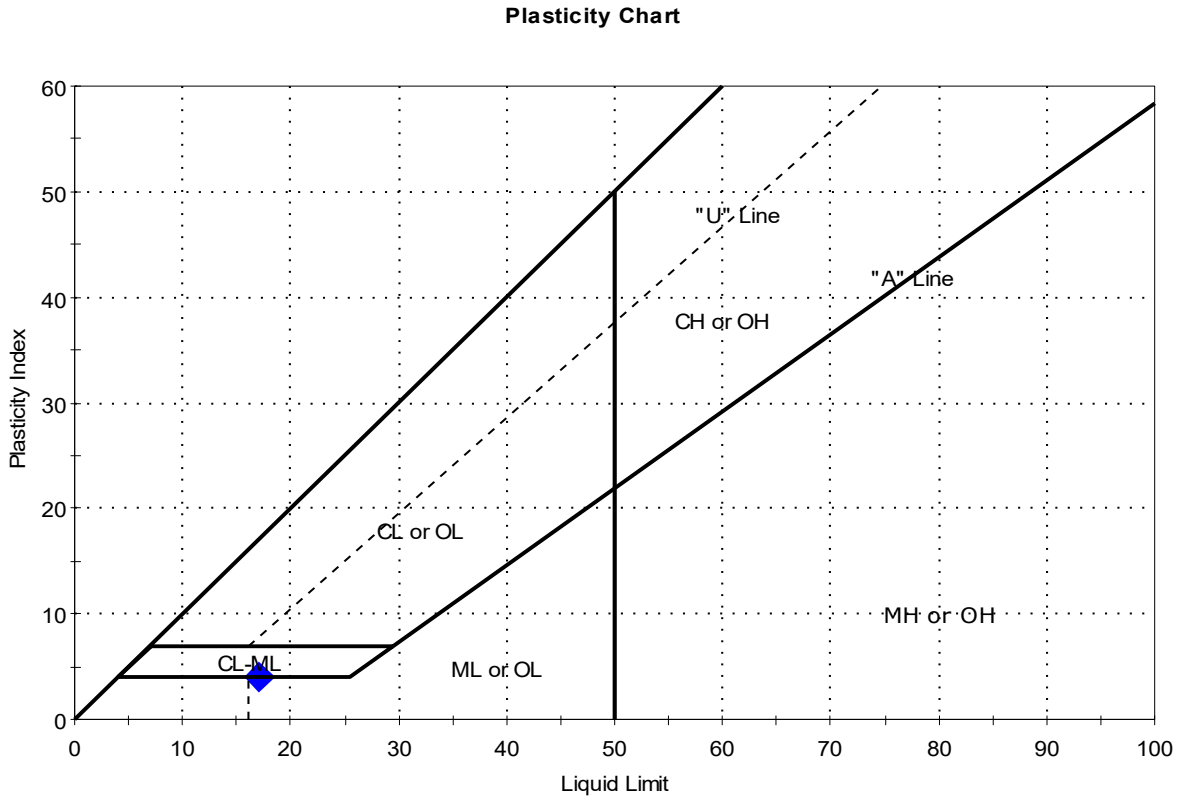


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-006	BH19-25	6.98-137. ft	12	17	11	6	0.1	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
7% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	01/08/20	Checked By:	jsc
Depth :	145.83-146.46 ft	Test Id:	537473		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



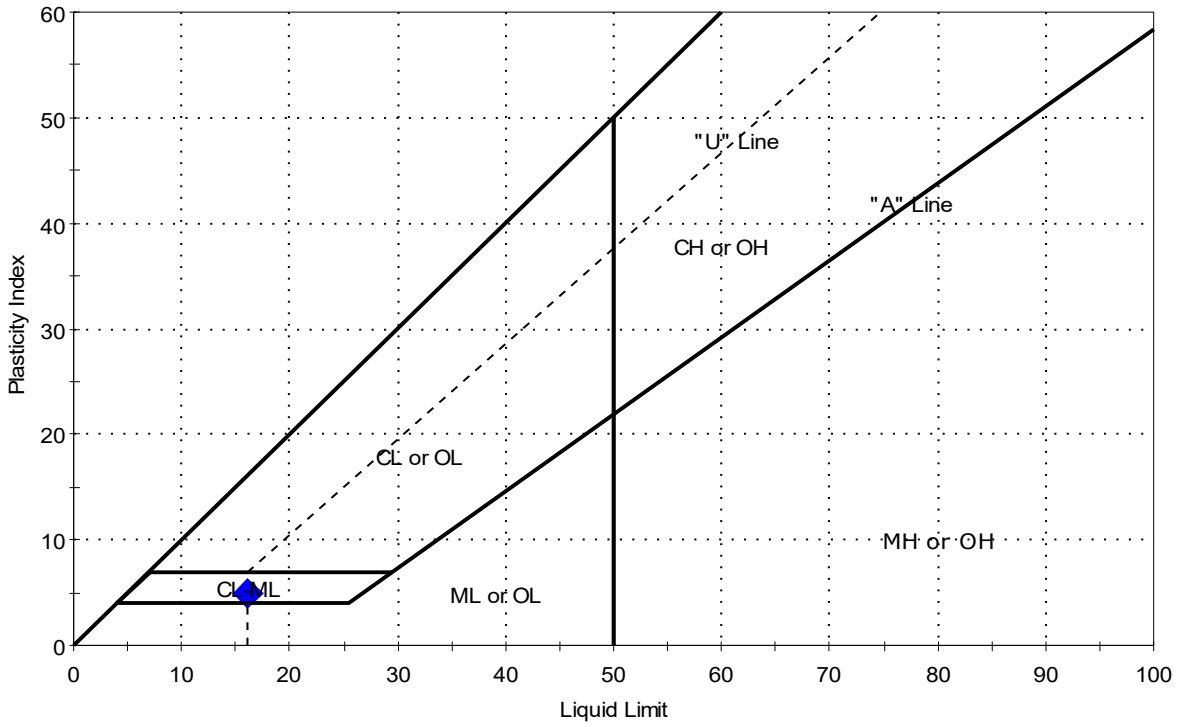
Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-007	BH19-25	5.83-146. ft	15	17	13	4	0.4	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
3% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	01/08/20	Checked By:	jsc
Depth :	155.94-156.56 ft	Test Id:	537474		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

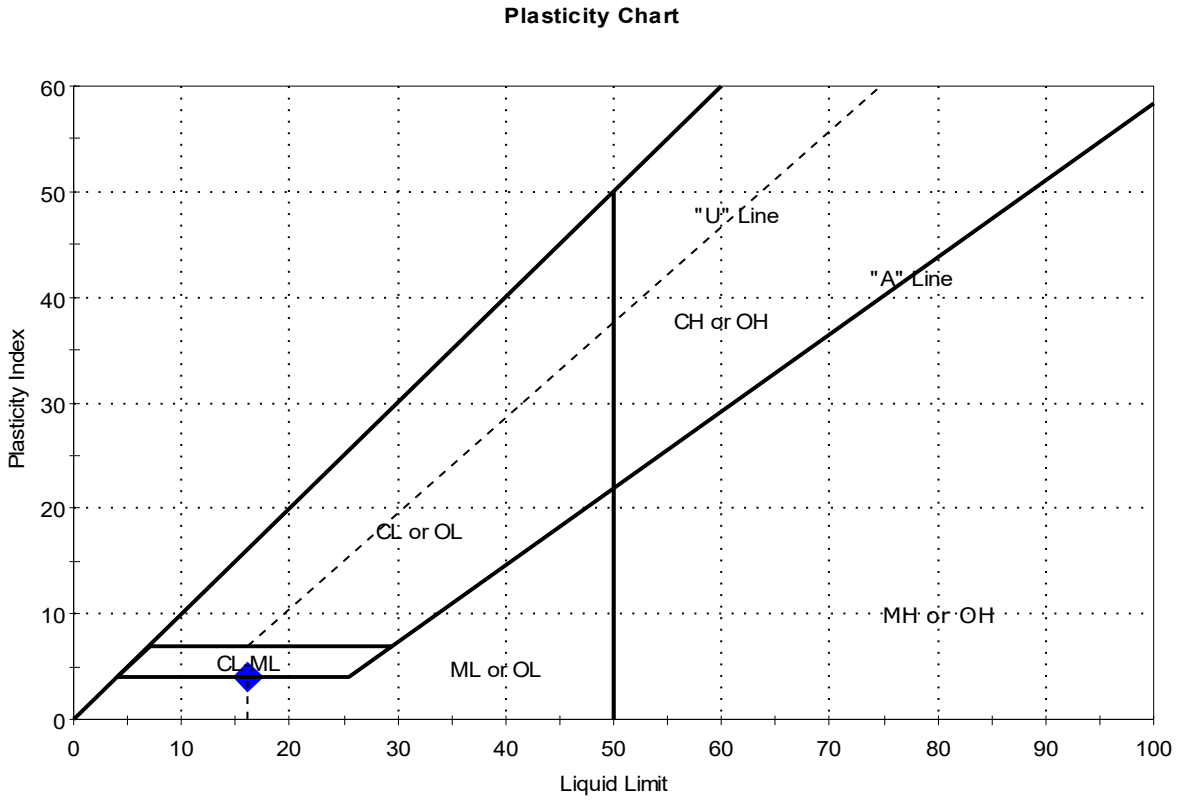


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-008	BH19-25	5.94-156. ft	12	16	11	5	0.2	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
5% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	01/08/20	Checked By:	jsc
Depth :	167.49-168.11 ft	Test Id:	537475		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

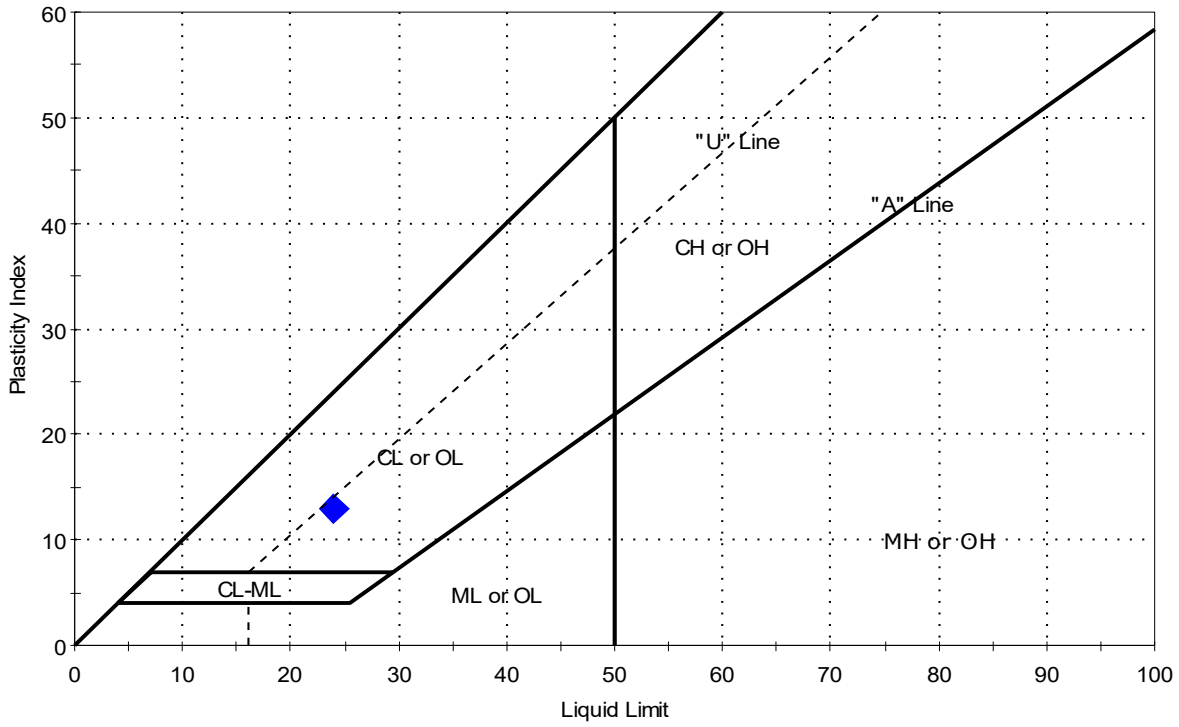


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-009	BH19-25	7.49-168. ft	13	16	12	4	0.2	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
4% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-010	Test Date:	01/08/20	Checked By:	jsc
Depth :	192.32-192.88 ft	Test Id:	537476		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

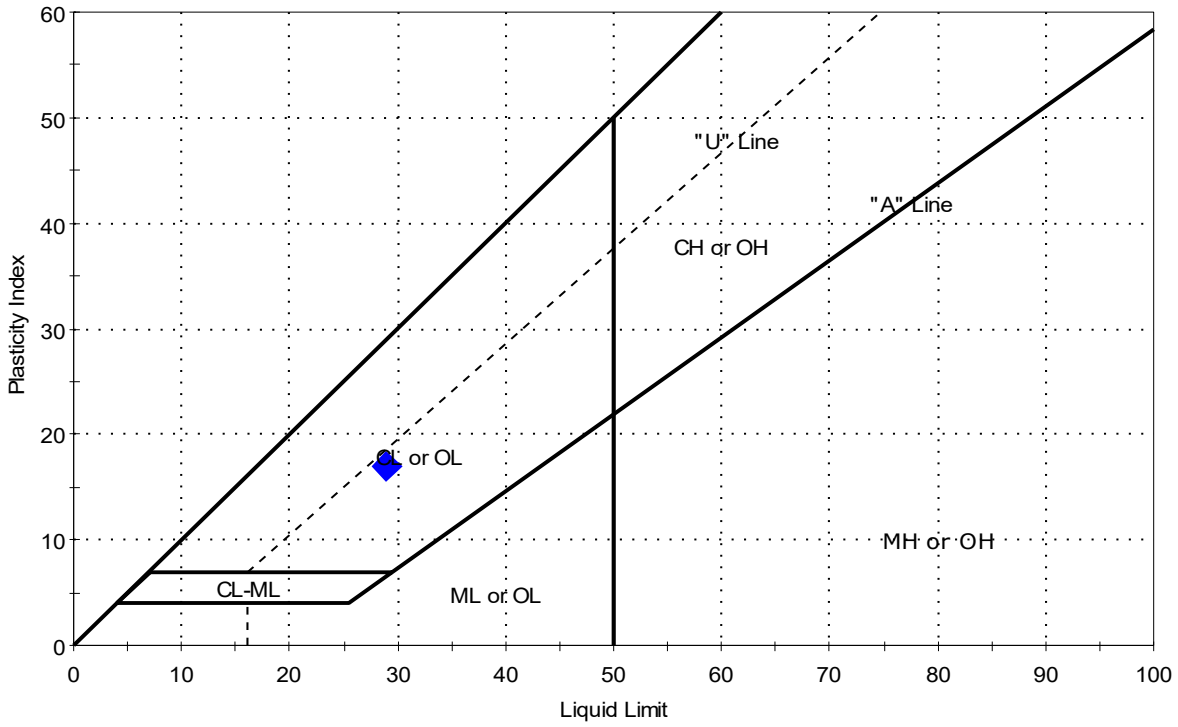


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-010	BH19-25	2.32-192. ft	12	24	11	13	0	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
16% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	01/08/20	Checked By:	jsc
Depth :	201.44-202.00 ft	Test Id:	537477		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

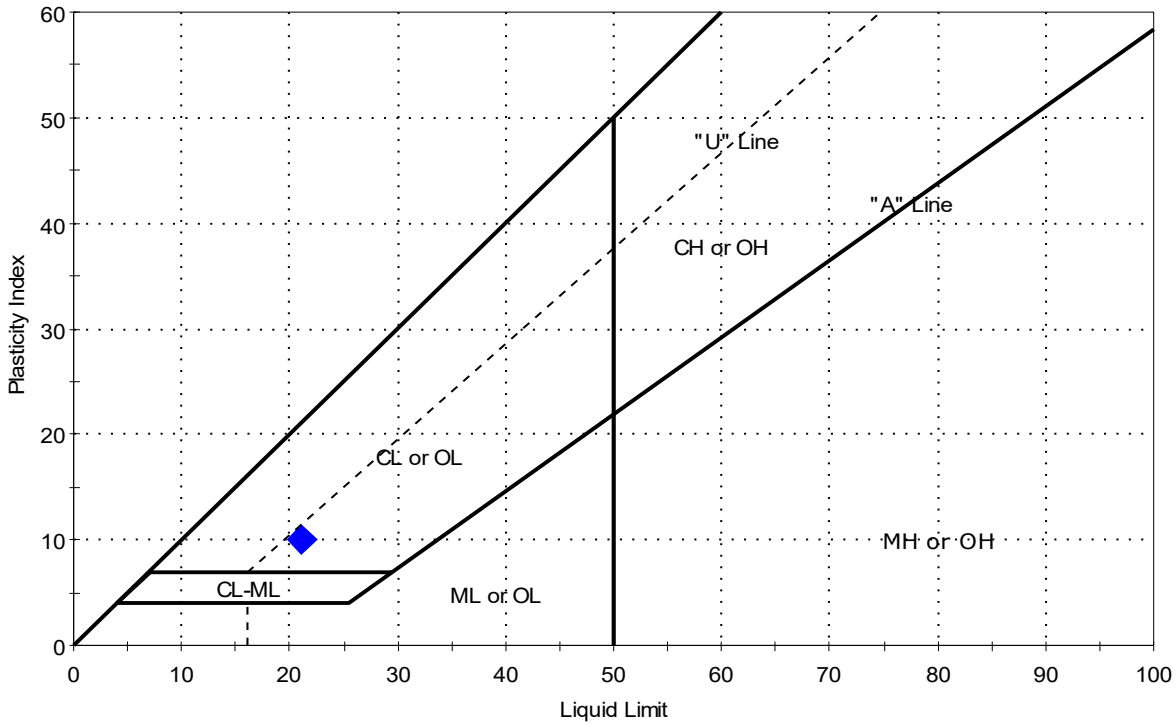


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-011	BH19-25	1.44-202. ft	12	29	12	17	0	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
10% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-012	Test Date:	01/08/20	Checked By:	jsc
Depth :	210.20-210.73 ft	Test Id:	537478		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

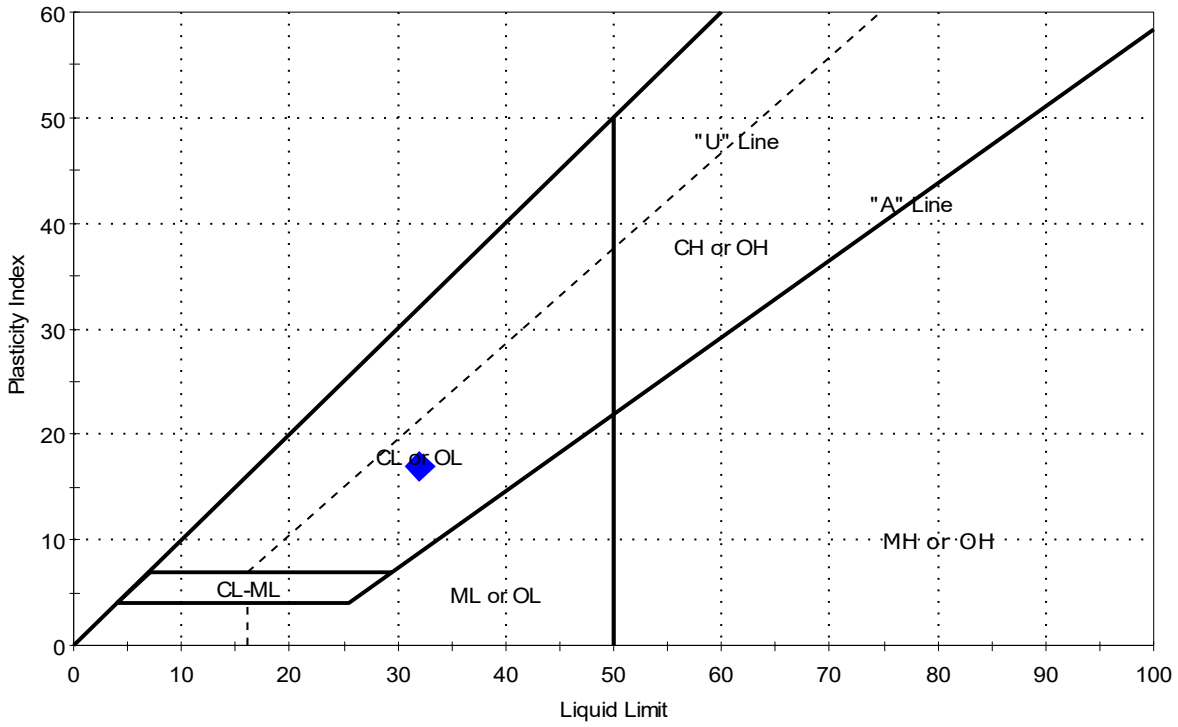


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-012	BH19-25	0.20-210. ft	11	21	11	10	0	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
16% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	01/08/20	Checked By:	jsc
Depth :	220.37-220.93 ft	Test Id:	537492		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

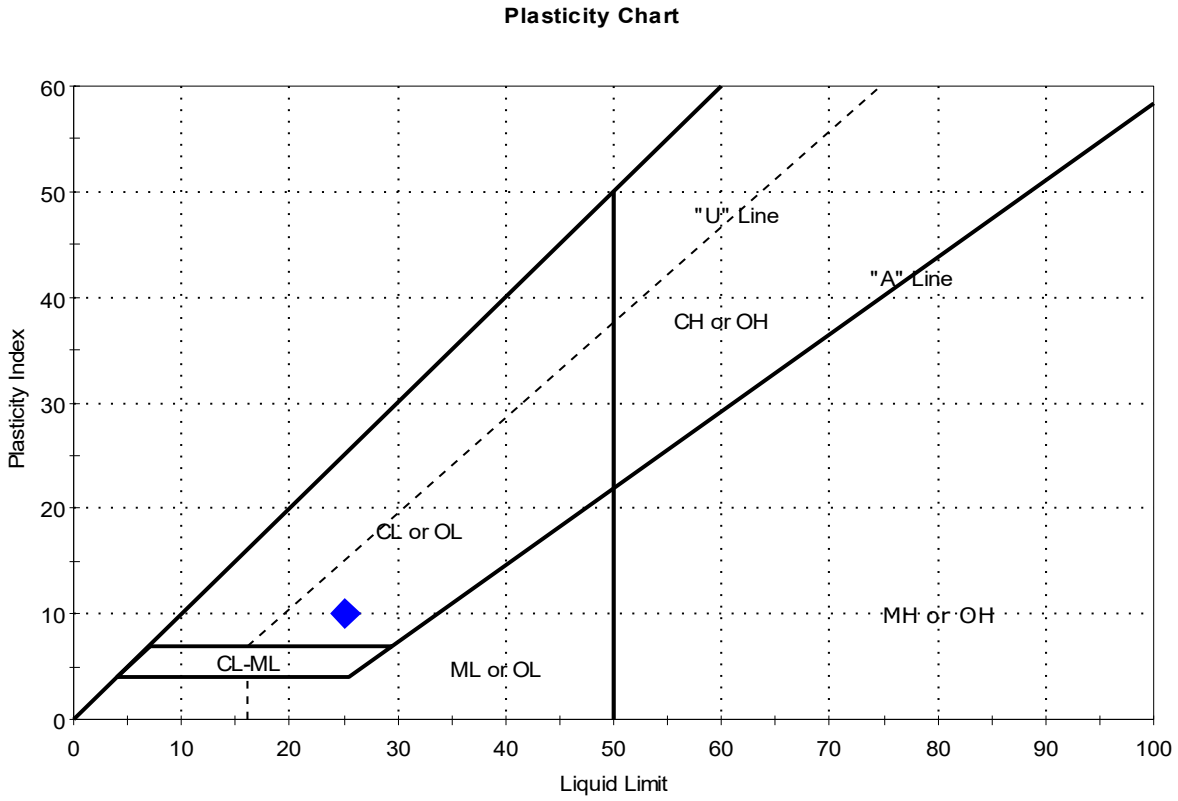


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-013	BH19-25	0.37-220. ft	19	32	15	17	0.3	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	01/08/20	Checked By:	jsc
Depth :	230.97-231.56 ft	Test Id:	537493		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-014	BH19-25	0.97-231. ft	17	25	15	10	0.2	

Sample Prepared using the WET method

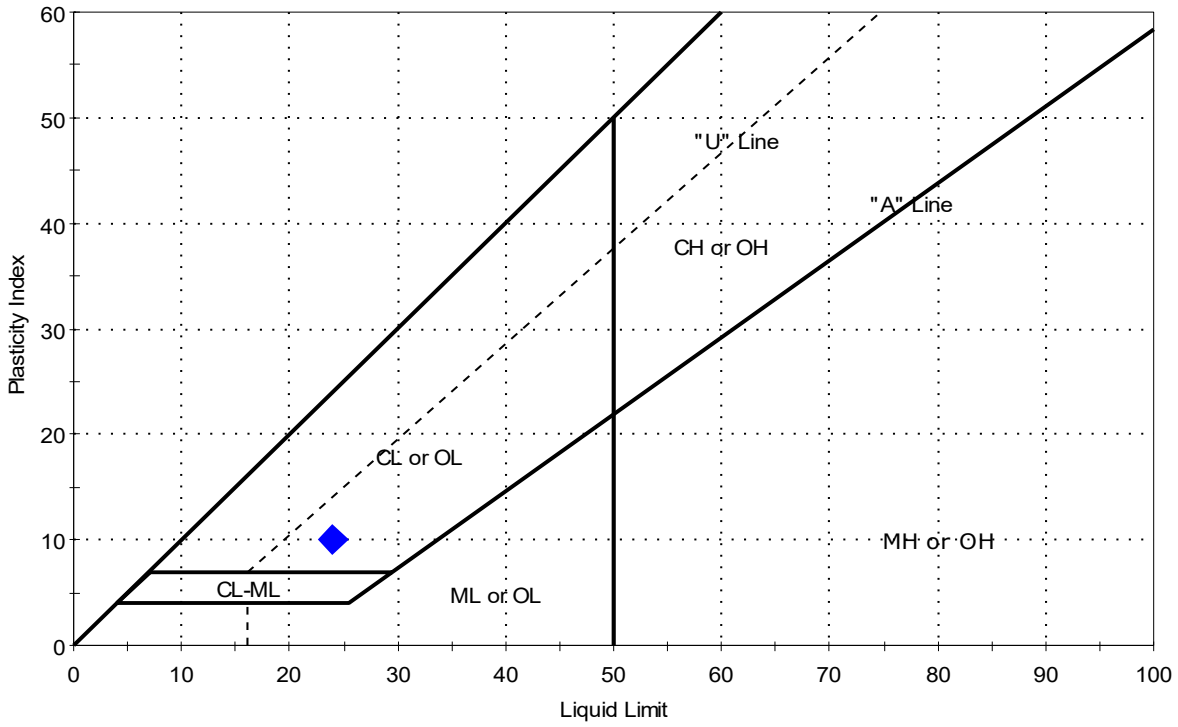
Dry Strength: MEDIUM

Dilatancy: SLOW

Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	01/08/20	Checked By:	jsc
Depth :	240.55-241.08 ft	Test Id:	537494		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

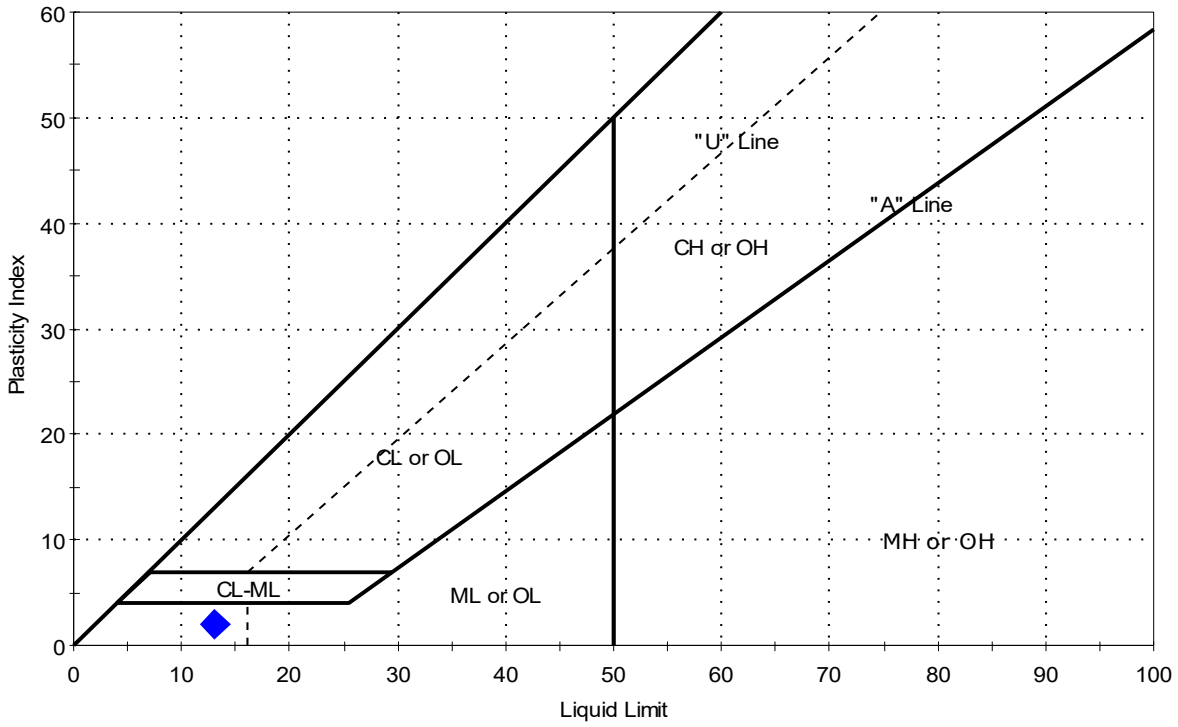


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-015	BH19-25	0.55-241. ft	17	24	14	10	0.3	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/27/19	Checked By:	jsc
Depth :	100.62-101.12 ft	Test Id:	533660		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

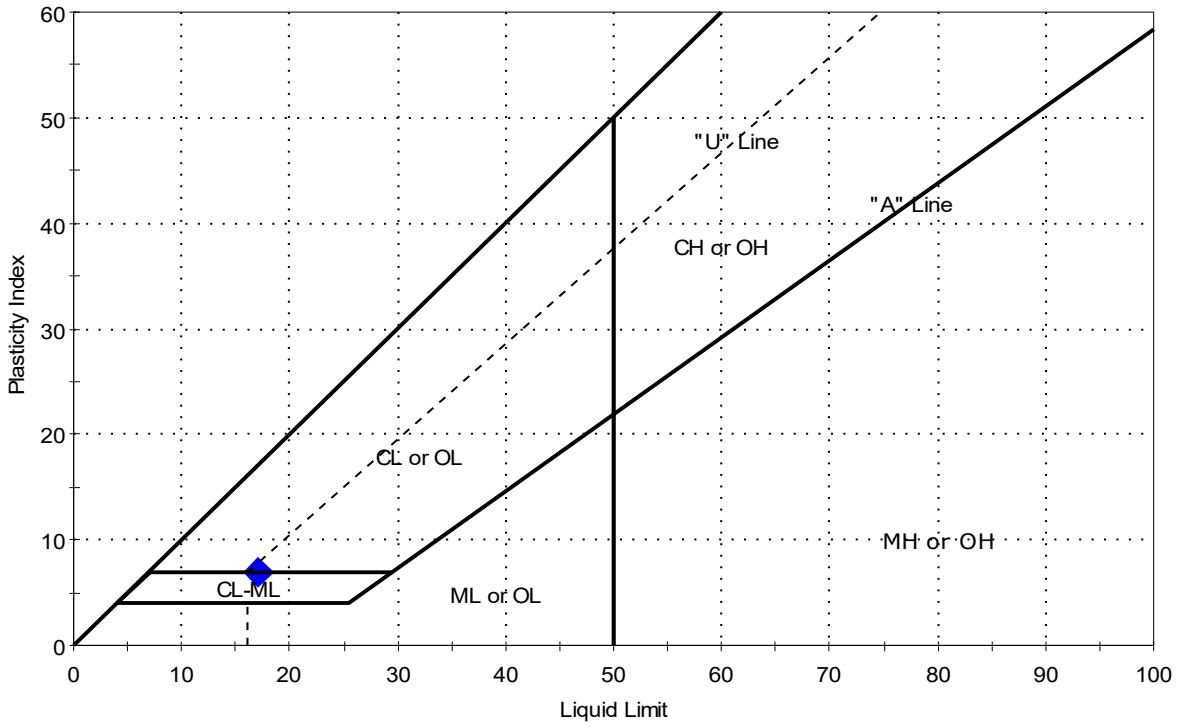


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-26	0.62-101. ft	13	13	11	2	1.1	Silty SAND (SM)

Sample Prepared using the WET method
3% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	01/06/20	Checked By:	jsc
Depth :	116.17-116.67 ft	Test Id:	533661		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



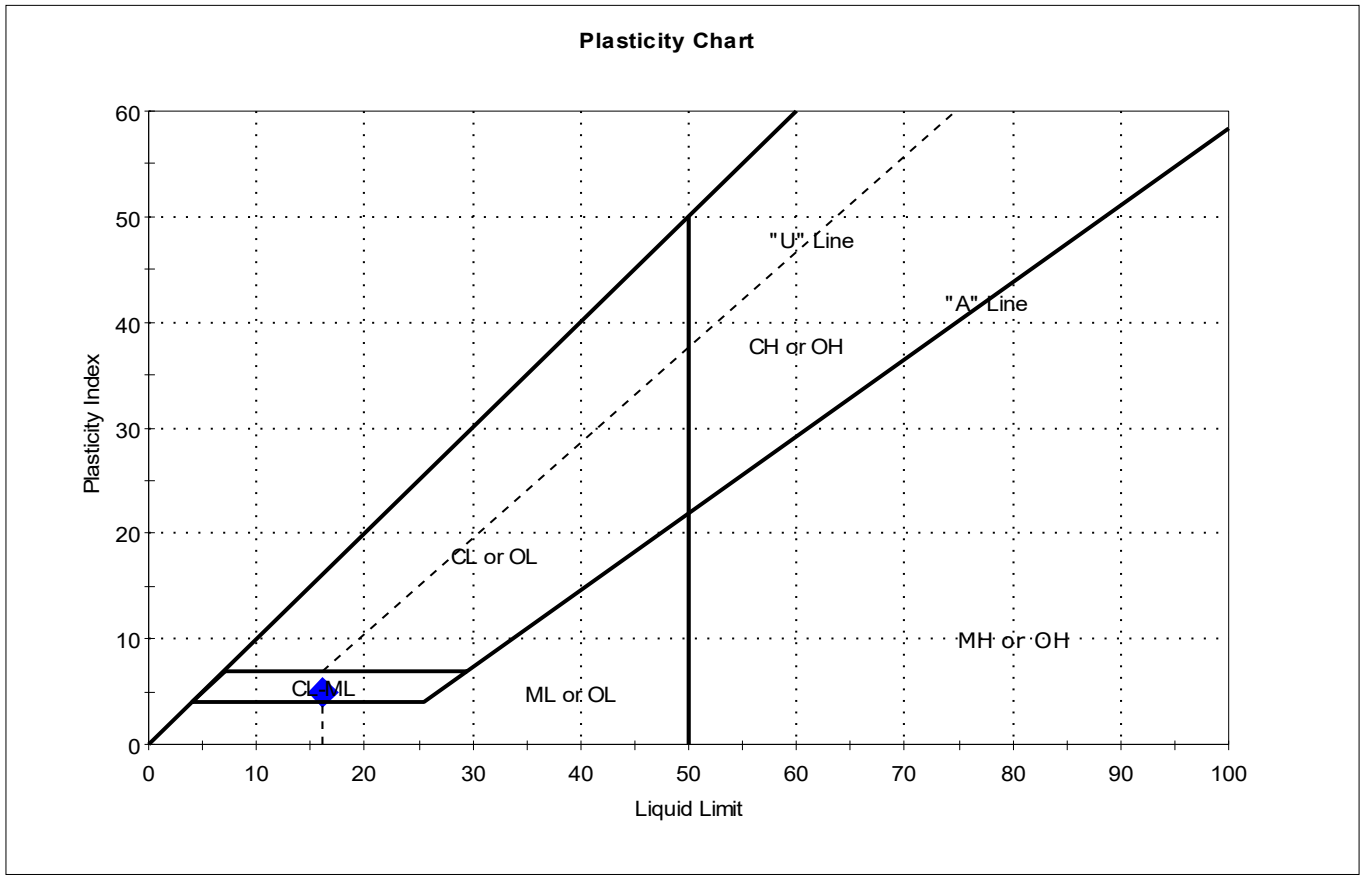
Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-26	6.17-116. ft	13	17	10	7	0.5	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
7% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: SLOW
Toughness: MEDIUM

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	126.02-126.58 ft	Test Id:	533662		
Test Comment:	---				
Visual Description:	Moist, brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

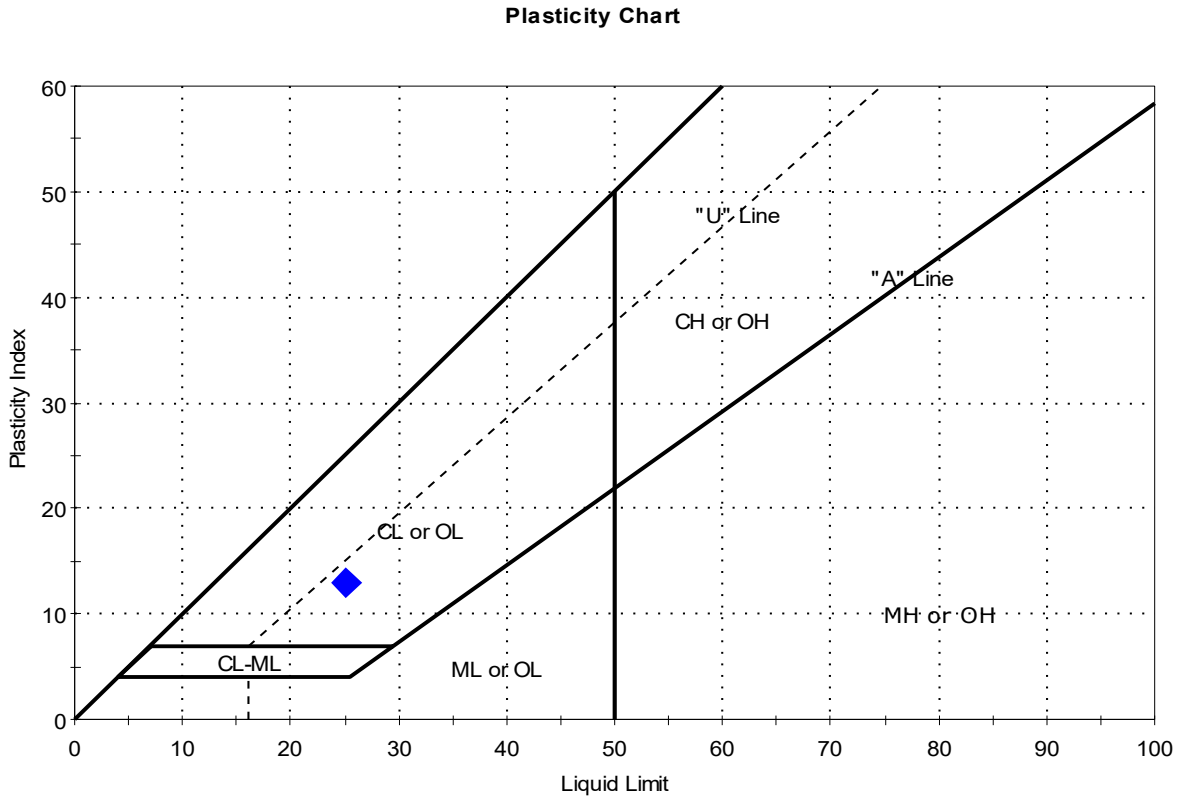


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-26	6.02-126. ft	12	16	11	5	0.2	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
4% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/27/19	Checked By:	jsc
Depth :	141.83-142.45 ft	Test Id:	533663		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

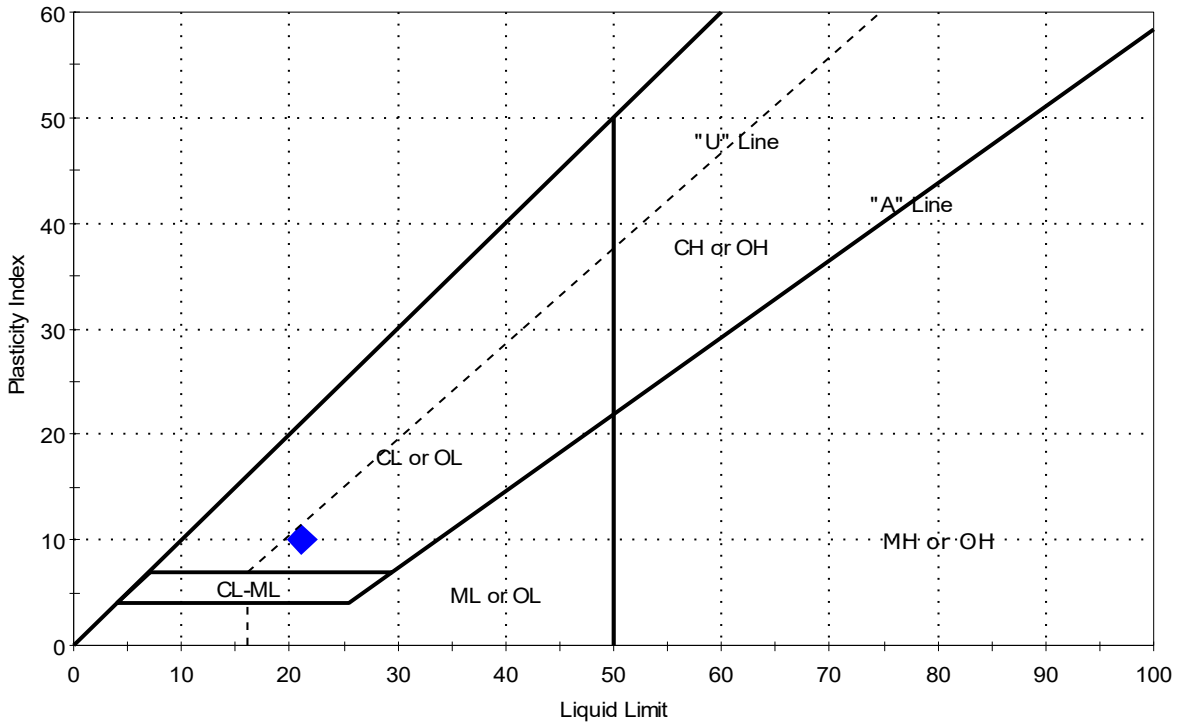


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-26	141.83-142.45 ft	12	25	12	13	0	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
2% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	01/06/20	Checked By:	jsc
Depth :	152.56-153.22 ft	Test Id:	533664		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

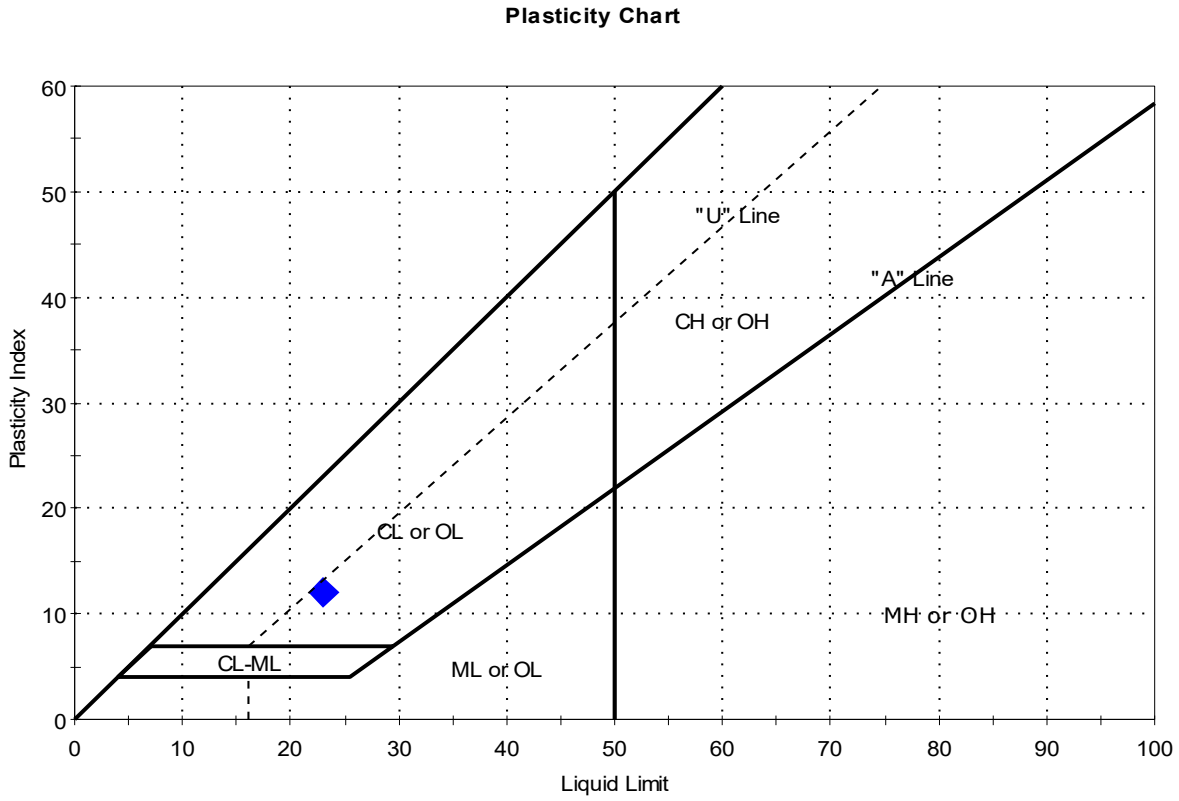


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-005	BH19-26	2.56-153. ft	9	21	11	10	-0.2	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
11% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-006	Test Date:	12/27/19	Checked By:	jsc
Depth :	189.12-159.68 ft	Test Id:	533665		
Test Comment:	---				
Visual Description:	Moist, brown clayey sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

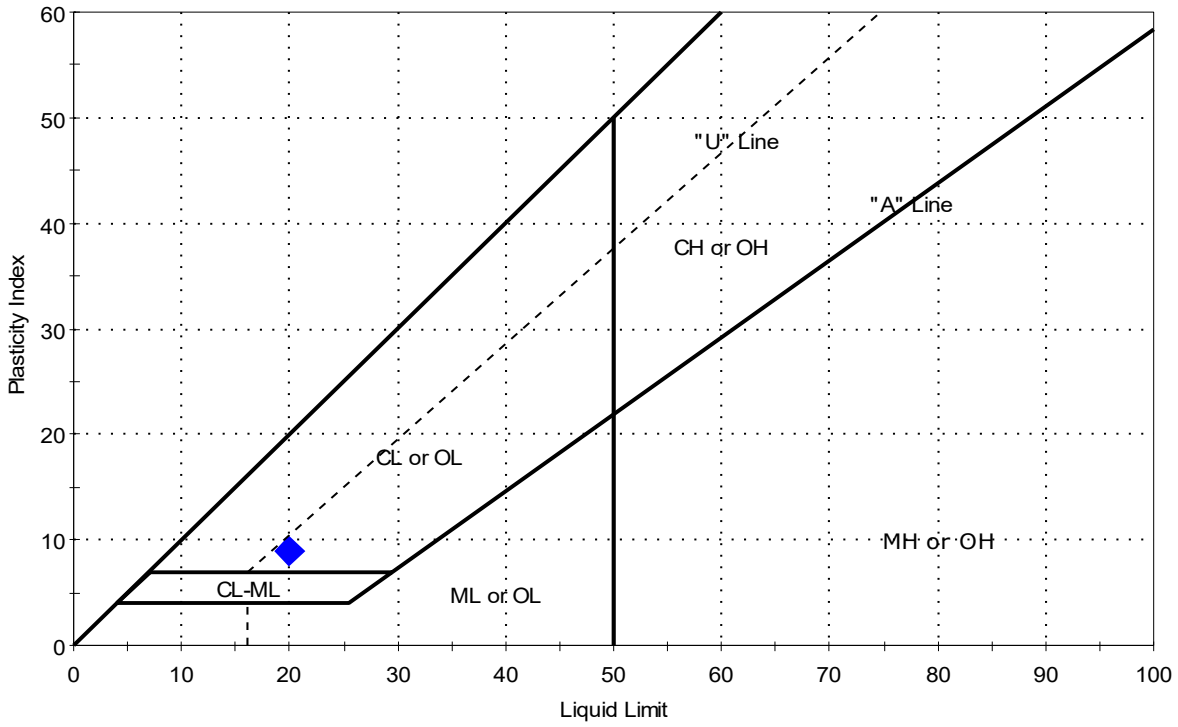


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-006	BH19-26	9.12-159. ft	10	23	11	12	-0.1	Clayey SAND (SC)

Sample Prepared using the WET method
21% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-007	Test Date:	12/27/19	Checked By:	jsc
Depth :	172.28-172.83 ft	Test Id:	533982		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

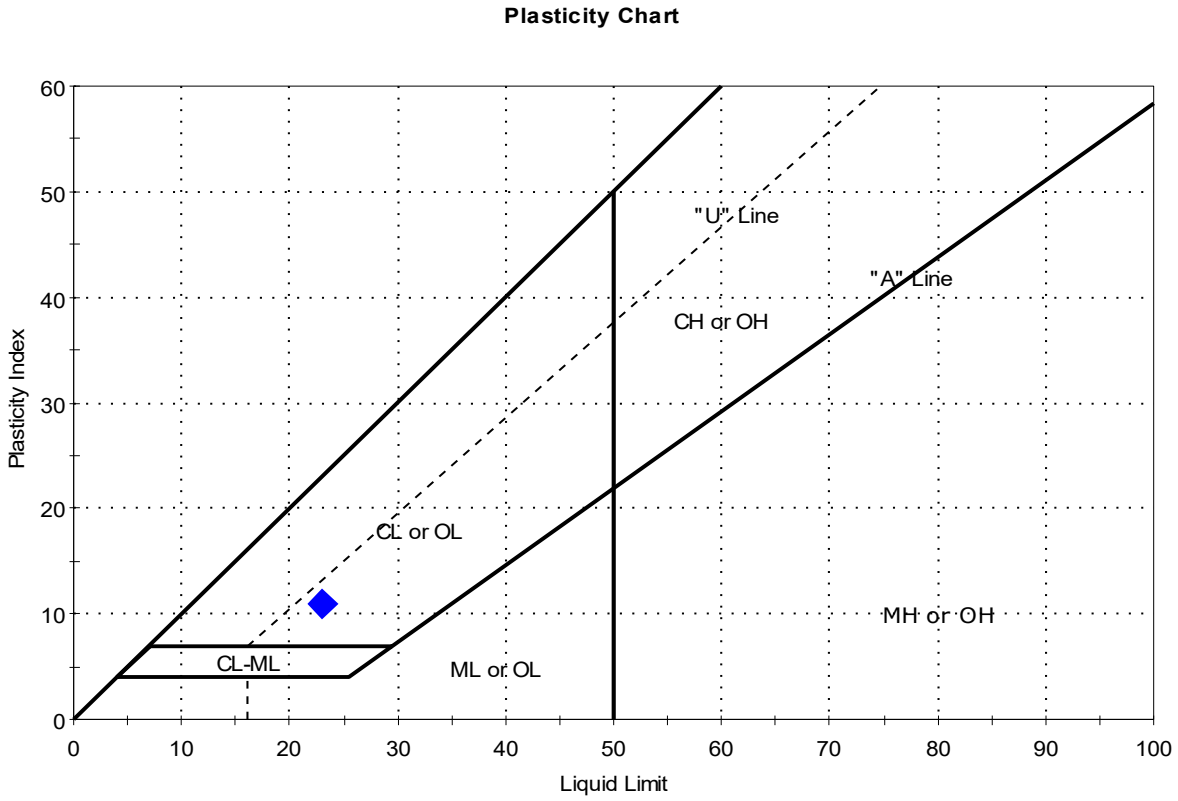


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-007	BH19-26	2.28-172. ft	10	20	11	9	-0.1	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
20% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	12/23/19	Checked By:	jsc
Depth :	180.48-181.07 ft	Test Id:	533983		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

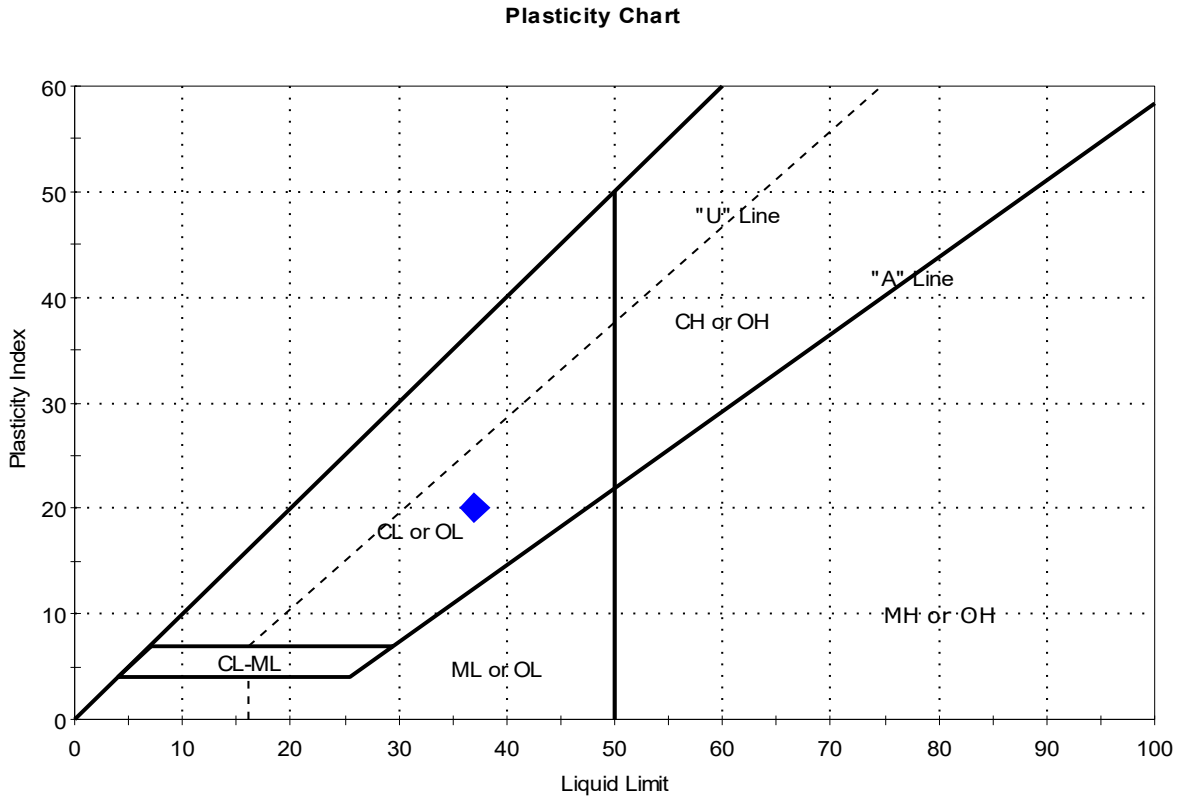


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-008	BH19-26	0.48-181. ft	12	23	12	11	0	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
9% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	12/27/19	Checked By:	jsc
Depth :	191.37-191.96 ft	Test Id:	533984		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



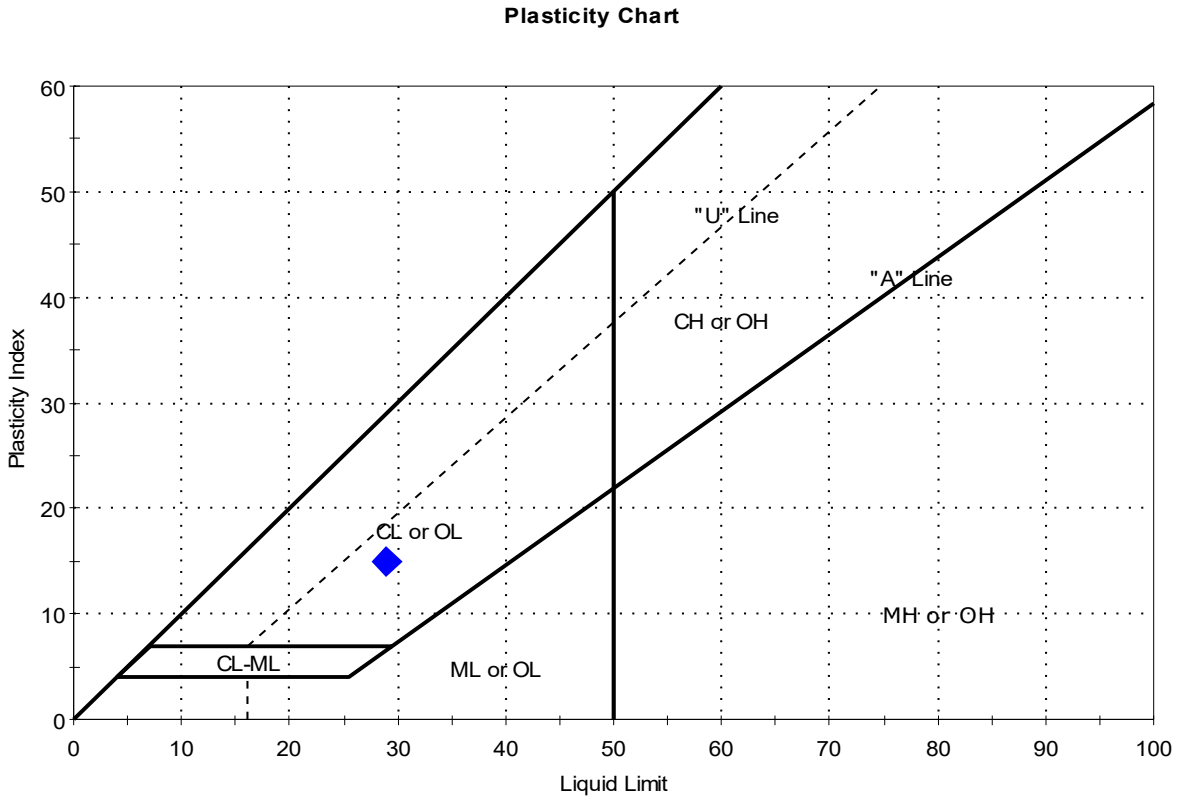
Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-009	BH19-26	1.37-191. ft	21	37	17	20	0.2	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-010	Test Date:	12/23/19	Checked By:	bfs
Depth :	198.92-199.44 ft	Test Id:	533985		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

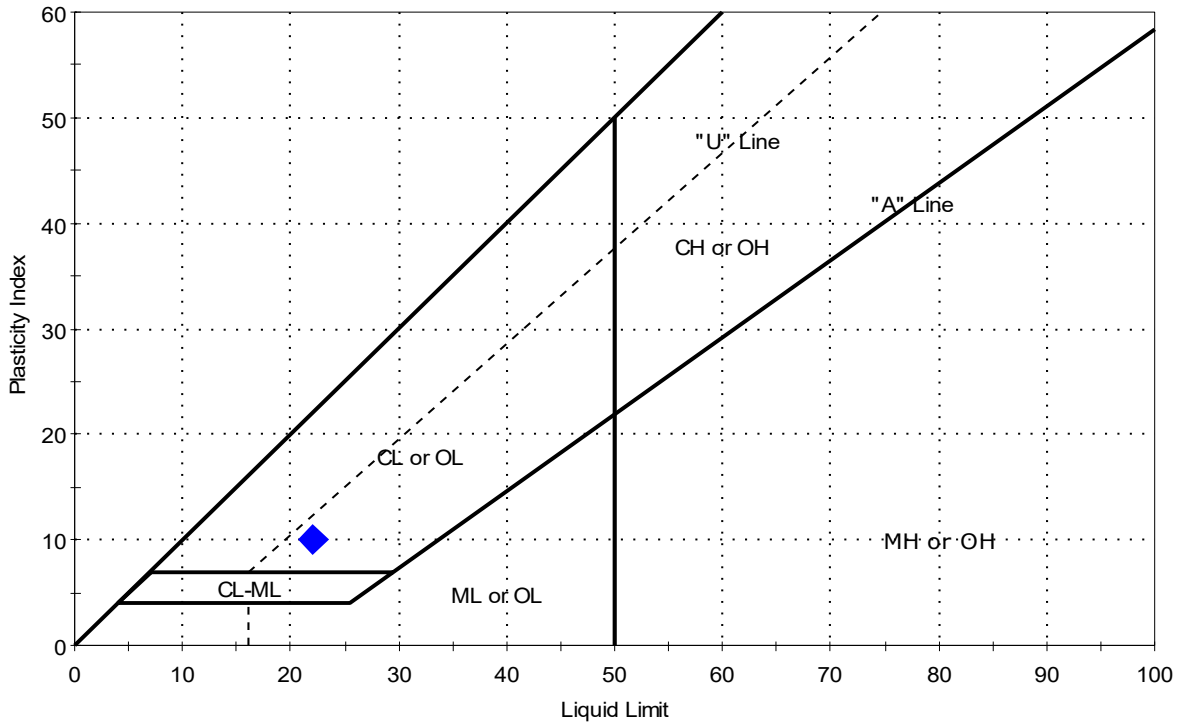


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-010	BH19-26	8.92-199. ft	16	29	14	15	0.2	Lean CLAY (CL)

Sample Prepared using the WET method
4% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	12/27/19	Checked By:	jsc
Depth :	209.94-210.50 ft	Test Id:	533986		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

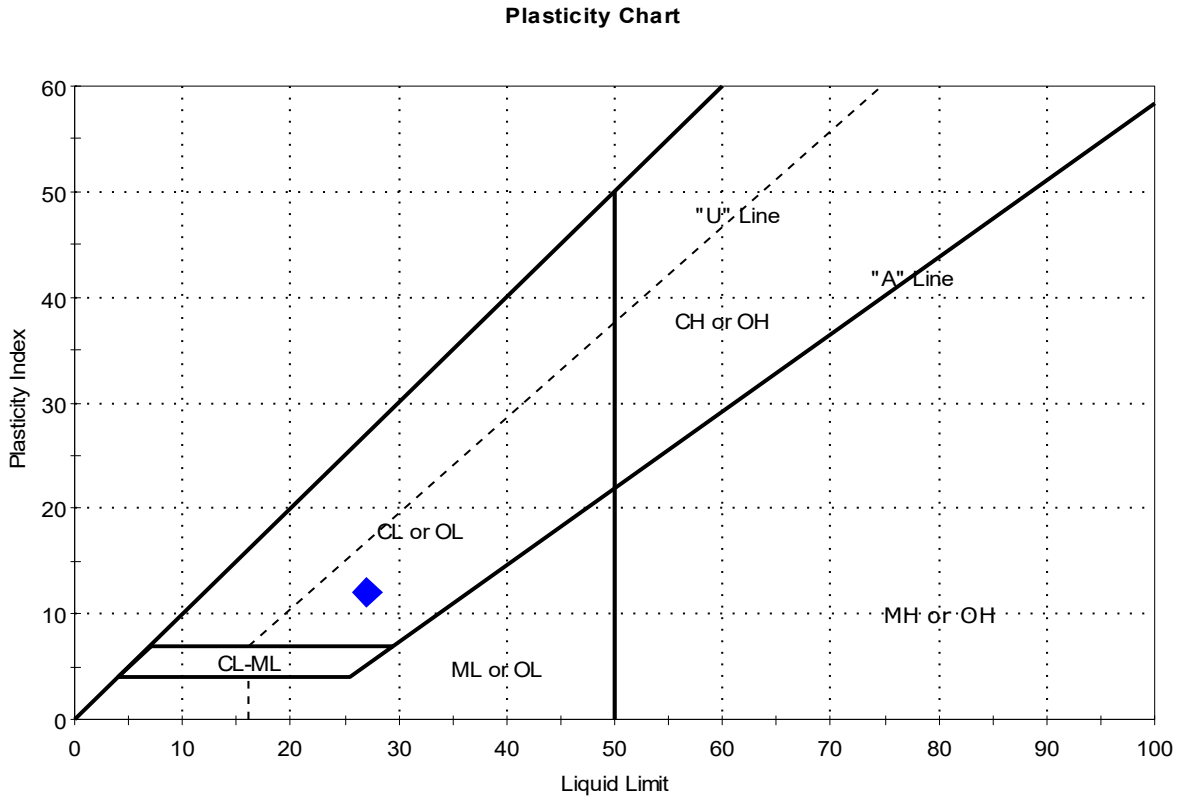


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-011	BH19-26	9.94-210. ft	13	22	12	10	0.1	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
16% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-012	Test Date:	12/27/19	Checked By:	jsc
Depth :	219.03-219.55 ft	Test Id:	533987		
Test Comment:	---				
Visual Description:	Moist, dark grayish brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

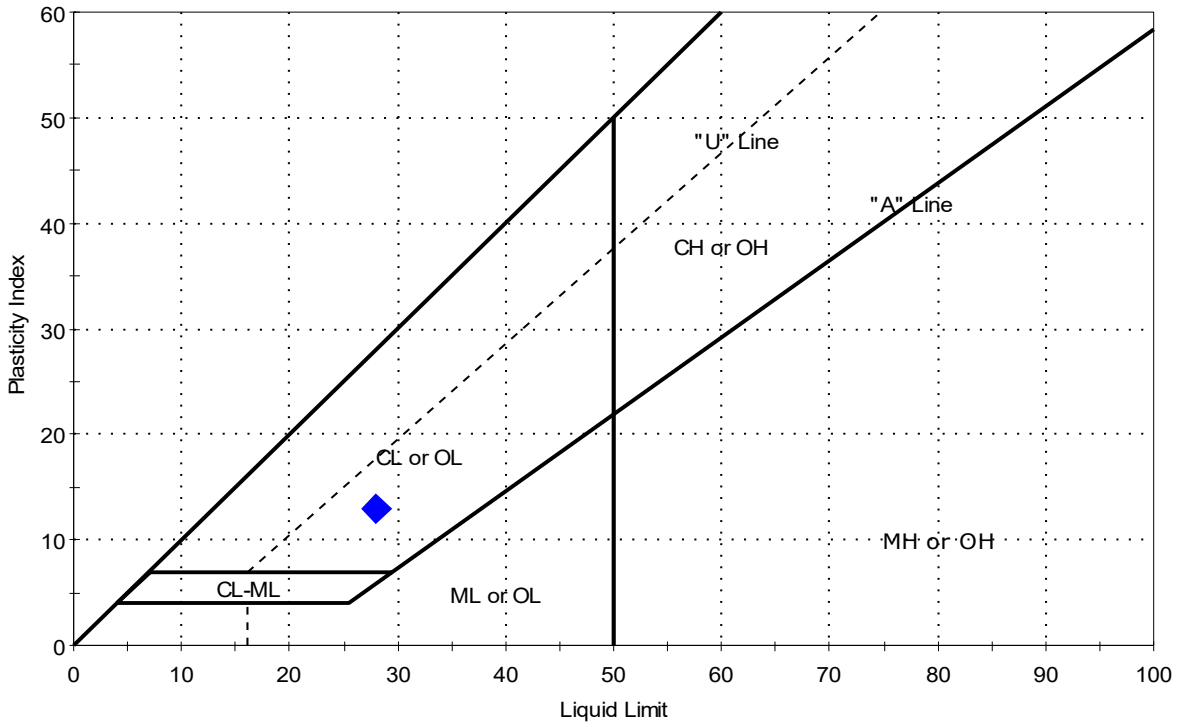


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-012	BH19-26	9.03-219. ft	16	27	15	12	0.1	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	01/06/20	Checked By:	jsc
Depth :	228.02-228.54 ft	Test Id:	532681		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

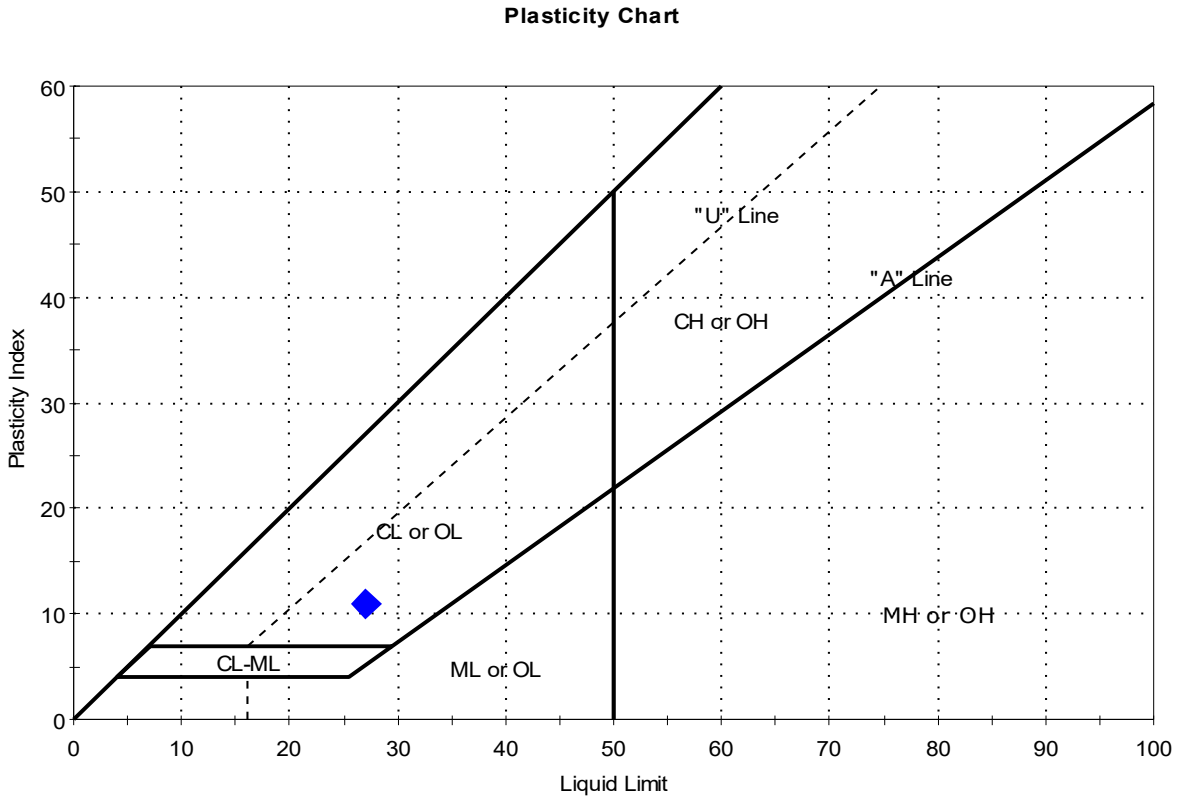


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-013	BH19-26	8.02-228. ft	16	28	15	13	0	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	12/23/19	Checked By:	bfs
Depth :	237.30-237.83 ft	Test Id:	532682		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

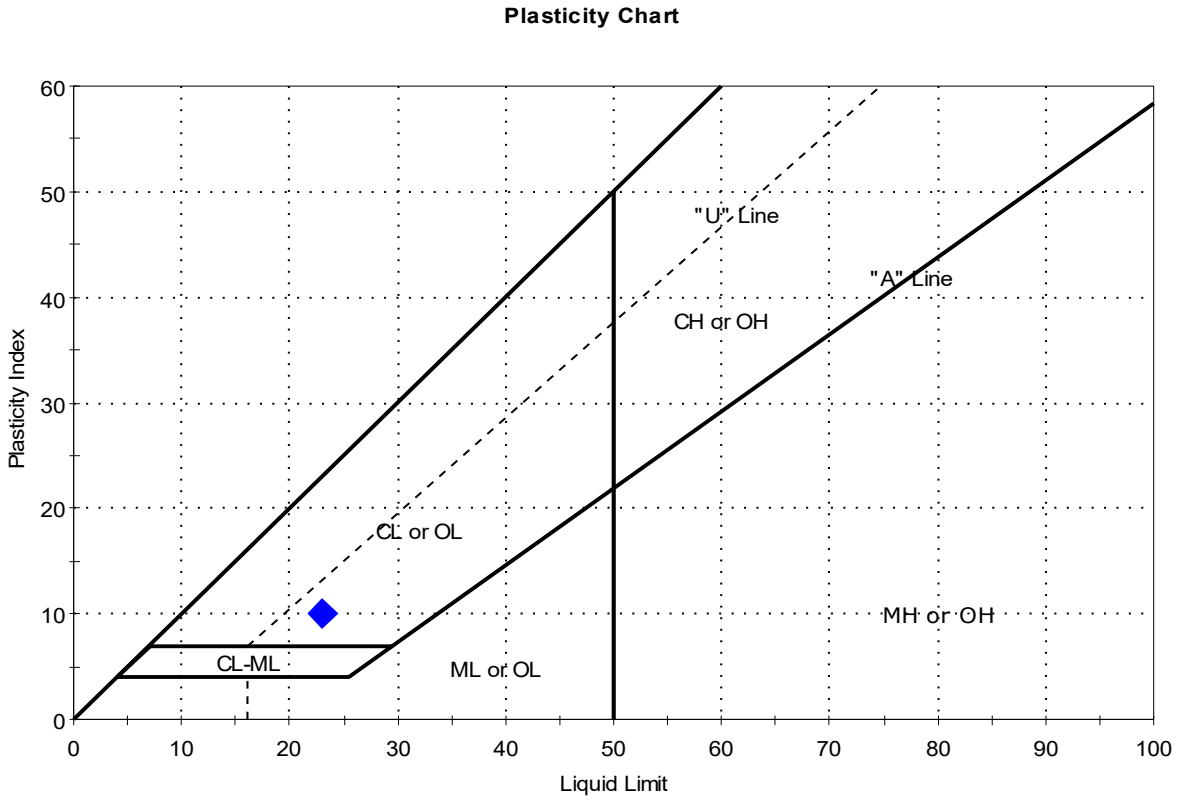


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-014	BH19-26	7.30-237. ft	17	27	16	11	0.1	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	01/06/20	Checked By:	jsc
Depth :	250.85-251.38 ft	Test Id:	532683		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

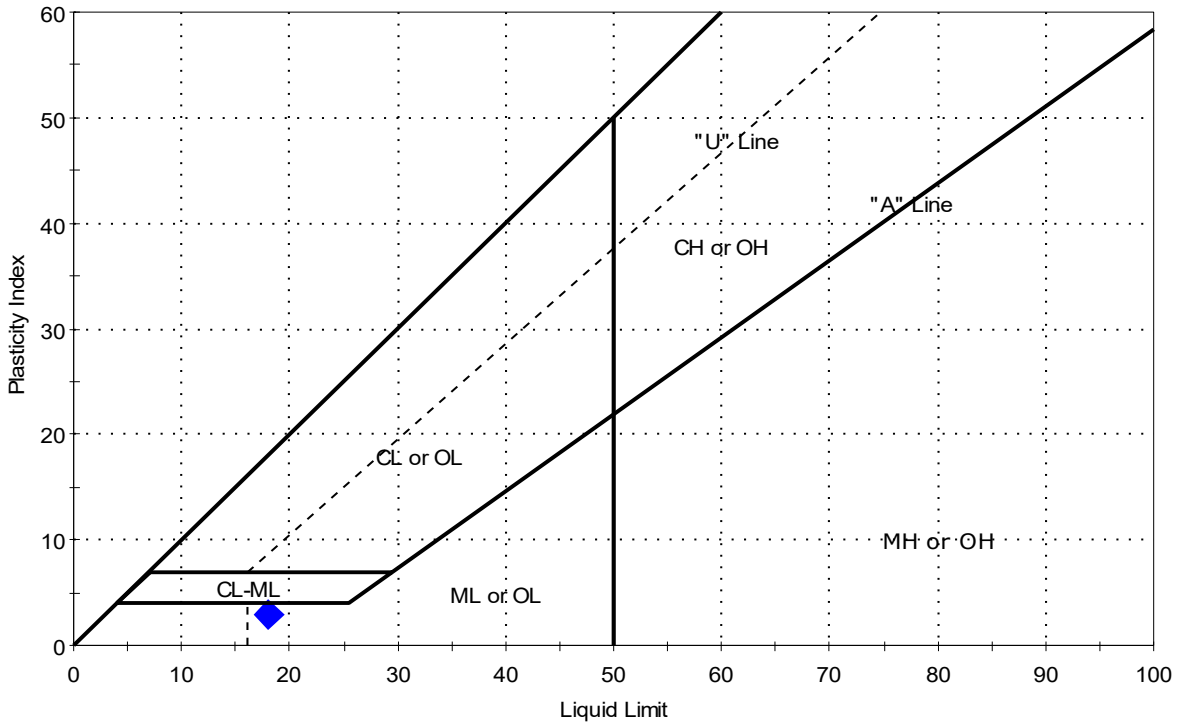


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-015	BH19-26	0.85-251. ft	18	23	13	10	0.5	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-016	Test Date:	12/27/19	Checked By:	jsc
Depth :	257.64-258.20 ft	Test Id:	532684		
Test Comment:	---				
Visual Description:	Moist, brown silt				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

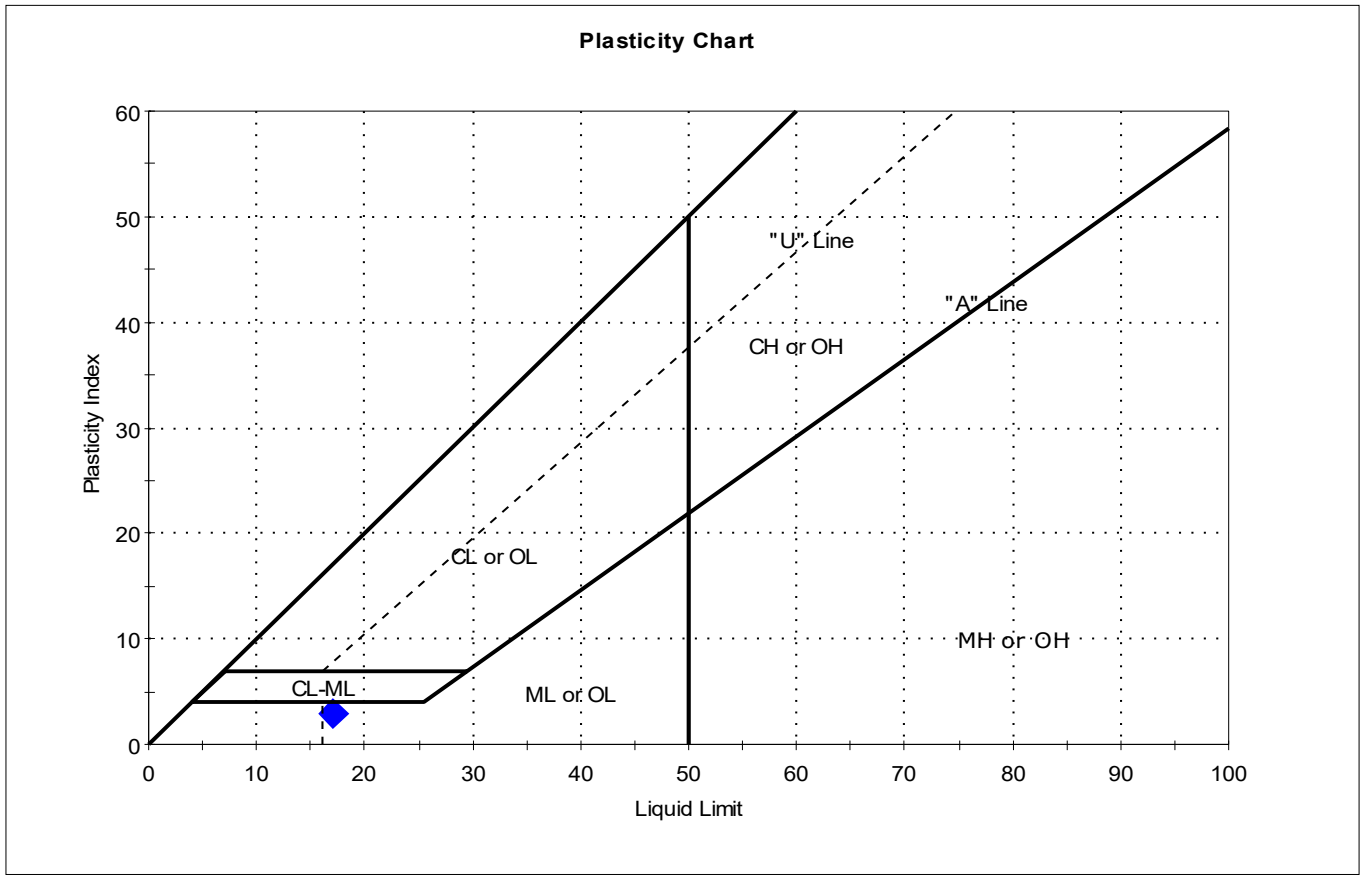


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-016	BH19-26	7.64-258. ft	14	18	15	3	-0.4	SILT (ML)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-017	Test Date:	01/06/20	Checked By:	jsc
Depth :	267.82-268.44 ft	Test Id:	532685		
Test Comment:	---				
Visual Description:	Moist, pale brown silt with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

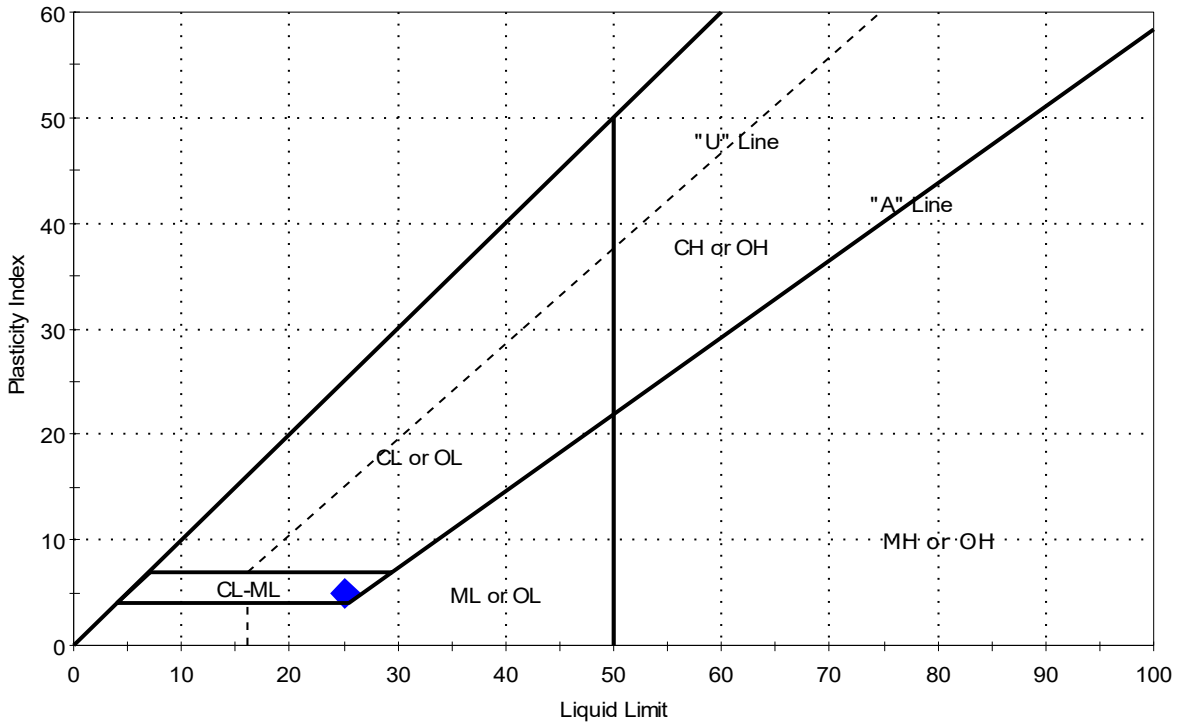


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-017	BH19-26	7.82-268. ft	17	17	14	3	1	SILT with Sand (ML)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: RAPID
Toughness: LOW

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-022	Test Date:	01/08/20	Checked By:	jsc
Depth :	321.75-322.18 ft	Test Id:	537537		
Test Comment:	---				
Visual Description:	Moist, gray silty clayey sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

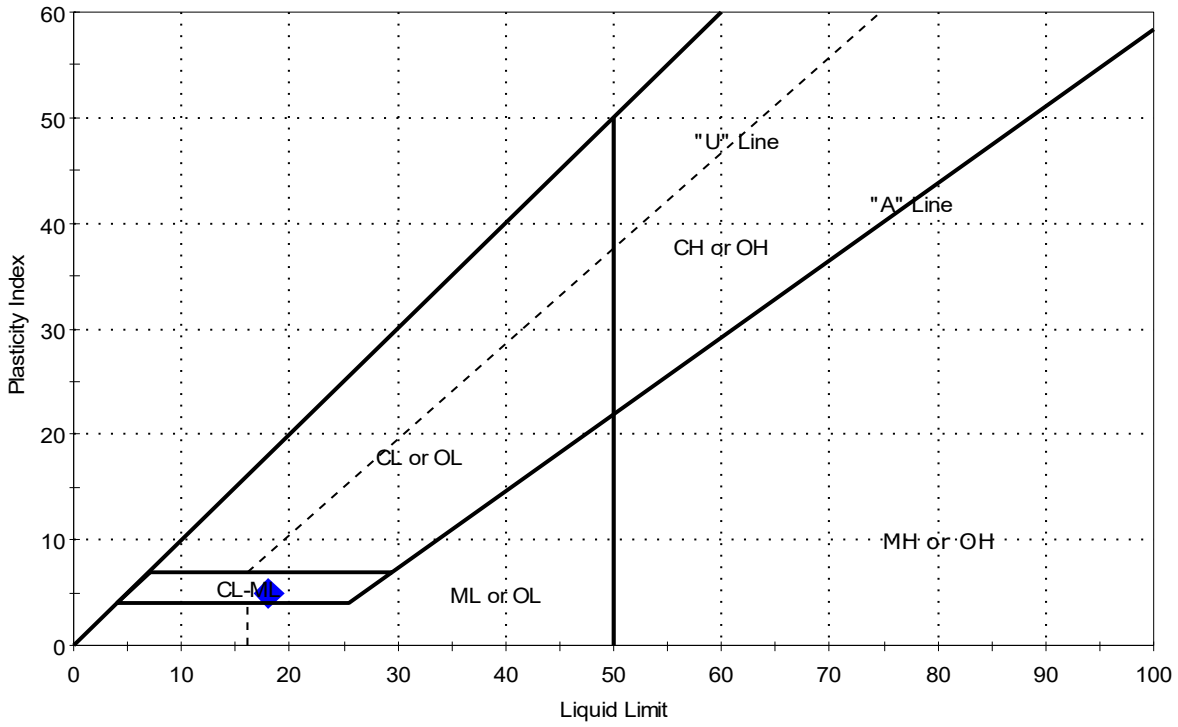


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-022	BH19-26	1.75-322. ft	11	25	20	5	-1.8	Silty, Clayey SAND (SC-SM)

Sample Prepared using the WET method
43% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	tube	Tested By:	GA
Sample ID:	ST-001	Test Date:	01/24/20	Checked By:	jsc
Depth :	104.99-107.35 ft	Test Id:	540881		
Test Comment:	---				
Visual Description:	Moist, brown silty clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

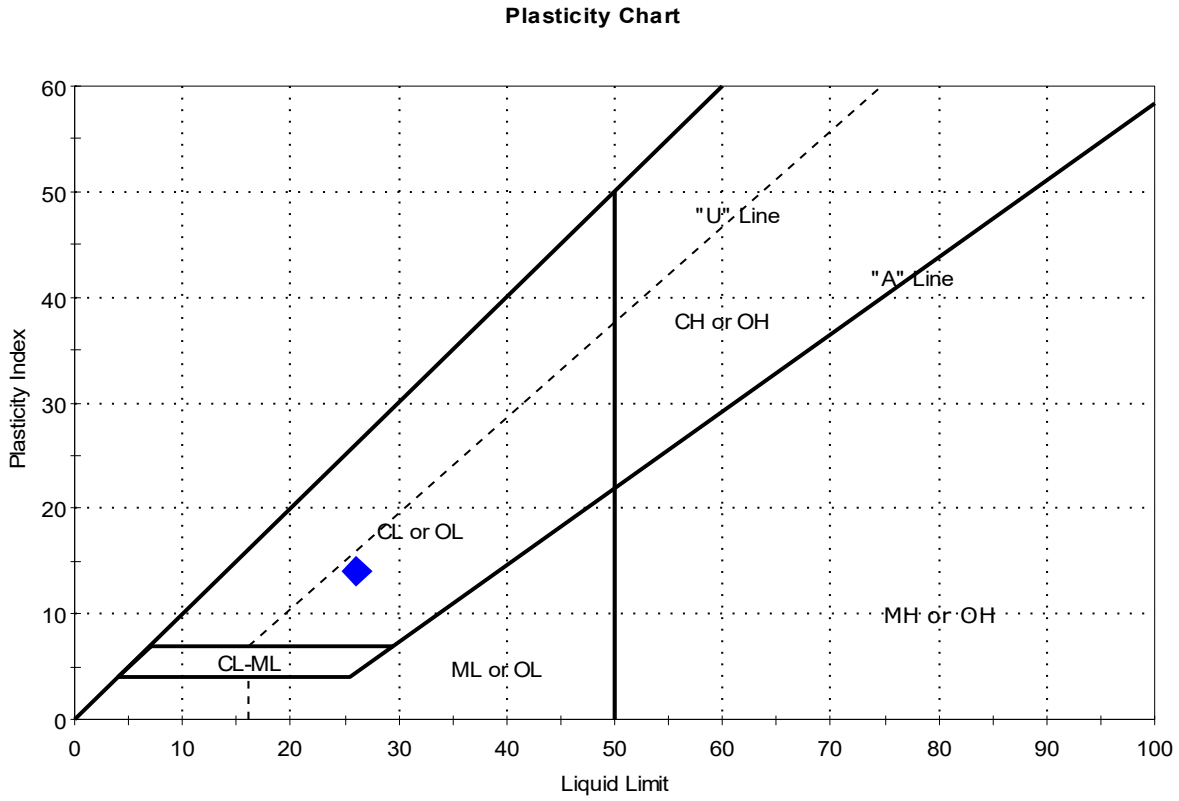


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	BH19-26-ST-001	BH19-26	4.99-107. ft	18	18	13	5	1	Silty CLAY with Sand (CL-ML)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	tube	Tested By:	GA
Sample ID:	ST-002	Test Date:	01/24/20	Checked By:	jsc
Depth :	134.51-135.47 ft	Test Id:	540882		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

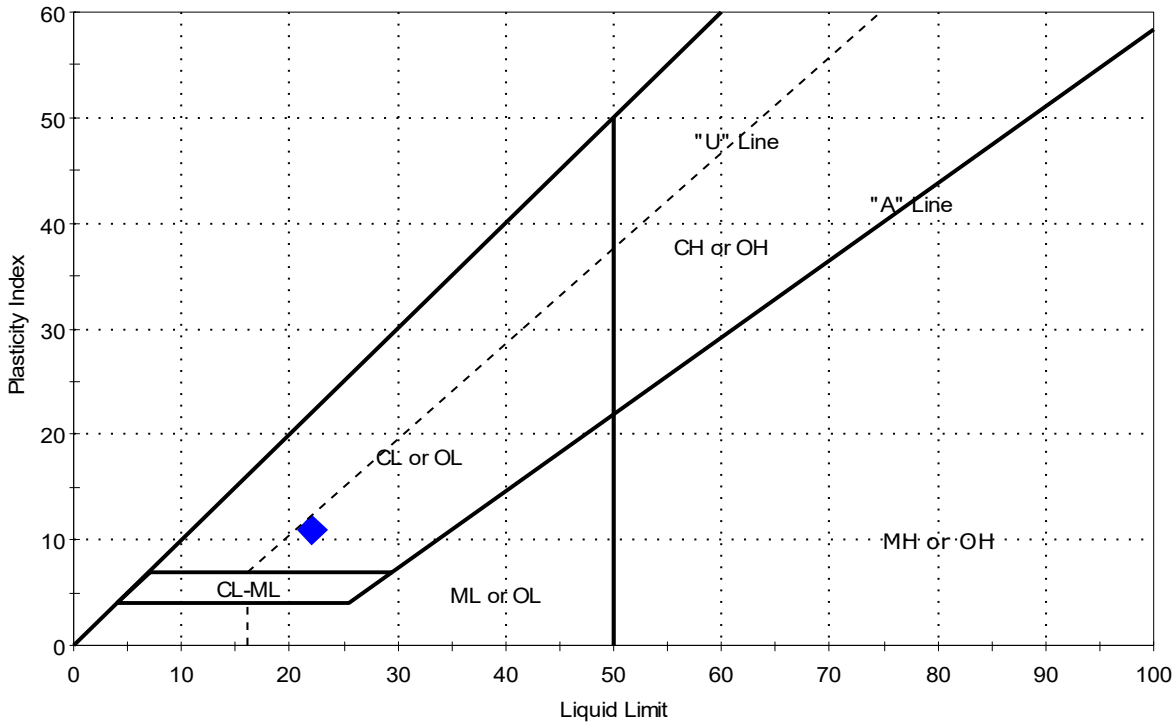


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	BH19-26-ST-002	BH19-26	4.51-135. ft	13	26	12	14	0.1	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
7% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/27/19	Checked By:	jsc
Depth :	120.31-120.90 ft	Test Id:	532894		
Test Comment:	---				
Visual Description:	Moist, brown clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

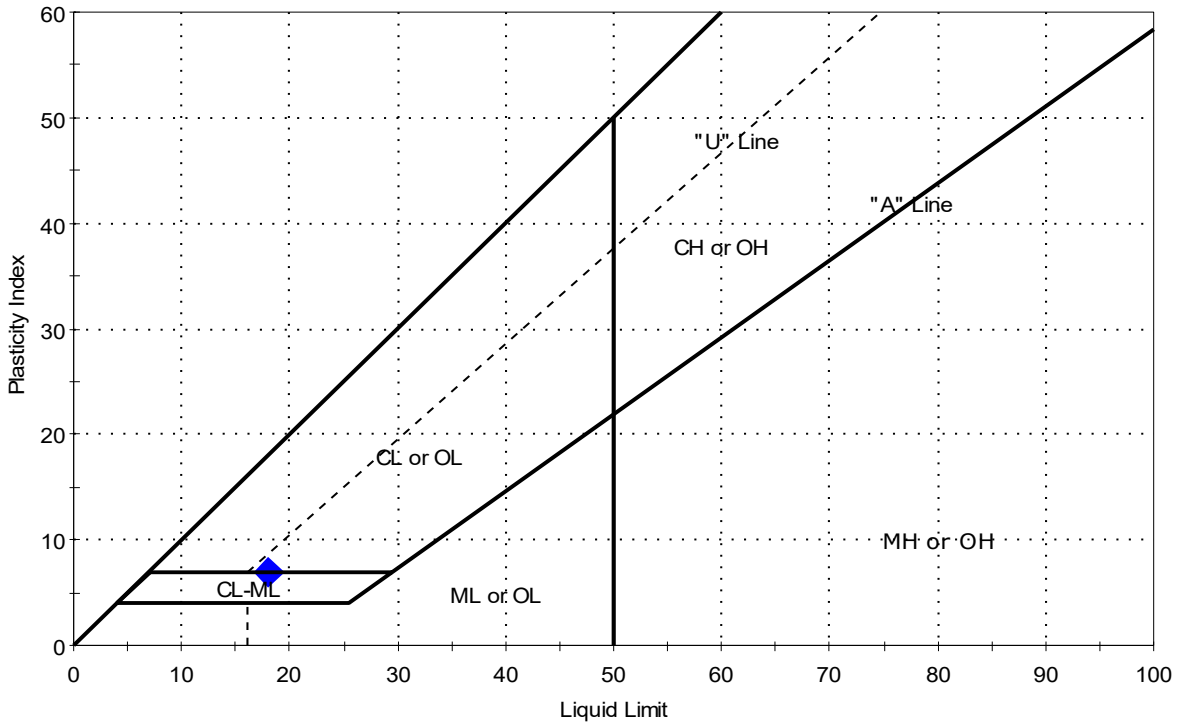


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-27	0.31-120. ft	12	22	11	11	0.1	Lean CLAY with Sand (CL)

Sample Prepared using the WET method
3% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/27/19	Checked By:	jsc
Depth :	133.20-133.69 ft	Test Id:	532895		
Test Comment:	---				
Visual Description:	Moist, brown silty clay with sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

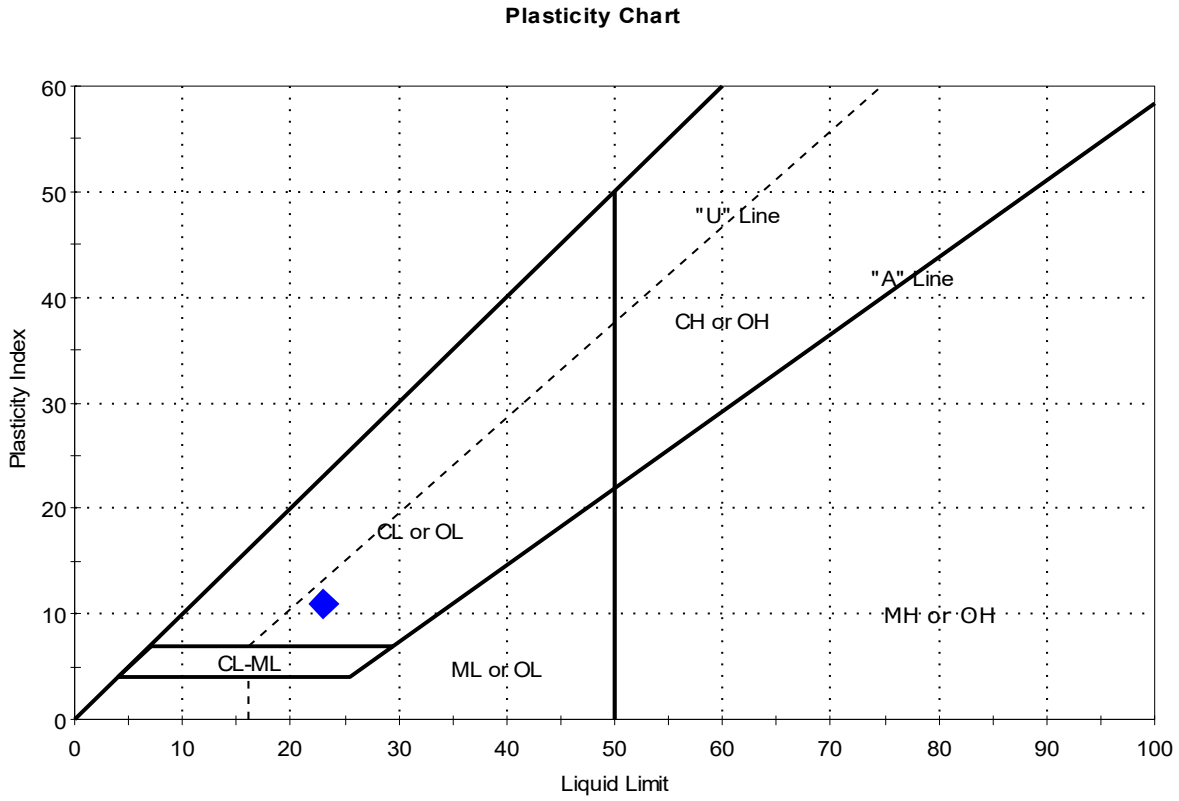


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-27	3.20-133. ft	12	18	11	7	0.2	Silty CLAY with Sand (CL-ML)

Sample Prepared using the WET method
4% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-003	Test Date:	12/27/19	Checked By:	jsc
Depth :	144.26-144.75 ft	Test Id:	532896		
Test Comment:	---				
Visual Description:	Dry, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

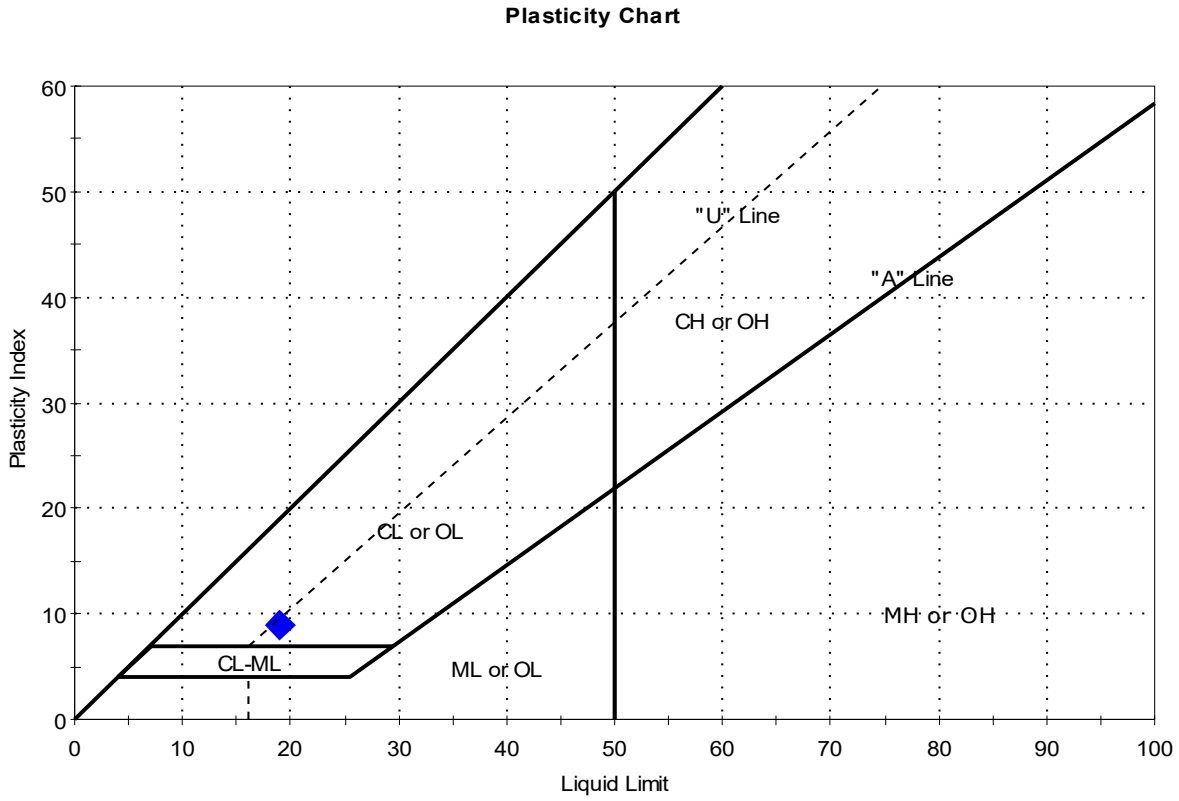


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-003	BH19-27	4.26-144. ft	7	23	12	11	-0.4	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
19% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/23/19	Checked By:	bfs
Depth :	153.35-153.94 ft	Test Id:	532897		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

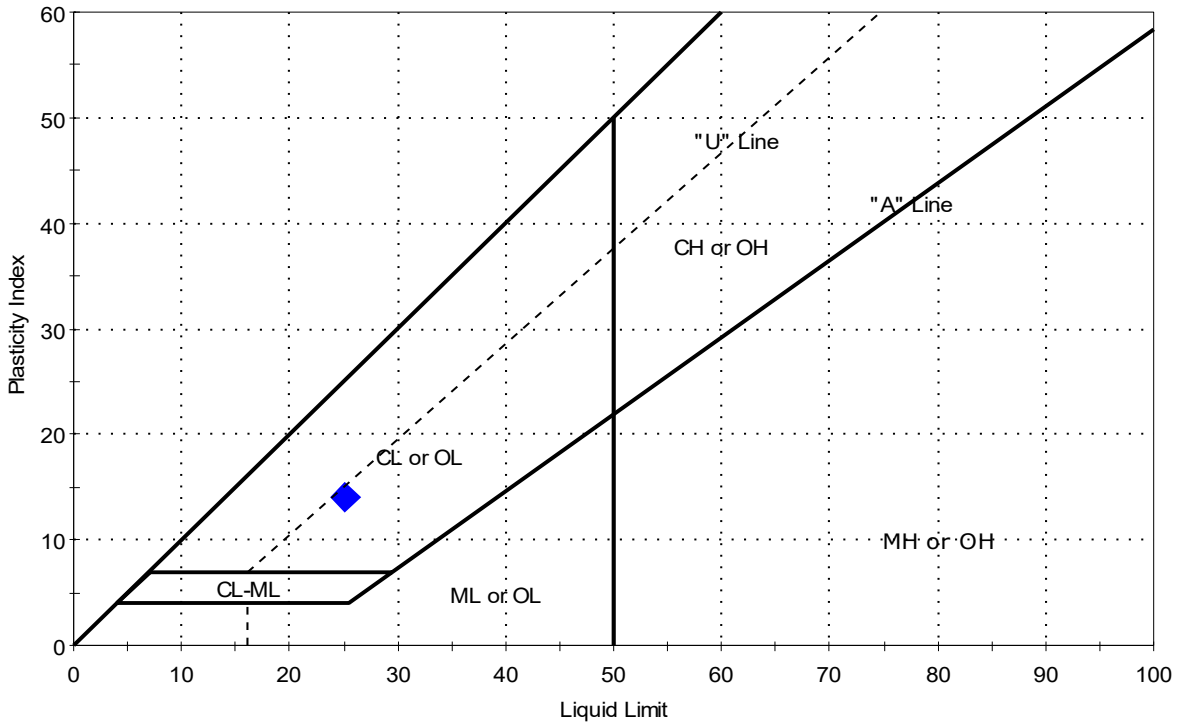


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-27	3.35-153. ft	7	19	10	9	-0.4	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
10% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	01/03/20	Checked By:	jsc
Depth :	162.40-162.86 ft	Test Id:	532898		
Test Comment:	---				
Visual Description:	Dry, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

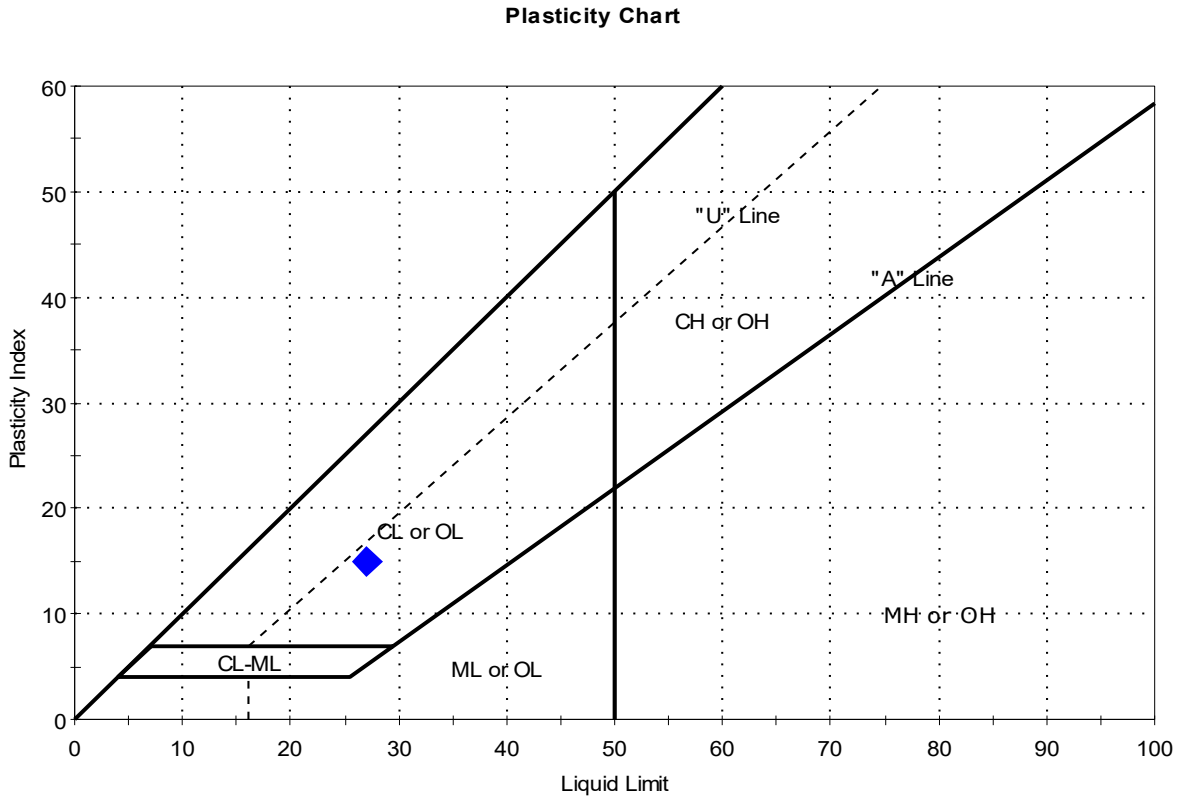


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-005	BH19-27	2.40-162. ft	5	25	11	14	-0.5	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
18% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-008	Test Date:	12/23/19	Checked By:	jsc
Depth :	195.37-195.87 ft	Test Id:	533965		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

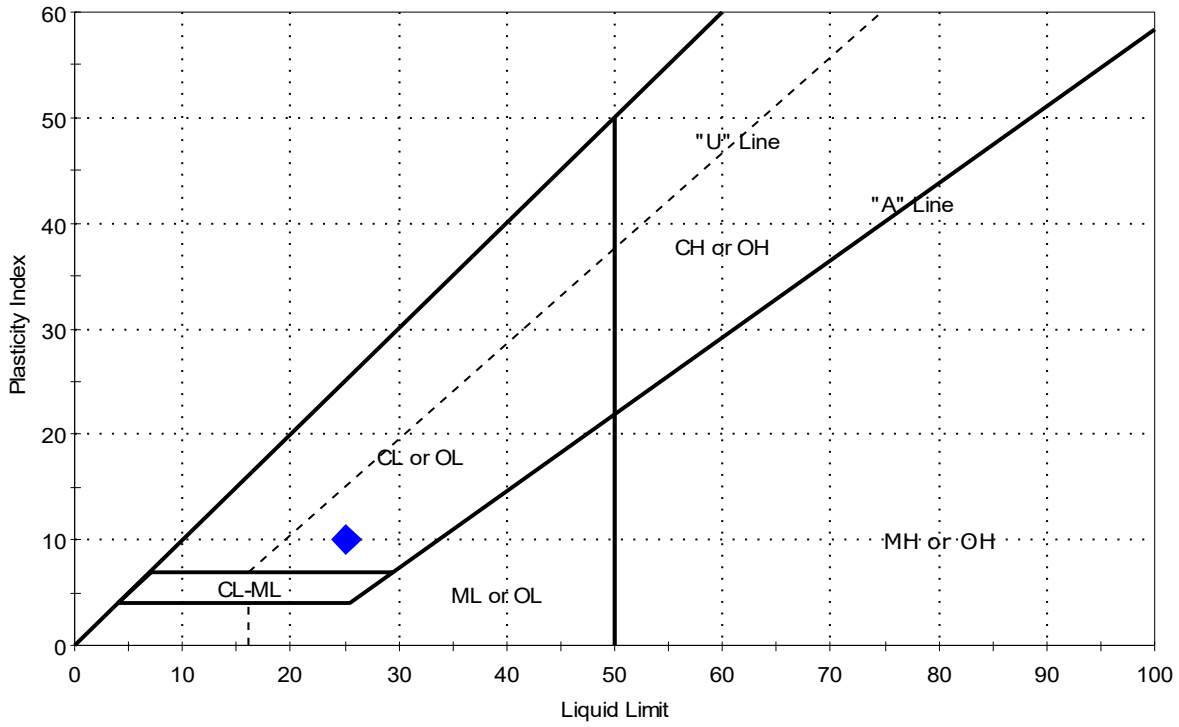


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-008	BH19-27	5.37-195. ft	11	27	12	15	-0.1	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
14% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-009	Test Date:	01/03/20	Checked By:	jsc
Depth :	198.33-198.82 ft	Test Id:	533966		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

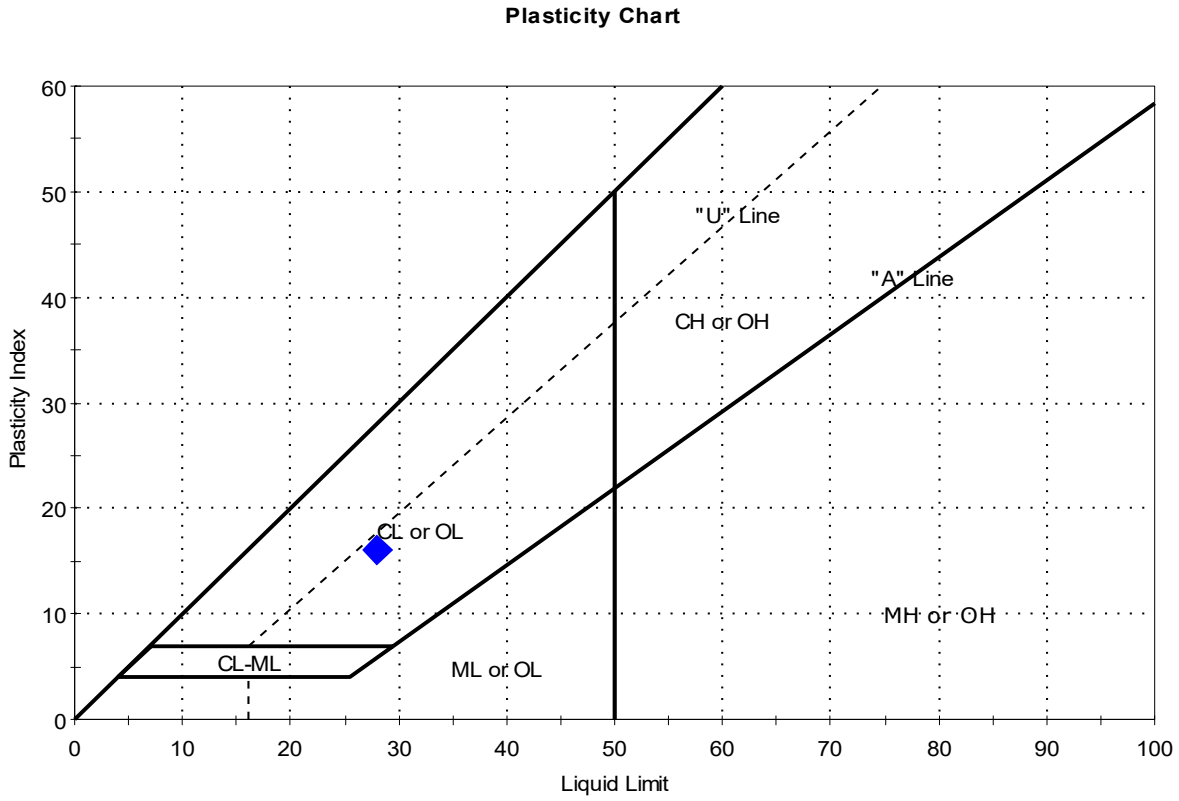


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-009	BH19-27	8.33-198. ft	12	25	15	10	-0.3	Lean CLAY (CL)

Sample Prepared using the WET method
1% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-011	Test Date:	01/06/20	Checked By:	jsc
Depth :	217.06-217.49 ft	Test Id:	533967		
Test Comment:	---				
Visual Description:	Moist, brown clayey sand with gravel				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

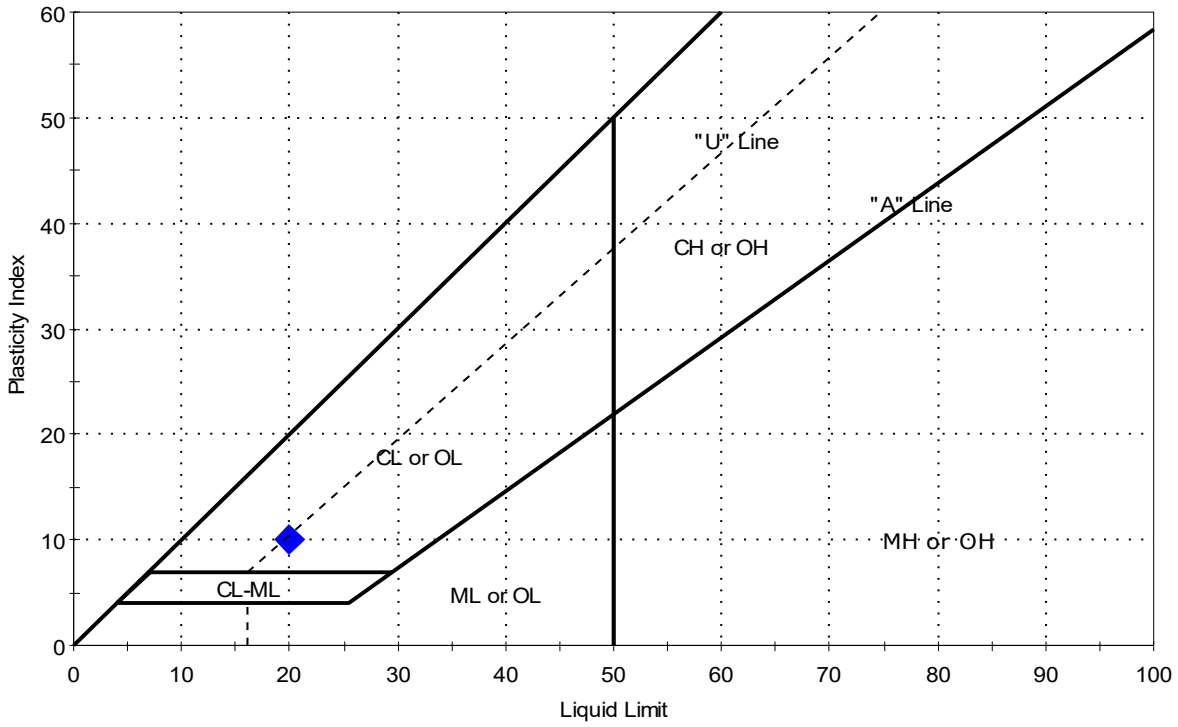


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-011	BH19-27	7.06-217. ft	7	28	12	16	-0.3	Clayey SAND with Gravel (SC)

Sample Prepared using the WET method
56% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-013	Test Date:	01/06/20	Checked By:	jsc
Depth :	232.28-232.81 ft	Test Id:	532775		
Test Comment:	---				
Visual Description:	Wet, brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-013	BH19-27	2.28-232. ft	43	20	10	10	3.3	

Sample Prepared using the WET method

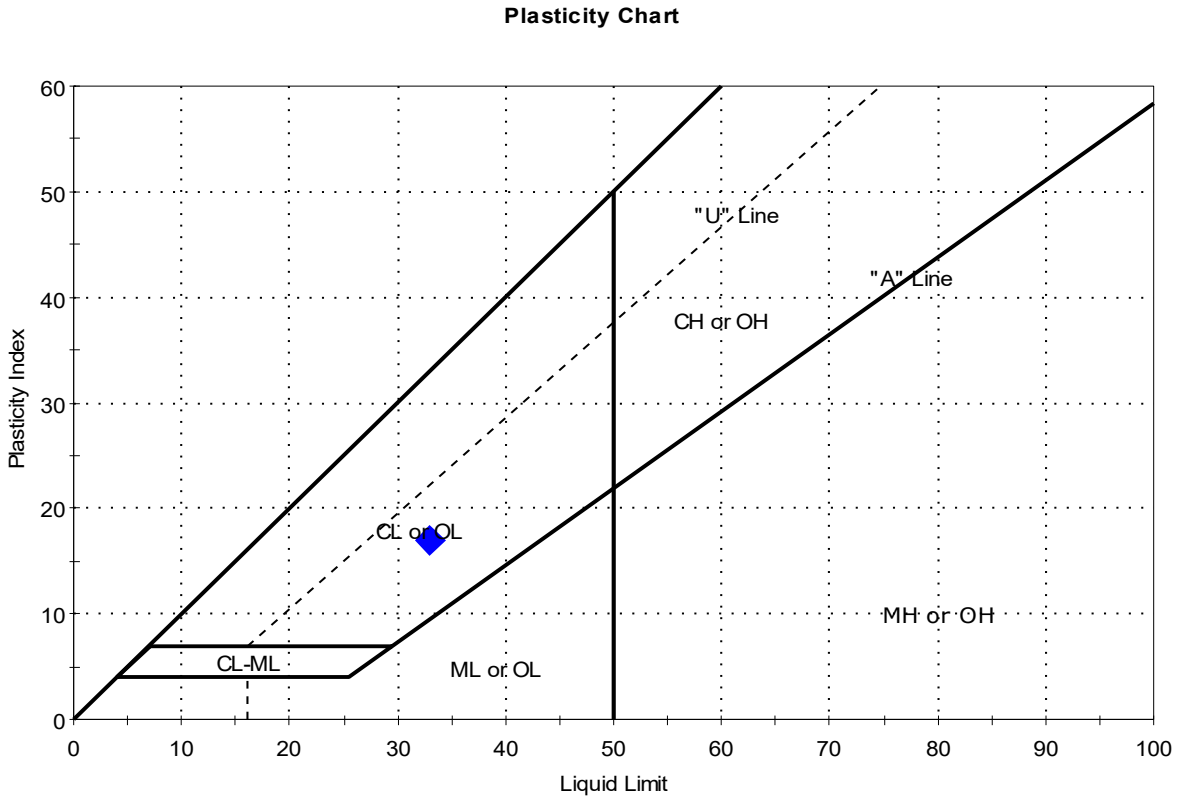
Dry Strength: VERY HIGH

Dilatancy: NONE

Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-014	Test Date:	12/23/19	Checked By:	bfs
Depth :	242.55-243.11 ft	Test Id:	532776		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

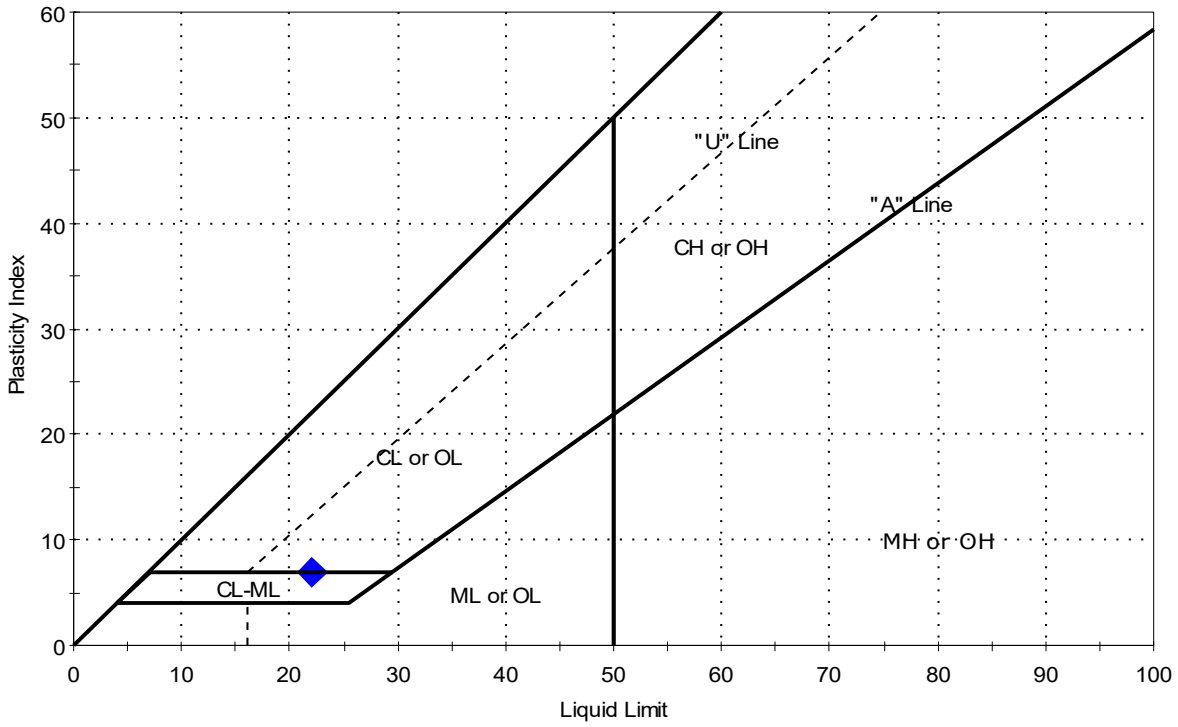


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-014	BH19-27	2.55-243. ft	16	33	16	17	0	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-015	Test Date:	01/06/20	Checked By:	jsc
Depth :	252.40-252.95 ft	Test Id:	532777		
Test Comment:	---				
Visual Description:	Moist, brown silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-015	BH19-27	2.40-252. ft	14	22	15	7	-0.1	

Sample Prepared using the WET method

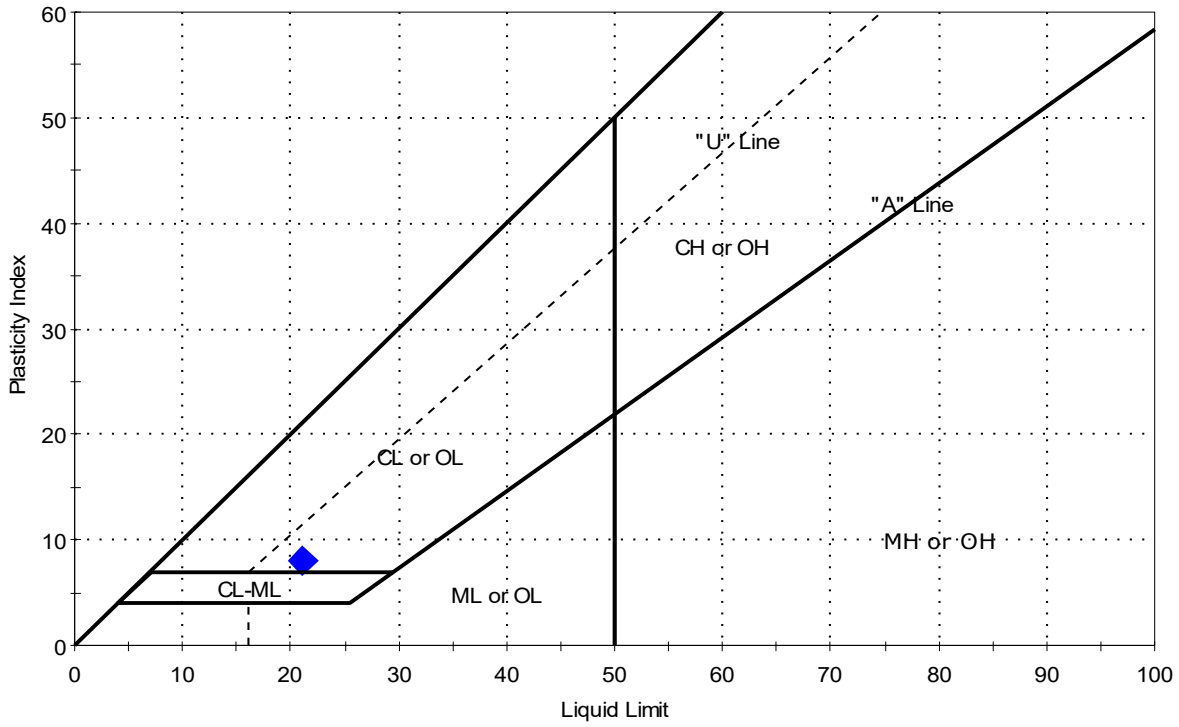
Dry Strength: HIGH

Dilatancy: SLOW

Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-016	Test Date:	12/23/19	Checked By:	bfs
Depth :	262.80-263.32 ft	Test Id:	532778		
Test Comment:	---				
Visual Description:	Moist, grayish brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

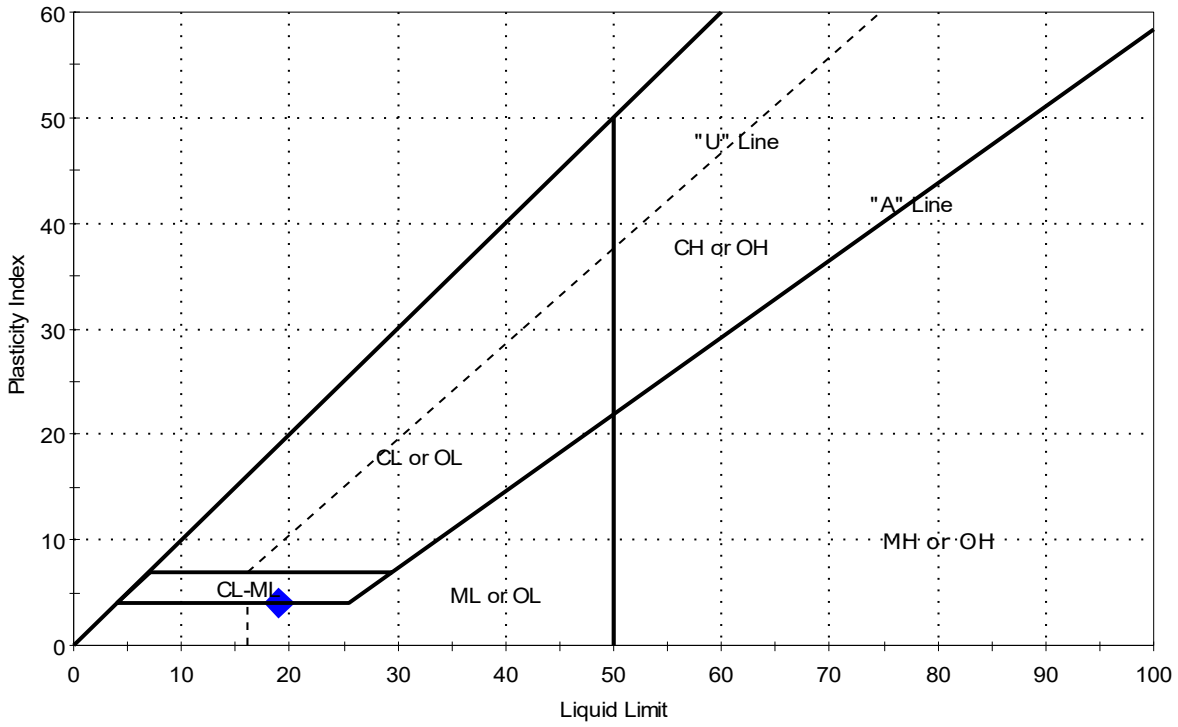


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-016	BH19-27	2.80-263. ft	14	21	13	8	0.1	Lean CLAY (CL)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-017	Test Date:	12/27/19	Checked By:	jsc
Depth :	271.10-271.62 ft	Test Id:	532779		
Test Comment:	---				
Visual Description:	Moist, brown silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-017	BH19-27	1.10-271. ft	17	19	15	4	0.4	

Sample Prepared using the WET method

Dry Strength: VERY HIGH

Dilatancy: NONE

Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-018	Test Date:	02/07/20	Checked By:	jsc
Depth :	281.17-280.68 ft	Test Id:	543981		
Test Comment:	---				
Visual Description:	Moist, light grayish brown sandy silt				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-018	BH19-27	1.17-280. ft	13	n/a	n/a	n/a	n/a	Sandy SILT (ML)

0% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	tube	Tested By:	GA
Sample ID:	ST-002	Test Date:	01/24/20	Checked By:	jsc
Depth :	127.95-129.92 ft	Test Id:	540883		
Test Comment:	---				
Visual Description:	Moist, brown silty sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

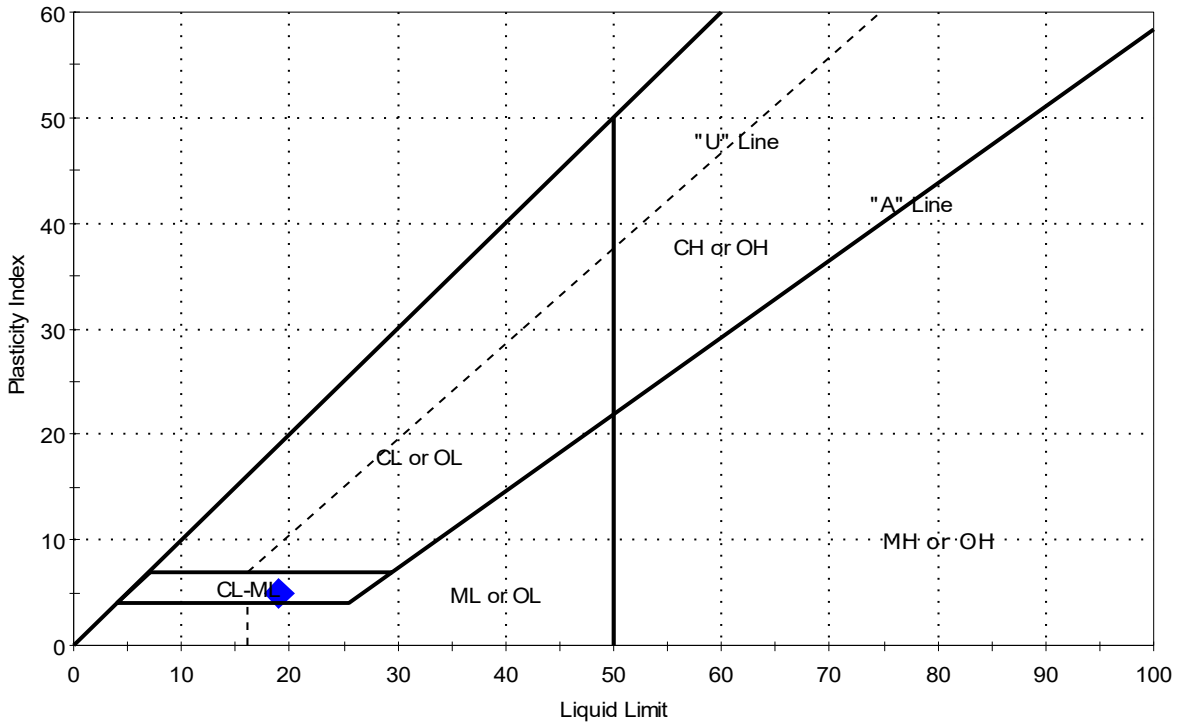
Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	BH19-27-ST-002	BH19-27	7.95-129. ft	13	n/a	n/a	n/a	n/a	Silty SAND (SM)

7% Retained on #40 Sieve
Dry Strength: NONE
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	tube	Tested By:	GA
Sample ID:	ST-003	Test Date:	01/24/20	Checked By:	jsc
Depth :	260.83-263.45 ft	Test Id:	540884		
Test Comment:	---				
Visual Description:	Moist, grayish brown silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

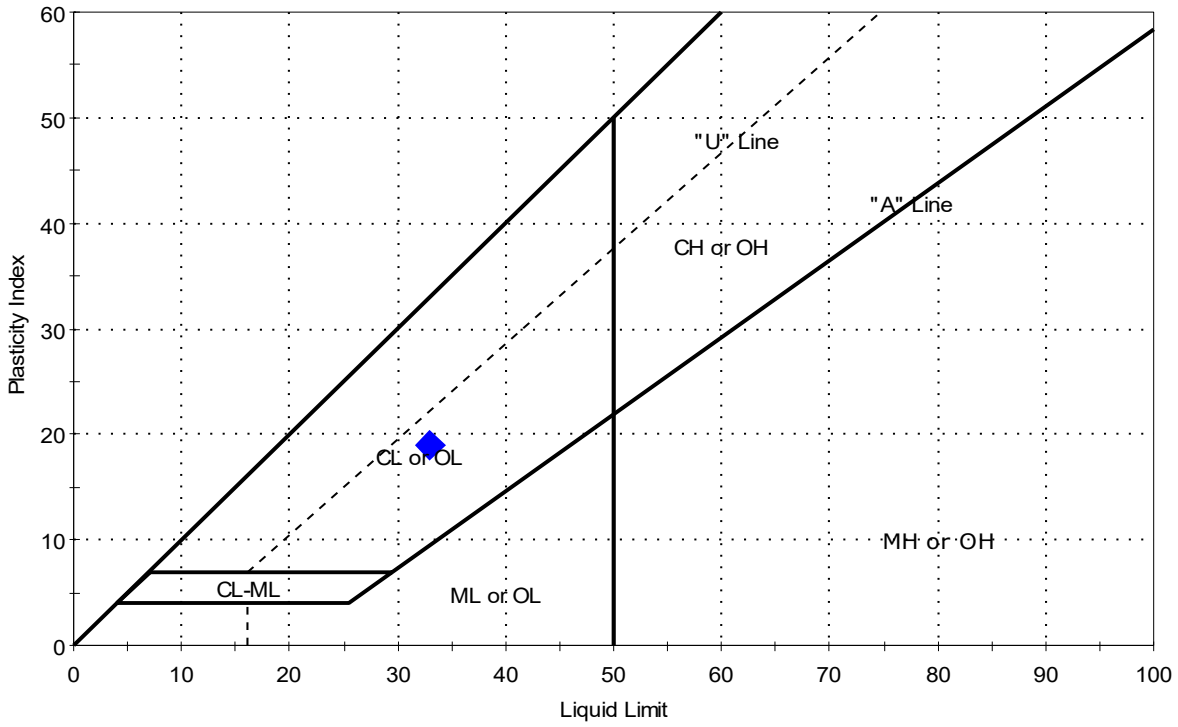


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	BH19-27-ST-003	BH19-27	0.83-263. ft	17	19	14	5	0.5	Silty CLAY (CL-ML)

Sample Prepared using the WET method
0% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	12/27/19	Checked By:	jsc
Depth :	87.5-88.12 ft	Test Id:	532727		
Test Comment:	---				
Visual Description:	Moist, brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

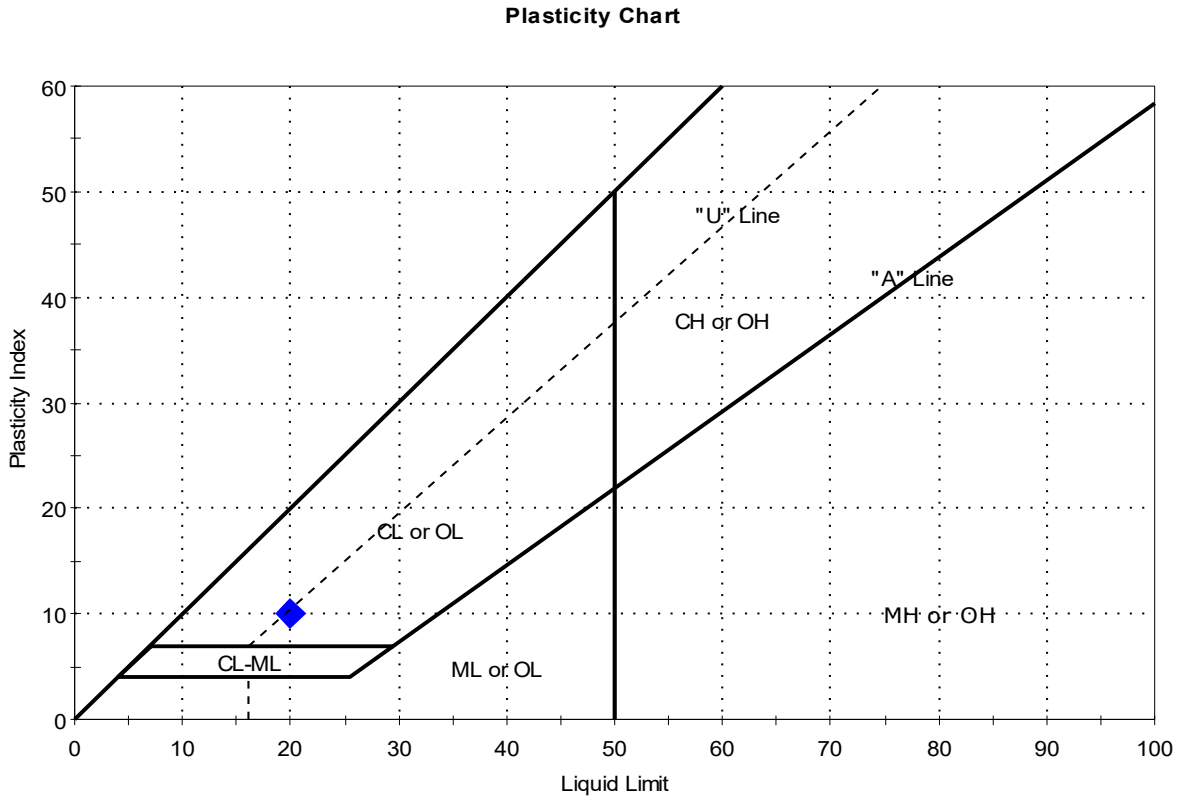


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-28	87.5-88.12 ft	12	33	14	19	-0.1	Lean CLAY (CL)

Sample Prepared using the WET method
5% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-002	Test Date:	12/27/19	Checked By:	jsc
Depth :	102.79-103.35 ft	Test Id:	532728		
Test Comment:	---				
Visual Description:	Moist, brown sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

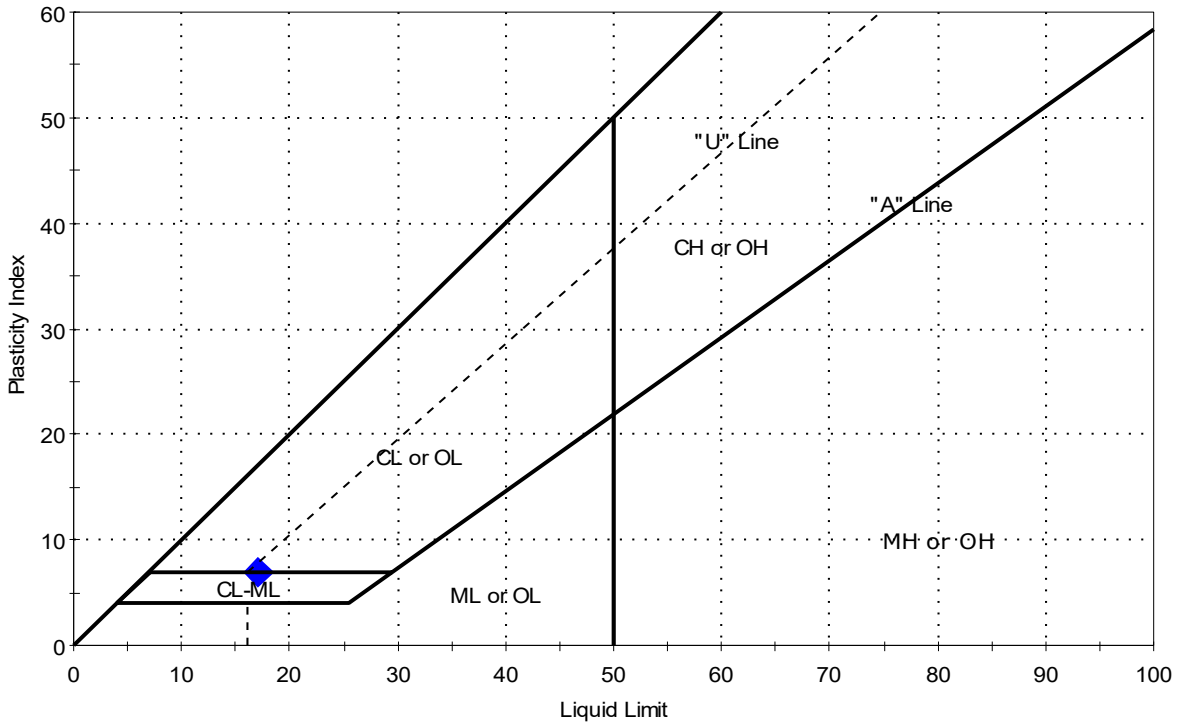


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-002	BH19-28	2.79-103. ft	10	20	10	10	0	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
16% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-004	Test Date:	12/27/19	Checked By:	jsc
Depth :	152.72-153.31 ft	Test Id:	532729		
Test Comment:	---				
Visual Description:	Dry, silty clayey sand				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

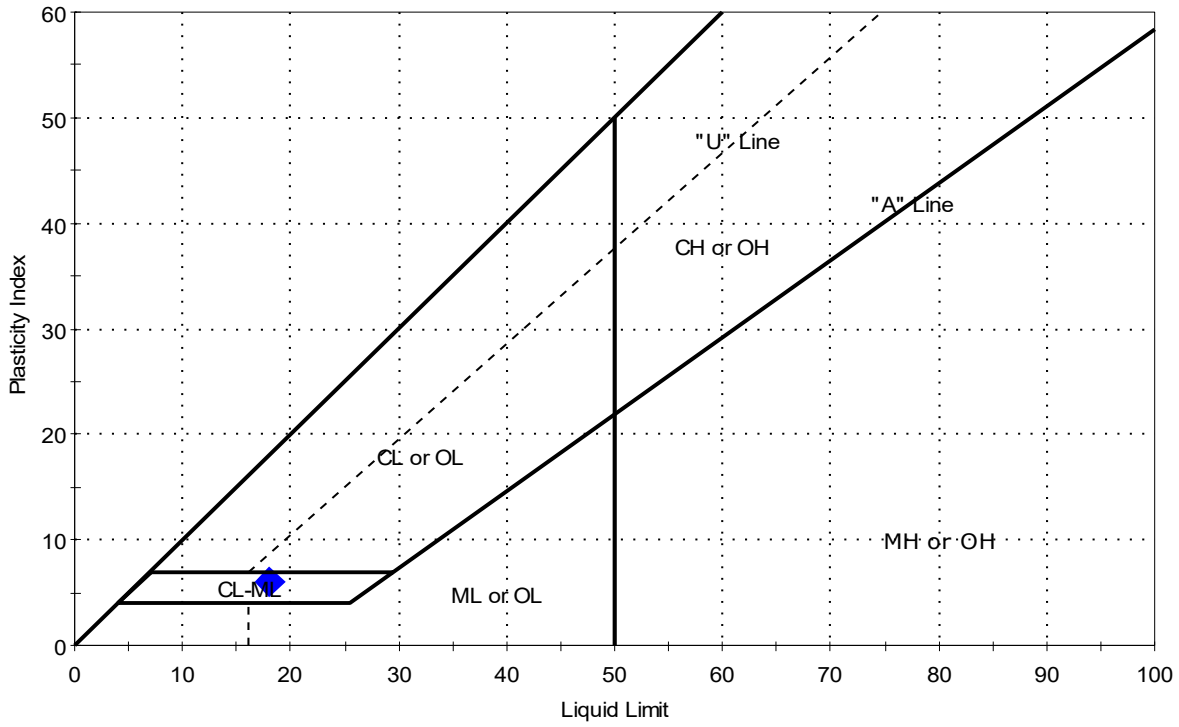


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-004	BH19-28	2.72-153. ft	5	17	10	7	-0.7	Silty, Clayey SAND (SC-SM)

Sample Prepared using the WET method
18% Retained on #40 Sieve
Dry Strength: MEDIUM
Dilatancy: SLOW
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-005	Test Date:	12/27/19	Checked By:	jsc
Depth :	156.46-156.92 ft	Test Id:	532730		
Test Comment:	---				
Visual Description:	Dry, pale brown sandy silty clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

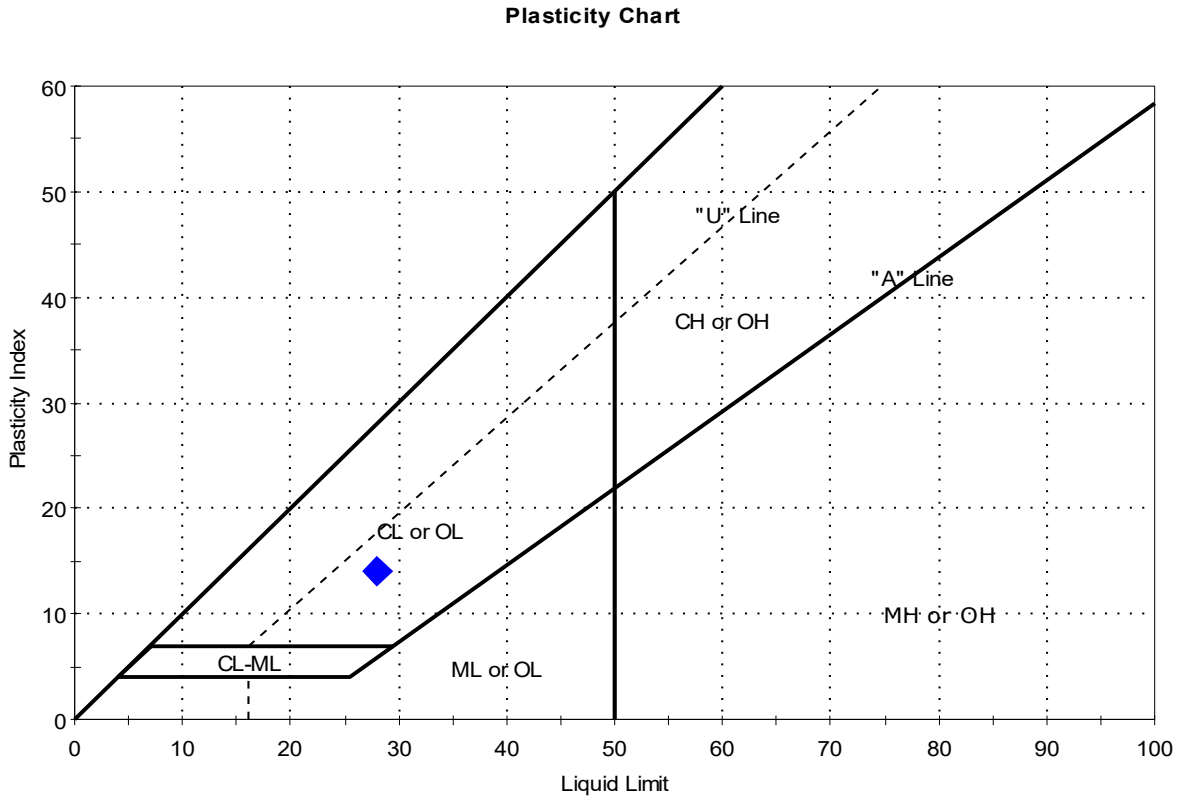


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-005	BH19-28	6.46-156. ft	2	18	12	6	-1.6	Sandy Silty CLAY (CL-ML)

Sample Prepared using the WET method
22% Retained on #40 Sieve
Dry Strength: HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	bag	Tested By:	GA
Sample ID:	LSB-001	Test Date:	01/06/20	Checked By:	jsc
Depth :	131.23-131.56 ft	Test Id:	532745		
Test Comment:	---				
Visual Description:	Moist, light brownish gray sandy clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318

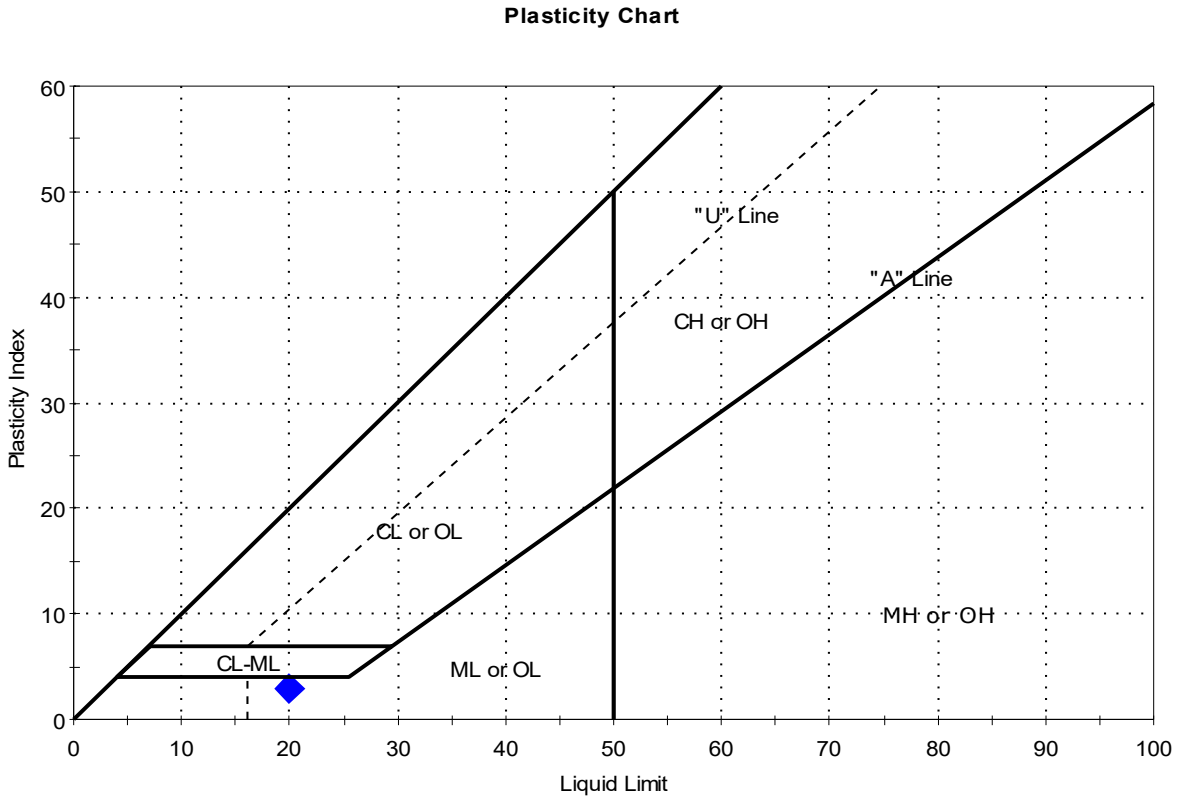


Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LSB-001	BH19-31	1.23-131. ft	14	28	14	14	0	Sandy Lean CLAY (CL)

Sample Prepared using the WET method
29% Retained on #40 Sieve
Dry Strength: VERY HIGH
Dilatancy: NONE
Toughness: MEDIUM

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	cam
Sample ID:	LRB-006	Test Date:	02/07/20	Checked By:	jsc
Depth :	202.10-203.08 ft	Test Id:	543128		
Test Comment:	---				
Visual Description:	Dry, reddish yellow silt				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	LRB-006	BH19-31	2.10-203. ft	8	20	17	3	-3.1	

Sample Prepared using the WET method

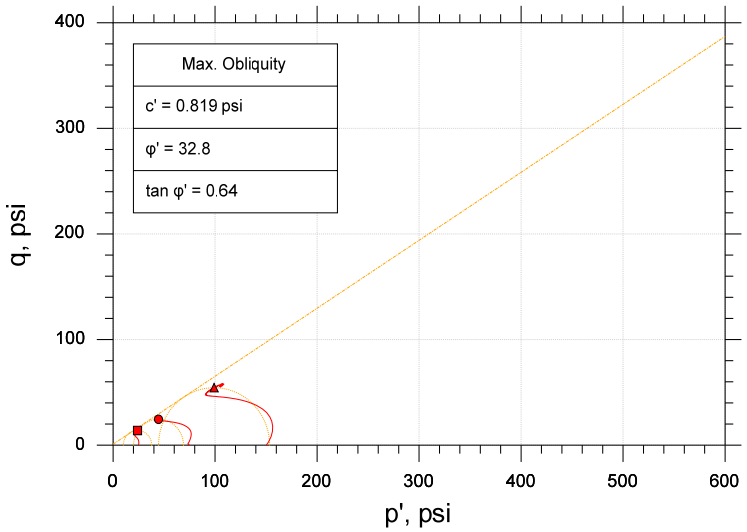
Dry Strength: HIGH

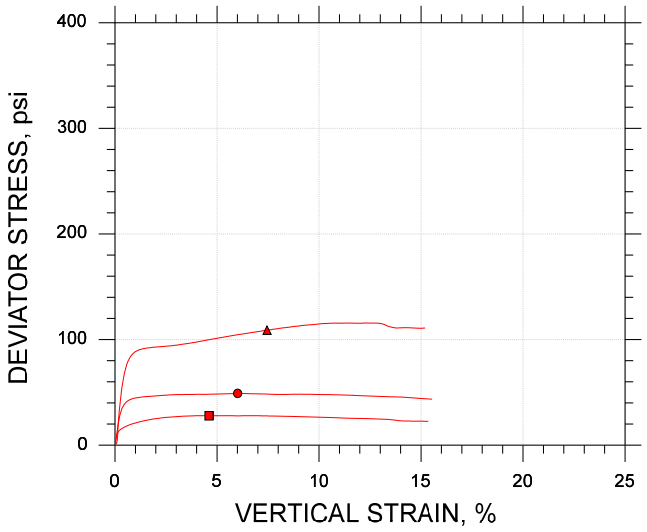
Dilatancy: SLOW

Toughness: LOW

Client: WSP	
Project Name: Line 5 Replacement and Tunnel	
Project Location: Straits of Mackinac	
Project Number: GTX-310187	
Tested By: trm	Checked By: mcm
Boring ID: BH19-26	
Preparation: Intact	
Description: Moist, light brown silty clay with sand	
Classification: Silty CLAY with Sand	
Group Symbol: CL-ML	
Liquid Limit: 18	Plastic Limit: 13
Plasticity Index: 5	Estimated Specific Gravity: 2.7

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

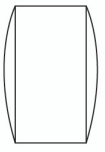


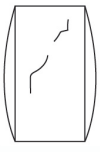


Symbol		■	●	▲	
Sample ID		BH19-26-ST-001	BH19-26-ST-001	BH19-26-ST-001	
Depth, ft		32.0-32.72	32.0-32.72	32.0-32.72	
Test Number		CU-2-1	CU-2-2	CU-2-3	
Initial	Height, in	6.100	6.520	6.070	
	Diameter, in	2.850	2.870	2.880	
	Moisture Content (from Cuttings), %	18.0	18.3	18.5	
	Dry Density, pcf	113.	108.	107.	
	Saturation (Wet Method), %	97.9	87.3	86.9	
	Void Ratio	0.498	0.567	0.576	
Before Shear	Moisture Content, %	17.6	18.4	17.9	
	Dry Density, pcf	114.	113.	114.	
	Cross-sectional Area (Method A), in²	6.326	6.262	6.230	
	Saturation, %	100.0	100.0	100.0	
	Void Ratio	0.475	0.496	0.483	
	Back Pressure, psi	170.8	170.6	135.0	
Vertical Effective Consolidation Stress, psi		24.95	74.92	149.9	
Horizontal Effective Consolidation Stress, psi		24.99	75.00	150.0	
Vertical Strain after Consolidation, %		0.6566	1.544	1.685	
Volumetric Strain after Consolidation, %		1.415	5.036	6.170	
Time to 50% Consolidation, min		---	---	2.890	
Shear Strength, psi		13.89	24.48	54.41	
Strain at Failure, %		4.61	6.01	7.45	
Strain Rate, %/min		0.01600	0.01600	0.01600	
Deviator Stress at Failure, psi		27.77	48.95	108.8	
Effective Minor Principal Stress at Failure, psi		10.07	20.05	44.67	
Effective Major Principal Stress at Failure, psi		37.84	69.01	153.5	
B-Value		0.95	0.95	0.96	

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Atterberg Limits determined by ASTM D4318.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

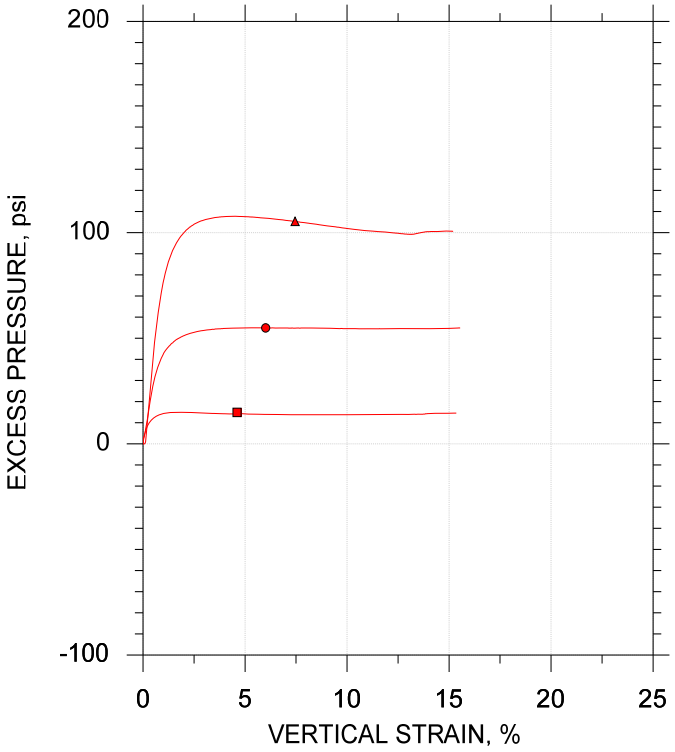
Remarks:

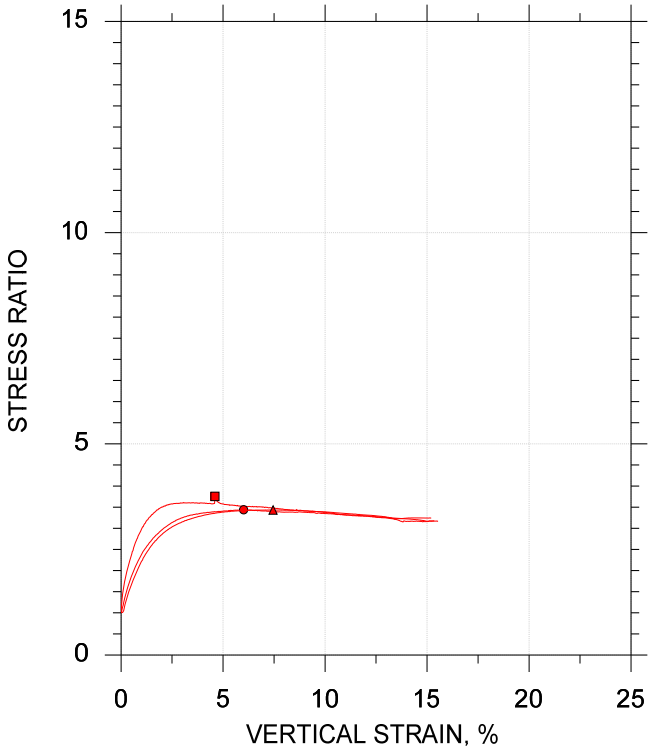


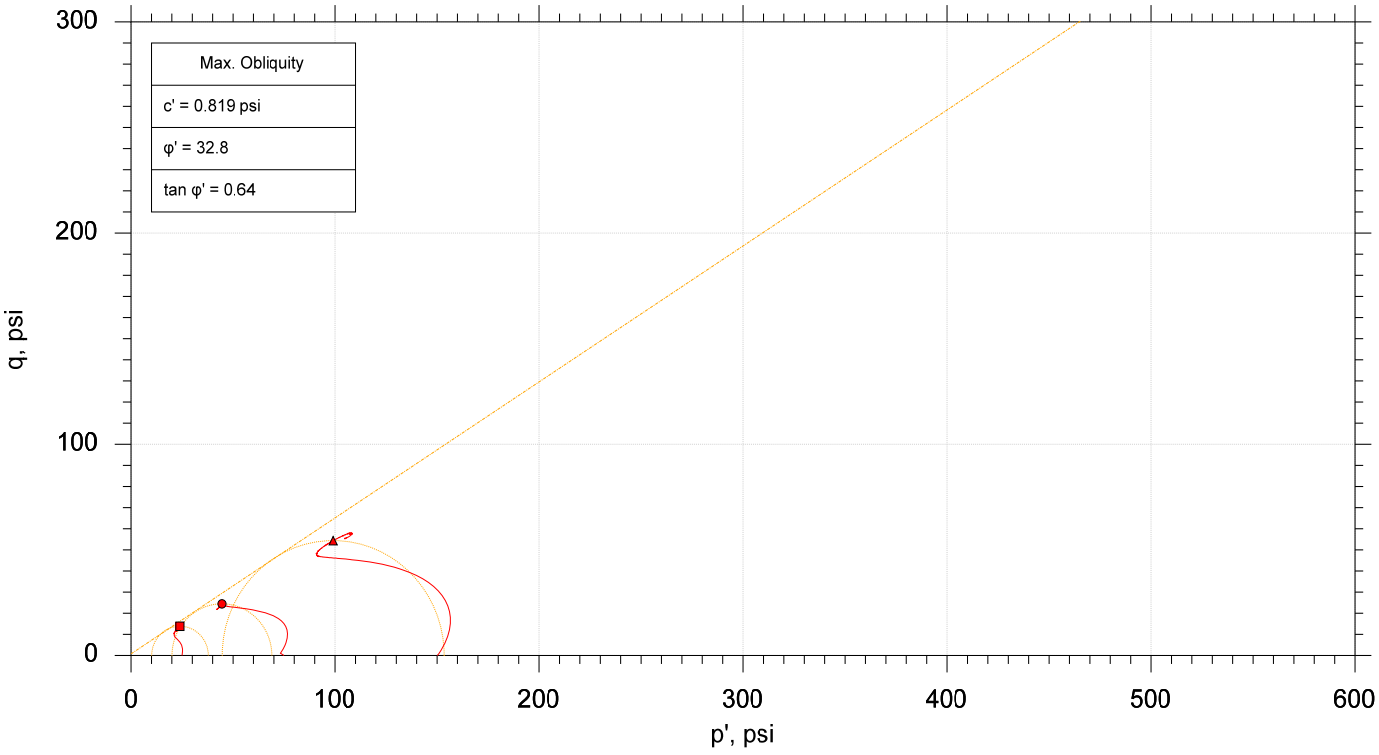


System PP

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767







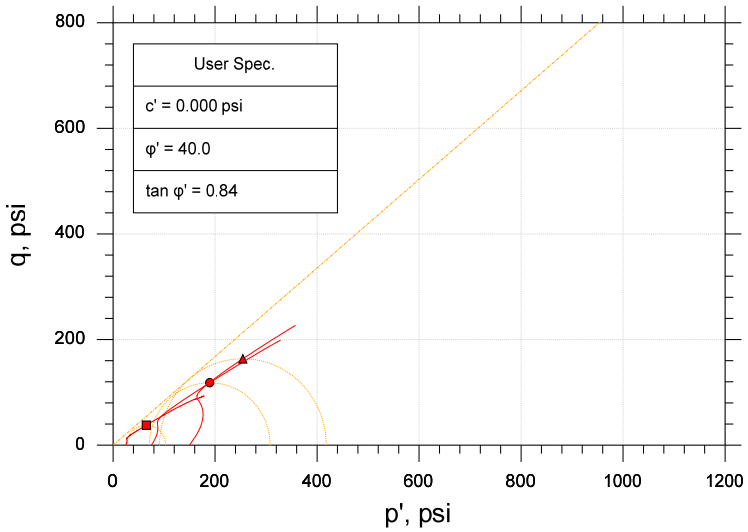
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
■	BH19-26-ST-001	CU-2-1	32.0-32.72	trm	1/24/20	mcm	2/12/20	310187-CU-2-1m.dat
●	BH19-26-ST-001	CU-2-2	32.0-32.72	trm	1/23/20	mcm	2/12/20	310187-CU-2-2m.dat
▲	BH19-26-ST-001	CU-2-3	32.0-32.72	trm	1/23/20	mcm	2/12/20	310187-CU-2-3m.dat

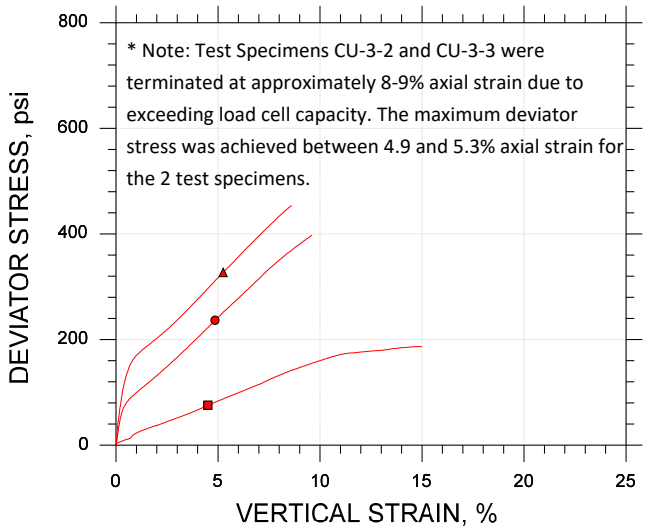
GeoTesting EXPRESS

Project: Line 5 Replacement and Tunnel	Location: Straits of Mackinac	Project No.: GTX-310187
Boring No.: BH19-26	Sample Type: Intact	
Description: Moist, light brown silty clay with sand		
Remarks: System PP		

Client: WSP	
Project Name: Line 5 Replacement and Tunnel	
Project Location: Straits of Mackinac	
Project Number: GTX-310187	
Tested By: trm	Checked By: mcm
Boring ID: BH-19-27	
Preparation: intact	
Description: Moist, brown silty sand	
Classification: Silty SAND	
Group Symbol: SM	
Liquid Limit: NP	Plastic Limit: NP
Plasticity Index: NP	Estimated Specific Gravity: 2.65

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





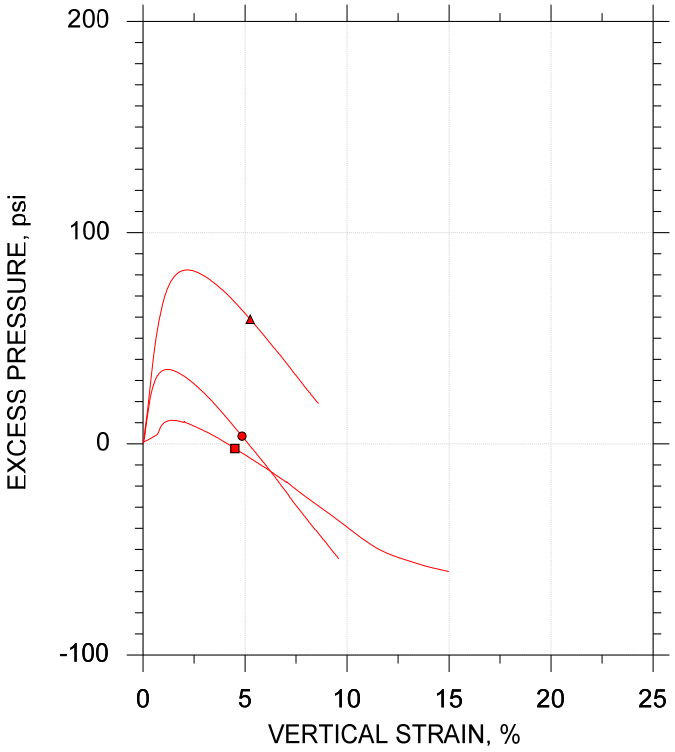
		■	●	▲	
Symbol					
Sample ID		BH19-27-ST-002	BH19-27-ST-002	BH-19-27 ST-002	
Depth, ft		39-39.6	39-39.6	39-39.6	
Test Number		CU-3-1	CU-3-2	CU-3-3	
Initial	Height, in	6.390	6.130	6.150	
	Diameter, in	2.870	2.870	2.870	
	Moisture Content (from Cuttings), %	15.0	13.7	14.1	
	Dry Density, pcf	117.	118.	118.	
	Saturation (Wet Method), %	97.4	90.3	91.7	
	Void Ratio	0.408	0.403	0.407	
Before Shear	Moisture Content, %	---	---	---	
	Dry Density, pcf	---	---	---	
	Cross-sectional Area (Method A), in²	---	---	---	
	Saturation, %	---	---	---	
	Void Ratio	---	---	---	
	Back Pressure, psi	159.0	171.0	147.0	
Vertical Effective Consolidation Stress, psi		25.01	74.98	150.0	
Horizontal Effective Consolidation Stress, psi		25.02	74.98	150.0	
Vertical Strain after Consolidation, %		0.1666	0.2007	0.5413	
Volumetric Strain after Consolidation, %		1.539	20.99	28.94	
Time to 50% Consolidation, min		---	---	0.3600	
Shear Strength, psi		37.87	118.2	163.5	
Strain at Failure, %		4.50	4.85	5.25	
Strain Rate, %/min		0.01600	0.01600	0.01600	
Deviator Stress at Failure, psi		75.73	236.4	327.0	
Effective Minor Principal Stress at Failure, psi		27.21	71.31	90.96	
Effective Major Principal Stress at Failure, psi		102.9	307.8	418.0	
B-Value		0.95	0.96	0.96	

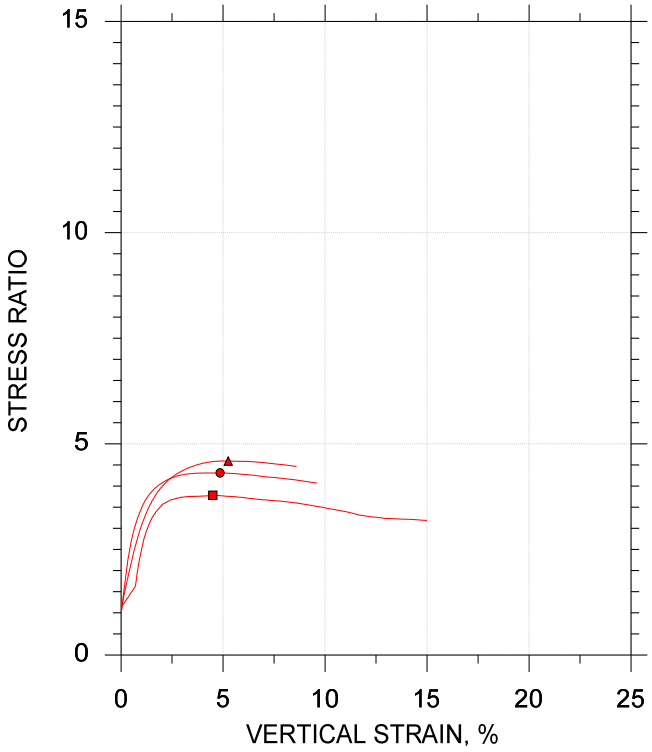
Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Atterberg Limits determined by ASTM D4318.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

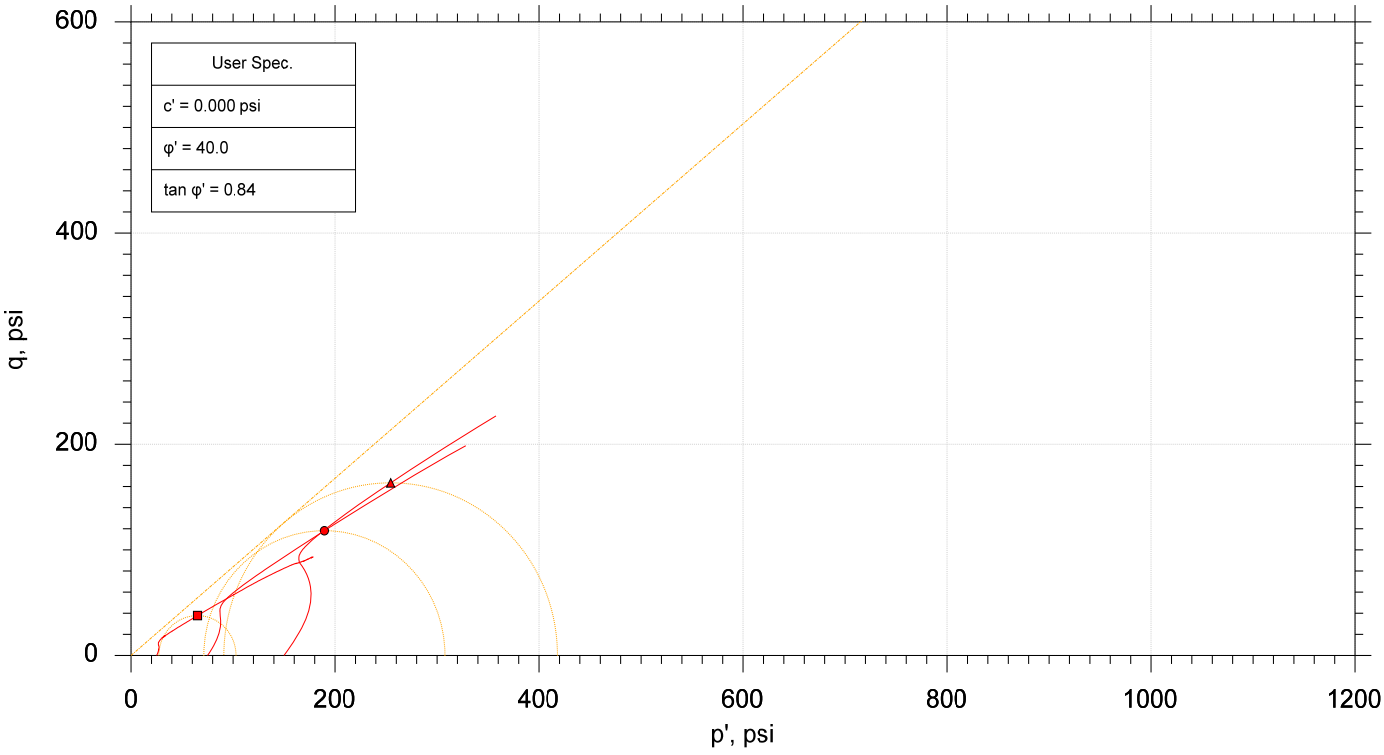
Remarks:

Before Shear data was not obtainable to specimens slumping durling sample breakdown after test.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767







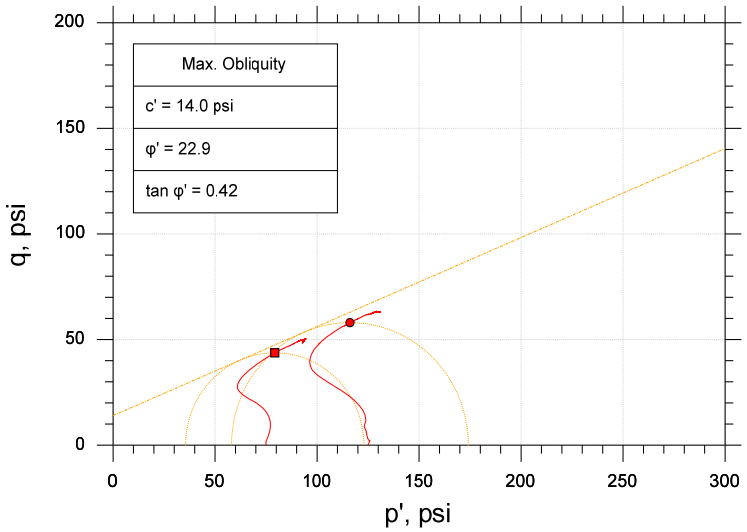
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
■	BH19-27-ST-002	CU-3-1	39-39.6	trm	1/24/20	mcm	2/12/20	310187-CU-3-1m.dat
●	BH19-27-ST-002	CU-3-2	39-39.6	trm	1/24/20	mcm	2/12/20	310187-CU-3-2m.dat
▲	BH-19-27 ST-002	CU-3-3	39-39.6	trm	1/24/20	mcm	2/11/20	310187-CU-3-3m.dat

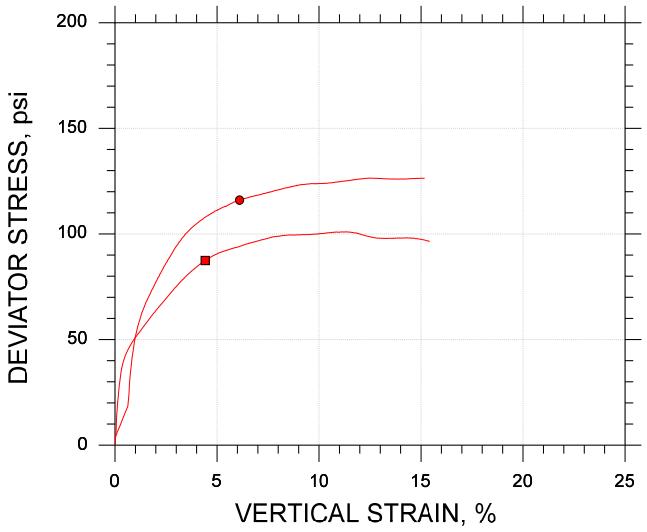
GeoTesting EXPRESS

Project: Line 5 Replacement and Tunnel	Location: Straits of Mackinac	Project No.: GTX-310187
Boring No.: BH-19-27	Sample Type: intact	
Description: Moist, brown silty sand		
Remarks: Before Shear data was not obtainable to specimens slumping durling sample breakdown after test.		

Client: WSP	
Project Name: Line 5 Replacement and Tunnel	
Project Location: Straits of Mackinac	
Project Number: GTX-310187	
Tested By: trm	Checked By: mcm
Boring ID: BH-19-27	
Preparation: intact	
Description: Moist, grayish brown silty clay	
Classification: Silty CLAY	
Group Symbol: CL-ML	
Liquid Limit: 19	Plastic Limit: 14
Plasticity Index: 5	Estimated Specific Gravity: 2.7

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





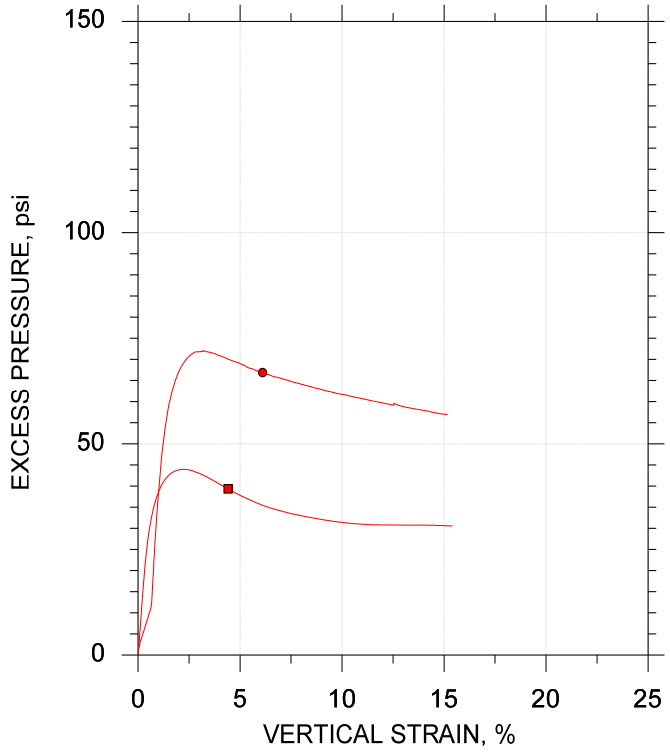
Symbol		■	●		
Sample ID		BH-19-27-ST-003	BH19-27 ST-003		
Depth, ft		79.5-80.3	79.5-80.3		
Test Number		CU-1-1	CU-1-2		
Initial	Height, in	6.230	6.400		
	Diameter, in	2.850	2.850		
	Moisture Content (from Cuttings), %	17.2	16.7		
	Dry Density, pcf	112.	112.		
	Saturation (Wet Method), %	91.0	90.5		
	Void Ratio	0.511	0.498		
Before Shear	Moisture Content, %	17.5	16.6		
	Dry Density, pcf	115.	116.		
	Cross-sectional Area (Method A), in²	6.362	6.265		
	Saturation, %	100.0	100.0		
	Void Ratio	0.471	0.448		
	Back Pressure, psi	170.9	160.8		
Vertical Effective Consolidation Stress, psi		74.84	124.9		
Horizontal Effective Consolidation Stress, psi		74.95	125.0		
Vertical Strain after Consolidation, %		2.129	1.438		
Volumetric Strain after Consolidation, %		1.848	2.850		
Time to 50% Consolidation, min		---	32.49		
Shear Strength, psi		43.70	58.02		
Strain at Failure, %		4.41	6.10		
Strain Rate, %/min		0.01600	0.01600		
Deviator Stress at Failure, psi		87.41	116.0		
Effective Minor Principal Stress at Failure, psi		35.54	58.09		
Effective Major Principal Stress at Failure, psi		123.0	174.1		
B-Value		0.95	0.95		

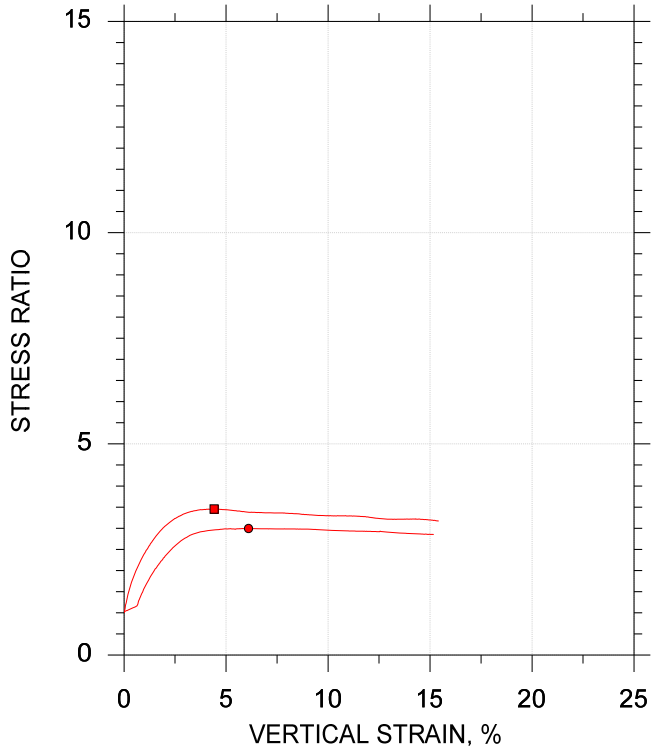
Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Atterberg Limits determined by ASTM D4318.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

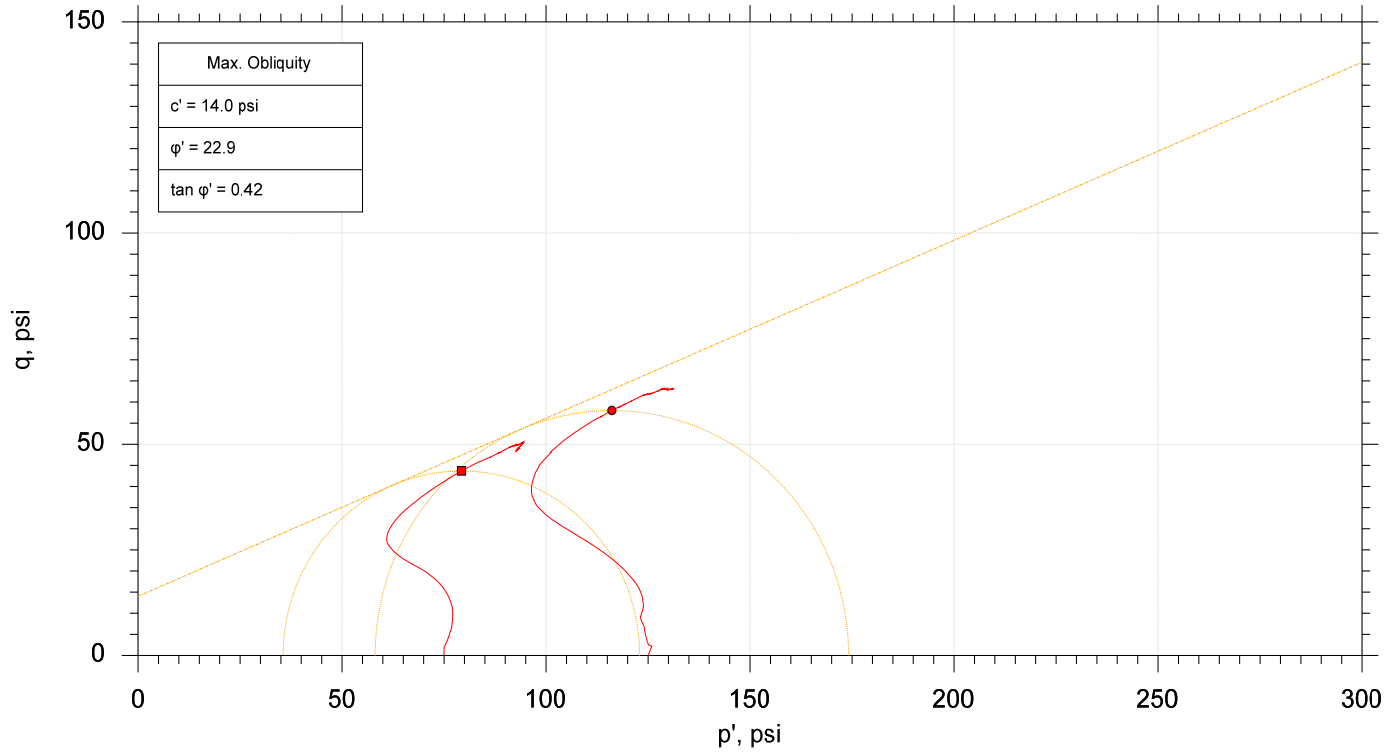
Remarks:

System E

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





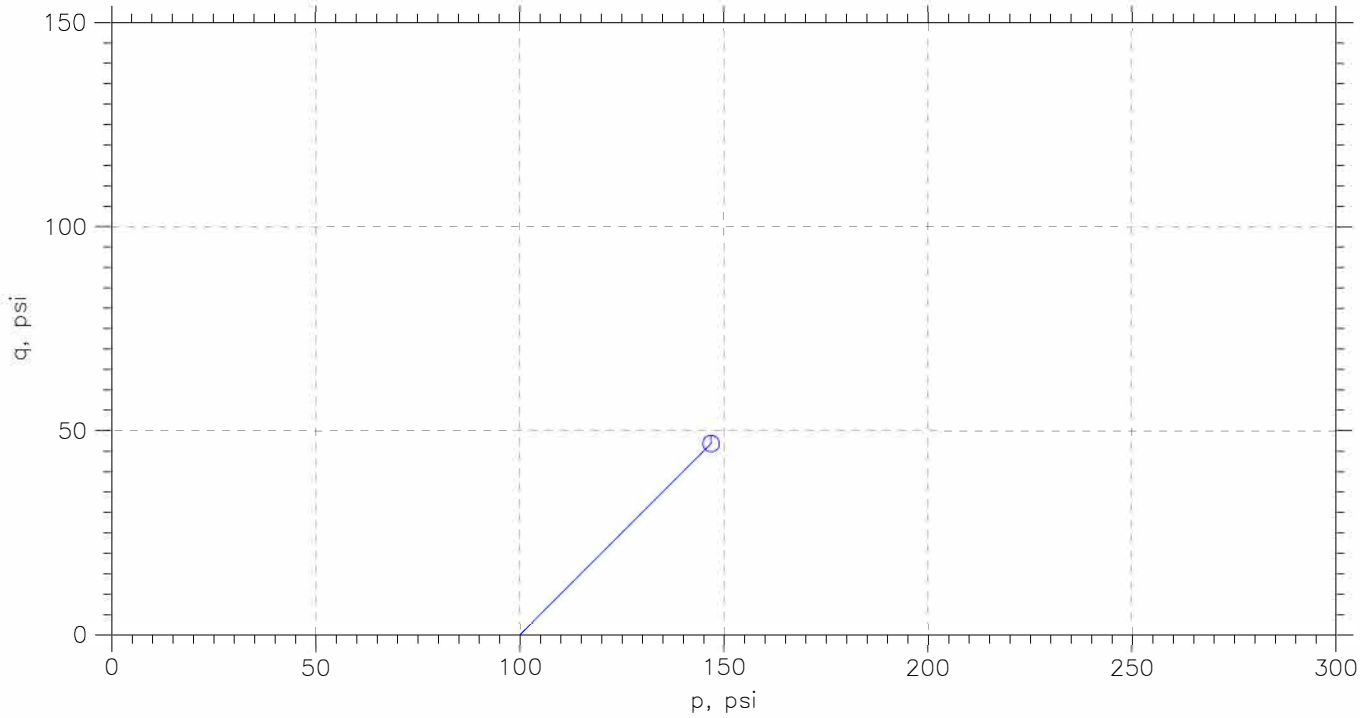


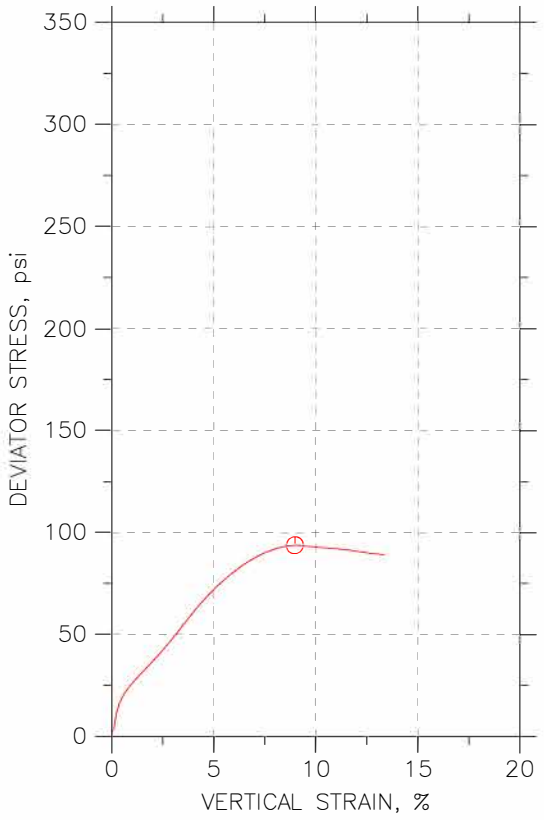
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
■	BH-19-27-ST-003	CU-1-1	79.5-80.3	trm	1/22/20	mcm	2/12/20	310187-CU-1-1m.dat
●	BH19-27 ST-003	CU-1-2	79.5-80.3	md	01/22/20	mcm	2/12/20	310187-CU-1-2m.dat

GeoTesting EXPRESS

Project: Line 5 Replacement and Tunnel	Location: Straits of Mackinac	Project No.: GTX-310187
Boring No.: BH-19-27	Sample Type: intact	
Description: Moist, grayish brown silty clay		
Remarks: System E		

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850





Symbol	⏲			
Sample No.	See below			
Test No.	UU-1			
Depth	See below			
Tested by	trm			
Test Date	1/23/20			
Checked by	anm			
Check Date	02/4/20			
Diameter, in	2.85			
Height, in	6.15			
Water Content, %	14.1			
Dry Density, pcf	119.6			
Saturation, %	98.8			
Void Ratio	0.375			
Confining Stress, psi	100			
Undrained Strength, psi	46.86			
Max. Dev. Stress, psi	93.73			
Strain at Failure, %	8.97			
Strain Rate, %/min	1			
Measured Specific Gravity	2.63			
Liquid Limit	26			
Plastic Limit	12			
Plasticity Index	14			

GeoTesting EXPRESS

Project: Line 5 Replacement

Location: Straits of Mackinac

Project No.: GTX-310187

Boring No.: BH19-26

Sample Type: intact

Description: Moist, brown clay with sand

Remarks: System VV, Sample Number: BH19-26-ST-002, Depth: 41.0-41.29 ft

Phase calculations based on start and end of test.

Tue, 04-FEB-2020 16:05:02

APPENDIX

E-2 *ROCK TEST RESULTS*

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	07/24/19	Checked By:	smd
Depth :	---	Test Id:	514961		

Mohs Hardness Test

Boring ID	Sample ID	Depth	Scale of Hardness Number
BH19-08	LRB-005	29.2 ft	2.5
BH19-08	LRB-009	34.5 ft	3.5
BH19-10	LRB-001	23.1 ft	3.5
BH19-15	LRB-003	138.3 - 138.5 ft	3.5
BH19-15	LRB-004	163.0 - 168.0 ft	3.5
BH19-15	LRB-005	218.0 - 223.0 ft	2
BH19-35	LRB-006	64.0 ft	3.5
BH19-07	LRB-001	80.9-81.2 ft	4.5
BH19-07	LRB-007	140.8-141 ft	5
BH19-07	LRB-010	178.0-178.8 ft	2.5
BH19-16	LRB-008	253.1 - 253.5 ft	1.5
BH19-16	LRB-012	317.5 - 318.1 ft	1.5

Notes: The value listed above is an estimate of the hardness of the rock sample provided using the Mohs Hardness method. This method is intended to represent the hardness of individual minerals not rock hardness

Tests performed on cut surface of rock core samples provided by client.

Mohs Table of Hardness Scale

1	Talc	6	Orthoclase
2	Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	07/12/19	Checked By:	smd
Depth :	---	Test Id:	513308		

Mohs Hardness Test

Boring ID	Sample ID	Depth	Scale of Hardness Number
BH19-17	LRB-002	368.1-368.8 ft	1
BH19-17	LRB-006 (A,B)	315.5-317 ft	1
BH19-37	LRB-005	201.2-201.5 ft	1.5
BH19-38	LRB-003	145.5-146 ft	3
BH19-38	LRB-008	187.1-187.7 ft	1
PZ19-42	SB-003	30 ft	2.5
PZ19-42	SB-004	45 ft	2.5
PZ19-42	SB-004	50 ft	2.5

Notes: The value listed above is an estimate of the hardness of the rock sample provided using the Mohs Hardness method. This method is intended to represent the hardness of individual minerals not rock hardness

Tests performed on cut surface of rock core samples provided by client.

Mohs Table of Hardness Scale

1	Talc	6	Orthoclase
2	Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	10/21/19	Checked By:	smd
Depth :	---	Test Id:	527308		

Mohs Hardness Test

Boring ID	Sample ID	Depth	Scale of Hardness Number
BH19-32	LRB-003	122.38 ft	3.5
BH19-32	LRB-004	124.67 ft	3.5

Notes: The value listed above is an estimate of the hardness of the rock sample provided using the Mohs Hardness method. This method is intended to represent the hardness of individual minerals not rock hardness

Tests performed on cut surface of rock core samples provided by client.

Mohs Table of Hardness Scale

1	Talc	6	Orthoclase
2	Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	12/09/19	Checked By:	smd
Depth :	---	Test Id:	532722		

Mohs Hardness Test

Boring ID	Sample ID	Depth	Scale of Hardness Number
BH19-19	LRB-001	84.97-85.14 ft	4.5
BH19-19	LRB-007	159.32-159.55 ft	3.5
BH19-36	LRB-002	157.48-157.81 ft	3.5

Notes: The value listed above is an estimate of the hardness of the rock sample provided using the Mohs Hardness method. This method is intended to represent the hardness of individual minerals not rock hardness

Tests performed on cut surface of rock core samples provided by client.

Mohs Table of Hardness Scale

1	Talc	6	Orthoclase
2	Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	12/18/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-19	LRB-002	94.28-94.45 ft	1.07	162	2.63	0.04

Notes: Results are based on the average of two saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-07	LRB-002	113-113.3	0.82	168	2.69	0.041

Notes: Results are based on two irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-07	LRB-006	138.4-138.8	1.44	166	2.66	0.050

Notes: Results are based on five irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-07	LRB-010	178.0-178.8	3.31	151	2.45	0.087

Notes: Results are based on four irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-08	LRB-002	22.4	0.26	144	2.31	0.122

Notes: Results are based on one irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-08	LRB-003	27.45	0.22	147	2.36	0.137

Notes: Results are based on one irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-08	LRB-011	45.2	0.54	143	2.28	0.163

Notes: Results are based on one irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-08	LRB-016	89.5	0.95	155	2.58	0.06

Notes: Results are based on the average of three saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-09	LRB-001	12.1	1.17	149	2.45	0.08

Notes: Results are based on the average of three saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-09	LRB-004	32.0	0.22	152	2.44	0.083

Notes: Results are based on one irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-09	LRB-014	76.5	1.26	156	2.58	0.07

Notes: Results are based on the average of three saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-10	LRB-002	31.8	1.95	142	2.37	0.12

Notes: Results are based on the average of three saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-10	LRB-005	59.8	0.69	155	2.57	0.04

Notes: Results are based on the average of two saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-10	LRB-008	88.7	2.07	139	2.23	0.175

Notes: Results are based on three irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/30/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-15	LRB-004	165.63-165.92	1.06	157	2.57	0.04

Notes: Results are based on the average of three saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/30/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-16	LRB-003	140.17-140.30	3.14	145	2.33	0.085

Notes: Results based on three irregular test specimens as received from the client.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/30/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-16	LRB-004	177.20-177.35	2.86	156	2.48	0.026

Notes: Results based on one irregular test specimen as received from the client.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/30/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-16	LRB-010	270.91-271.19	1.75	197	3.16	0.047

Notes: Results based on four irregular test specimens as received from the client.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-33	LRB-007	182.61	0.30	170	2.71	0.024

Notes: Results are based on one irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-37	LRB-007	225.8-226.9	2.47	151	2.41	0.084

Notes: Results are based on three irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-38	LRB-001	128-128.8	2.26	152	2.43	0.143

Notes: Results are based on two irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-38	LRB-002	144.5-144.7	0.77	160	2.58	0.082

Notes: Results are based on one irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/17/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
PZ19-42	SB-002	20	2.37	152	2.42	0.108

Notes: Results are based on two irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/17/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
PZ19-42	SB-003	38	1.49	154	2.48	0.091

Notes: Results are based on four irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/17/2019
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 3

Boring ID	Sample ID	Depth, ft.	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
PZ19-42	SB-004	50	1.73	151	2.42	0.117

Notes: Results are based on two irregular test specimens.
Unit weight obtained by buoyancy technique.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/23/2020
Tested By:	tlm
Checked By:	smd

Unit Weight, Porosity & Specific Gravity of Rock - ISRM Method 2

Boring ID	Sample ID	Depth	Average Moisture Content, %	Average Dry Unit Weight, pcf	Average Bulk Specific Gravity	Average Porosity
BH19-24A	LRB-001	230.97-232.61 ft	3.25	139	2.23	0.07

Notes: Results are based on the average of three saw-cut test specimens.
Unit weight obtained by digital caliper measurement.
Pore Volume obtained by water saturation.
Bulk Specific Gravity obtained by buoyancy technique.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-004	Test Date:	02/11/20	Checked By:	jsc
Depth :	127.95 ft	Test Id:	534014		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LSB-004	127.95 ft	1	1.1	0.9	1.00	
			2	0.8	0.4	0.60	
			3	1.5	1.5	1.50	
			4	1.1	1.4	1.25	
			5	1.3	1.5	1.40	
			Average CAIs			1.15	
			Average CAI *			1.62	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

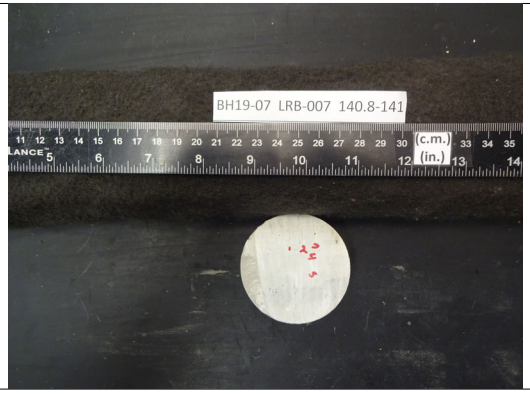
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	08/28/19	Checked By:	smd
Depth :	140.8-141 ft	Test Id:	518439		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-07	LRB-007	140.8-141 ft	1	2.8	2.9	2.85	
			2	2.7	2.8	2.75	
			3	3.7	3.8	3.75	
			4	3.0	3.1	3.05	
			5	1.8	1.9	1.85	
			Average CAIs			2.85	
			Average CAI *			3.30	
CERCHAR Abrasiveness Index Classification						**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

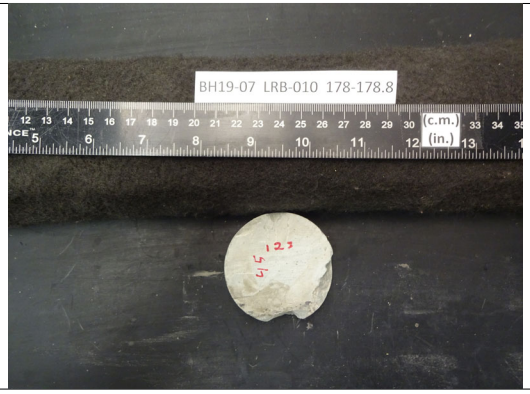
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	08/28/19	Checked By:	smd
Depth :	178.0-178.8 ft	Test Id:	518444		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-07	LRB-010	178-178.8 ft	1	2.9	3.0	2.95	
			2	2.1	2.2	2.15	
			3	1.2	1.3	1.25	
			4	1.7	1.8	1.75	
			5	2.6	2.5	2.55	
			Average CAIs			2.13	
			Average CAI *			2.59	
CERCHAR Abrasiveness Index Classification						**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



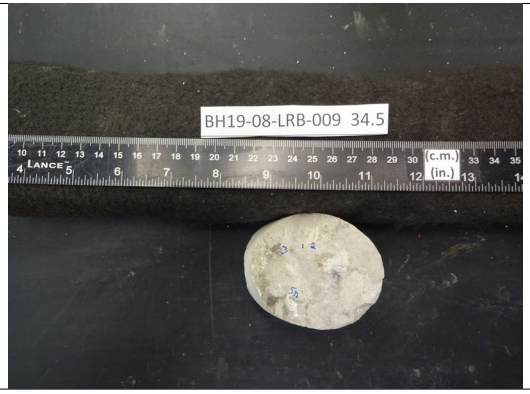
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-08	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	09/06/19	Checked By:	smd
Depth :	34.5 ft	Test Id:	519362		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-08	LRB-009	34.5 ft	1	0.8	0.7	0.75	
			2	0.5	0.6	0.55	
			3	0.8	0.9	0.85	
			4	0.3	0.3	0.30	
			5	0.3	0.4	0.35	
			Average CAIs			---	
			Average CAI			0.56	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Natural
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

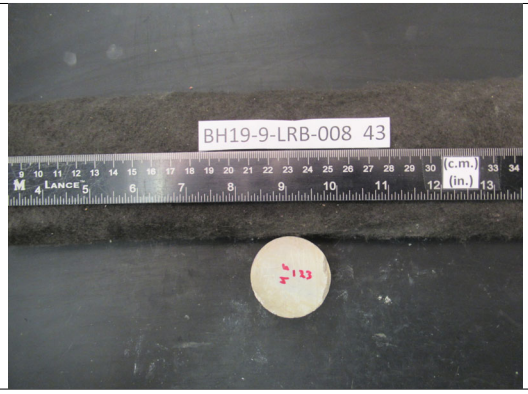
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	08/29/19	Checked By:	smd
Depth :	43.0 ft	Test Id:	519358		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-09	LRB-008	43.0 ft	1	3.5	3.6	3.55	
			2	3.1	3.2	3.15	
			3	3.2	3.3	3.25	
			4	4.9	4.8	4.85	
			5	2.8	2.9	2.85	
			Average CAIs			3.53	
			Average CAI *			3.97	
				CERCHAR Abrasiveness Index Classification		**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

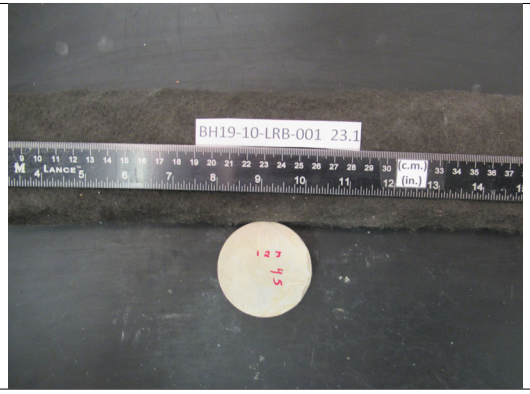
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-10	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	08/28/19	Checked By:	smd
Depth :	23.1 ft	Test Id:	519426		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-10	LRB-001	23.1 ft	1	1.5	1.4	1.45	
			2	2.4	2.5	2.45	
			3	1.9	2.0	1.95	
			4	2.9	3.0	2.95	
			5	1.9	2.0	1.95	
			Average CAIs			2.15	
			Average CAI *			2.61	
					CERCHAR Abrasiveness Index Classification	**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

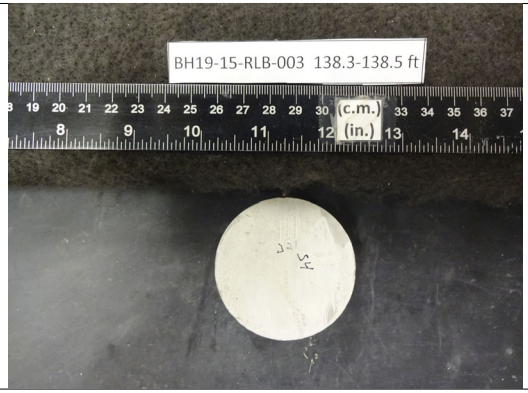
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	07/30/19	Checked By:	smd
Depth :	138.3-138.5 ft	Test Id:	514972		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-15	LRB-003	138.3-138.5 ft	1	1.1	1.3	1.20	
			2	1.2	1.3	1.25	
			3	1.4	1.5	1.45	
			4	1.1	1.2	1.15	
			5	1.1	1.2	1.15	
			Average CAIs			1.24	
			Average CAI *			1.71	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

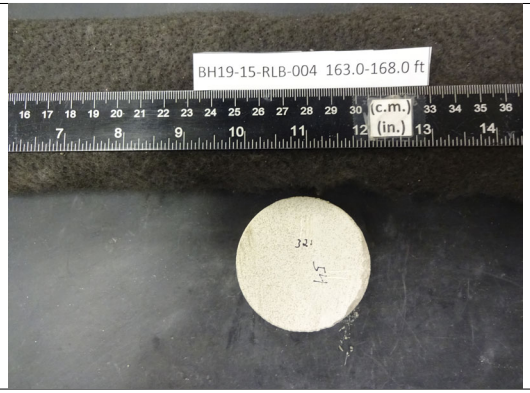
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	07/30/19	Checked By:	smd
Depth :	163.0-168.0 ft	Test Id:	514974		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-15	LRB-004	163.0-168.0 ft	1	0.6	0.5	0.55	
			2	1.0	0.9	0.95	
			3	1.0	1.1	1.05	
			4	1.0	0.9	0.95	
			5	0.6	0.7	0.65	
			Average CAIs			0.83	
			Average CAI *			1.30	
				CERCHAR Abrasiveness Index Classification		**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

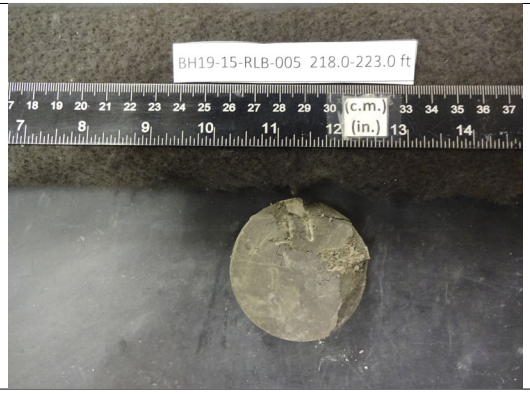
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	07/30/19	Checked By:	smd
Depth :	218.0-223.0 ft	Test Id:	514983		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-15	LRB-005	218.0-223.0 ft	1	0.1	0.2	0.15	
			2	0.2	0.4	0.30	
			3	0.2	0.3	0.25	
			4	0.3	0.4	0.35	
			5	0.5	0.6	0.55	
			Average CAIs			0.32	
			Average CAI *			0.80	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	07/30/19	Checked By:	smd
Depth :	253.1-253.5 ft	Test Id:	515080		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-16	LRB-008	253.1 - 253.5 ft	1	0.2	0.3	0.25	
			2	0.1	0.3	0.20	
			3	0.2	0.4	0.30	
			4	0.2	0.3	0.25	
			5	0.5	0.7	0.60	
			Average CAIs			0.32	
			Average CAI *			0.80	
CERCHAR Abrasiveness Index Classification						**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

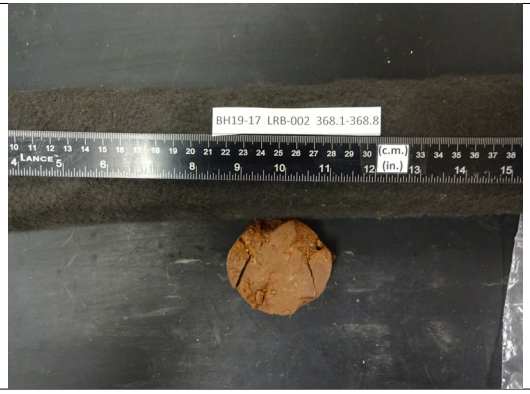
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	08/28/19	Checked By:	smd
Depth :	368.1-368.8 ft	Test Id:	518389		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-17	LRB-002	368.1-368.8 ft	1	0.1	0.2	0.15	
			2	0.1	0.1	0.10	
			3	0.2	0.1	0.15	
			4	0.2	0.1	0.15	
			5	0.2	0.2	0.20	
			Average CAIs			0.15	
			Average CAI *			0.63	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

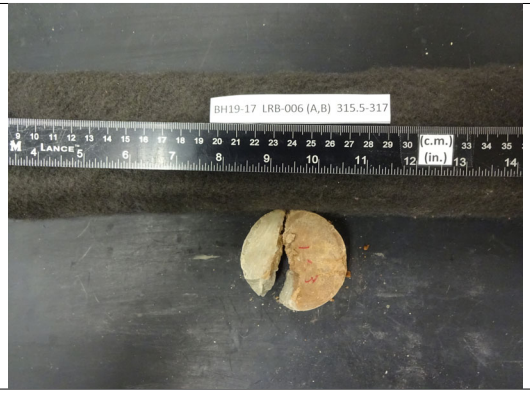
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006 (A,B)	Test Date:	08/28/19	Checked By:	smd
Depth :	315.5-317 ft	Test Id:	518401		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-17	LRB-006 (A,B)	315.5-317 ft	1	0.1	0.2	0.15	
			2	0.2	0.3	0.25	
			3	0.1	0.2	0.15	
			4	0.1	0.2	0.15	
			5	0.1	0.2	0.15	
			Average CAIs			0.17	
			Average CAI *			0.65	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

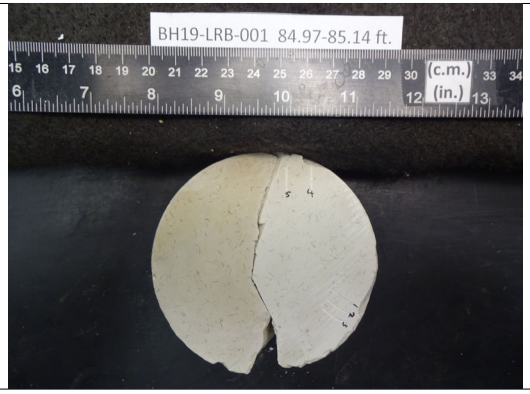
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-19	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	12/10/19	Checked By:	jsc
Depth :	84.97-85.14 ft	Test Id:	532805		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-19	LRB-001	84.97-85.14 ft.	1	0.5	0.8	0.65	
			2	0.4	0.7	0.55	
			3	0.4	0.5	0.45	
			4	0.3	0.3	0.30	
			5	0.4	0.7	0.55	
			Average CAIs			0.5	
			Average CAI *			0.98	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-19	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	12/10/19	Checked By:	smd
Depth :	159.32-159.55 ft	Test Id:	532815		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-19	LRB-007	159.36-159.46 ft	1	0.3	0.3	0.30	
			2	0.8	0.8	0.80	
			3	2.3	2.1	2.20	
			4	2.4	2.1	2.25	
			5	1.9	2.1	2.00	
			Average CAIs			1.51	
			Average CAI *			1.97	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

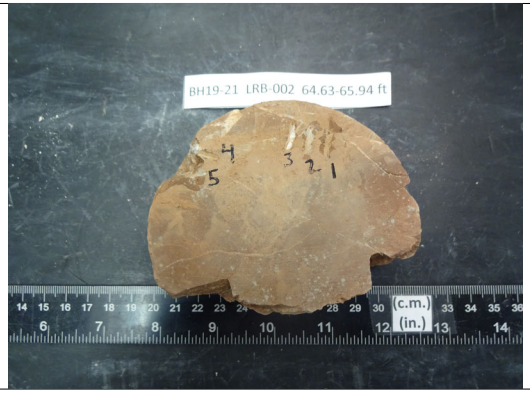
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/28/20	Checked By:	jsc
Depth :	64.63-65.94 ft	Test Id:	537746		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-21	LRB-002	64.63-65.94 ft	1	0.2	0.2	0.20	
			2	0.1	0.2	0.15	
			3	0.4	0.3	0.35	
			4	0.1	0.0	0.05	
			5	0.1	0.1	0.10	
			Average CAIs			0.17	
			Average CAI *			0.65	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/28/20	Checked By:	jsc
Depth :	180.12-180.45 ft	Test Id:	537760		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LRB-005	180.12-180.45 ft	1	0.1	0.1	0.10	
			2	0.0	0.0	0.00	
			3	0.1	0.1	0.10	
			4	0.0	0.0	0.00	
			5	0.1	0.2	0.15	
			Average CAIs			0.07	
			Average CAI *			0.55	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

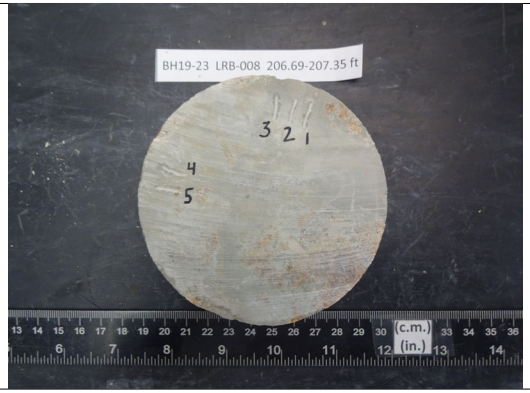
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	01/28/20	Checked By:	jsc
Depth :	206.69-207.35 ft	Test Id:	537766		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LRB-008	206.69-207.35 ft	1	0.1	0.2	0.15	
			2	0.8	1.0	0.90	
			3	0.1	0.1	0.10	
			4	0.3	0.2	0.25	
			5	0.7	0.4	0.55	
			Average CAIs			0.39	
			Average CAI *			0.87	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

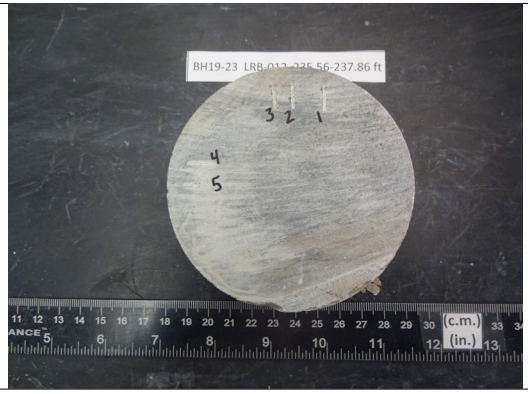
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-012	Test Date:	01/28/20	Checked By:	jsc
Depth :	235.56-237.86 ft	Test Id:	537772		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LRB-012	235.56-237.86 ft	1	0.9	0.9	0.90	
			2	0.1	0.1	0.10	
			3	0.1	0.1	0.10	
			4	0.3	0.1	0.20	
			5	0.0	0.0	0.00	
			Average CAIs			0.26	
			Average CAI *			0.74	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-005	Test Date:	02/11/20	Checked By:	jsc
Depth :	137.53 ft	Test Id:	534015		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LSB-005	137.53 ft	1	1.8	1.3	1.55	
			2	1.1	1.2	1.15	
			3	1.4	0.8	1.10	
			4	1.4	1.2	1.30	
			5	1.2	0.8	1.00	
			Average CAIs			1.22	
			Average CAI *			1.69	
CERCHAR Abrasiveness Index Classification						**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

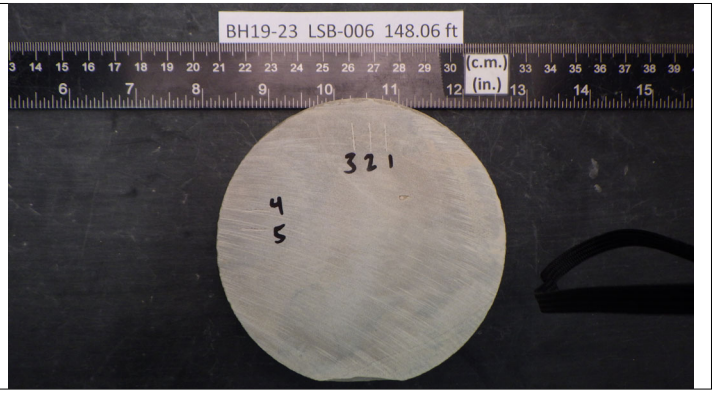
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-006	Test Date:	02/11/20	Checked By:	jsc
Depth :	148.06 ft	Test Id:	534016		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LSB-006	148.06 ft	1	1.1	2.2	1.65	
			2	2.2	1.3	1.75	
			3	2.0	1.5	1.75	
			4	1.1	1.7	1.40	
			5	1.9	1.0	1.45	
			Average CAIs			1.6	
			Average CAI *			2.06	
					CERCHAR Abrasiveness Index Classification	**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

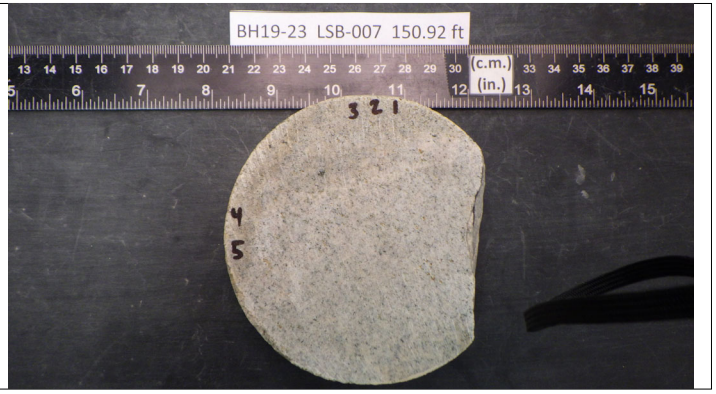
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-007	Test Date:	02/11/20	Checked By:	jsc
Depth :	150.92 ft	Test Id:	534017		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-23	LSB-007	150.92 ft	1	4.0	3.7	3.85	
			2	3.4	3.6	3.50	
			3	4.2	4.1	4.15	
			4	3.9	3.7	3.80	
			5	3.8	3.8	3.80	
			Average CAIs			3.82	
			Average CAI *			4.26	
CERCHAR Abrasiveness Index Classification						**Extreme abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	02/10/20	Checked By:	jsc
Depth :	249.34-251.31 ft	Test Id:	537791		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-24A	LRB-004	249.34-251.31 ft	1	0.3	0.2	0.25	
			2	0.8	0.8	0.80	
			3	0.1	0.0	0.05	
			4	0.1	0.1	0.10	
			5	0.0	0.0	0.00	
			Average CAIs			0.24	
			Average CAI *			0.72	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

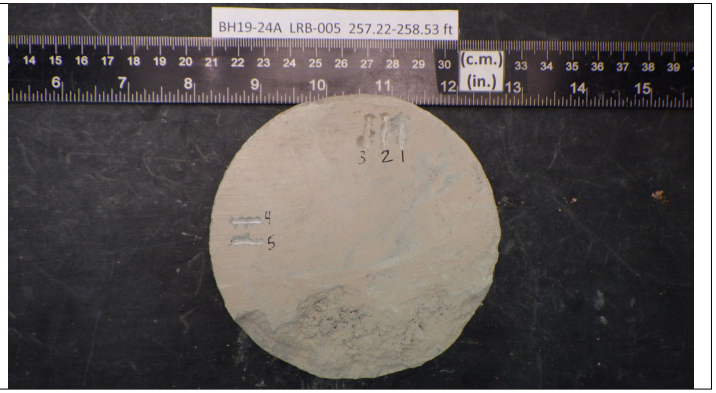
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	02/10/20	Checked By:	jsc
Depth :	257.22-258.53 ft	Test Id:	537796		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-24A	LRB-005	257.22-258.53 ft	1	0.6	0.4	0.50	
			2	0.0	0.1	0.05	
			3	2.0	1.8	1.90	
			4	0.5	0.5	0.50	
			5	0.2	0.2	0.20	
			Average CAIs			0.63	
			Average CAI *			1.10	
				CERCHAR Abrasiveness Index Classification		**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	02/10/20	Checked By:	jsc
Depth :	269.69-271.98 ft	Test Id:	537799		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-24A	LRB-006	269.69-271.98 ft	1	0.2	0.2	0.20	
			2	0.3	0.5	0.40	
			3	0.4	0.4	0.40	
			4	0.1	0.3	0.20	
			5	0.2	0.4	0.30	
			Average CAIs			0.3	
			Average CAI *			0.78	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

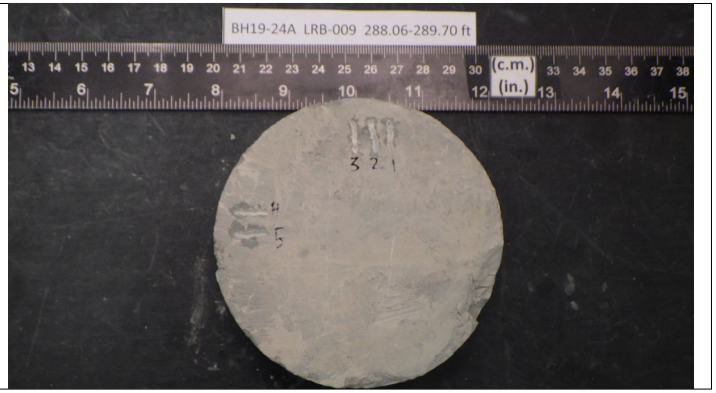
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	02/10/20	Checked By:	jsc
Depth :	288.06-289.70 ft	Test Id:	537807		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-24A	LRB-009	288.06-289.70 ft	1	0.0	0.0	0.00	
			2	0.1	0.1	0.10	
			3	0.0	0.3	0.15	
			4	0.1	0.2	0.15	
			5	0.3	0.0	0.15	
			Average CAIs			0.11	
			Average CAI *			0.59	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



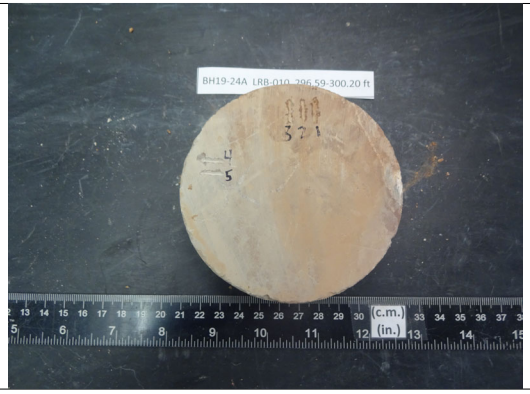
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/28/20	Checked By:	jsc
Depth :	296.59-300.20 ft	Test Id:	537813		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-24A	LRB-010	296.59-300.20 ft	1	0.2	0.3	0.25	
			2	0.0	0.0	0.00	
			3	0.1	0.2	0.15	
			4	0.0	0.0	0.00	
			5	0.0	0.0	0.00	
			Average CAIs			0.08	
			Average CAI *			0.56	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

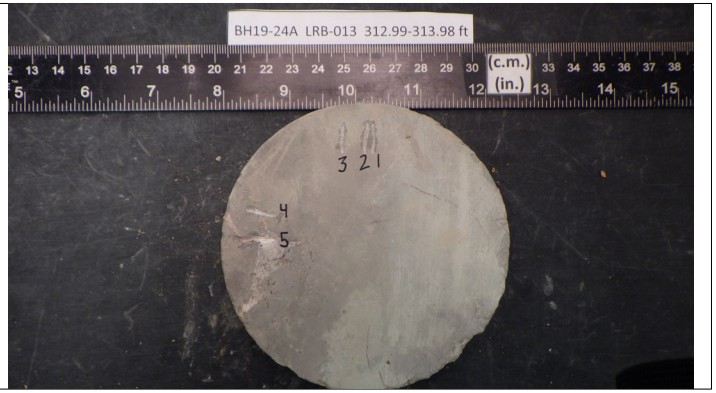
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-013	Test Date:	02/10/20	Checked By:	jsc
Depth :	312.99-313.98 ft	Test Id:	537824		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-24A	LRB-013	312.99-313.98 ft	1	0.0	0.0	0.00	
			2	0.0	0.1	0.05	
			3	0.2	0.1	0.15	
			4	0.0	0.1	0.05	
			5	0.0	0.0	0.00	
			Average CAIs			0.05	
			Average CAI *			0.53	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

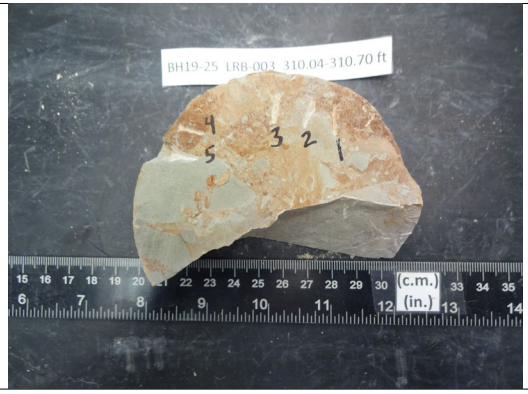
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	01/28/20	Checked By:	jsc
Depth :	310.04-310.70 ft	Test Id:	537832		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-25	LRB-003	310.04-310.70 ft	1	0.5	0.7	0.60	
			2	0.3	0.2	0.25	
			3	0.1	0.3	0.20	
			4	0.5	0.6	0.55	
			5	0.0	0.0	0.00	
			Average CAIs			0.32	
			Average CAI *			0.80	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

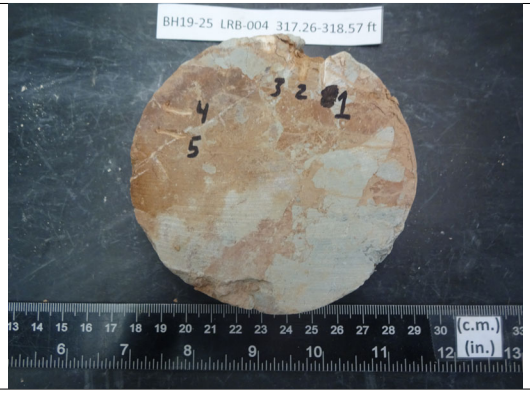
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/28/20	Checked By:	jsc
Depth :	317.26-318.57 ft	Test Id:	537835		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-25	LRB-004	317.26-318.58 ft	1	0.0	0.2	0.10	
			2	0.1	0.1	0.10	
			3	0.0	0.0	0.00	
			4	0.1	0.1	0.10	
			5	0.1	0.1	0.10	
			Average CAIs			0.08	
			Average CAI *			0.56	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

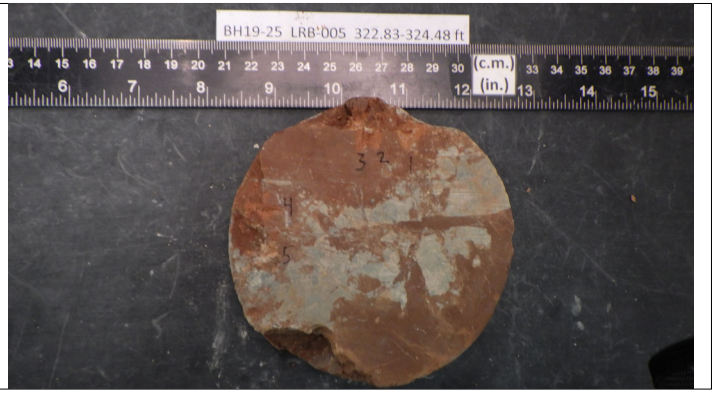
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	02/11/20	Checked By:	jsc
Depth :	322.83-324.48 ft	Test Id:	537877		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-25	LRB-005	322.83-324.48 ft	1	0.1	0.1	0.10	
			2	0.0	0.0	0.00	
			3	0.0	0.1	0.05	
			4	0.2	0.3	0.25	
			5	0.1	0.1	0.10	
			Average CAIs			0.1	
			Average CAI *			0.58	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



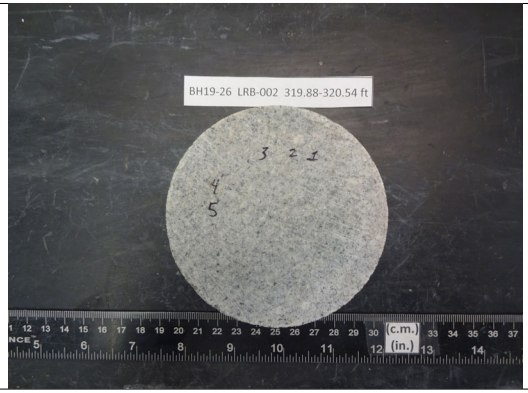
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/28/20	Checked By:	jsc
Depth :	319.88-320.54 ft	Test Id:	538115		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-26	LRB-002	319.88-320.54 ft	1	4.2	3.7	3.95	
			2	3.1	3.3	3.20	
			3	3.6	3.7	3.65	
			4	3.7	3.7	3.70	
			5	5.1	5.4	5.25	
			Average CAIs			3.95	
			Average CAI *			4.39	
CERCHAR Abrasiveness Index Classification						**Extreme abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/28/20	Checked By:	jsc
Depth :	333.01-333.99 ft	Test Id:	538122		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-26	LRB-004	333.01-333.99 ft	1	0.4	1.1	0.75	
			2	0.0	0.2	0.10	
			3	0.3	0.0	0.15	
			4	1.7	1.2	1.45	
			5	3.5	3.0	3.25	
			Average CAIs			1.14	
			Average CAI *			1.61	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

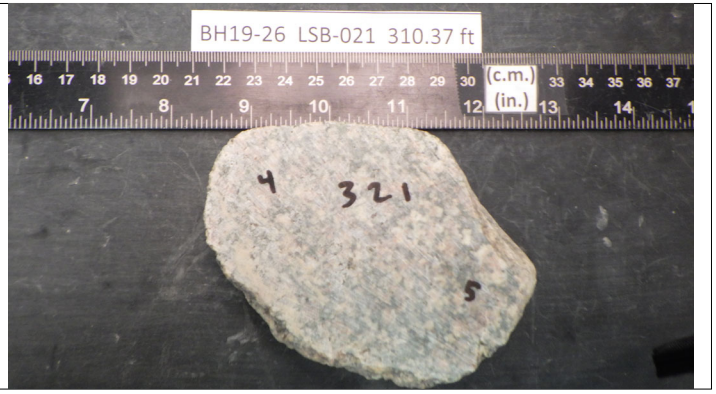
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-021	Test Date:	02/11/20	Checked By:	jsc
Depth :	310.37 ft	Test Id:	537540		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-26	LSB-021	310.37 ft	1	3.8	3.7	3.75	
			2	3.7	3.5	3.60	
			3	3.8	3.3	3.55	
			4	3.6	3.5	3.55	
			5	3.1	3.3	3.20	
			Average CAIs			3.53	
			Average CAI *			3.97	
CERCHAR Abrasiveness Index Classification						**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	01/28/20	Checked By:	jsc
Depth :	292.98-294.62 ft	Test Id:	538124		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-27	LRB-001	292.98-294.62 ft	1	0.1	0.1	0.10	
			2	0.2	0.1	0.15	
			3	0.0	0.3	0.15	
			4	0.3	0.5	0.40	
			5	0.2	0.2	0.20	
			Average CAIs			0.2	
			Average CAI *			0.68	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/28/20	Checked By:	jsc
Depth :	300.20-300.52 ft	Test Id:	538128		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-27	LRB-002	300.20-300.52 ft	1	0.1	0.3	0.20	
			2	0.2	0.1	0.15	
			3	0.4	0.0	0.20	
			4	0.1	0.0	0.05	
			5	0.2	0.1	0.15	
			Average CAIs			0.15	
			Average CAI *			0.63	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	02/11/20	Checked By:	jsc
Depth :	310.04-310.70 ft	Test Id:	538136		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-27	LRB-004	310.04-310.70 ft	1	0.0	0.0	0.00	
			2	0.4	0.4	0.40	
			3	0.1	0.0	0.05	
			4	0.2	0.1	0.15	
			5	0.1	0.1	0.10	
			Average CAIs			0.14	
			Average CAI *			0.62	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-010	Test Date:	02/11/20	Checked By:	jsc
Depth :	205.54 ft	Test Id:	533980		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-27	LSB-010	205.54 ft	1	3.8	3.6	3.70	
			2	2.9	3.5	3.20	
			3	3.9	4.1	4.00	
			4	3.9	3.7	3.80	
			5	3.8	3.8	3.80	
			Average CAIs			3.7	
			Average CAI *			4.14	
CERCHAR Abrasiveness Index Classification						**Extreme abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

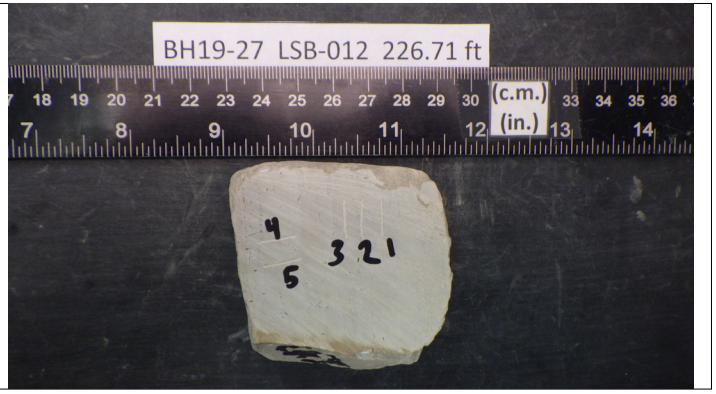
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	bag	Tested By:	tlm
Sample ID:	LSB-012	Test Date:	02/11/20	Checked By:	jsc
Depth :	226.71 ft	Test Id:	533981		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-27	LSB-012	226.71 ft	1	1.0	0.9	0.95	
			2	1.3	1.3	1.30	
			3	1.0	0.7	0.85	
			4	1.0	1.2	1.10	
			5	1.2	0.7	0.95	
			Average CAIs			1.03	
			Average CAI *			1.50	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	02/10/20	Checked By:	jsc
Depth :	172.24-173.23 ft	Test Id:	538145		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-28	LRB-001	172.24-173.23 ft	1	0.1	0.1	0.10	
			2	0.0	0.0	0.00	
			3	0.1	0.0	0.05	
			4	0.2	0.3	0.25	
			5	0.2	0.2	0.20	
			Average CAIs			0.12	
			Average CAI *			0.60	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

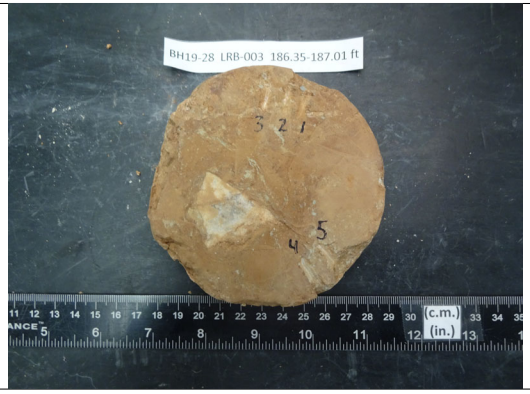
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	01/28/20	Checked By:	jsc
Depth :	186.35-187.01 ft	Test Id:	538154		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-28	LRB-003	186.35-187.01 ft	1	0.0	0.0	0.00	
			2	0.3	0.1	0.20	
			3	0.2	0.1	0.15	
			4	0.0	0.0	0.00	
			5	0.0	0.0	0.00	
			Average CAIs			0.07	
			Average CAI *			0.55	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



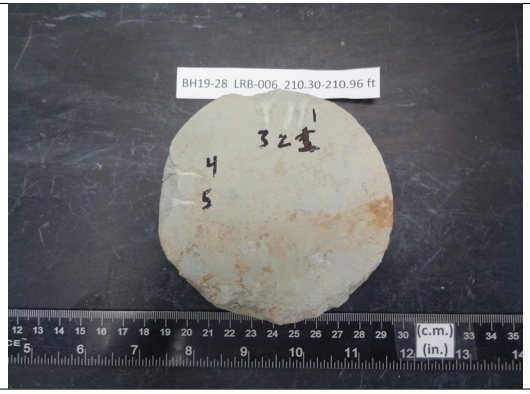
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	01/28/20	Checked By:	jsc
Depth :	210.30-210.96 ft	Test Id:	538167		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-28	LRB-006	210.30-210.96 ft	1	0.7	1.5	1.10	
			2	0.0	0.1	0.05	
			3	0.2	0.3	0.25	
			4	0.1	0.1	0.10	
			5	0.1	0.1	0.10	
			Average CAIs			0.32	
			Average CAI *			0.80	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



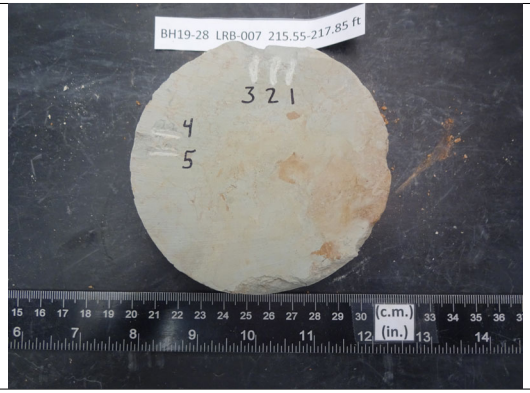
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	01/28/20	Checked By:	jsc
Depth :	215.55-217.85 ft	Test Id:	538169		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-28	LRB-007	215.55-217.85 ft	1	0.0	0.0	0.00	
			2	0.0	0.0	0.00	
			3	0.0	0.1	0.05	
			4	0.0	0.0	0.00	
			5	0.0	0.0	0.00	
			Average CAIs			0.01	
			Average CAI *			0.49	
				CERCHAR Abrasiveness Index Classification		**Very low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	02/10/20	Checked By:	jsc
Depth :	239.83-241.14 ft	Test Id:	538179		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-28	LRB-010	239.83-241.14 ft	1	0.1	0.4	0.25	
			2	0.0	0.0	0.00	
			3	0.2	0.2	0.20	
			4	0.2	0.1	0.15	
			5	0.2	0.2	0.20	
			Average CAIs			0.16	
			Average CAI *			0.64	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

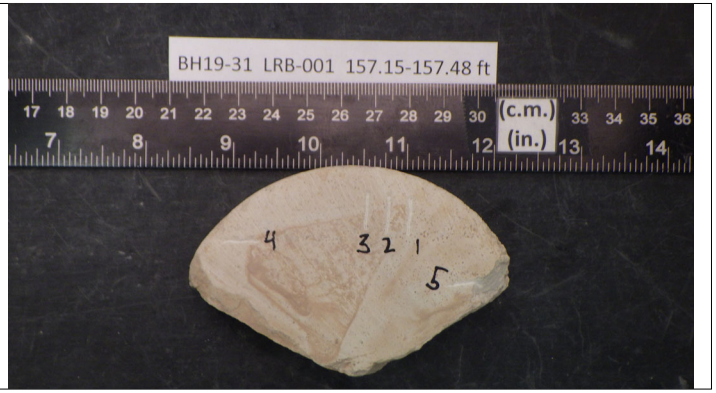
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	02/11/20	Checked By:	jsc
Depth :	157.15-157.48 ft	Test Id:	538324		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-31	LRB-001	157.15-157.48 ft	1	0.4	0.5	0.45	
			2	0.8	0.5	0.65	
			3	0.7	0.5	0.60	
			4	0.9	1.5	1.20	
			5	0.7	0.8	0.75	
			Average CAIs			0.73	
			Average CAI *			1.20	
				CERCHAR Abrasiveness Index Classification		**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	02/10/20	Checked By:	jsc
Depth :	166.34-166.67 ft	Test Id:	538328		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-31	LRB-003	166.34-166.67 ft	1	1.4	1.4	1.40	
			2	4.0	4.0	4.00	
			3	1.1	1.3	1.20	
			4	1.7	3.5	2.60	
			5	1.6	1.1	1.35	
			Average CAIs			2.11	
			Average CAI *			2.57	
				CERCHAR Abrasiveness Index Classification		**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/28/20	Checked By:	jsc
Depth :	195.87-197.83 ft	Test Id:	538333		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-31	LRB-005	195.87-197.83 ft	1	0.3	0.2	0.25	
			2	0.2	0.1	0.15	
			3	0.1	0.3	0.20	
			4	0.0	0.3	0.15	
			5	0.2	0.2	0.20	
			Average CAIs			0.19	
			Average CAI *			0.67	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

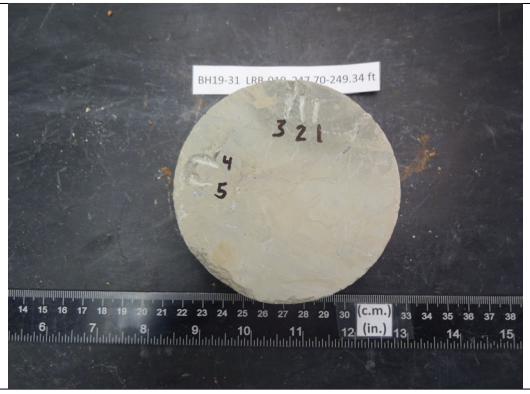
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/28/20	Checked By:	jsc
Depth :	247.70-249.34 ft	Test Id:	538352		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-31	LRB-010	247.70-249.34 ft	1	0.0	0.0	0.00	
			2	0.0	0.0	0.00	
			3	0.2	0.1	0.15	
			4	0.1	0.1	0.10	
			5	0.3	0.1	0.20	
			Average CAIs			0.09	
			Average CAI *			0.57	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



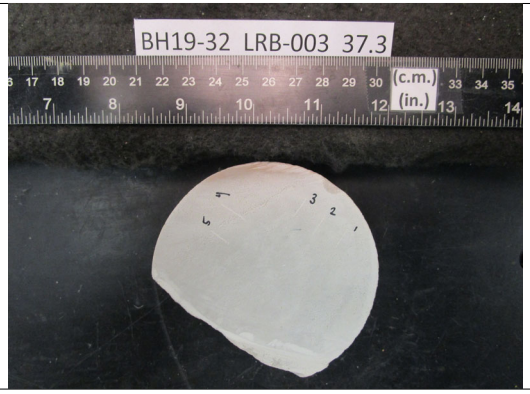
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	11/05/19	Checked By:	smd
Depth :	122.38 ft	Test Id:	527305		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-32	LRB-003	122.38 ft	1	2.2	2.5	2.35	
			2	2.5	2.7	2.60	
			3	2.1	1.9	2.00	
			4	2.0	2.2	2.10	
			5	3.1	2.5	2.80	
			Average CAIs			2.37	
			Average CAI *			2.83	
CERCHAR Abrasiveness Index Classification						**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	11/05/19	Checked By:	smd
Depth :	124.67 ft	Test Id:	527307		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-32	LRB-004	124.67 ft	1	2.2	3.0	2.60	
			2	2.5	2.1	2.30	
			3	2.3	2.1	2.20	
			4	2.6	3.0	2.80	
			5	2.3	2.0	2.15	
			Average CAIs			2.41	
			Average CAI *			2.87	
				CERCHAR Abrasiveness Index Classification		**High abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

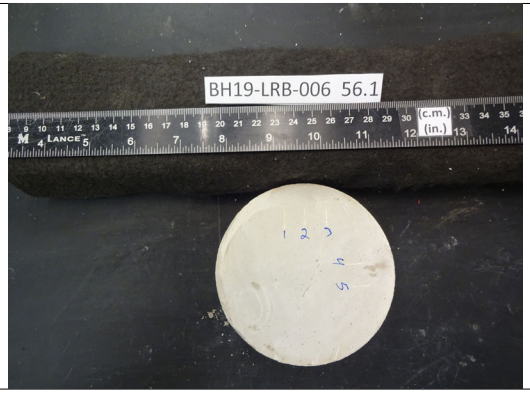
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	09/06/19	Checked By:	smd
Depth :	184.05 ft	Test Id:	519176		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-32	LRB-006	184.05 ft	1	1.7	1.8	1.75	
			2	0.9	1.0	0.95	
			3	0.9	1.0	0.95	
			4	1.5	1.7	1.60	
			5	0.8	0.7	0.75	
			Average CAIs			1.2	
			Average CAI *			1.67	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

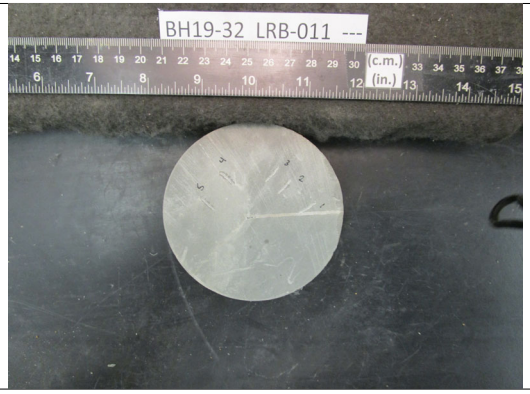
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-011	Test Date:	11/05/19	Checked By:	smd
Depth :	196.9-197.2 ft	Test Id:	527322		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-32	LRB-011	196.9-197.2 ft	1	0.1	0.2	0.15	
			2	0.3	0.2	0.25	
			3	0.3	0.3	0.30	
			4	0.4	0.6	0.50	
			5	0.9	0.5	0.70	
			Average CAIs			0.38	
			Average CAI *			0.86	
CERCHAR Abrasiveness Index Classification						**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-33	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	09/06/19	Checked By:	smd
Depth :	153.05 ft	Test Id:	519182		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-33	LRB-005	153.05 ft	1	0.2	0.2	0.20	
			2	0.3	0.4	0.35	
			3	0.2	0.3	0.25	
			4	0.2	0.3	0.25	
			5	0.3	0.4	0.35	
			Average CAIs			0.28	
			Average CAI *			0.76	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

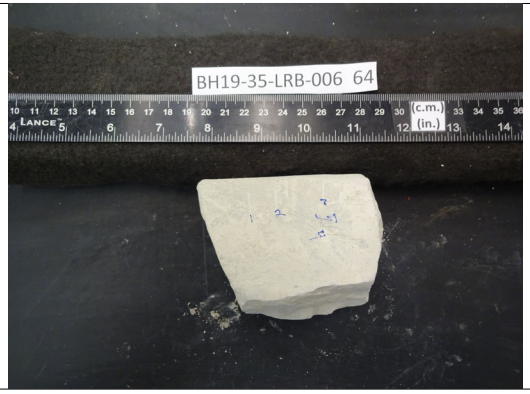
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-35	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	09/06/19	Checked By:	smd
Depth :	209.97 ft	Test Id:	519208		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-35	LRB-006	209.97 ft	1	1.8	1.9	1.85	
			2	0.9	1.1	1.00	
			3	2.4	2.3	2.35	
			4	0.3	0.4	0.35	
			5	0.4	0.5	0.45	
			Average CAIs			---	
			Average CAI			1.20	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Natural
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



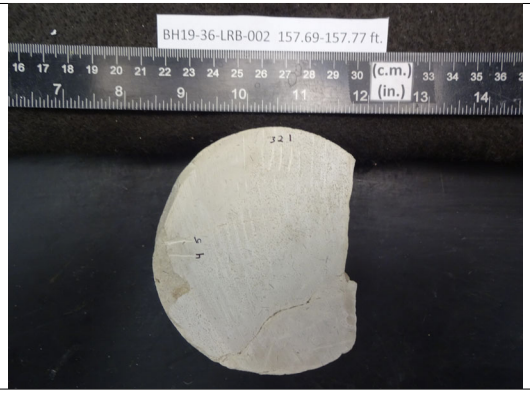
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-36	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	12/10/19	Checked By:	jsc
Depth :	157.48-157.81 ft	Test Id:	532720		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-36	LRB-002	157.69-157.77 ft.	1	0.7	1.0	0.85	
			2	1.4	1.2	1.30	
			3	1.0	1.3	1.15	
			4	2.1	1.8	1.95	
			5	0.4	0.3	0.35	
			Average CAIs			1.12	
			Average CAI *			1.59	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

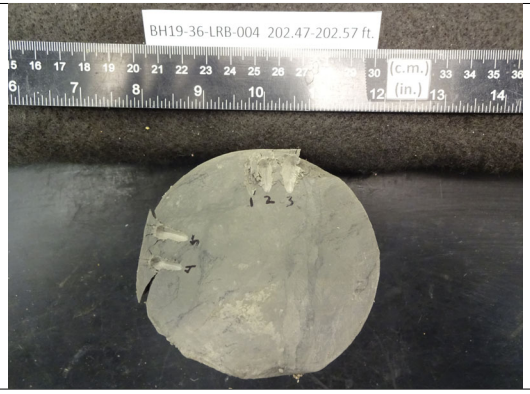
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-36	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	12/10/19	Checked By:	smd
Depth :	202.43-203.74	Test Id:	532772		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-36	LRB-004	202.47-202.57 ft	1	0.0	0.0	0.00	
			2	0.0	0.0	0.00	
			3	0.0	0.0	0.00	
			4	0.0	0.0	0.00	
			5	0.0	0.0	0.00	
			Average CAIs			0	
			Average CAI *			0.48	
				CERCHAR Abrasiveness Index Classification		**Very low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 40/42 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	08/28/19	Checked By:	smd
Depth :	201.2-201.5 ft	Test Id:	518383		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-37	LRB-005	201.2-201.5 ft	1	0.2	0.2	0.20	
			2	0.4	0.5	0.45	
			3	0.2	0.3	0.25	
			4	0.1	0.2	0.15	
			5	0.5	0.6	0.55	
			Average CAIs			0.32	
			Average CAI *			0.80	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:

GeoTesting EXPRESS

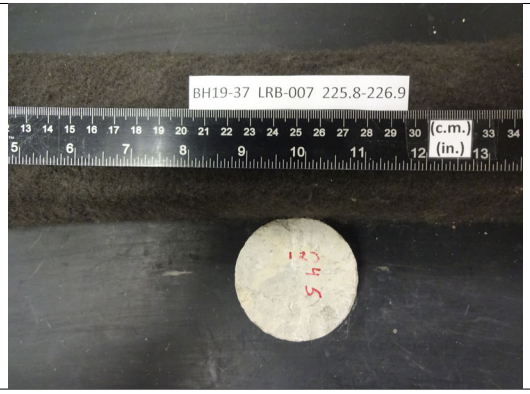
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	09/09/19	Checked By:	smd
Depth :	225.8-226.9 ft	Test Id:	518516		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-37	LRB-007	225.8-226.9 ft	1	0.3	0.3	0.30	
			2	0.2	0.3	0.25	
			3	0.2	0.1	0.15	
			4	0.5	0.5	0.50	
			5	1.2	1.3	1.25	
			Average CAIs			0.49	
			Average CAI *			0.97	
				CERCHAR Abrasiveness Index Classification		**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



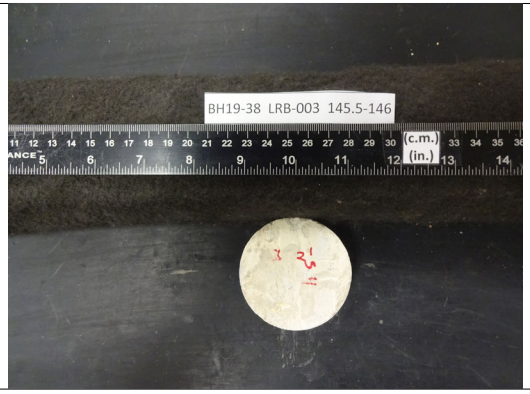
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	08/28/19	Checked By:	smd
Depth :	145.5-146 ft	Test Id:	518415		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-38	LRB-003	145.5-146 ft	1	0.5	0.6	0.55	
			2	0.5	0.6	0.55	
			3	0.8	0.7	0.75	
			4	0.2	0.3	0.25	
			5	1.2	1.3	1.25	
			Average CAIs			0.67	
			Average CAI *			1.14	
					CERCHAR Abrasiveness Index Classification	**Medium abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



GeoTesting EXPRESS

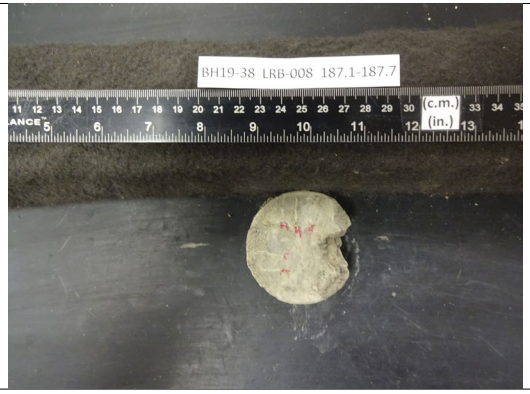
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	08/28/19	Checked By:	smd
Depth :	187.1-187.7 ft	Test Id:	518424		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Abrasiveness of Rock Using the Cerchar Method by ASTM D7625

Boring ID	Sample ID	Depth	Stylus No	Reading 1	Reading 2	Average	Comments
BH19-38	LRB-008	187.1-187.7 ft	1	0.2	0.3	0.25	
			2	0.5	0.6	0.55	
			3	0.3	0.4	0.35	
			4	0.7	0.8	0.75	
			5	0.6	0.7	0.65	
			Average CAIs			0.51	
			Average CAI *			0.98	
					CERCHAR Abrasiveness Index Classification	**Low abrasiveness**	

Notes

Test Surface: Saw Cut
Moisture Condition: As Received
Apparatus Type: Original CERCHAR
Stylus Hardness: Rockwell Hardess 54/56 HRC
Stylus Displacement Relative to Rock Fabric:
Styli 1-3: Normal; Styli 4-5: Parallel
* CAI = (0.99 * CAIs) + 0.48
CAIs = CERCHAR index for smooth (saw cut) surface
CAI = CERCHAR index for natural surface
Comments:



Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-012	Test Date:	08/23/19	Checked By:	smd
Depth :	194.9-195.9 ft	Test Id:	518451		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-07	LRB-012	194.9-195.9 ft	See photograph(s)	58.0	21	5.6	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	07/31/19	Checked By:	smd
Depth :	223.5-224.0 ft	Test Id:	514991		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-15	LRB-006	223.5 - 224.0 ft	See photograph(s)	63.2	21	9.7	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	07/31/19	Checked By:	smd
Depth :	252.1-253.1 ft	Test Id:	514949		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-16	LRB-007	252.1 - 253.1 ft	See photograph(s)	49.0	21	12.1	Type II

Comments: Description of the appearance of the fragments retained in the drum:

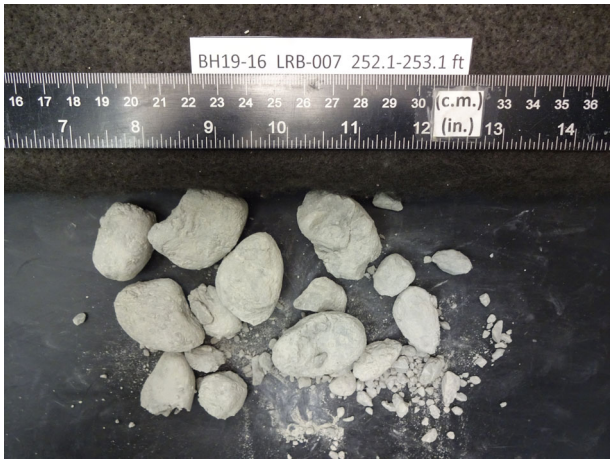
Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:



GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006 (A,B)	Test Date:	08/23/19	Checked By:	smd
Depth :	315.5-317 ft	Test Id:	518402		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-17	LRB-006 (A,B)	315.5-317 ft	See photograph(s)	41.0	21	11.0	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-19	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	12/18/19	Checked By:	smd
Depth :	99.74-100.23 ft	Test Id:	532879		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
---	BH19-19-LRB-003	99.74-100.23 ft	See photograph(s)	62.6	21	1.8	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	01/24/20	Checked By:	smd
Depth :	215.22-215.55 ft	Test Id:	537769		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-23	LRB-009	215.22 - 215.55 ft	See photograph(s)	7.2	21	6.7	Type III

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/24/20	Checked By:	smd
Depth :	249.34-251.31 ft	Test Id:	537794		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-24A	LRB-004	249.34 - 251.55 ft	See photograph(s)	28.4	20	7.2	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-013	Test Date:	01/24/20	Checked By:	smd
Depth :	312.99-313.98 ft	Test Id:	537826		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-24A	LRB-013	312.99 - 313.98 ft	See photograph(s)	76.9	20	5.2	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/24/20	Checked By:	smd
Depth :	308.73-309.71 ft	Test Id:	537831		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-25	LRB-002	308.73 - 309.71 ft	See photograph(s)	40.4	20	7.9	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	01/24/20	Checked By:	smd
Depth :	292.98-294.62 ft	Test Id:	538126		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-27	LRB-001	292.98 - 294.62 ft	See photograph(s)	16.5	20	14.7	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/24/20	Checked By:	smd
Depth :	247.70-249.34 ft	Test Id:	538354		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
BH19-31	LRB-010	247.70 - 249.34 ft	See photograph(s)	70.6	20	1.9	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-35	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	08/30/19	Checked By:	smd
Depth :	215.72 ft	Test Id:	519199		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
---	BH19-35-LRB-002	215.72 ft	See photograph(s)	22.6	21	10.0	Type III

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-35	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	08/30/19	Checked By:	smd
Depth :	189.67 ft	Test Id:	519203		
Test Comment:	---				
Visual Description:	See photograph(s)				
Sample Comment:	---				

Slake Durability of Shales and Similar Weak Rocks by ASTM D4644

Boring ID	Sample ID	Depth	Visual Description	Slake Durability Index %	Average water temperature, degrees C	As-Received Water Content %	Description of Fragments
---	BH19-35-LRB-004	189.67 ft	See photograph(s)	27.8	21	10.9	Type II

Comments: Description of the appearance of the fragments retained in the drum:

Type I - Retained pieces remain virtually unchanged

Type II - Retained materials consist of large and small fragments

Type III - Retained material is exclusively small fragments

Before Test:

After Test:

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits Of Mackinac
GTX #:	310187
Test Date:	1/21/2020-2/6/2020
Tested By:	tlm
Checked By:	smd

Total Hardness of Intact Rock Core Specimens

Boring ID	Sample ID	Depth, ft	Specimen Diameter, in	Specimen Length, in	Schmidt Hammer (L-type), H_R	Modified Taber Abrasion, H_A	Total Hardness, H_T
BH19-23	LSB-012	235.56-237.86	3.96	9.10	45.0	0.416	29.0

Notes: Testing performed in accordance with Tarkoy, Peter J., 1985

All specimens tested at standard laboratory temperature.

Samples oven dried at 105° C.

$$H_T = H_R x \sqrt{H_A}$$

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	01/30/20	Checked By:	smd
Depth :	161.75-164.04 ft	Test Id:	537751		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Direct Tensile Strength of Rock ASTM D2936

Specimen Depth	Diameter, in	Length, in	Area, sq in	Specimen Mass, grams	Bulk Density, pcf	Peak Load, lbs	Tensile Strength, psi
161.75 - 164.04 ft	3.94	8.77	12.19	3700	132	140	010

Notes: Density determined on rock core samples by measuring dimensions and weight and then calculating.
Specimens tested at the as-received moisture content
Rate of strain was 0.005 in./minute
Tensile Strength reported to the nearest 5 psi

After cutting

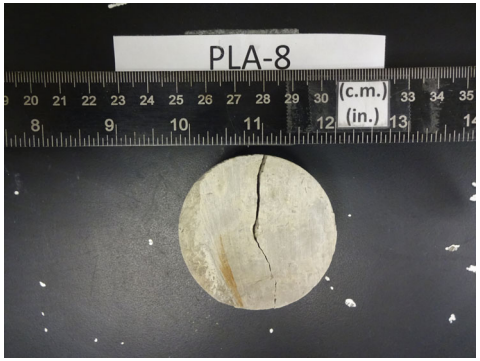
After break

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	08/21/19	Checked By:	smd
Depth :	80.9-81.2 ft	Test Id:	518430		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-8	80.9-81.2 ft	2.4	1.12	1,016	3.41	1.85	298	0.972	289	19	5,650

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

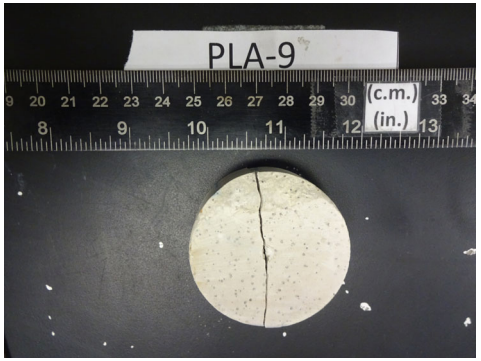
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	08/21/19	Checked By:	smd
Depth :	113-113.3 ft	Test Id:	518433		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-9	113-113.3 ft	2.4	0.96	1,027	2.92	1.71	351	0.939	330	18	6,320

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

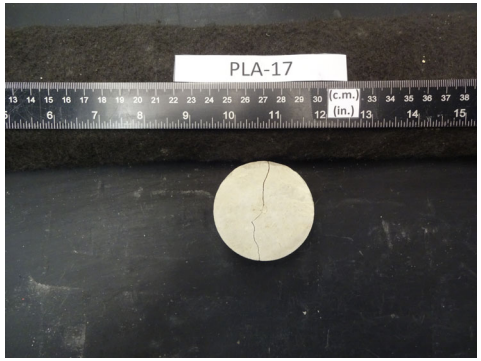
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-08	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	08/27/19	Checked By:	smd
Depth :	27.83 ft	Test Id:	519331		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-17	27.83 ft	2.4	1.13	857	3.43	1.85	250	0.973	243	19	4,740

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

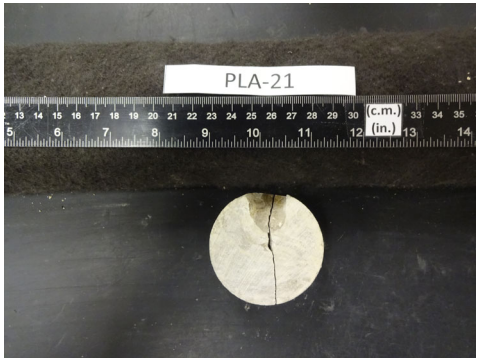
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-08	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-014	Test Date:	08/27/19	Checked By:	smd
Depth :	71.1 ft	Test Id:	519422		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-21	71.1 ft	2.39	1.12	2,799	3.41	1.85	820	0.972	797	19	15,600

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

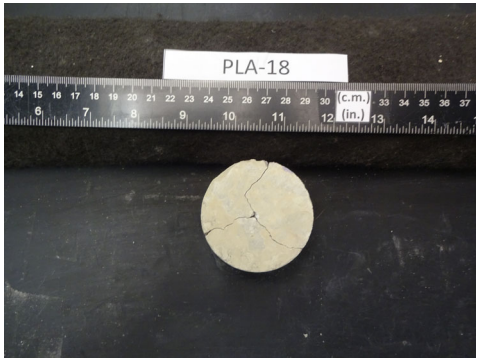
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	08/27/19	Checked By:	smd
Depth :	38.5 ft	Test Id:	519357		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-18	38.5 ft	2.39	1.33	1,796	4.04	2.01	444	1.010	448	19	8,440

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

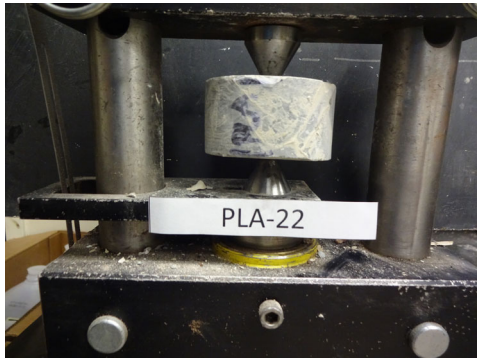
F = the size correction factor

Is(50) = the size corrected point load strength index

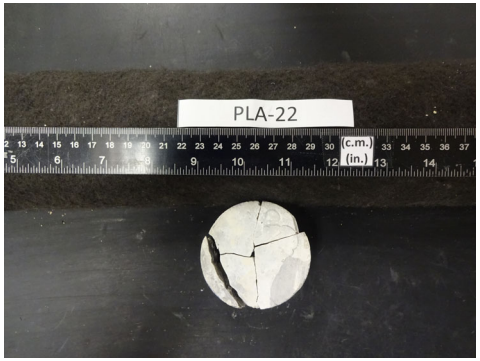
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-016	Test Date:	08/27/19	Checked By:	smd
Depth :	81.0 ft	Test Id:	519320		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-22	81.0 ft	2.38	1.31	490	3.96	1.99	124	1.005	124	19	2,350



Before



After

Intact material and Discontinuity Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

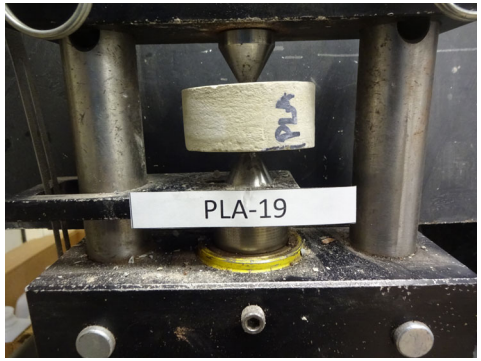
F = the size correction factor

Is(50) = the size corrected point load strength index

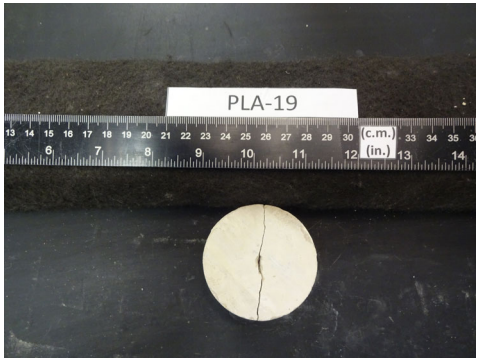
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-10	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	08/27/19	Checked By:	smd
Depth :	41.1 ft	Test Id:	519829		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-19	41.1 ft	2.38	1.10	1,675	3.35	1.83	500	0.968	484	19	9,500



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-10	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	08/27/19	Checked By:	smd
Depth :	87.1 ft	Test Id:	519449		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-23	87.1 ft	2.39	1.16	2,819	3.53	1.88	798	0.979	781	19	15,200

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

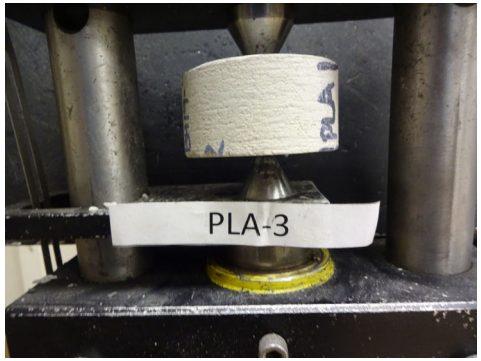
F = the size correction factor

Is(50) = the size corrected point load strength index

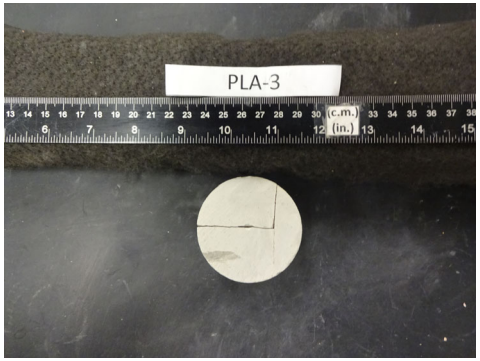
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	07/30/19	Checked By:	smd
Depth :	132.2-132.5 ft	Test Id:	514970		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-3	132.21 - 132.31 ft	2.37	1.23	1,722	3.70	1.92	465	0.990	460	19	8,840



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

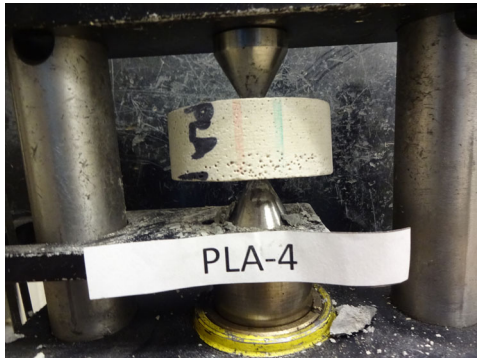
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP		
Project:	Line 5 Replacement and Tunnel Project		
Location:	Straits of Mackinac		Project No: GTX-310187
Boring ID:	BH19-15	Sample Type: cylinder	Tested By: tlm
Sample ID:	LRB-004	Test Date: 07/30/19	Checked By: smd
Depth :	163.0-168.0 ft	Test Id: 514977	
Test Comment:	---		
Visual Description:	---		
Sample Comment:	---		

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-4	165.93 - 166.02 ft	2.4	0.97	1,529	2.96	1.72	517	0.941	486	18	9,300



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

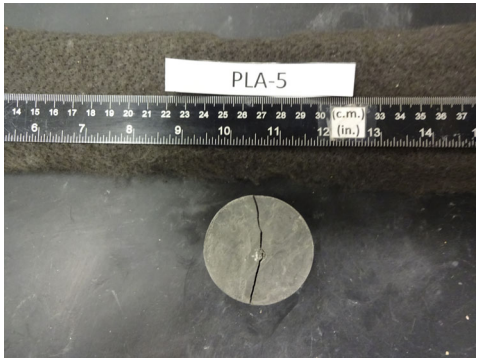
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	07/30/19	Checked By:	smd
Depth :	218.0-223.0 ft	Test Id:	514985		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-5	219.22 - 219.31 ft	2.36	1.12	286	3.37	1.84	85	0.969	82	19	1,610

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

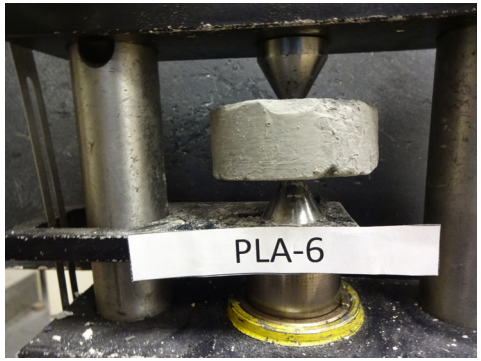
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	07/30/19	Checked By:	smd
Depth :	208.2-208.5 ft	Test Id:	514945		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-6	208.25 - 208.35 ft	2.39	0.97	115	2.95	1.72	39	0.941	37	18	699



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	07/30/19	Checked By:	smd
Depth :	233.5-234.1 ft	Test Id:	514947		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-7	233.62 - 233.71 ft	2.33	0.98	103	2.89	1.70	36	0.936	34	18	644

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

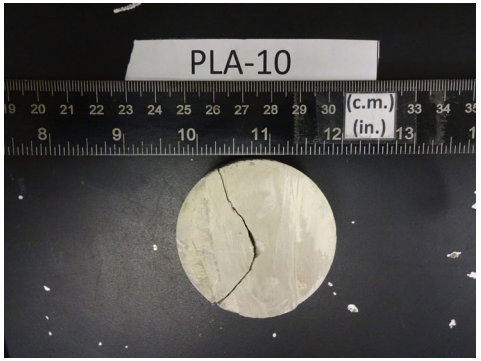
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	08/21/19	Checked By:	smd
Depth :	250-250.5 ft	Test Id:	518506		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-10	250-250.5 ft	2.39	1.33	1,005	4.04	2.01	249	1.009	251	19	4,730

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

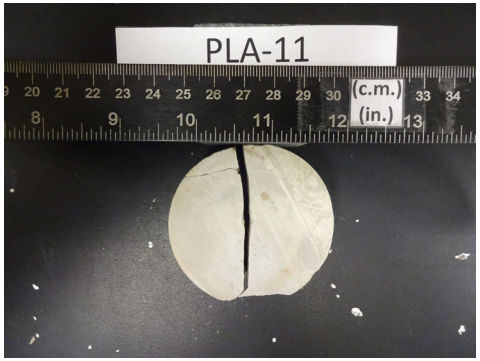
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-011	Test Date:	08/21/19	Checked By:	smd
Depth :	221.1-221.5 ft	Test Id:	518507		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-11	221.1-221.5 ft	2.39	0.99	2,046	3.01	1.74	679	0.945	642	18	12,200

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-013	Test Date:	08/27/19	Checked By:	smd
Depth :	159.2-159.7 ft	Test Id:	518509		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-24	159.2-159.7 ft	2.39	1.08	1,419	3.29	1.81	431	0.964	415	19	8,190

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

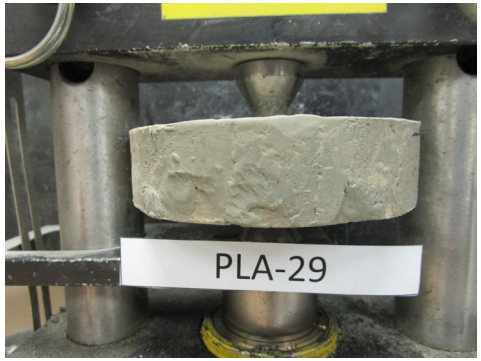
F = the size correction factor

Is(50) = the size corrected point load strength index

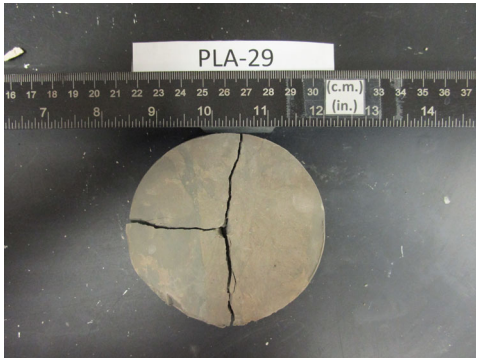
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-19	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	12/19/19	Checked By:	smd
Depth :	166.54-167.26 ft	Test Id:	532890		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-29	166.85 - 166.97 ft	4	1.20	196	6.12	2.47	32	1.108	35	19	607



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-21	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	01/27/20	Checked By:	smd
Depth :	55.77-56.76 ft	Test Id:	537742		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-31	55.77 - 56.76 ft	3.93	1.51	501	7.53	2.74	67	1.161	77	21	1,400

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

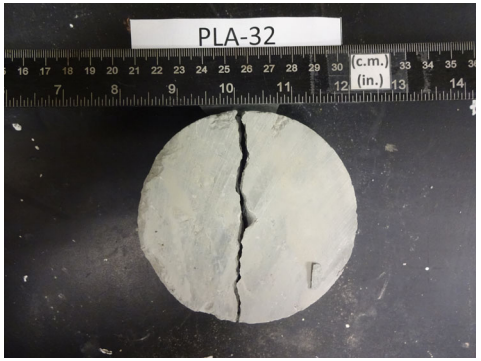
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/27/20	Checked By:	smd
Depth :	180.12-180.45 ft	Test Id:	537761		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-32	180.12 - 180.45 ft	3.96	1.59	492	8.01	2.83	61	1.177	72	21	1,290

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

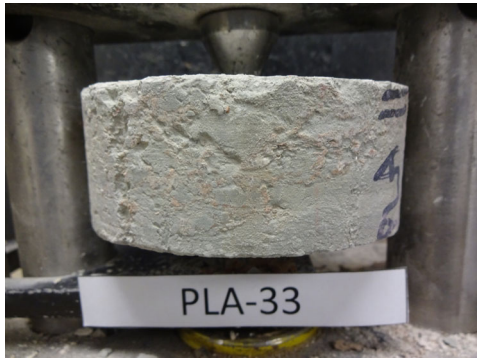
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	01/27/20	Checked By:	smd
Depth :	190.29-190.94 ft	Test Id:	537764		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-33	190.29 - 190.94 ft	3.93	1.62	499	8.09	2.84	62	1.180	73	21	1,300



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

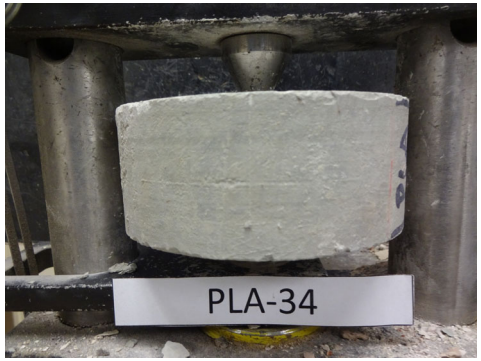
F = the size correction factor

Is(50) = the size corrected point load strength index

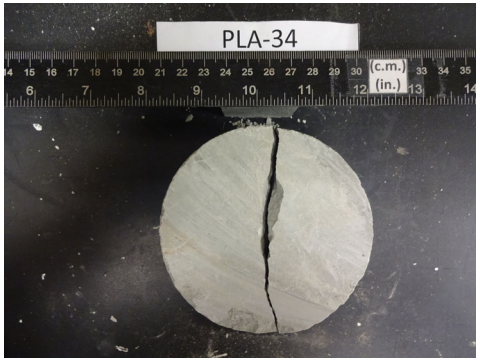
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	01/27/20	Checked By:	smd
Depth :	194.88-195.54 ft	Test Id:	537765		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-34	194.88 - 195.54 ft	3.95	1.63	1,030	8.21	2.86	125	1.184	149	21	2,630



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

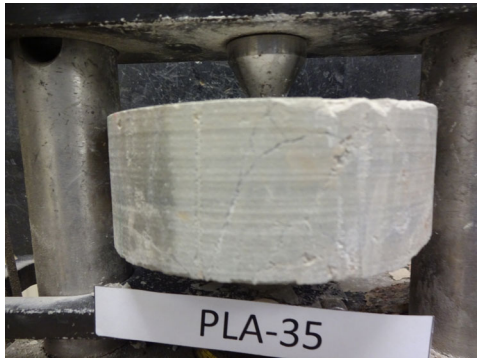
F = the size correction factor

Is(50) = the size corrected point load strength index

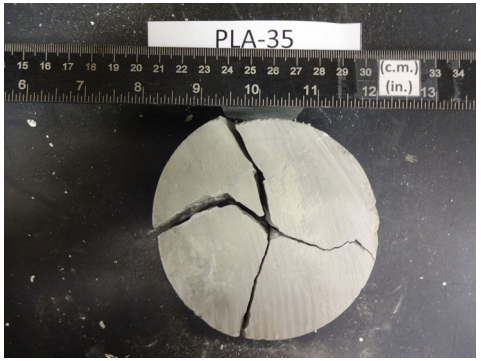
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	01/27/20	Checked By:	smd
Depth :	206.69-207.35 ft	Test Id:	537767		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-35	206.69 - 207.35 ft	3.97	1.56	1,450	7.86	2.80	184	1.173	216	21	3,870



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

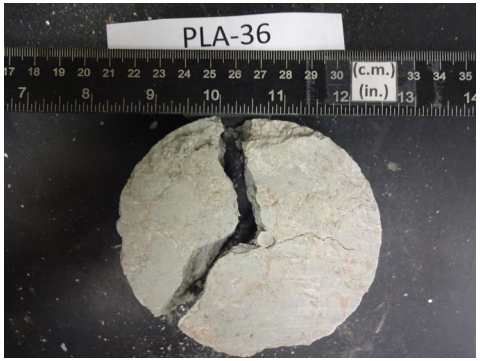
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	01/27/20	Checked By:	smd
Depth :	215.22-215.55 ft	Test Id:	537768		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-36	215.22 - 215.55 ft	3.98	1.52	589	7.68	2.77	77	1.166	89	21	1,610

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/27/20	Checked By:	smd
Depth :	216.86-217.19 ft	Test Id:	537770		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-37	216.86 - 217.19 ft	3.95	1.52	146	7.64	2.76	19	1.165	22	21	402

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

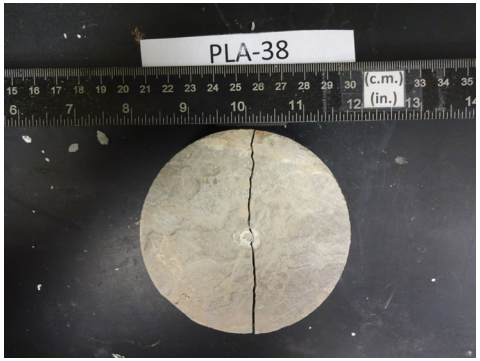
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-011	Test Date:	01/27/20	Checked By:	smd
Depth :	228.67-229.00 ft	Test Id:	537771		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-38	228.67 - 229.00 ft	3.99	1.45	3,871	7.37	2.72	525	1.156	607	21	11,000

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

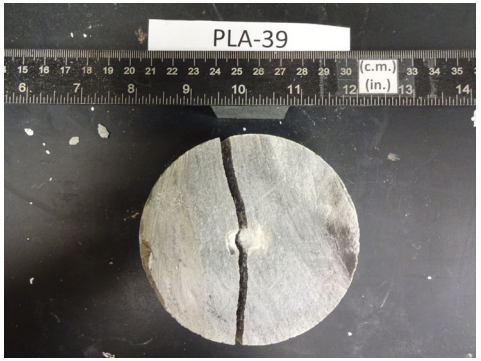
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-23	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-012	Test Date:	01/27/20	Checked By:	smd
Depth :	235.56-237.86 ft	Test Id:	537773		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-39	235.56 - 237.86 ft	3.96	1.62	1,751	8.19	2.86	214	1.183	253	21	4,490

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

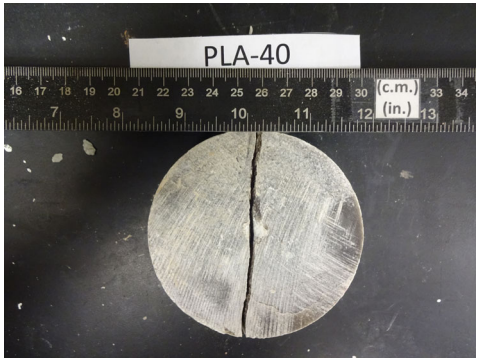
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/27/20	Checked By:	smd
Depth :	234.25-234.91 ft	Test Id:	537784		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-40	234.25 - 234.91 ft	3.7	1.47	809	6.95	2.64	117	1.140	133	21	2,450

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/28/20	Checked By:	smd
Depth :	249.34-251.31 ft	Test Id:	537793		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-41	249.34 - 251.31 ft	3.87	1.64	353	8.09	2.84	44	1.180	52	21	916

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

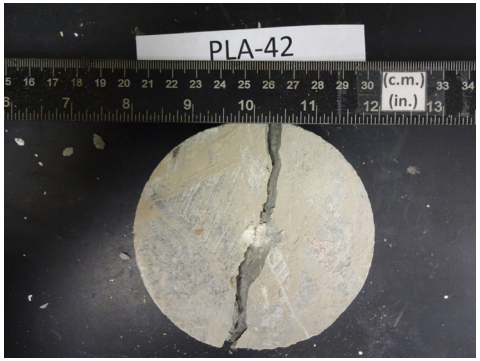
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/28/20	Checked By:	smd
Depth :	257.22-258.53 ft	Test Id:	537797		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-42	257.22 - 258.53 ft	3.93	1.70	728	8.49	2.91	86	1.193	102	21	1,800

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	01/28/20	Checked By:	smd
Depth :	269.69-271.98 ft	Test Id:	537801		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-43	269.69 - 271.98 ft	3.94	1.43	241	7.16	2.68	34	1.148	39	21	705

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

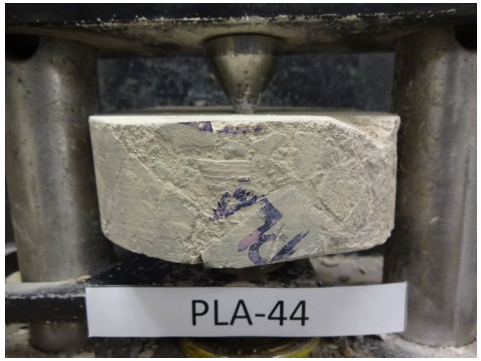
F = the size correction factor

Is(50) = the size corrected point load strength index

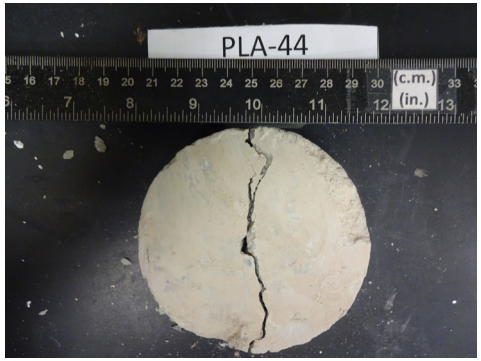
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	01/28/20	Checked By:	smd
Depth :	276.57-276.90 ft	Test Id:	537805		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-44	276.57 - 276.90 ft	3.93	1.58	625	7.90	2.81	79	1.174	93	21	1,660



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-008	Test Date:	01/28/20	Checked By:	smd
Depth :	281.82-282.48 ft	Test Id:	537806		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-45	281.82 - 282.48 ft	3.93	1.31	2,059	6.57	2.56	314	1.126	353	19	5,960

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

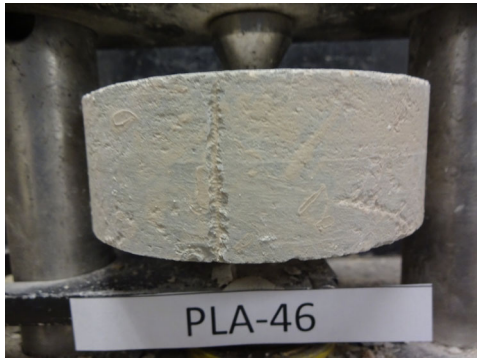
F = the size correction factor

Is(50) = the size corrected point load strength index

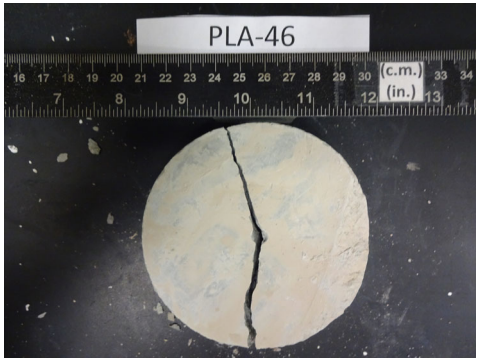
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	01/28/20	Checked By:	smd
Depth :	288.06-289.70 ft	Test Id:	537809		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-46	288.06 - 289.70 ft	3.93	1.43	1,621	7.17	2.68	226	1.148	260	21	4,750



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/28/20	Checked By:	smd
Depth :	296.59-300.20 ft	Test Id:	537816		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-47	296.59 - 300.20 ft	3.93	1.56	1,578	7.84	2.80	201	1.172	236	21	4,230

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

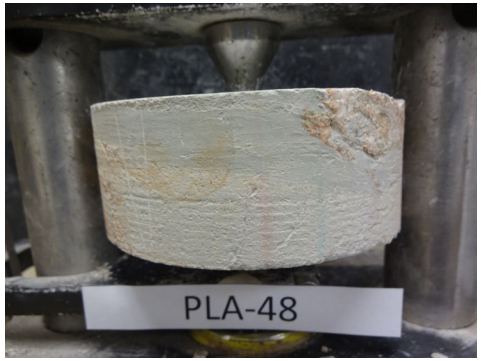
F = the size correction factor

Is(50) = the size corrected point load strength index

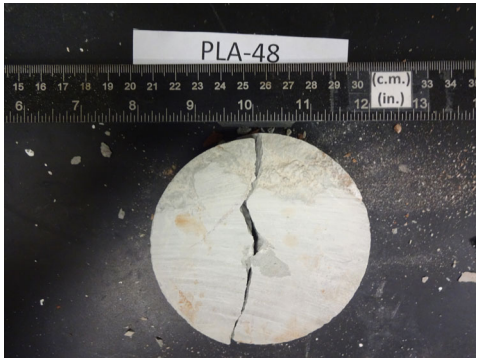
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-011	Test Date:	01/28/20	Checked By:	smd
Depth :	306.10-306.43 ft	Test Id:	537822		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-48	306.10 - 306.43 ft	3.94	1.60	3,197	8.01	2.83	399	1.178	470	21	8,380



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-012	Test Date:	01/28/20	Checked By:	smd
Depth :	311.02-311.35 ft	Test Id:	537823		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-49	311.02 - 311.35 ft	3.94	1.38	263	6.90	2.63	38	1.139	43	19	724

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

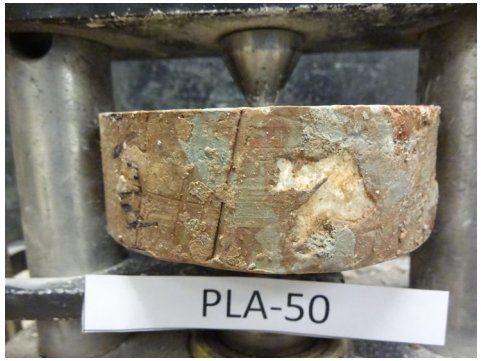
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/28/20	Checked By:	smd
Depth :	308.73-309.71 ft	Test Id:	537829		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-50	308.73 - 309.71 ft	3.93	1.32	263	6.59	2.57	40	1.127	45	19	758



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	01/28/20	Checked By:	smd
Depth :	310.04-310.70 ft	Test Id:	537833		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-51	310.04 - 310.70 ft	3.93	1.42	126	7.09	2.66	18	1.146	20	21	373

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

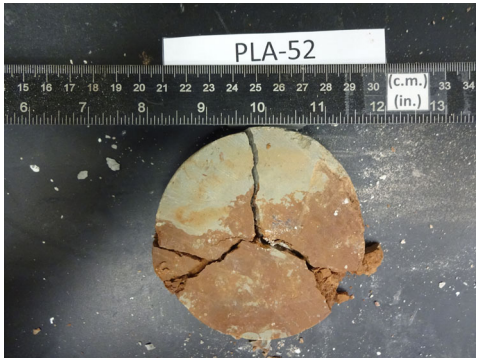
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-25	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/28/20	Checked By:	smd
Depth :	322.83-324.48 ft	Test Id:	537878		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-52	322.83 - 324.48 ft	3.94	1.26	103	6.32	2.51	16	1.116	18	19	311

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

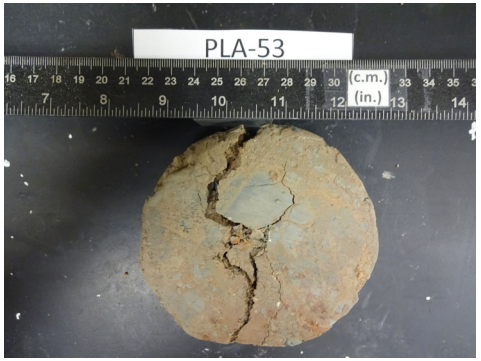
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	01/28/20	Checked By:	smd
Depth :	292.98-294.62 ft	Test Id:	538125		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-53	292.98 - 294.62 ft	3.99	1.66	81	8.42	2.90	10	1.191	11	21	202

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/28/20	Checked By:	smd
Depth :	300.20-300.52 ft	Test Id:	538130		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-54	300.20 - 300.52 ft	3.95	1.32	121	6.62	2.57	18	1.128	21	19	348

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	01/28/20	Checked By:	smd
Depth :	302.17-304.46	Test Id:	538132		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-55	302.17 - 304.46 ft	2.96	1.11	092	4.19	2.05	22	1.018	22	19	418

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

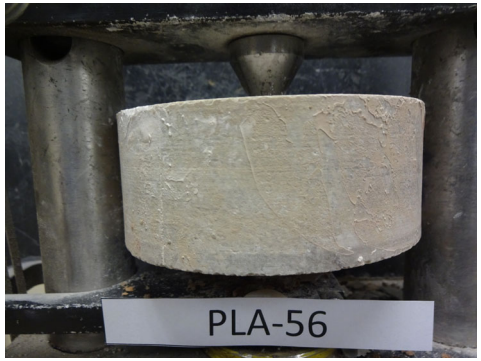
F = the size correction factor

Is(50) = the size corrected point load strength index

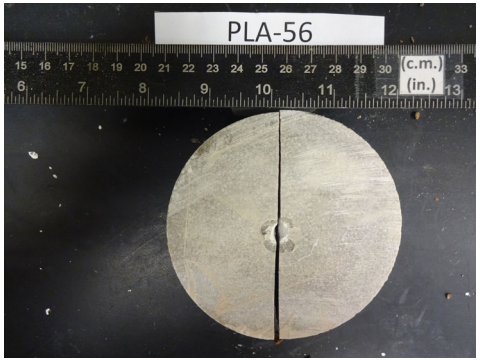
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/28/20	Checked By:	smd
Depth :	310.04-310.70 ft	Test Id:	538137		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-56	310.04 - 310.70 ft	3.94	1.60	2,345	8.01	2.83	293	1.178	345	21	6,140



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/28/20	Checked By:	smd
Depth :	318.24-318.57 ft	Test Id:	538141		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-57	318.24 - 318.57 ft	3.94	1.38	4,069	6.91	2.63	588	1.139	670	19	11,200

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

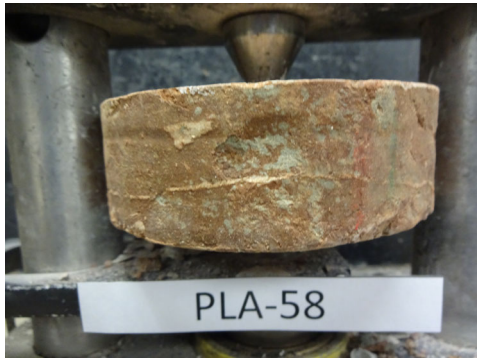
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	01/28/20	Checked By:	smd
Depth :	321.52-322.18 ft	Test Id:	538142		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-58	321.52 - 322.18 ft	3.91	1.33	180	6.60	2.57	27	1.127	31	19	518



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	01/28/20	Checked By:	smd
Depth :	186.35-187.01 ft	Test Id:	538155		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-59	186.35 - 187.01 ft	3.97	1.26	067	6.35	2.52	11	1.118	12	19	202

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

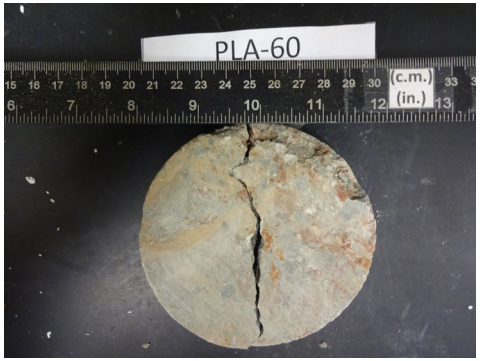
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	01/28/20	Checked By:	smd
Depth :	210.30-210.96 ft	Test Id:	538168		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-60	210.30 - 210.96 ft	3.85	1.62	411	7.94	2.82	52	1.175	61	21	1,090

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

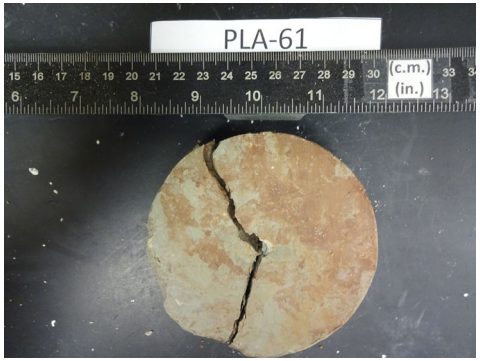
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	01/28/20	Checked By:	smd
Depth :	215.55-217.85 ft	Test Id:	538170		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-61	215.55 - 217.85 ft	3.94	1.67	252	8.36	2.89	30	1.189	36	21	632

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

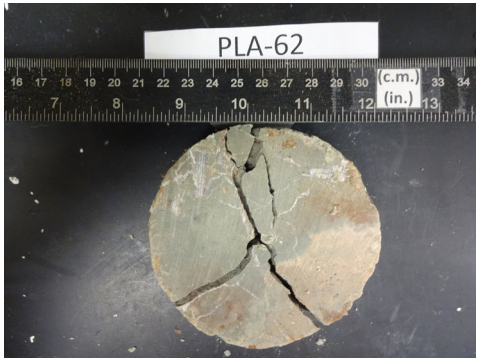
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	01/28/20	Checked By:	smd
Depth :	229.99-231.30 ft	Test Id:	538175		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-62	229.99 - 231.30 ft	3.93	1.26	209	6.29	2.51	33	1.115	37	19	631

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/28/20	Checked By:	smd
Depth :	239.83-241.14 ft	Test Id:	538184		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-63	239.83 - 241.14 ft	3.95	1.33	272	6.71	2.59	41	1.131	46	19	771

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

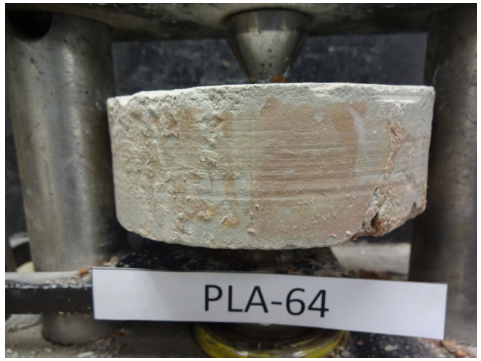
F = the size correction factor

Is(50) = the size corrected point load strength index

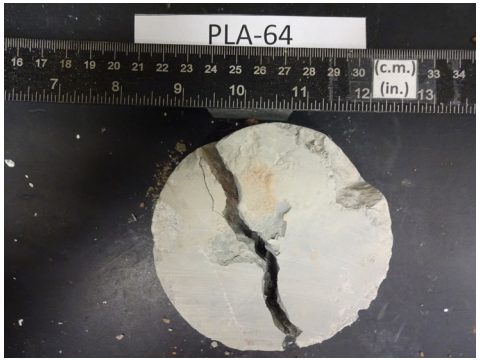
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-011	Test Date:	01/28/20	Checked By:	smd
Depth :	247.70-248.36 ft	Test Id:	538189		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-64	247.70 - 248.36 ft	3.94	1.41	268	7.09	2.66	38	1.146	43	19	717



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/28/20	Checked By:	smd
Depth :	195.87-197.83 ft	Test Id:	538335		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-65	195.87 - 197.83 ft	3.88	1.64	103	8.10	2.85	13	1.181	15	21	268

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

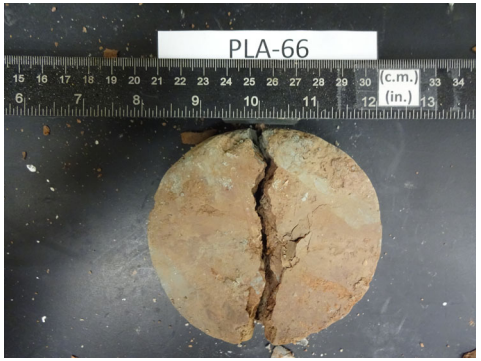
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	01/28/20	Checked By:	smd
Depth :	202.10-203.08 ft	Test Id:	538340		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-66	202.10 - 203.08 ft	3.91	1.74	088	8.67	2.94	10	1.199	12	21	212

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

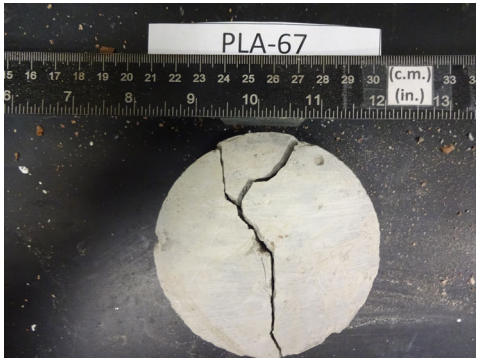
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	01/28/20	Checked By:	smd
Depth :	230.64-230.97 ft	Test Id:	538346		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-67	230.64 - 230.97 ft	3.92	1.30	1,864	6.49	2.55	287	1.123	322	19	5,450

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	10/31/19	Checked By:	smd
Depth :	100.39 ft	Test Id:	527300		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-25	100.39 ft	3.98	1.45	1,039	7.38	2.72	141	1.156	163	21	2,960

Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

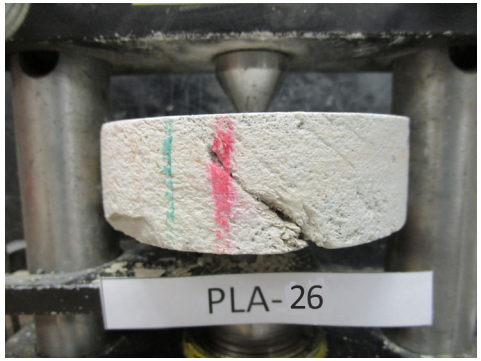
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	10/31/19	Checked By:	smd
Depth :	122.05 ft	Test Id:	527302		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-26	122.05 ft	3.96	1.20	1,974	6.07	2.46	325	1.106	360	19	6,180



Before

After

Intact material and Discontinuity Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

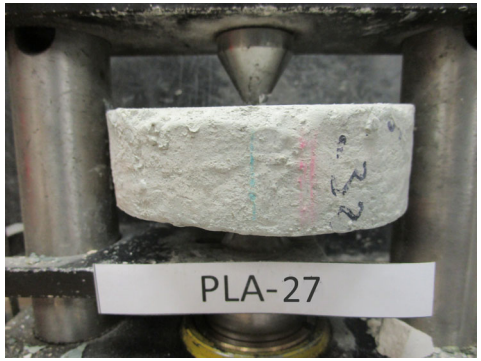
F = the size correction factor

Is(50) = the size corrected point load strength index

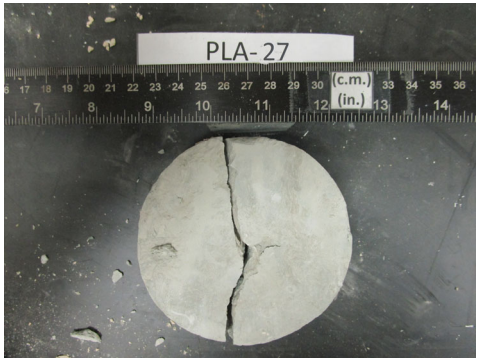
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	10/31/19	Checked By:	smd
Depth :	163.22-164.04 ft	Test Id:	527316		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-27	163.22-164.04 ft	3.87	1.20	245	5.90	2.43	42	1.099	46	19	789



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

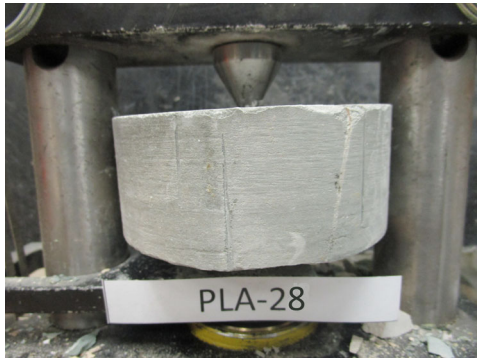
Is(50) = the size corrected point load strength index

GeoTesting EXPRESS

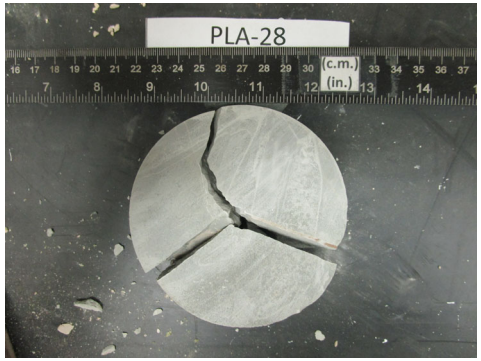
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-32	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-011	Test Date:	10/31/19	Checked By:	smd
Depth :	196.9-197.2 ft	Test Id:	527328		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-28	196.9-197.2 ft	3.87	1.59	567	7.84	2.80	72	1.172	85	21	1,520



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

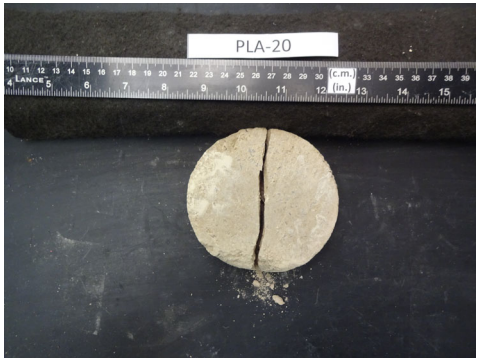
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-33	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	08/27/19	Checked By:	smd
Depth :	135.17 ft	Test Id:	519220		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-20	135.17 ft	3.97	1.15	769	5.82	2.41	132	1.096	145	19	2,510

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

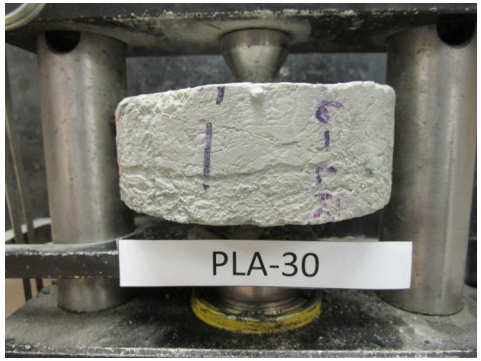
F = the size correction factor

Is(50) = the size corrected point load strength index

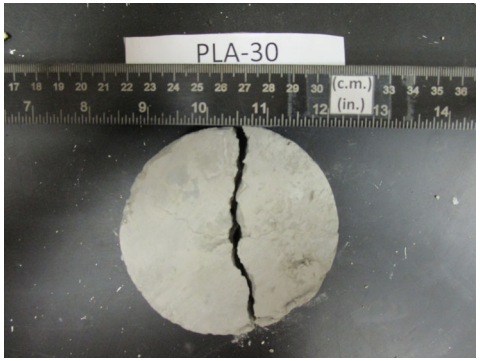
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-36	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-003	Test Date:	12/19/19	Checked By:	smd
Depth :	173.06-173.56 ft	Test Id:	532764		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-30	173.22 - 173.37 ft	3.9	1.42	205	7.05	2.66	29	1.144	33	21	609



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

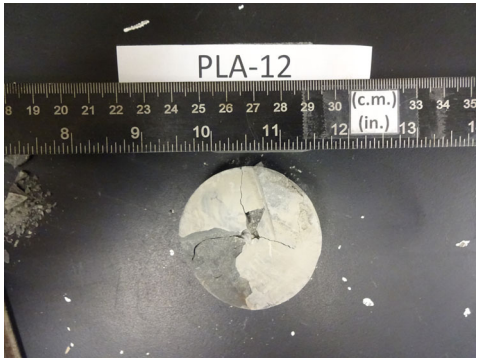
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	08/21/19	Checked By:	smd
Depth :	200.7-201.0 ft	Test Id:	518382		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-12	200.7-201.0 ft	2.38	0.87	656	2.64	1.62	249	0.917	228	18	4,480

Before



After

Intact material and Discontinuity Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

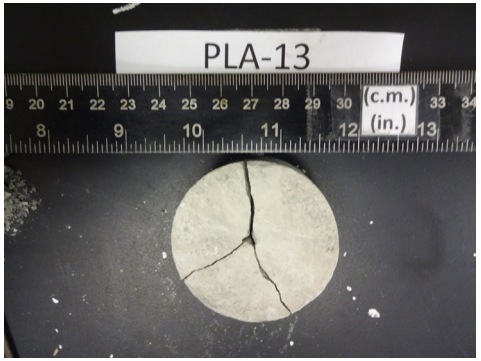
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-37	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-007	Test Date:	08/21/19	Checked By:	smd
Depth :	225.8-226.9 ft	Test Id:	518538		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-13	225.8-226.9 ft	2.37	1.17	964	3.53	1.88	274	0.979	268	19	5,200

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

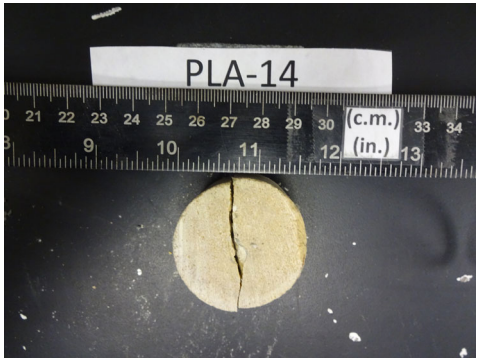
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	08/21/19	Checked By:	smd
Depth :	128-128.8 ft	Test Id:	518410		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-14	128-128.8 ft	1.77	1.29	623	2.89	1.70	215	0.936	202	19	4,090

Before



After

Intact material and Discontinuity Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

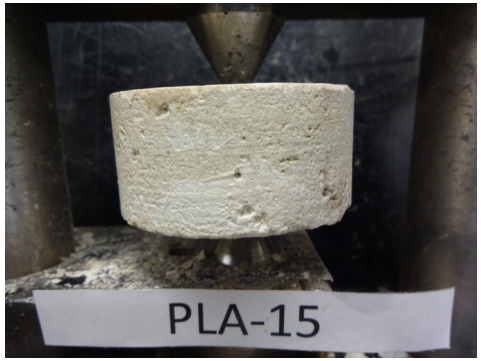
F = the size correction factor

Is(50) = the size corrected point load strength index

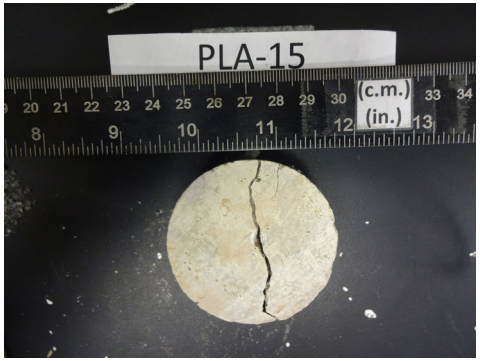
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	08/21/19	Checked By:	smd
Depth :	150.6-151.1 ft	Test Id:	518420		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-15	150.6-151.1 ft	2.4	1.15	1,102	3.52	1.88	313	0.979	306	19	5,940



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

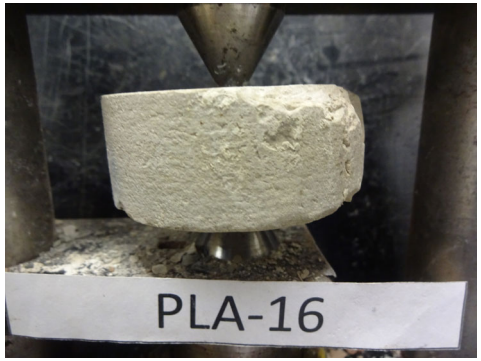
F = the size correction factor

Is(50) = the size corrected point load strength index

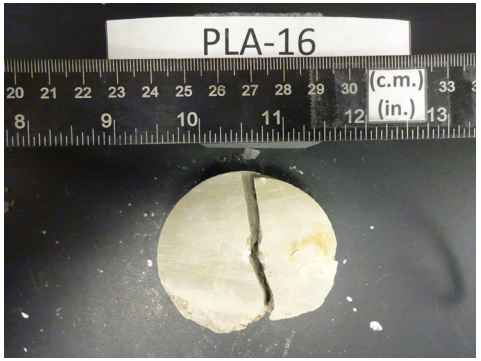
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-38	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	08/21/19	Checked By:	smd
Depth :	190.1-190.4 ft	Test Id:	518428		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-16	190.1-190.4 ft	2.4	0.97	825	2.97	1.72	278	0.942	262	18	5,000



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

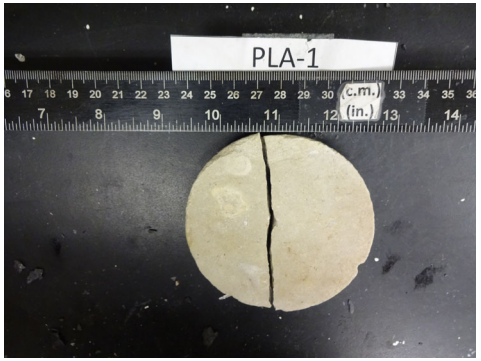
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	PZ19-42	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	SB-003	Test Date:	07/16/19	Checked By:	smd
Depth :	20 ft	Test Id:	513309		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-1	20 ft	3.64	1.05	1,039	4.87	2.21	213	1.053	224	19	4,050

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

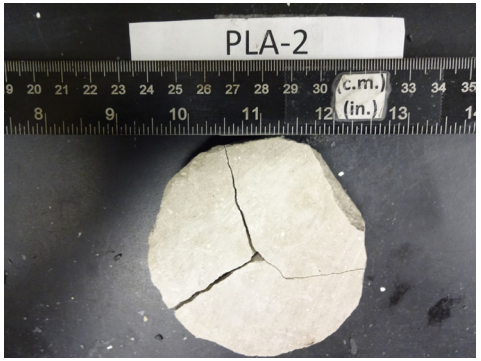
Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	PZ19-42	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	SB-004	Test Date:	07/16/19	Checked By:	smd
Depth :	50 ft	Test Id:	513311		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Axial Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLA-2	50 ft	3.65	1.07	1,553	4.97	2.23	312	1.058	330	19	5,940

Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

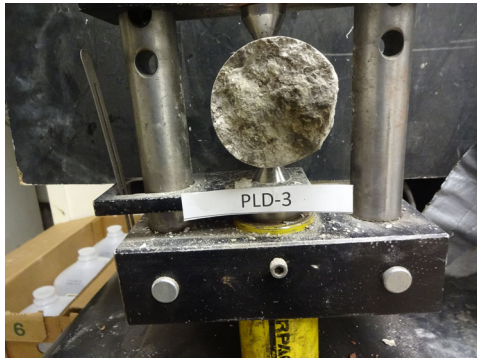
F = the size correction factor

Is(50) = the size corrected point load strength index

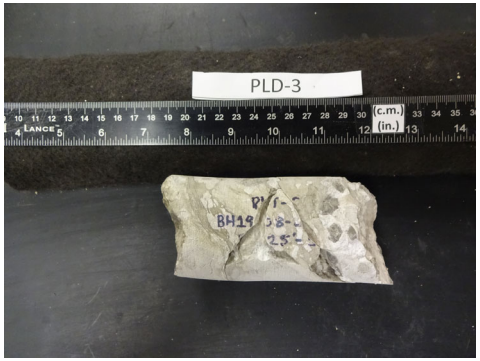
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-08	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-013	Test Date:	08/27/19	Checked By:	smd
Depth :	55.25 ft	Test Id:	519416		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

DIAMETRAL Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLD-3	55.25 ft	2.38	4.46	2,403	5.69	2.38	423	1.090	461	24.5	10,400



Before



After

Discontinuity Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

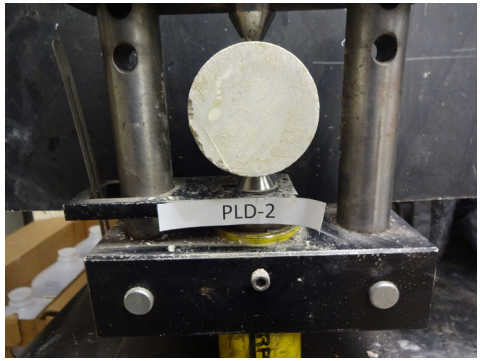
F = the size correction factor

Is(50) = the size corrected point load strength index

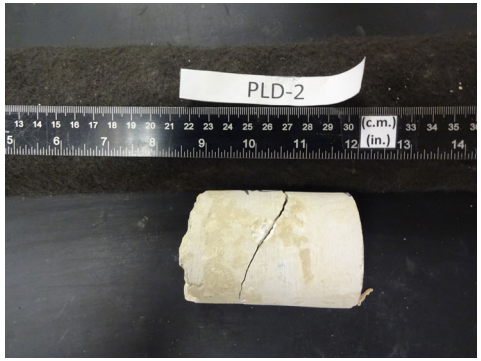
Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	08/27/19	Checked By:	smd
Depth :	12.6 ft	Test Id:	519339		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

DIAMETRAL Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLD-2	12.6 ft	2.39	3.29	1,893	5.70	2.39	332	1.091	362	24.5	8,140



Before



After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

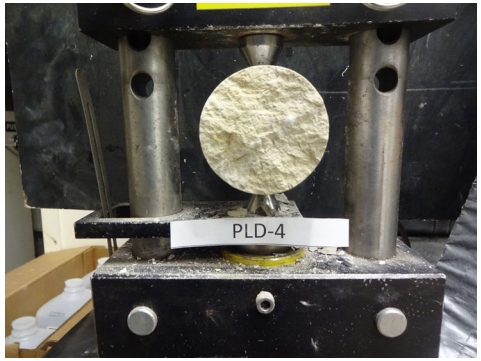
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-10	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	08/27/19	Checked By:	smd
Depth :	70.2 ft	Test Id:	519432		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

DIAMETRAL Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLD-4	70.2 ft	2.39	4.43	1,347	5.70	2.39	236	1.091	258	24.5	5,790



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

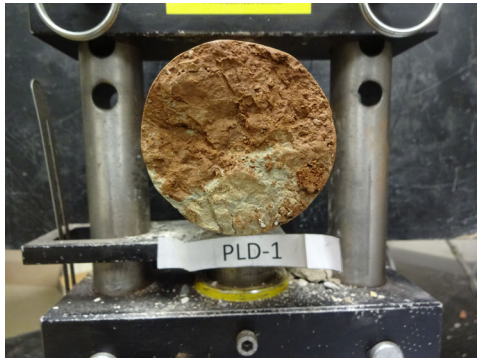
F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	08/21/19	Checked By:	smd
Depth :	338-338.5 ft	Test Id:	519141		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

DIAMETRAL Point Load Strength Index of Rock by ASTM D5731

Test No.	Specimen Depth	Diameter, in	Thickness, in	Failure Load (P), lbs	De, sq in	De, in	Is, psi	F	Is(50mm), psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PLD-1	338-338.5 ft	2.33	6.00	031	5.42	2.33	06	1.079	06	24.5	142



Before

After

Intact Material Failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D5731 Table 1.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

De = the equivalent core diameter

Is = the uncorrected point load strength index

F = the size correction factor

Is(50) = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-19	LRB-010	187.99-188.98	PLL-33	Irregular Lump	3.93	1.79	9.47	234	12.05	3.47	19	1.291	25	21	410

PLL-33 before

PLL-33 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-21	LRB-002	64.63-65.94	PLL-34	Irregular Lump	4.14	2.17	15.92	164	20.27	4.50	8	1.451	12	24	190

PLL-34 before

PLL-34 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-25	LRB-001	300.52-300.85	PLL-23	Irregular Lump	2.98	1.20	5.89	6506	7.50	2.74	868	1.160	1007	19	16,480

PLL-23 before

PLL-23 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-25	LSB-016	285.43	PLL-24	Irregular Lump	6.00	1.86	14.25	6868	18.14	4.26	379	1.415	536	23	8,710

PLL-24 before

PLL-24 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, m	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-25	LSB-017	292.82	PLL-25	Irregular Lump	4.92	1.76	12.50	8356	15.92	3.99	525	1.374	721	21	11,020

PLL-25 before

PLL-25 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, m	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-26	LRB-001	315.94-316.27	PLL-26	Irregular Lump	5.24	1.52	10.42	8819	13.27	3.64	665	1.319	877	21	13,960

PLL-26 before

PLL-26 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-26	LSB-021	310.37	PLL-27	Irregular Lump	5.86	2.05	15.30	5449	19.47	4.41	280	1.438	402	24	6,720

PLL-27 before

PLL-27 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-27	LRB-007	323.82-324.15	PLL-28	Irregular Lump	5.46	1.87	13.20	2752	16.80	4.10	164	1.391	228	23	3,770

PLL-28 before

PLL-28 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-28	LRB-001	172.24-173.23	PLL-35	Irregular Lump	5.92	1.95	15.82	277	20.14	4.49	14	1.449	20	23	320

PLL-35 before

PLL-35 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-28	LRB-005	200.46-201.77	PLL-36	Irregular Lump	5.95	2.63	19.26	236	24.53	4.95	10	1.515	15	24.5	240

PLL-36 before

PLL-36 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-31	LRB-001	157.15-157.48	PLL-29	Irregular Lump	3.16	1.35	6.33	1169	8.06	2.84	145	1.179	171	19	2,760

PLL-29 before

PLL-29 after

Intact material failure

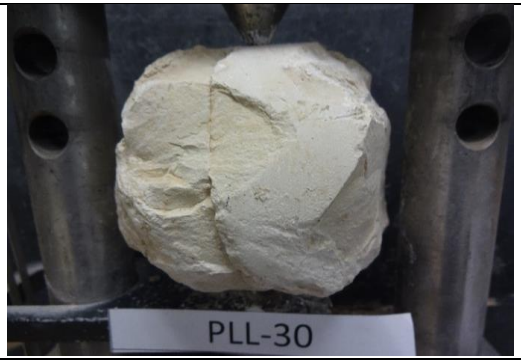
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-31	LRB-002	159.12-159.45	PLL-30	Irregular Lump	4.55	1.78	13.77	1535	17.54	4.19	88	1.404	123	21	1,840

PLL-30 before



PLL-30 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-31	LRB-003	166.34-166.67	PLL-31	Irregular Lump	4.20	1.52	9.05	3682	11.52	3.39	320	1.278	408	21	6,710

PLL-31 before

PLL-31 after

Intact material failure

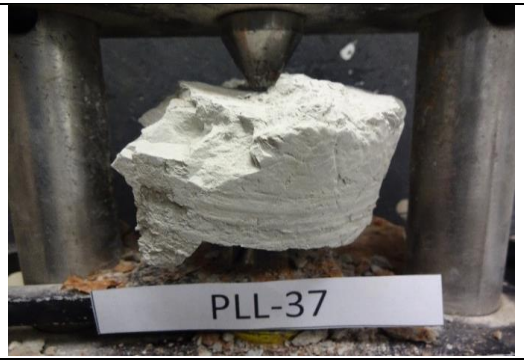
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-31	LRB-004	180.12-182.09	PLL-37	Irregular Lump	5.88	2.03	12.35	303	15.72	3.97	19	1.370	26	23	440

PLL-37 before



PLL-37 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	01/27/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-31	LRB-007	203.08-203.41	PLL-32	Irregular Lump	6.00	2.17	23.40	207	29.80	5.46	7	1.582	11	24	170

PLL-32 before

PLL-32 after

Intact material failure

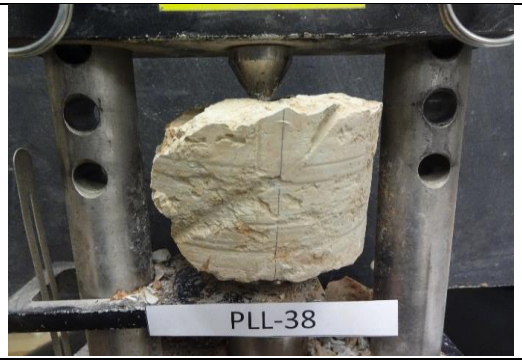
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-31	LRB-008	210.30-211.61	PLL-38	Irregular Lump	5.87	2.02	15.16	391	19.30	4.39	20	1.435	29	23	470

PLL-38 before



PLL-38 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	02/06/20
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-36	LRB-004	202.43-203.74	PLL-39	Irregular Lump	5.87	1.94	11.51	103	14.65	3.83	7	1.349	10	23	160

PLL-39 before

PLL-39 after

Intact material failure

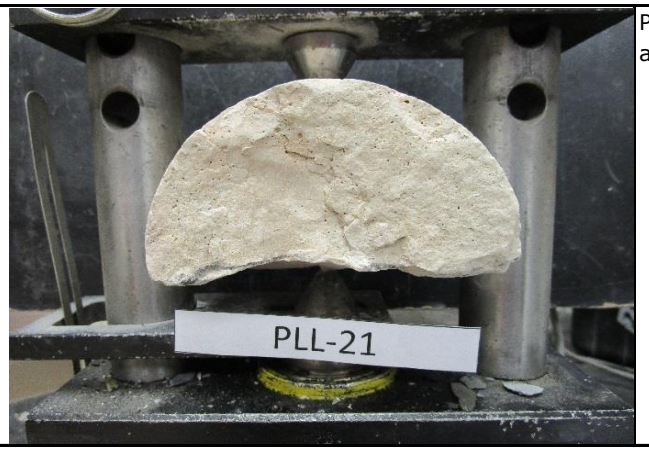
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	12/19/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

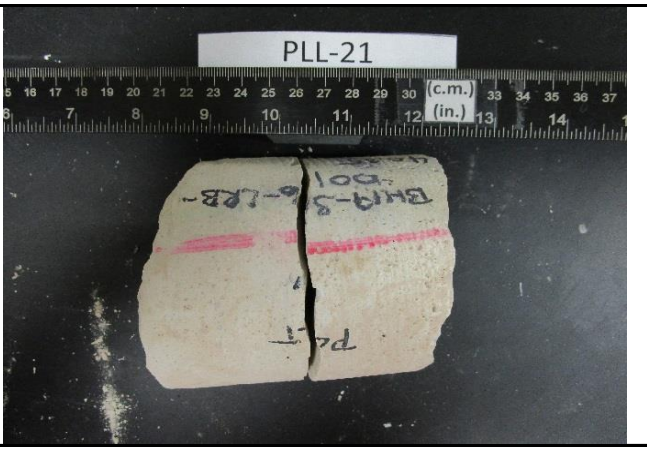
Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-36	LRB-001	132.38-132.45	PLL-21	Irregular Lump	3.94	2.19	9.37	2032	11.93	3.45	170	1.288	219	24	4,090

PLL-21 before



PLL-21 after



Intact material failure

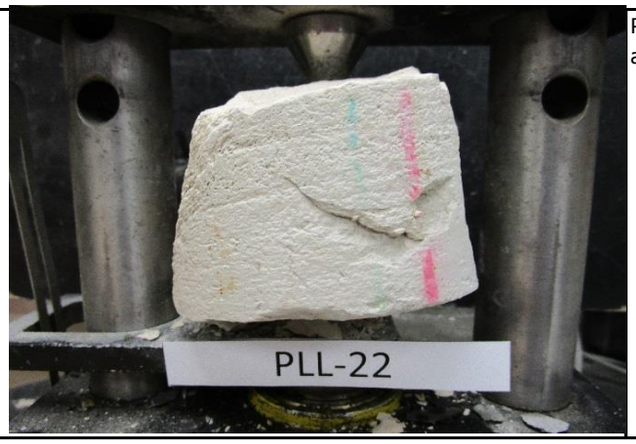
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	12/19/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-36	LRB-002	157.48-157.68	PLL-22	Irregular Lump	5.92	2.15	14.60	1857	18.59	4.31	100	1.423	142	24	2,400

PLL-22 before



PLL-22 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.

D_e = the equivalent core diameter

I_s = the uncorrected point load strength index

F = the size correction factor

$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-07	LRB-008	144.7-145	PLL-9	Irregular Lump	2.37	1.59	3.69	650	4.70	2.17	138	1.045	144	21	2,900

PLL-9
before

PLL-9
after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-07	LRB-011	194.2-194.9	PLL-10	Irregular Lump	3.58	1.35	5.95	225	7.57	2.75	30	1.163	35	19	560

PLL-10
before

PLL-10
after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

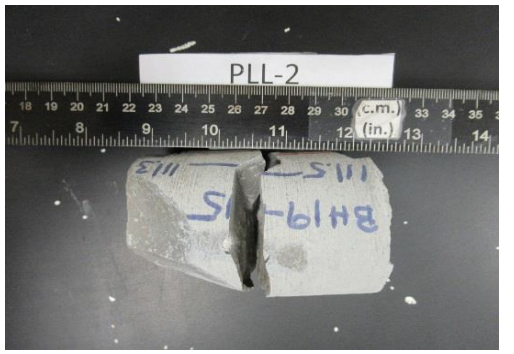
Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-15	LRB-001	111.3-111.5	PLL-2	Irregular Lump	2.34	1.63	5.03	3365	6.40	2.53	526	1.120	588	21	11,040

PLL-2
before

PLL-2
after



Intact material failure

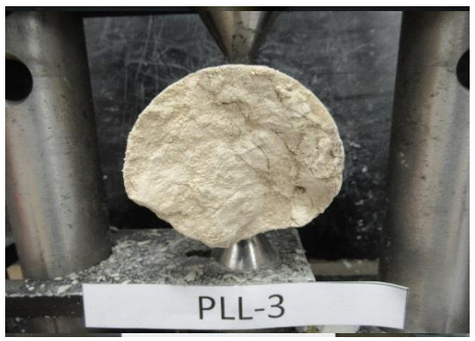
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-16	LRB-001	133.2-133.5	PLL-3	Irregular Lump	3.57	1.55	7.76	668	9.88	3.14	68	1.234	83	21	1,420

PLL-3
before



PLL-3
after

Intact material failure

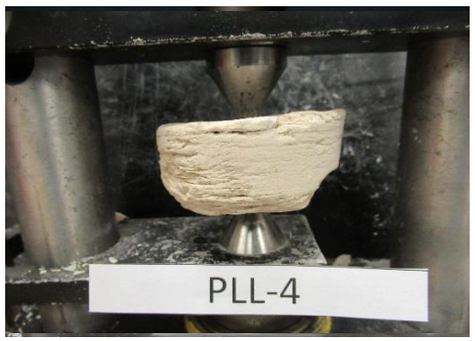
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-16	LRB-002	133.6-133.8	PLL-4	Irregular Lump	3.59	1.50	4.30	472	5.47	2.34	86	1.081	93	21	1,810

PLL-4
before



PLL-4
after

Intact material failure

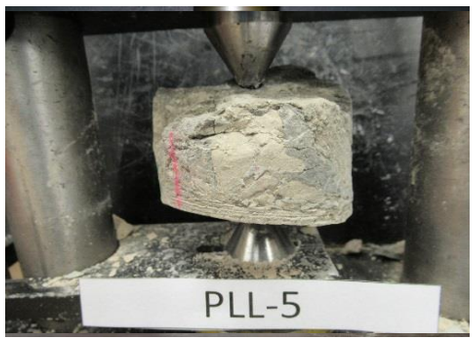
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-16	LRB-003	140.0-140.16	PLL-5	Irregular Lump	3.57	1.36	5.86	97	7.47	2.73	13	1.159	15	19	250

PLL-5
before



PLL-5
after

Intact material failure

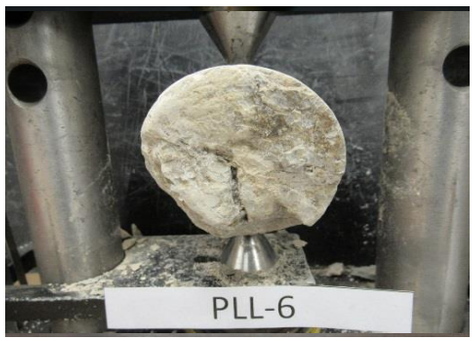
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-16	LRB-004	177.36-177.50	PLL-6	Irregular Lump	3.59	1.49	8.57	1342	10.91	3.30	123	1.262	155	21	2,580

PLL-6
before



PLL-6
after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-16	LRB-011	285.2-285.9	PLL-7	Irregular Lump	3.60	1.24	6.51	263	8.28	2.88	32	1.186	38	19	600

PLL-7
before

PLL-7
after

Intact material failure

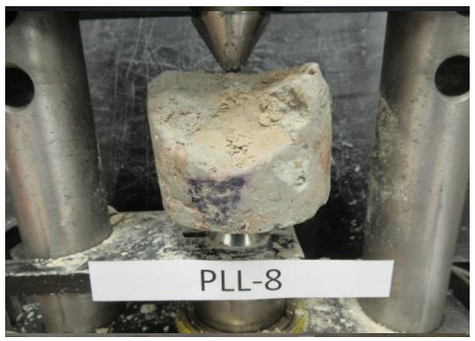
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/31/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-16	LRB-012	317.50-317.64	PLL-8	Irregular Lump	3.60	1.21	6.80	108	8.66	2.94	12	1.198	15	19	240

PLL-8 before



PLL-8 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-17	LRB-001	373-373.7	PLL-11	Irregular Lump	3.60	2.29	8.40	171	10.70	3.27	16	1.257	20	24.5	390

PLL-11
before

PLL-11
after

Intact material failure

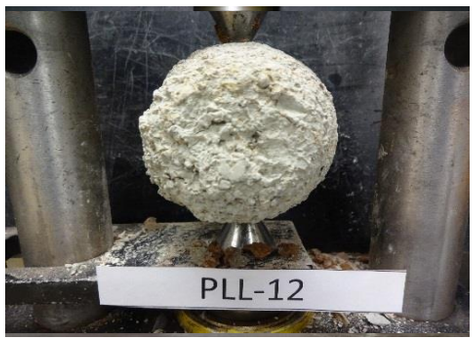
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-17	LRB-008	313-313.8	PLL-12	Irregular Lump	3.56	1.58	8.39	139	10.69	3.27	13	1.256	16	21	270

PLL-12
before



PLL-12
after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

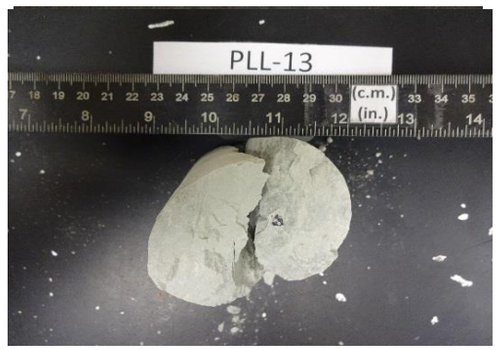
Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-17	LRB-009	280-280.5	PLL-13	Irregular Lump	3.58	1.23	8.45	124	10.75	3.28	11	1.258	14	19	220

PLL-13
before

PLL-13
after



Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-17	LRB-011	194.2-194.6	PLL-14	Irregular Lump	3.53	1.40	8.18	22	10.42	3.23	2	1.249	3	19	40

PLL-14
before

PLL-14
after

Intact material failure

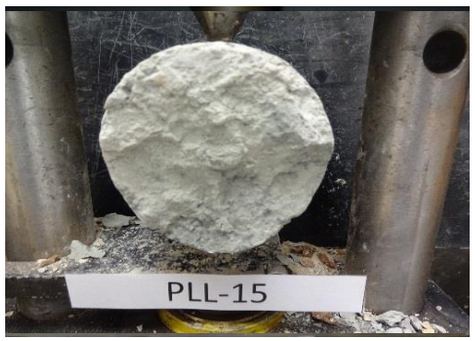
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-17	LRB-014	139.7-140.2	PLL-15	Irregular Lump	3.60	1.57	8.63	166	10.99	3.31	15	1.264	19	21	320

PLL-15
before



PLL-15
after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/27/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	jw
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-33	LRB-001	122.85	PLL-19	Irregular Lump	5.96	2.15	18.92	6124	24.09	4.91	254	1.509	383	24	6,100

PLL-19 before

PLL-19 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.

D_e = the equivalent core diameter

I_s = the uncorrected point load strength index

F = the size correction factor

$I_{s(50)}$ = the size corrected point load strength index

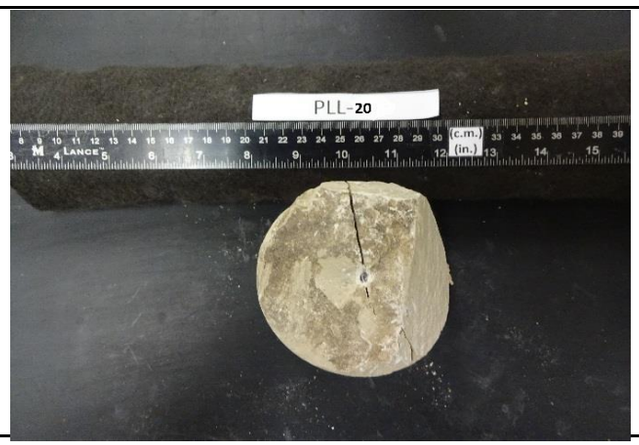
Client:	WSP	Test Date:	08/27/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	jw
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-33	LRB-002	122.83	PLL-20	Irregular Lump	5.11	1.95	12.45	6308	15.85	3.98	398	1.373	546	23	9,150

PLL-20 before

PLL-20 after



Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/27/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	jw
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-33	LRB-005	153.05	PLL-18	Irregular Lump	5.92	1.90	7.87	133	10.02	3.17	13	1.238	16	23	300

PLL-18 before

PLL-18 after

Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.

D_e = the equivalent core diameter

I_s = the uncorrected point load strength index

F = the size correction factor

$I_{s(50)}$ = the size corrected point load strength index

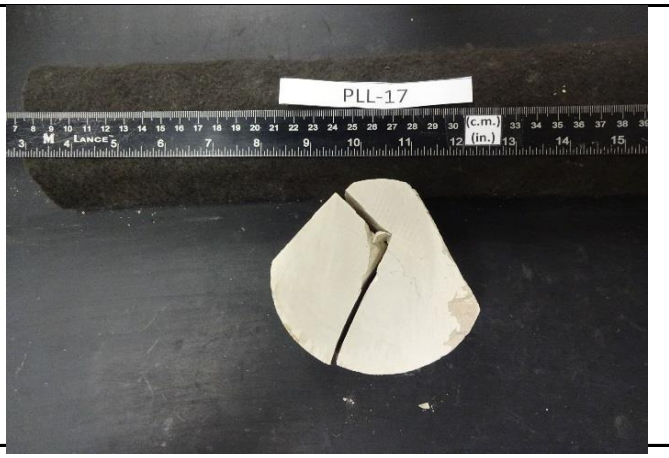
Client:	WSP	Test Date:	08/27/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	jw
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	$D_e^{2,}$ in^2	$D_{e,}$ in.	$I_{s,}$ psi	F	$I_{s(50),}$ psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-33	LRB-007	182.61	PLL-17	Irregular Lump	3.66	1.54	7.29	3837	9.28	3.05	414	1.217	503	21	8,690

PLL-17 before

PLL-17 after



Intact material failure

Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	08/21/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
BH19-37	LRB-001	168.6-169.1	PLL-16	Irregular Lump	2.63	1.07	4.56	133	5.81	2.41	23	1.096	25	19	430

PLL-16
before

PLL-16
after

Intact failure

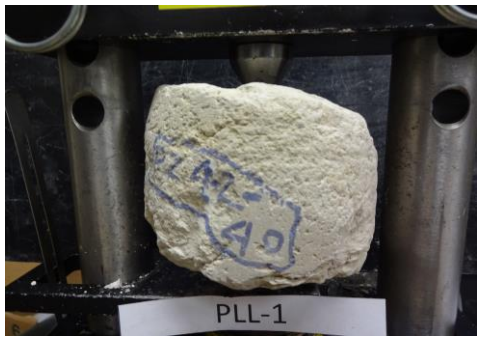
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

Client:	WSP	Test Date:	07/16/19
Project Name:	Line 5 Replacement Tunnel	Tested By:	tlm
Project Location	Straits of Mackinac	Checked By:	smd
GTX #:	310187	Sample Type:	rock lump

Point Load Strength Index of Rock by ASTM D5731

Boring No.	Sample No.	Depth, ft.	Test No.	Test Type	Width (W), in.	Depth (D), in.	Area, in^2	Failure Load (P), lb	D_e^2, in^2	D_e, in.	I_s, psi	F	$I_{s(50)}$, psi	Generalized Correction Factor, K	Estimated Compressive Strength, psi
PZ19-42	SB-004	40	PLL-1	Irregular Lump	3.49	1.85	8.83	1102	11.24	3.35	98	1.271	125	23	2,250

PLL-1
before



PLL-1
after

Intact material failure

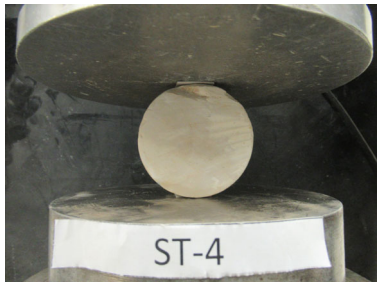
Notes: Generalized correction factor, K, used to estimate the compressive strength based on the specimen depth and ASTM D 5731 Table 1.
D_e = the equivalent core diameter
I_s = the uncorrected point load strength index
F = the size correction factor
$I_{s(50)}$ = the size corrected point load strength index

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	08/23/19	Checked By:	smd
Depth :	118.8-119.1 ft	Test Id:	518436		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
118.8-119.1 ft	ST-4	1.12	2.38	0.47	2,247	537	1



Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

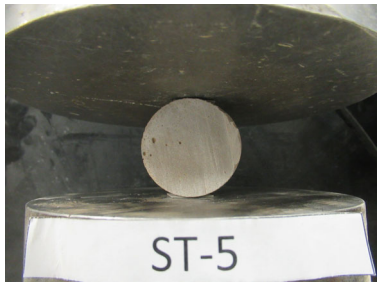
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

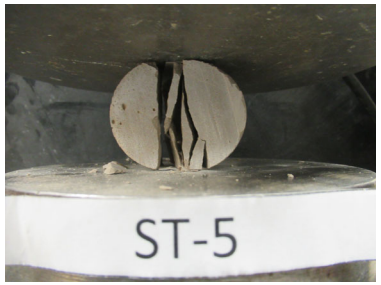
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-07	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	08/23/19	Checked By:	smd
Depth :	164.8-165.2 ft	Test Id:	518443		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
164.8-165.2 ft	ST-5	1.18	1.76	0.67	5,073	1,550	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

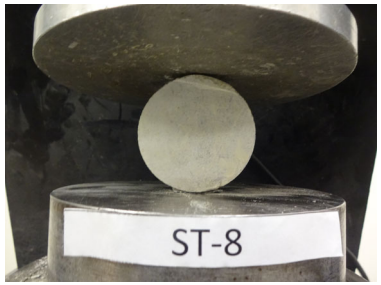
The reported diameter(D) is the average of three measurements.

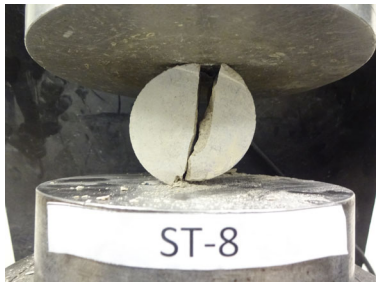
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-08	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	08/28/19	Checked By:	smd
Depth :	21.9 ft	Test Id:	519327		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
21.9 ft	ST-8	1.41	2.39	0.59	9,533	1,800	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

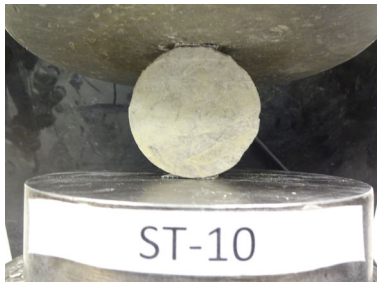
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

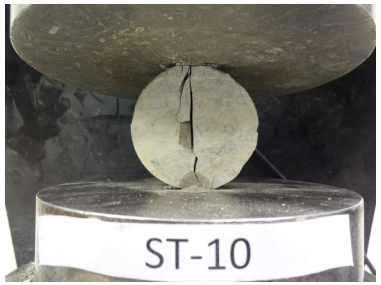
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-015	Test Date:	08/28/19	Checked By:	smd
Depth :	80.8 ft	Test Id:	519319		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
80.8 ft	ST-10	1.22	2.38	0.51	3,239	711	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

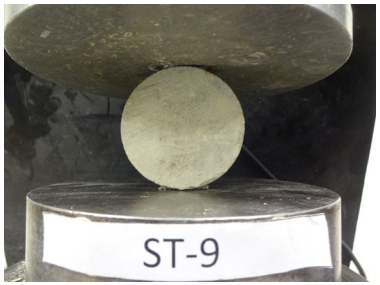
The reported diameter(D) is the average of three measurements.

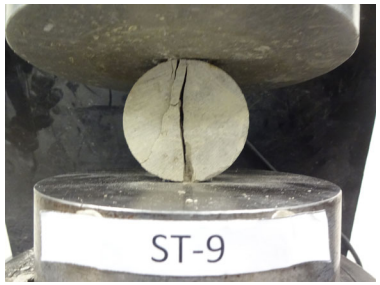
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-09	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	08/28/19	Checked By:	smd
Depth :	32.5 ft	Test Id:	519355		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
32.5 ft	ST-9	1.04	2.39	0.44	2,856	729	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

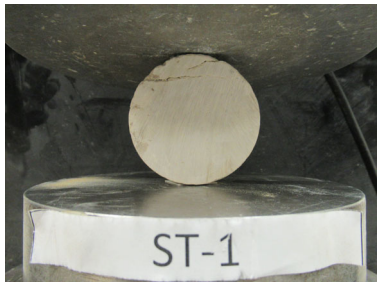
The reported diameter(D) is the average of three measurements.

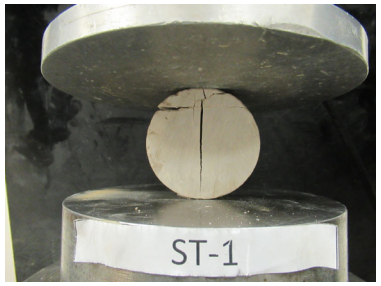
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	07/31/19	Checked By:	smd
Depth :	163.0-168.0 ft	Test Id:	514979		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
163.47 - 163.57 ft	ST-1	0.99	2.4	0.41	2,566	688	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

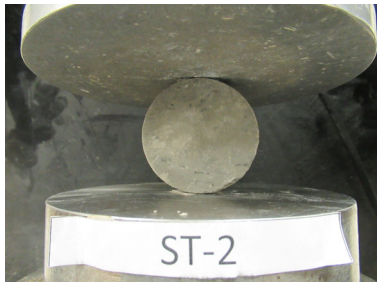
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

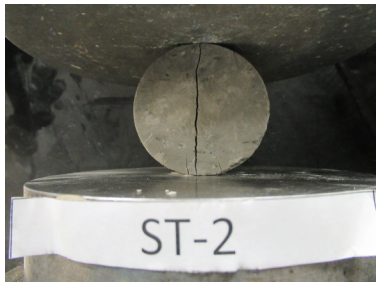
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-15	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	07/31/19	Checked By:	smd
Depth :	218.0-223.0 ft	Test Id:	514988		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
218.31 - 218.41 ft	ST-2	1.07	2.36	0.45	246	062	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

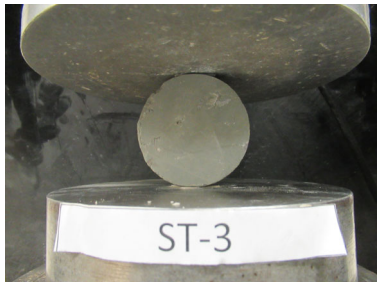
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

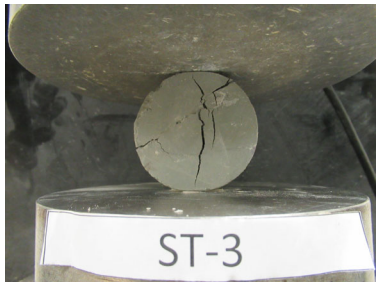
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-16	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	07/31/19	Checked By:	smd
Depth :	233.5-234.1 ft	Test Id:	514948		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
233.72 - 233.81 ft	ST-3	1.18	2.36	0.50	059	014	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

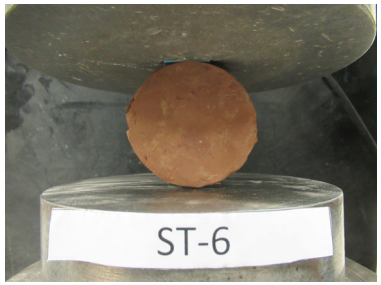
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

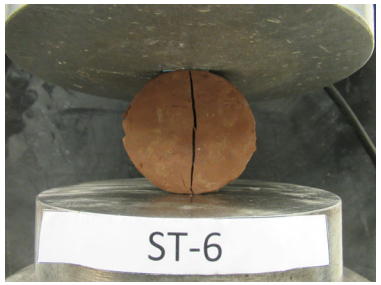
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-17	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-001	Test Date:	08/23/19	Checked By:	smd
Depth :	373-373.7 ft	Test Id:	518514		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
373-373.7 ft	ST-6	1.22	2.4	0.51	057	012	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

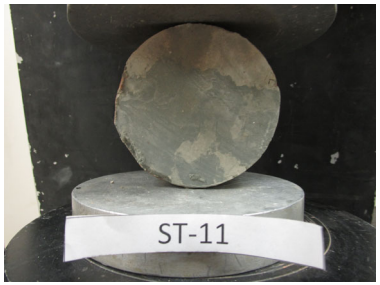
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

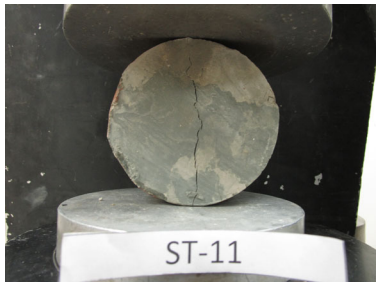
GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-19	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-009	Test Date:	12/19/19	Checked By:	smd
Depth :	173.33-174.38 ft	Test Id:	532825		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
173.42 - 173.55 ft	ST-11	1.59	3.95	0.40	639	065	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

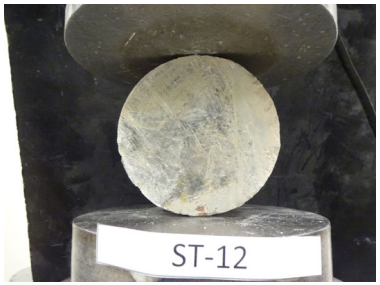
The reported diameter(D) is the average of three measurements.

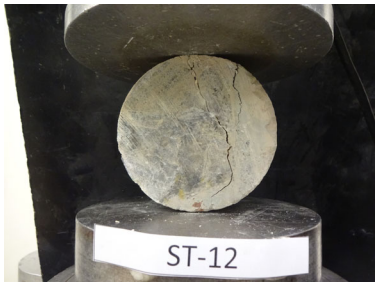
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-24A	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-005	Test Date:	01/24/20	Checked By:	smd
Depth :	257.22-258.53 ft	Test Id:	537798		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
257.22 - 258.53 ft	ST-12	1.39	3.93	0.35	2,199	257	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

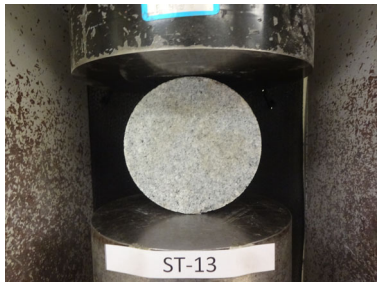
The reported diameter(D) is the average of three measurements.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/24/20	Checked By:	smd
Depth :	319.88-320.54 ft	Test Id:	538117		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
319.88 - 320.54 ft	ST-13	1.31	3.97	0.33	12,148	1,490	1



Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

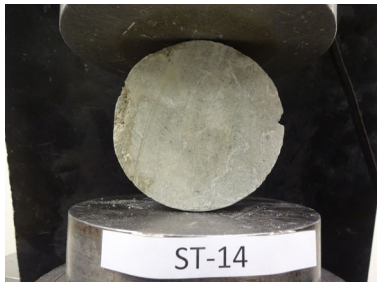
The reported diameter(D) is the average of three measurements.

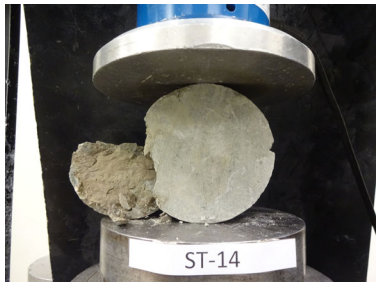
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-26	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/24/20	Checked By:	smd
Depth :	333.01-333.99 ft	Test Id:	538123		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
333.01 - 333.99 ft	ST-14	1.64	3.9	0.42	831	083	3





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

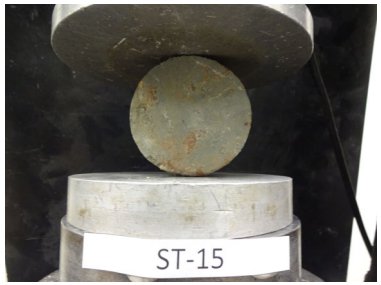
The reported diameter(D) is the average of three measurements.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-27	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-004	Test Date:	01/24/20	Checked By:	smd
Depth :	310.04-310.70 ft	Test Id:	538139		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
310.04 - 310.70 ft	ST-15	1.08	2.96	0.36	142	028	1



Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

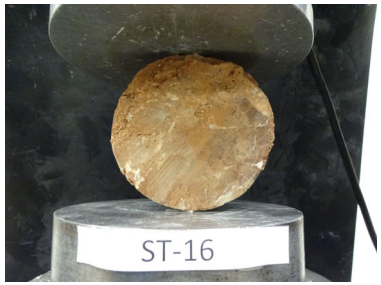
The reported diameter(D) is the average of three measurements.

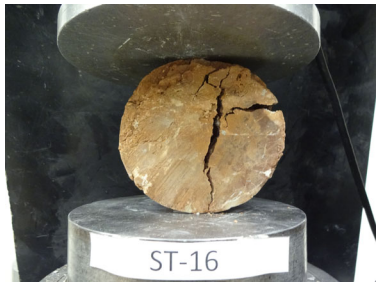
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-28	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-002	Test Date:	01/24/20	Checked By:	smd
Depth :	180.77-182.41 ft	Test Id:	538151		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
180.77 - 182.41 ft	ST-16	1.47	3.90	0.38	302	034	3





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

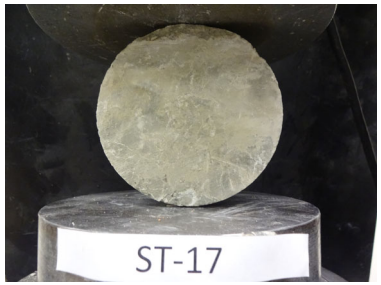
The reported diameter(D) is the average of three measurements.

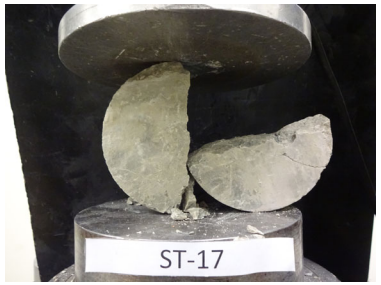
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-31	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-010	Test Date:	01/24/20	Checked By:	smd
Depth :	247.70-249.34 ft	Test Id:	538355		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
247.70 - 249.34 ft	ST-17	1.39	3.93	0.35	657	077	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

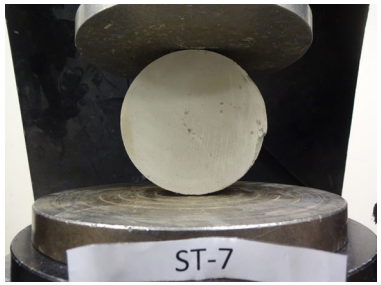
The reported diameter(D) is the average of three measurements.

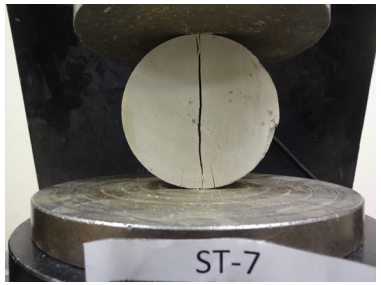
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP				
Project:	Line 5 Replacement Tunnel				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	BH19-33	Sample Type:	cylinder	Tested By:	tlm
Sample ID:	LRB-006	Test Date:	08/28/19	Checked By:	smd
Depth :	184.05 ft	Test Id:	519178		
Test Comment:	---				
Visual Description:	---				
Sample Comment:	---				

Splitting Tensile Strength of Intact Rock Core Specimens by ASTM D3967

Specimen Depth	Test No	Thickness (L), in	Diameter (D), in	Thickness to Diameter Ratio (L/D)	Failure Load (P), lbs	Splitting Tensile Strength, psi	Failure Type
184.05 ft	ST-7	1.72	3.98	0.43	7,604	708	1





Notes: Strain rate: 2.5%/min.

ASTM requires the thickness-to-diameter ratio (L/D) of each test specimen to be between 0.2 and 0.75.

The reported thickness (L) is the average of three measurements.

The reported diameter(D) is the average of three measurements.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/21/19
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth, ft	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-07	LRB-003	118.4-118.8	162	3,170	1,426	0.20	0.37
BH19-07	LRB-010	178.0-178.8	151	---*	---*	---*	---*
BH19-07	LRB-011	194.2-194.9	125	4,045	3,025	0.43	0.13
BH19-17	LRB-002	368.1-368.8	130	---*	---*	---*	---*
BH19-17	LRB-007	314.9-315.5	129	---*	---*	---*	---*
BH19-17	LRB-013	159.2-159.7	166	8,280	5,046	2.19	0.20
BH19-37	LRB-006	209.7-210.2	154	---*	---*	---*	---*
BH19-38	LRB-001	128-128.8	148	6,097	3,681	1.05	0.21
BH19-38	LRB-002	144.5-144.7	157	10,426	7,272	3.65	0.03

Notes:
*No measureable waves could be propagated through the test specimen.
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/11/19
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-09	LRB-003*	26.5 ft	149	12,385	7,208	4.15	0.24
BH19-09	LRB-011*	53.5 ft	159	9,657	5,639	2.71	0.24

Notes:
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.
*ASTM D2845 was performed on this specimen prior to unconfined compression by ASTM D7012C testing.

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/7/19
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth, ft	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-15	LRB- 004*	166.26-166.72	165	7,218	5,502	1.74	0.19
BH19-15	LRB- 005	221.31-221.82	131	3,580	2,861	0.29	0.38
BH19-16*	LRB-010	270.44-270.90	168	8,846	5,090	2.35	0.25

Notes:
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.
*ASTM D2845 was performed on this specimen prior to unconfined compression by ASTM D7012C testing.

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/19
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-33	LRB-003	134.28 ft	162	7,226	4,071	1.47	0.27
BH19-35	LRB-003*	176.84 ft	149	6,063	4,645	1.22	0.21
BH19-35	LRB-005	202.76 ft	167	9,368	4,919	2.28	0.31

Notes:
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.
*ASTM D2845 was performed on this specimen prior to unconfined compression by ASTM D7012C testing.

GeoTesting EXPRESS

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/28/20
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth, ft	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-21	LRB-002	64.63-65.94	137	---*	---*	---*	---*
BH19-23	LRB-004	173.56-175.20	134	---*	---*	---*	---*
BH19-23	LRB-012	235.56-237.86	144	11,734	6,085	3.02	0.32
BH19-24A	LRB-001	230.97-232.61	138	---*	---*	---*	---*
BH19-24A	LRB-003	243.11-244.42	142	---*	---*	---*	---*
BH19-24A	LRB-006	269.69-271.98	139	---*	---*	---*	---*
BH19-24A	LRB-009	288.06-289.70	140	4,826	3,695	0.65	0.21
BH19-24A	LRB-010	296.59-300.20	142	4,421	3,556	0.45	0.42
BH19-25	LRB-004	317.26-318.57	137	---*	---*	---*	---*

Notes: * No measureable waves could be propagated through the test specimen.
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	St Ignace, MI
GTX #:	310187
Test Date:	1/28/20
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth, ft	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-26	LRB-003	328.74-330.05	137	---*	---*	---*	---*
BH19-27	LRB-003	302.17-304.46	131	---*	---*	---*	---*
BH19-28	LRB-001	172.24-173.23	137	---*	---*	---*	---*
BH19-28	LRB-010	239.83-241.14	134	---*	---*	---*	---*
BH19-31	LRB-004	180.12-182.09	145	---*	---*	---*	---*
BH19-31	LRB-008	210.30-211.61	136	---*	---*	---*	---*
BH19-31	LRB-011	261.48-262.47	135	---*	---*	---*	---*

Notes: * No measureable waves could be propagated through the test specimen.
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	12/11/19
Tested By:	cmh
Checked By:	jsc

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845 - Summary Table

Boring ID	Sample ID	Depth, ft	Bulk Density, lbs/ft^3	P-Wave Velocity, (ft/sec) (Axial)	S-Wave Velocity, (ft/sec) (Axial)	Young's Modulus, (psi) 10^6	Poisson's Ratio
BH19-19	LRB-006	136.81-137.70	147	---*	---*	---*	---*
BH19-19	LRB-010	187.99-188.98	146	---*	---*	---*	---*
BH19-36	LRB-004	202.43-203.74	139	---*	---*	---*	---*
BH19-36	LRB-005	211.61-212.27	144	---*	---*	---*	---*

Notes: * No measureable waves could be propagated through the test specimen.
Density determined on rock core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
No coupling medium was used.

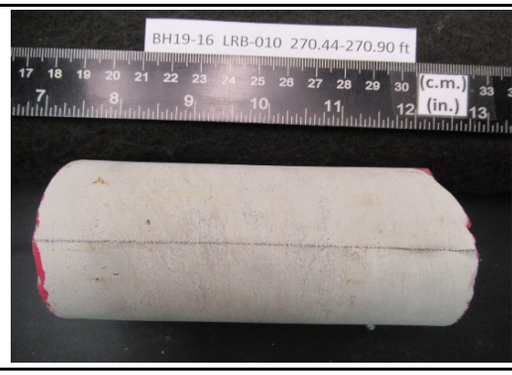
Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-15
LRB-004
166.26-166.72 ft

BH19-15
LRB-005
221.31-221.82 ft

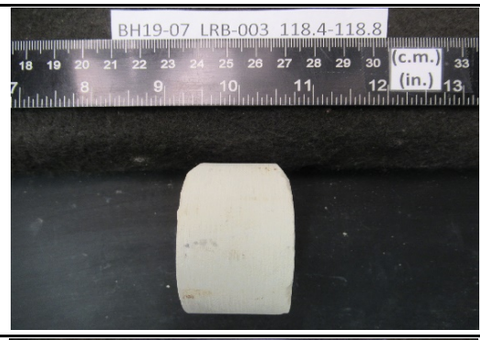
BH19-16
LRB-010
270.44-270.90 ft



Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-07
LRB-003
118.4-118.8 ft



BH19-07
LRB-010
178.0-178.8 ft

BH19-07
LRB-011
194.2-194.9 ft

BH19-17
LRB-002
368.1-368.8 ft

BH19-17
LRB-007
314.9-315.5 ft

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187

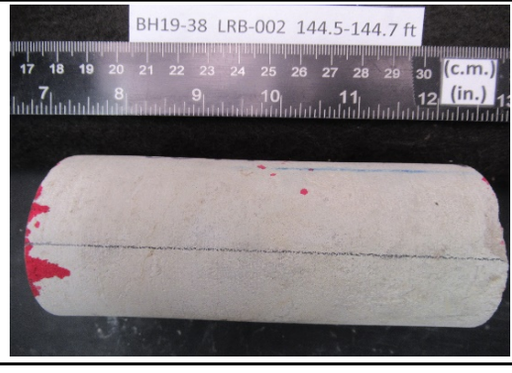
Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-17
LRB-013
159.2-159.7 ft

BH19-37
LRB-006
209.7-210.2 ft

BH19-38
LRB-001
128-128.8 ft

BH19-38
LRB-002
144.5-144.7 ft



Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	St Ignace, MI
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-33
LRB-003
134.28 ft

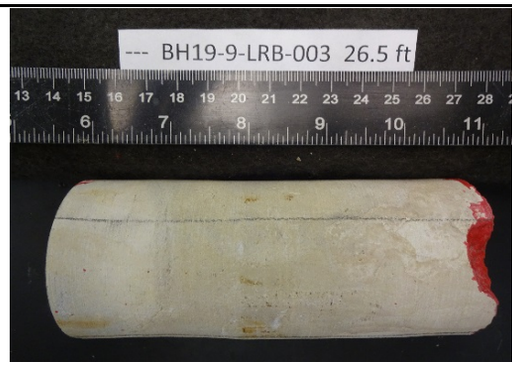
BH19-35
LRB-003
176.84 ft

BH19-35
LRB-005
202.76 ft

Client:	WSP
Project Name:	Line 5 Replacement Tunnel
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-09
LRB-003
26.5 ft



BH19-09
LRB-011
53.5 ft

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-19
LRB-006
136.81-137.70 ft

BH19-19
LRB-010
187.99-188.98 ft

BH19-36
LRB-004
202.43-203.74 ft

BH19-36
LRB-005
211.61-212.27 ft

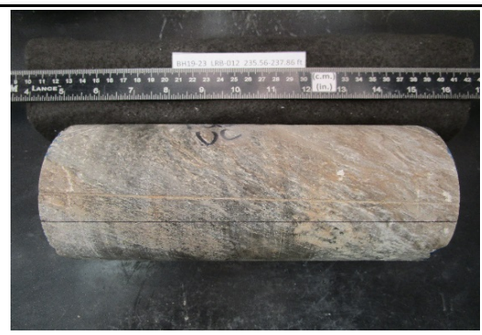
Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

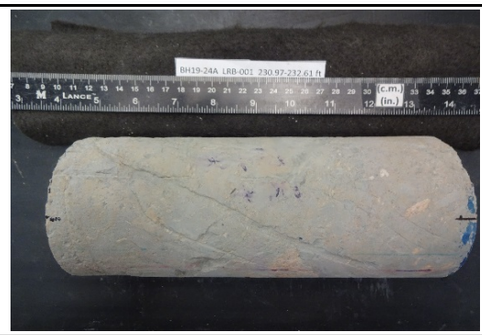
BH19-21
LRB-002
64.63-65.94 ft

BH19-23
LRB-004
173.56-175.20 ft

BH19-23
LRB-012
235.56-237.86 ft



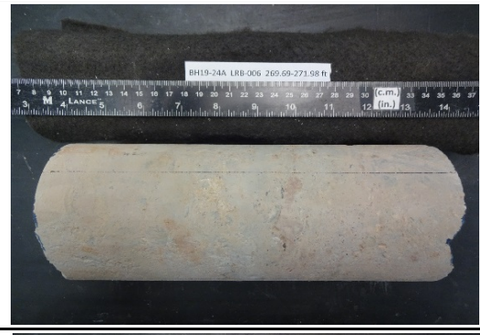
BH19-24A
LRB-001
230.97-232.61 ft



BH19-24A
LRB-003
243.11-244.42 ft

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-24A LRB-006 269.69-271.98 ft	
BH19-24A LRB-009 288.06-289.70 ft	
BH19-24A LRB-010 296.59-300.20 ft	
BH19-25 LRB-004 317.26-318.57 ft	
BH19-26 LRB-003 328.74-330.05 ft	

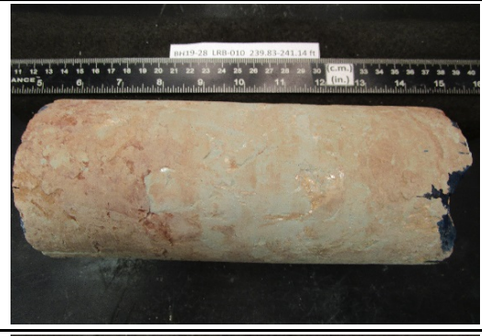
Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187

Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-27
LRB-003
302.17-304.46 ft

BH19-28
LRB-001
172.24-173.23 ft

BH19-28
LRB-010
239.83-241.14 ft



BH19-31
LRB-004
180.12-182.09 ft

BH19-31
LRB-008
210.30-211.61 ft

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187

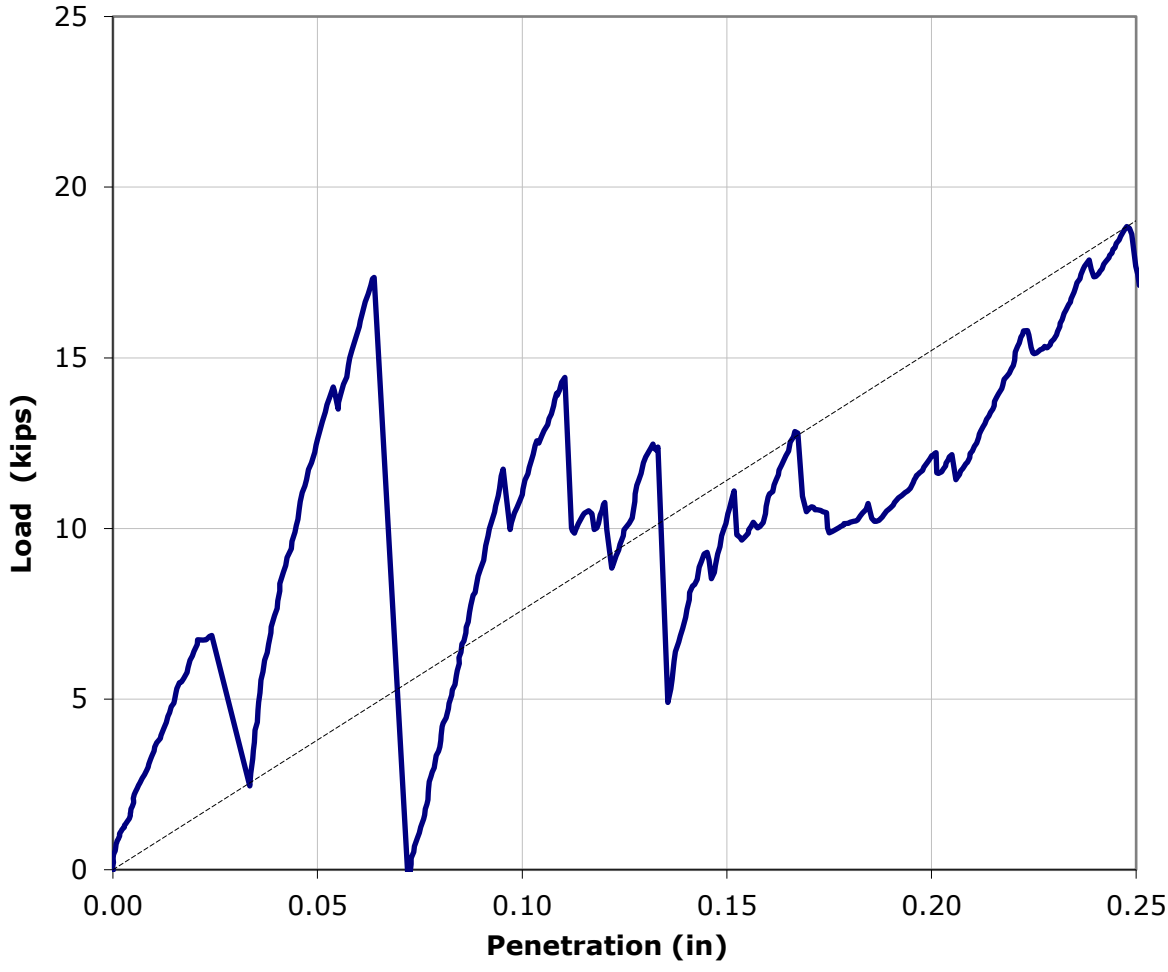
Pulse Velocities and Ultrasonic Elastic Constants of Rock by ASTM D2845

BH19-31
LRB-011
261.48-262.47 ft

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/22/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-07
Sample ID:	LRB-007
Depth, ft:	140.8-141
Visual Description:	---

Punch Penetration Index Test

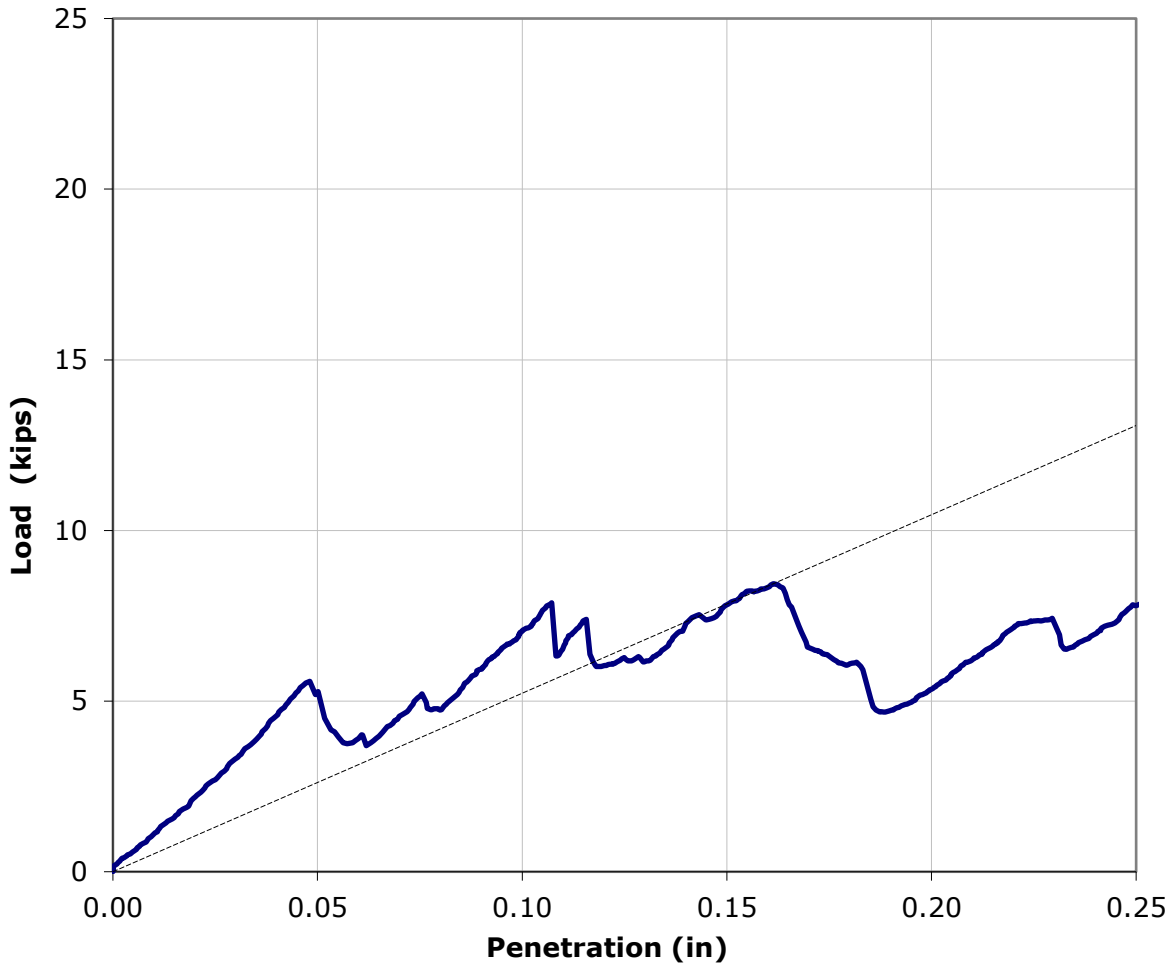
Moisture Condition:	as-received	Maximum Load, lbs:	18847
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	76.1



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/22/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-07
Sample ID:	LRB-010
Depth, ft:	178.0-178.8
Visual Description:	---

Punch Penetration Index Test

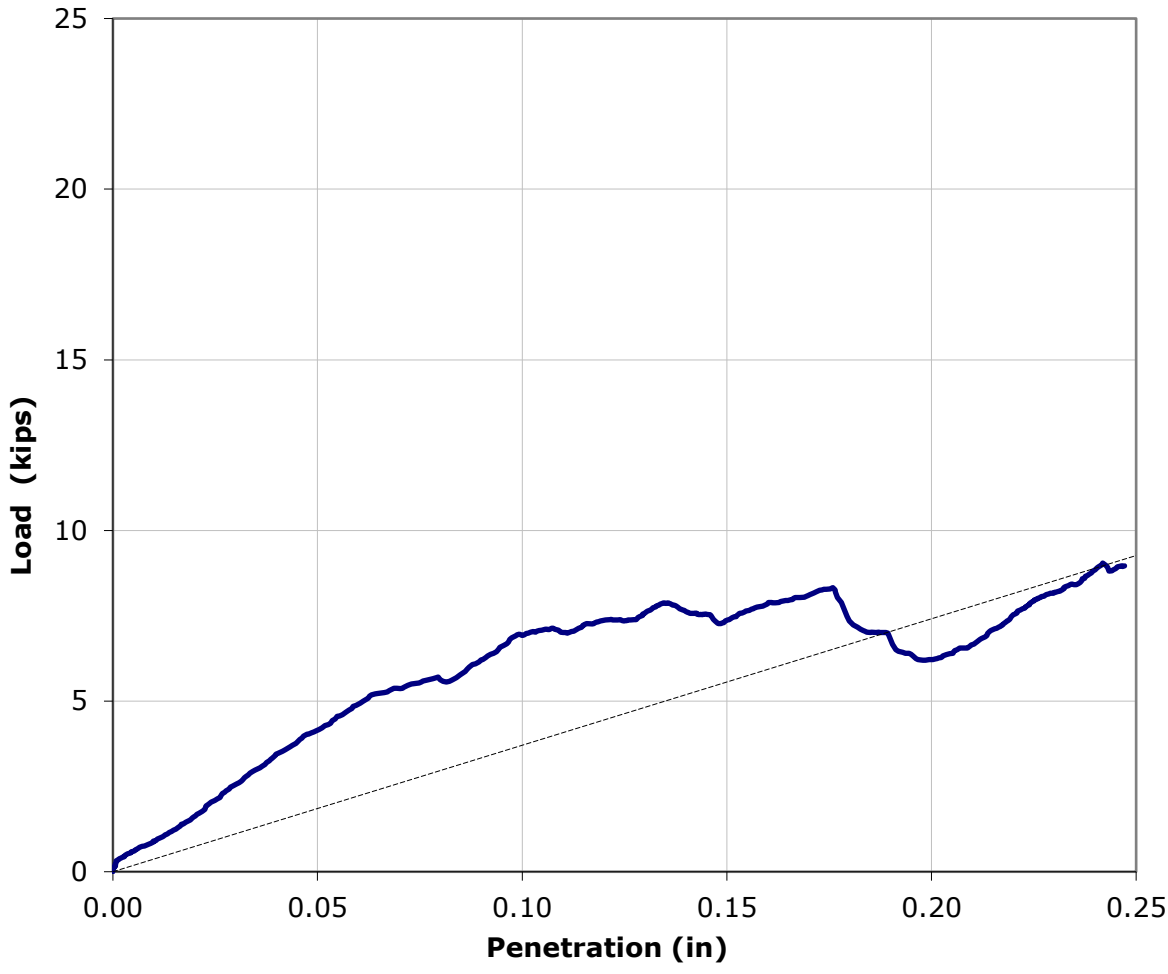
Moisture Condition:	as-received	Maximum Load, lbs:	8440
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	52.3



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-08
Sample ID:	LRB-010
Depth, ft:	44.6
Visual Description:	---

Punch Penetration Index Test

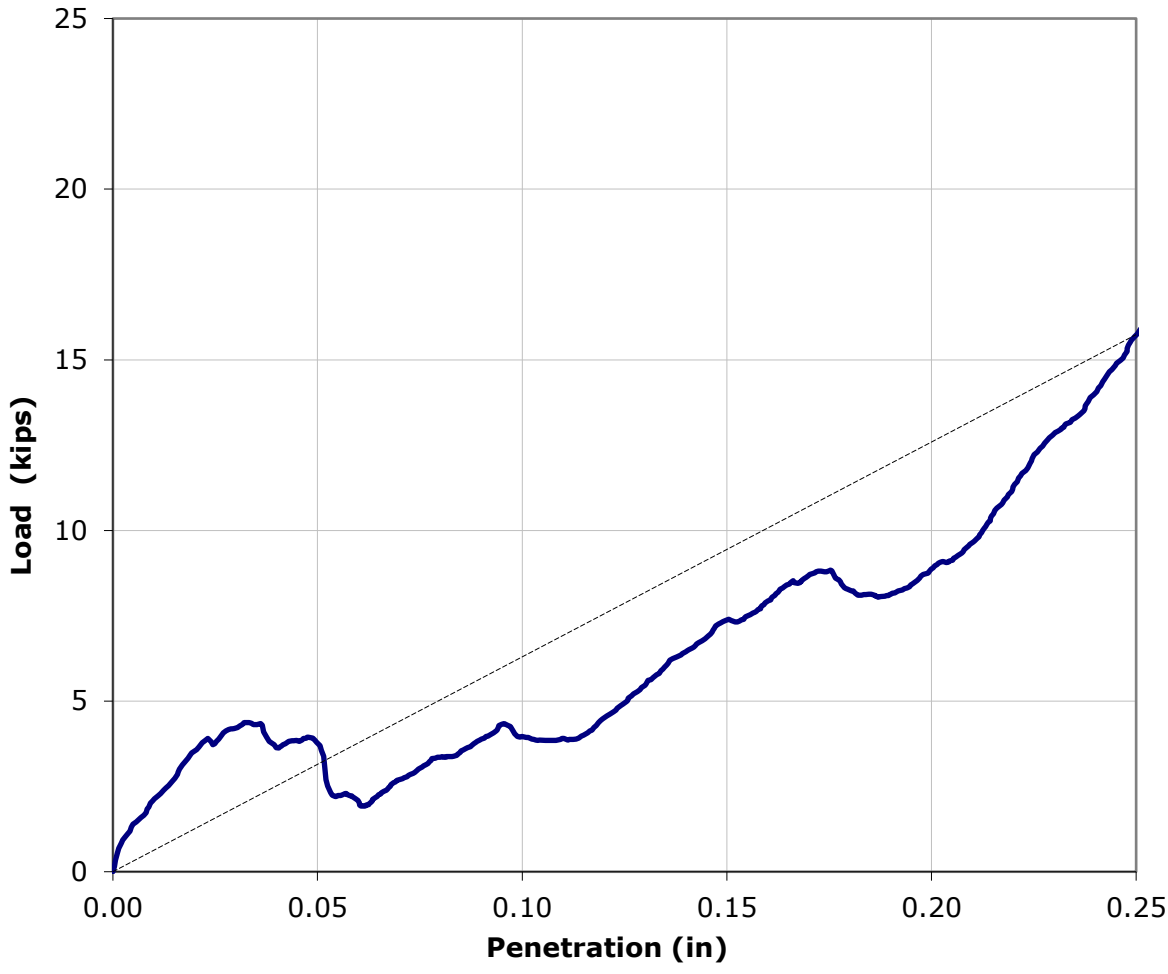
Moisture Condition:	as-received	Maximum Load, lbs:	9268
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	37.1



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-08
Sample ID:	LRB-015
Depth, ft:	82.6
Visual Description:	---

Punch Penetration Index Test

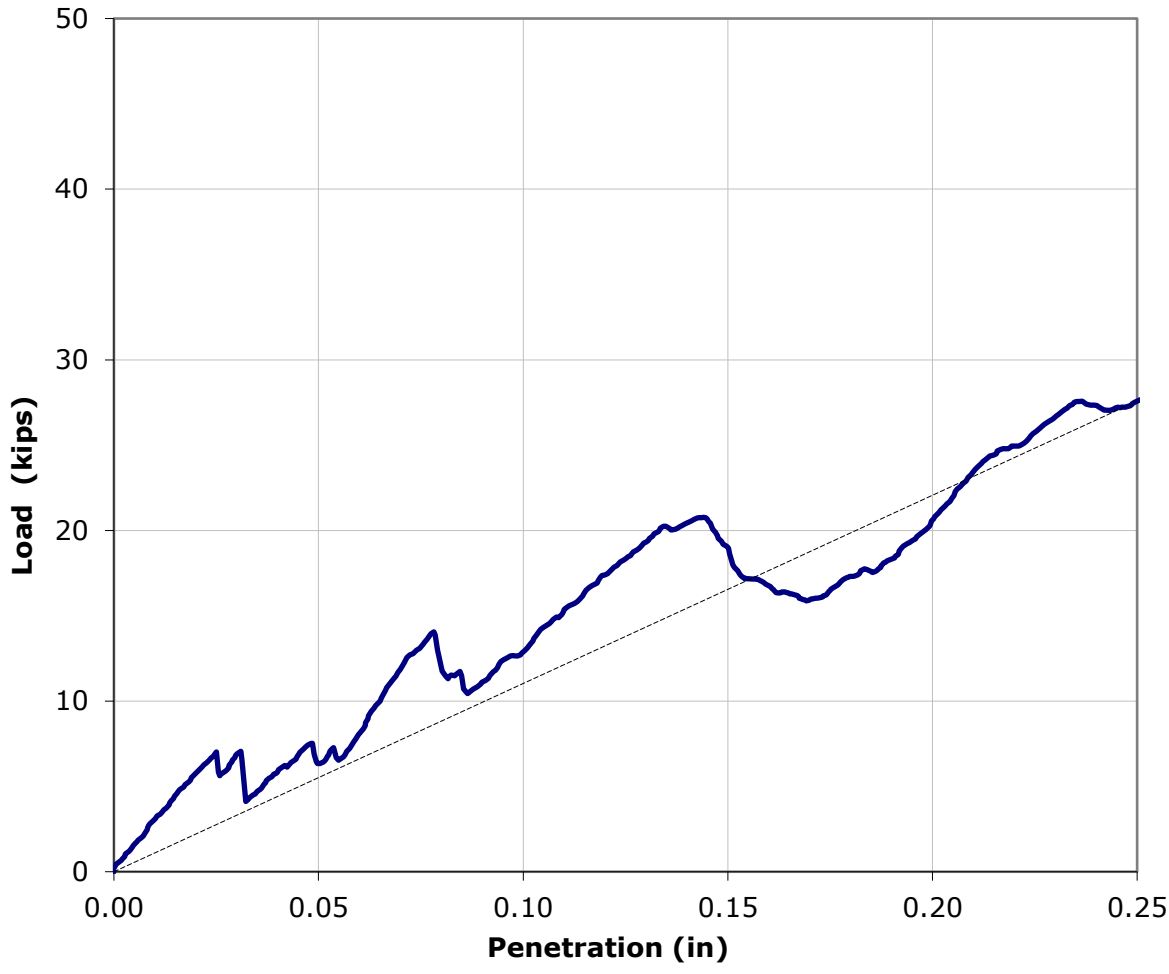
Moisture Condition:	as-received	Maximum Load, lbs:	15757
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	63.0



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-09
Sample ID:	LRB-006
Depth, ft:	38.0
Visual Description:	---

Punch Penetration Index Test

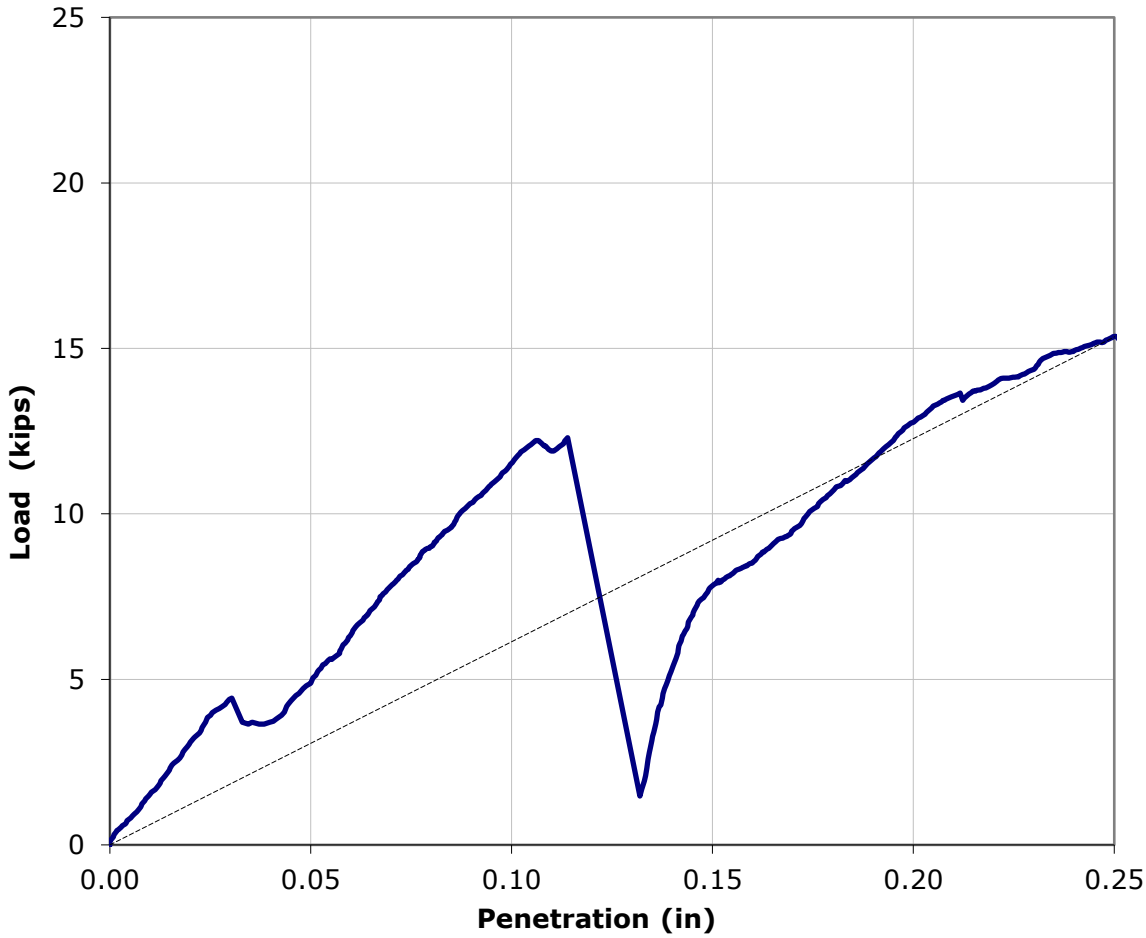
Moisture Condition:	as-received	Maximum Load, lbs:	27610
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	110



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-09
Sample ID:	LRB-013
Depth, ft:	74.0
Visual Description:	---

Punch Penetration Index Test

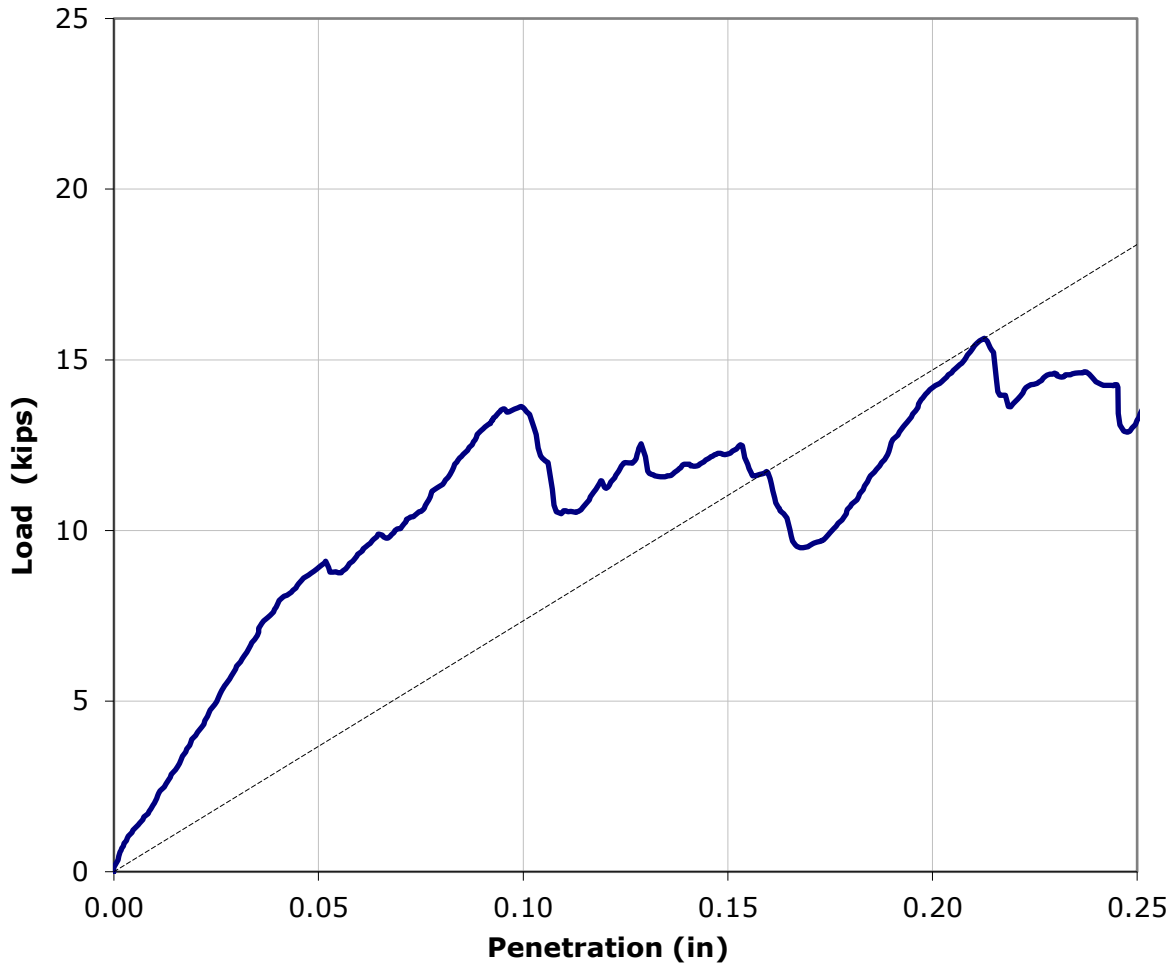
Moisture Condition:	as-received	Maximum Load, lbs:	15575
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	61.4



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-10
Sample ID:	LRB-004
Depth, ft:	58.0
Visual Description:	---

Punch Penetration Index Test

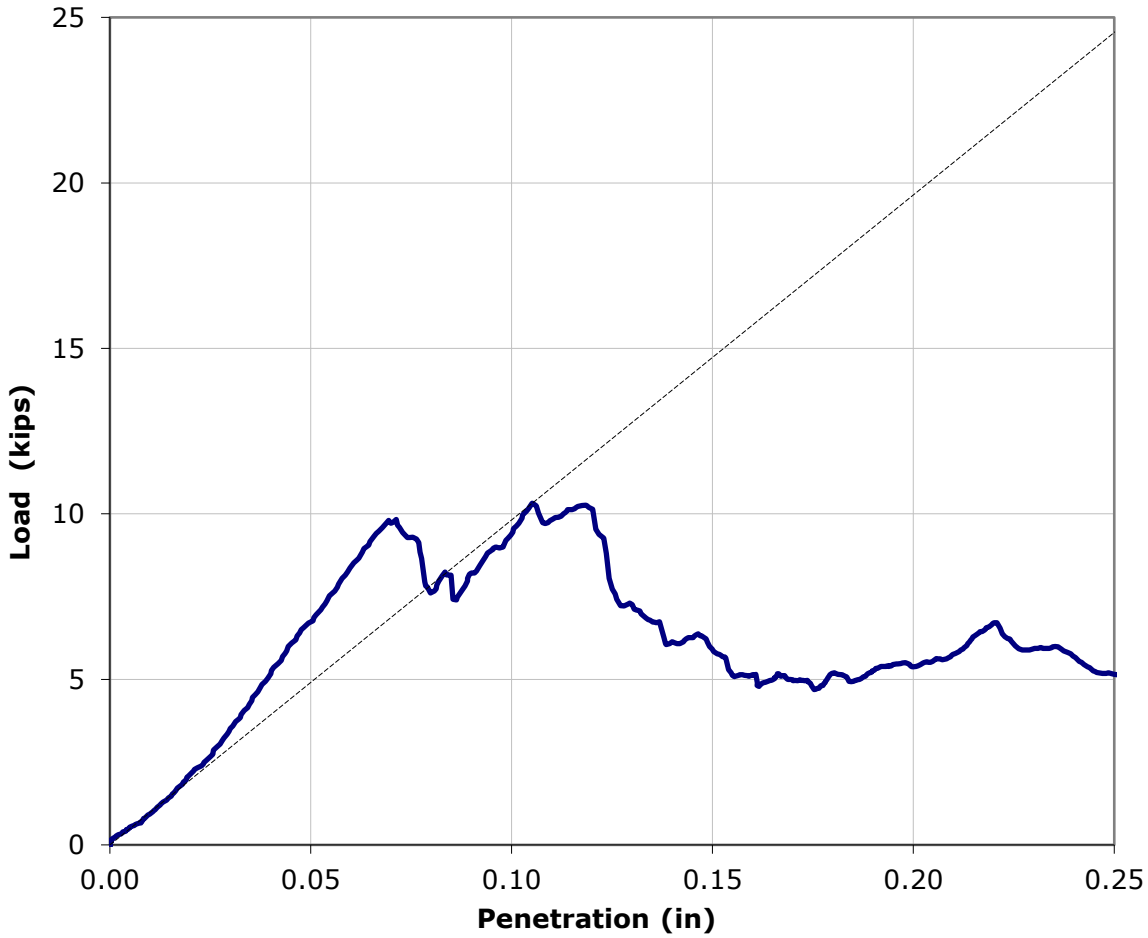
Moisture Condition:	as-received	Maximum Load, lbs:	15631
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	73.5



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/5/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-15
Sample ID:	LRB-004
Depth, ft:	163.33-163.46
Visual Description:	---

Punch Penetration Index Test

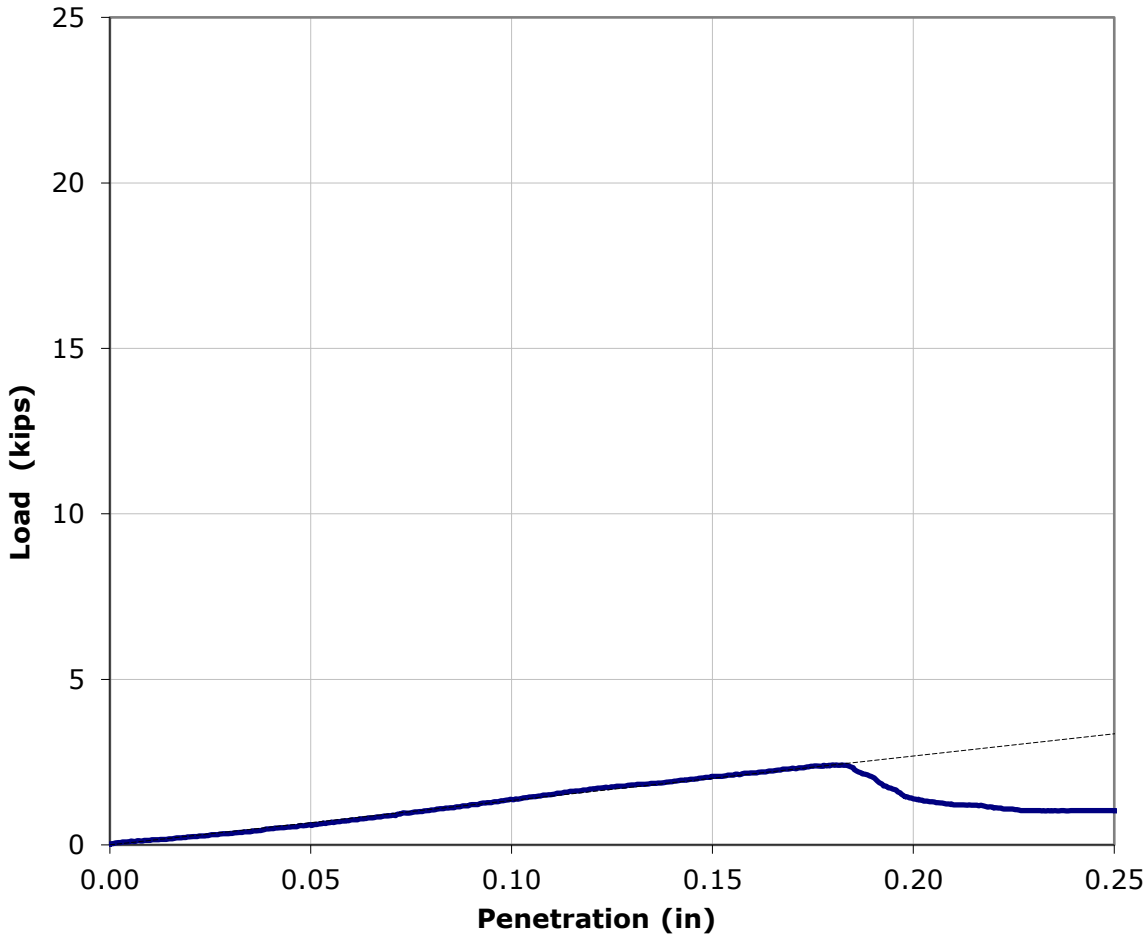
Moisture Condition:	as-received	Maximum Load, lbs:	10336
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	98.2



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/5/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-15
Sample ID:	LRB-005
Depth, ft.:	219.06-219.21
Visual Description:	---

Punch Penetration Index Test

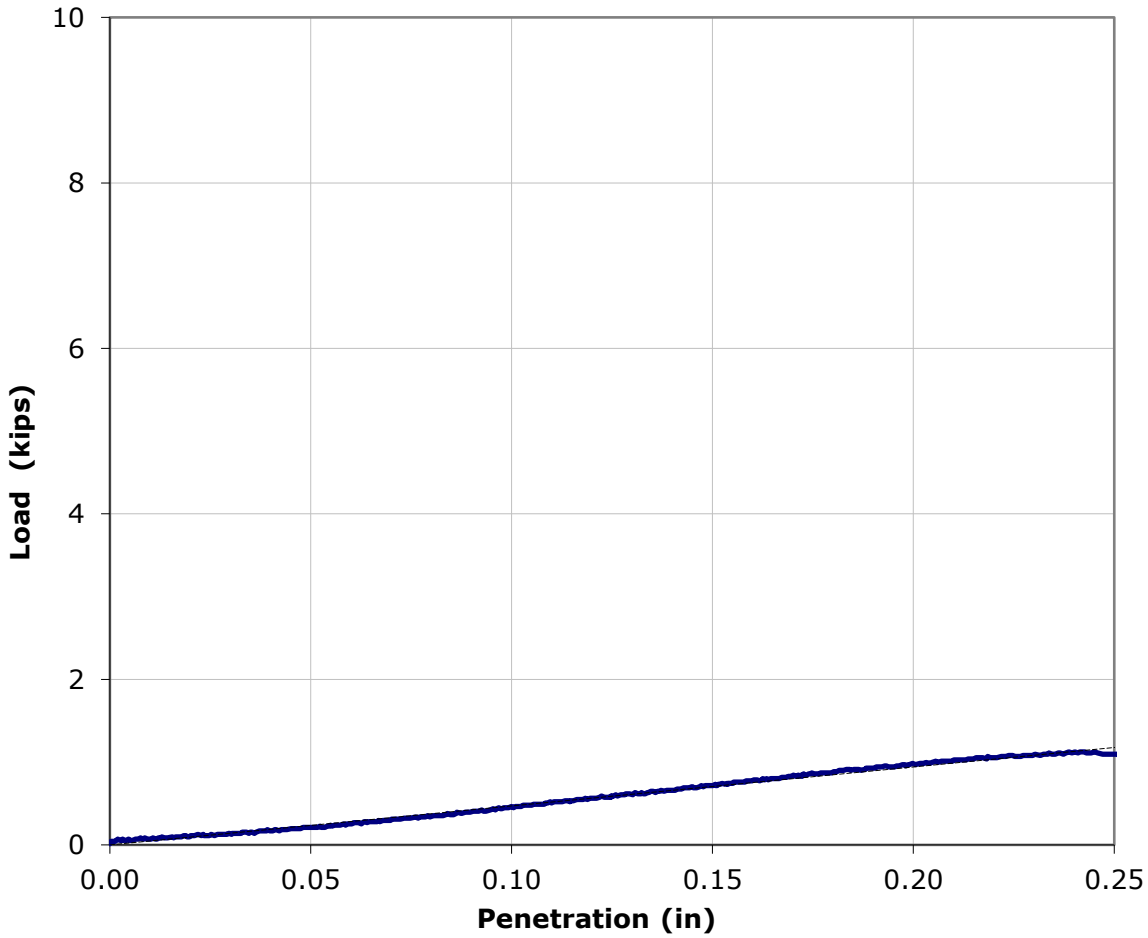
Moisture Condition:	as-received	Maximum Load, lbs:	2416
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	13.4



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/5/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-16
Sample ID:	LRB-008
Depth, ft:	253.28-253.41
Visual Description:	---

Punch Penetration Index Test

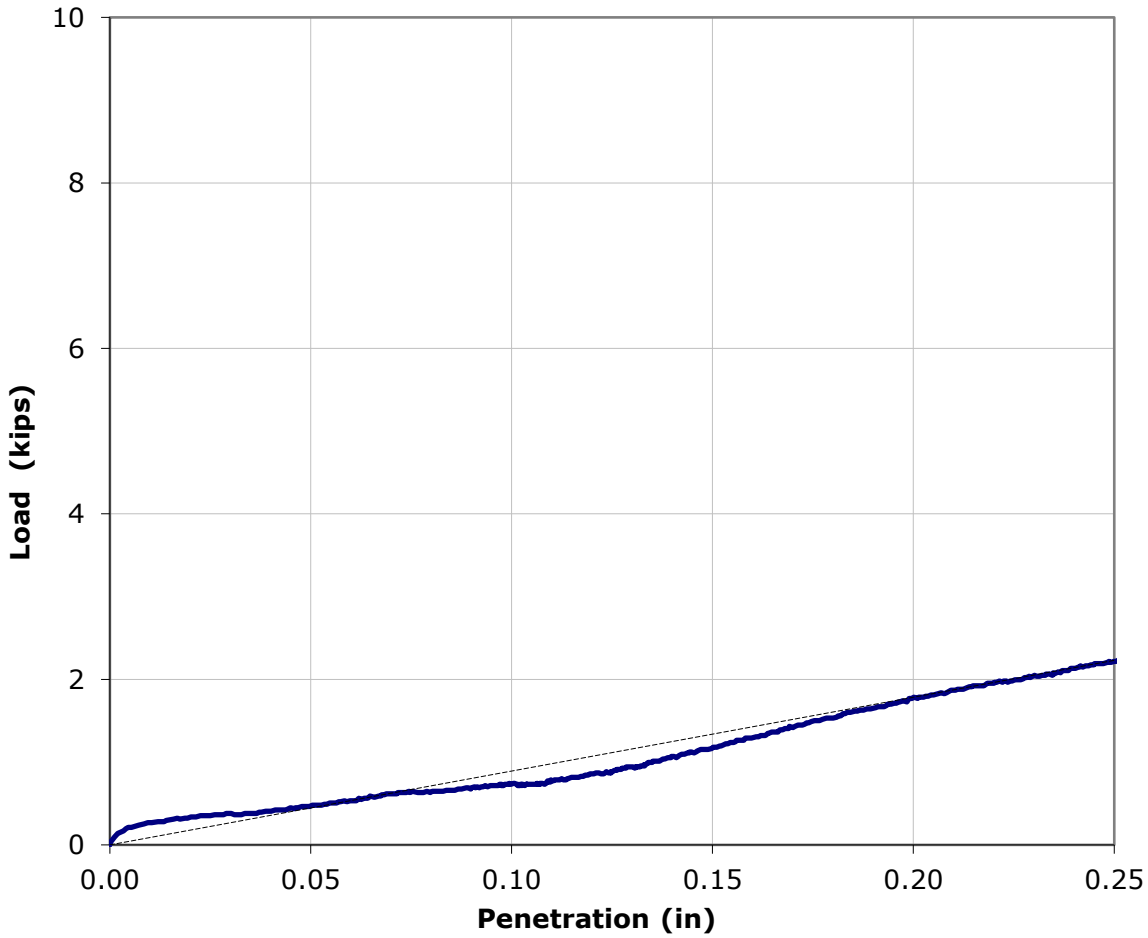
Moisture Condition:	as-received	Maximum Load, lbs:	1124
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	4.7



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/5/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-16
Sample ID:	LRB-012
Depth, ft:	317.65-317.77
Visual Description:	---

Punch Penetration Index Test

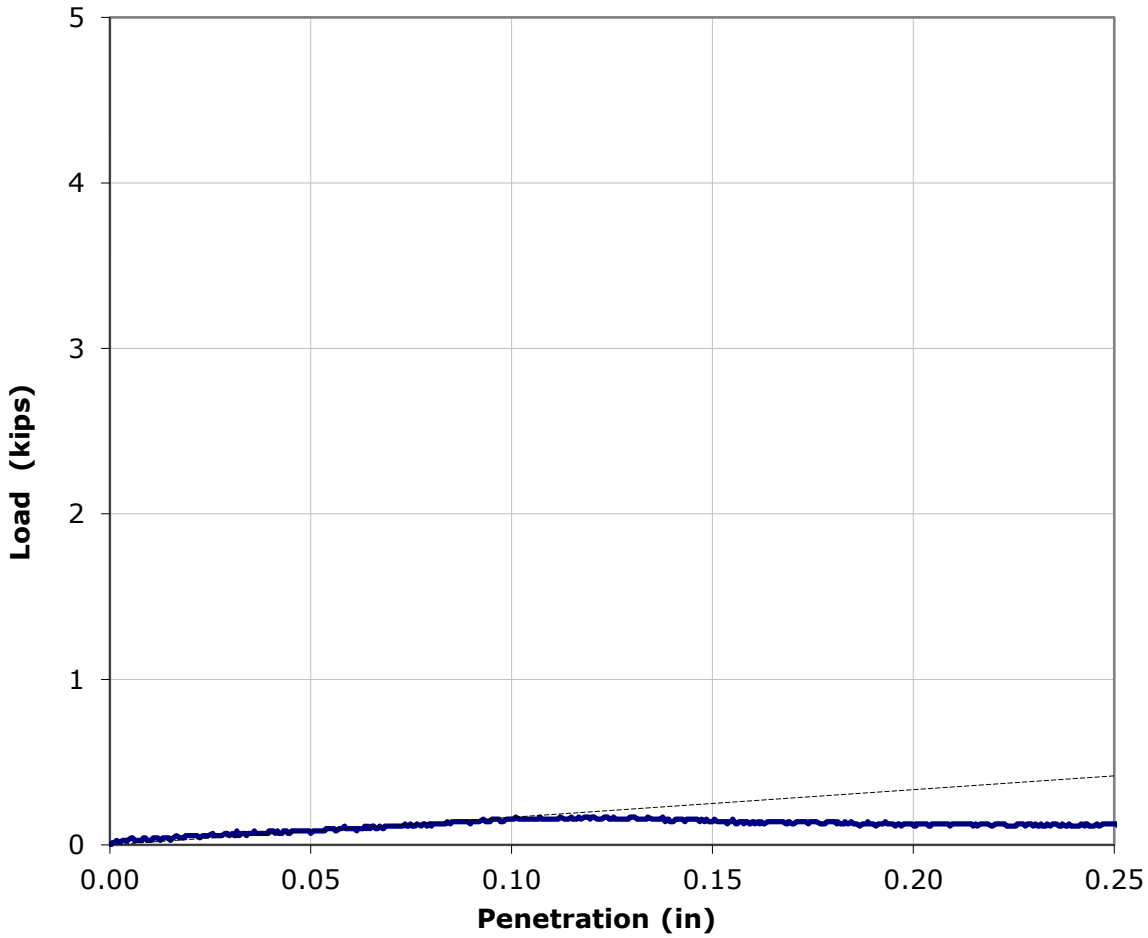
Moisture Condition:	as-received	Maximum Load, lbs:	2486
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	8.9



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/22/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-17
Sample ID:	LRB-002
Depth, ft:	368.1-368.8
Visual Description:	---

Punch Penetration Index Test

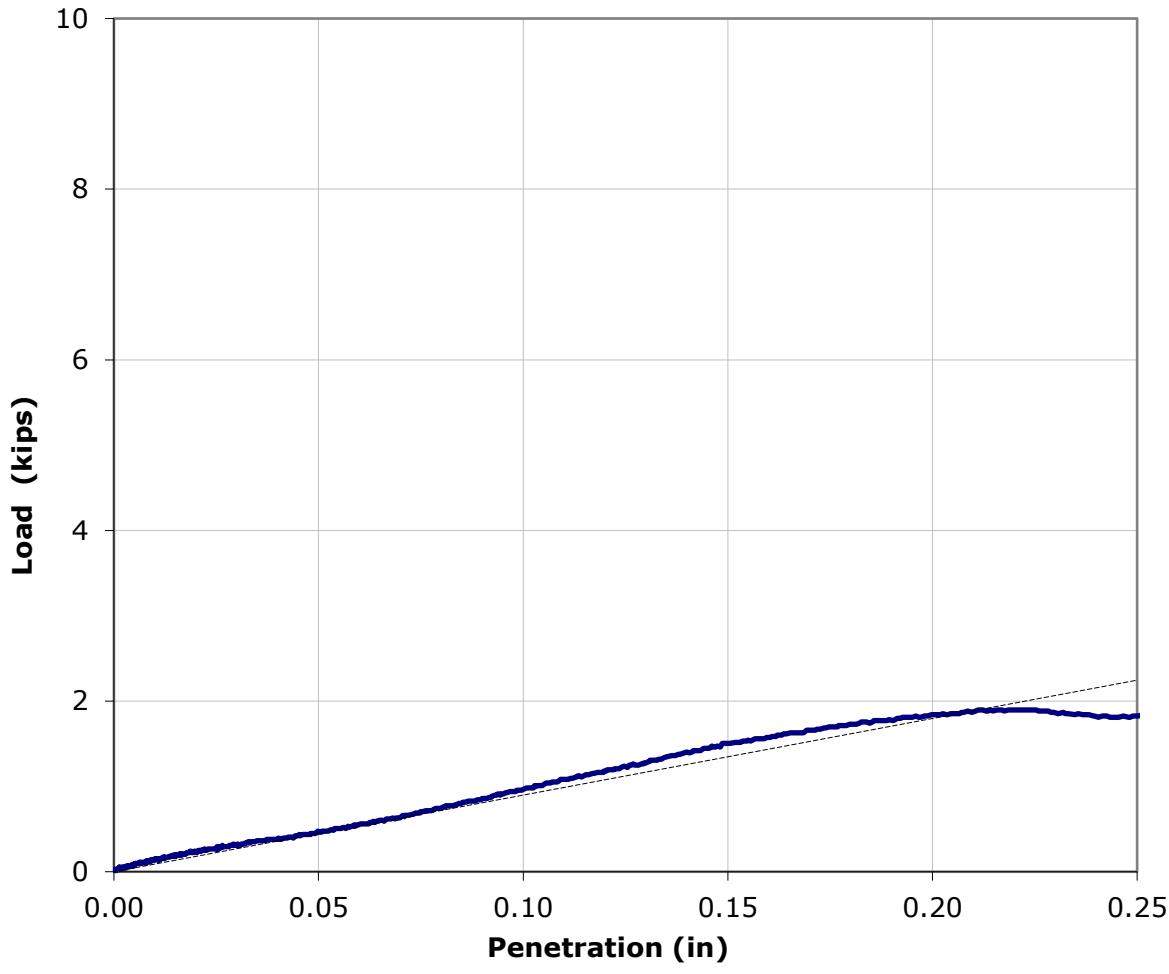
Moisture Condition:	as-received	Maximum Load, lbs:	169
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	1.17



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	12/19/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-19
Sample ID:	LRB-009
Depth, ft:	174.05-174.25
Visual Description:	---

Punch Penetration Index Test

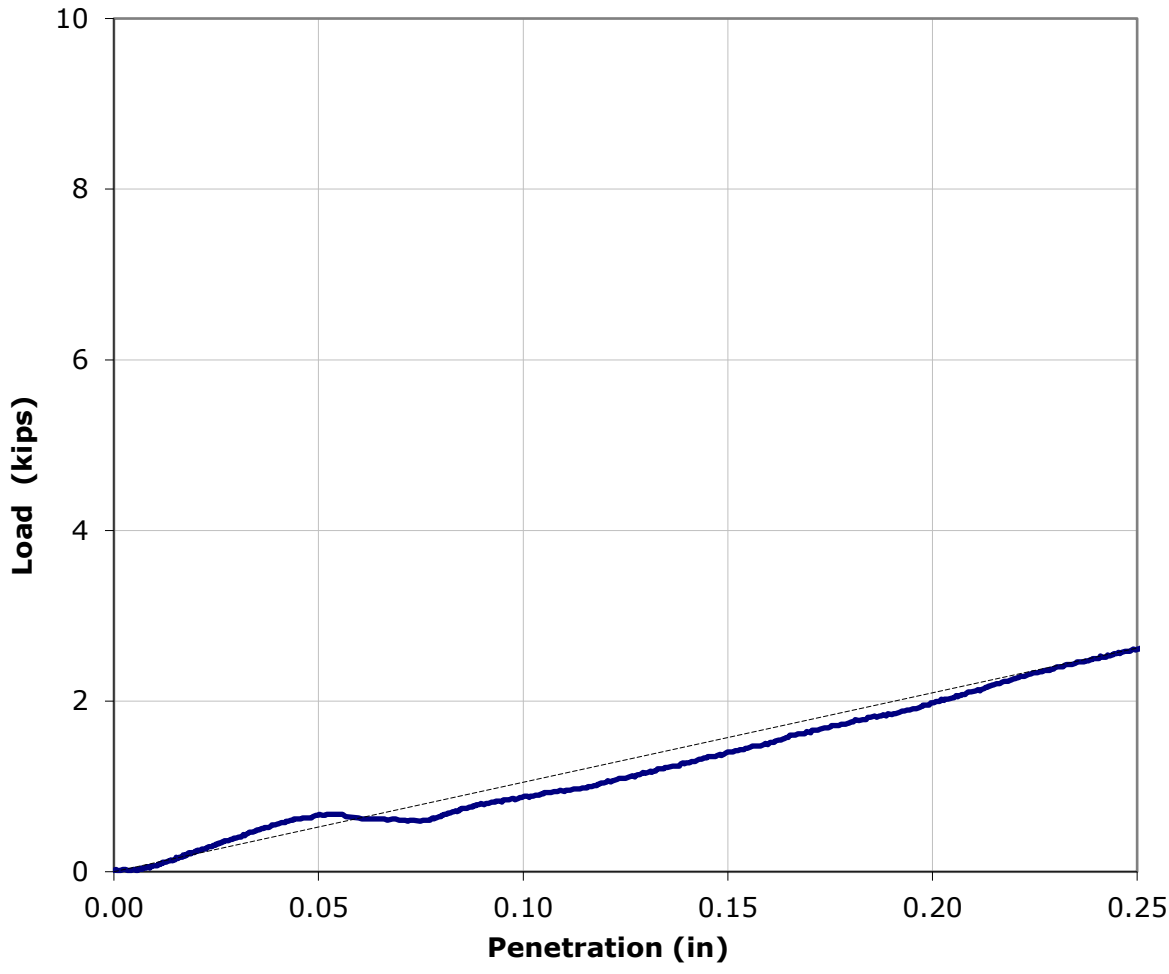
Moisture Condition:	as-received	Maximum Load, lbs:	1910
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	9.0



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/23/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-23
Sample ID:	LRB-003
Depth, ft:	161.75-164.04
Visual Description:	---

Punch Penetration Index Test

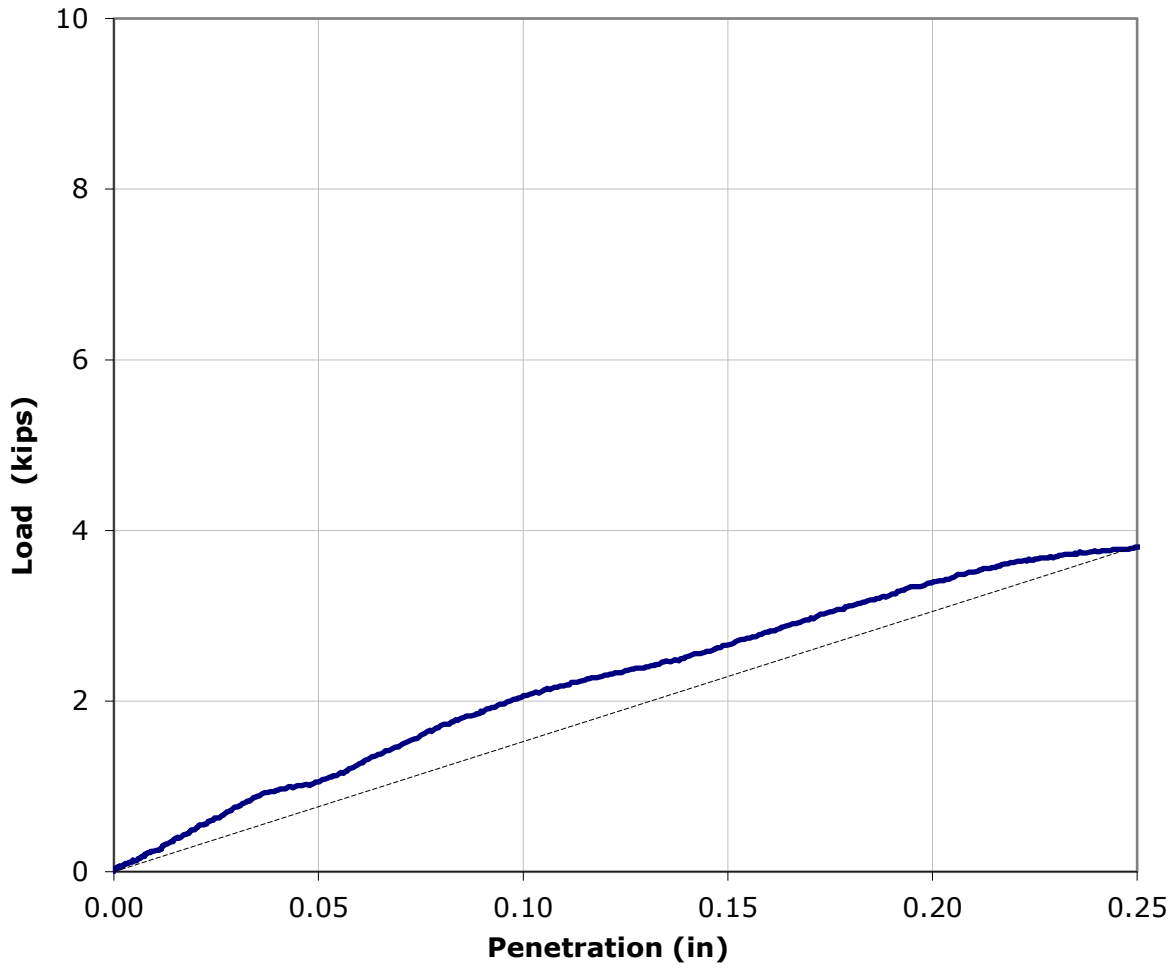
Moisture Condition:	as-received	Maximum Load, lbs:	2612
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	10.5



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/23/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-23
Sample ID:	LRB-005
Depth, ft:	180.12-180.45
Visual Description:	---

Punch Penetration Index Test

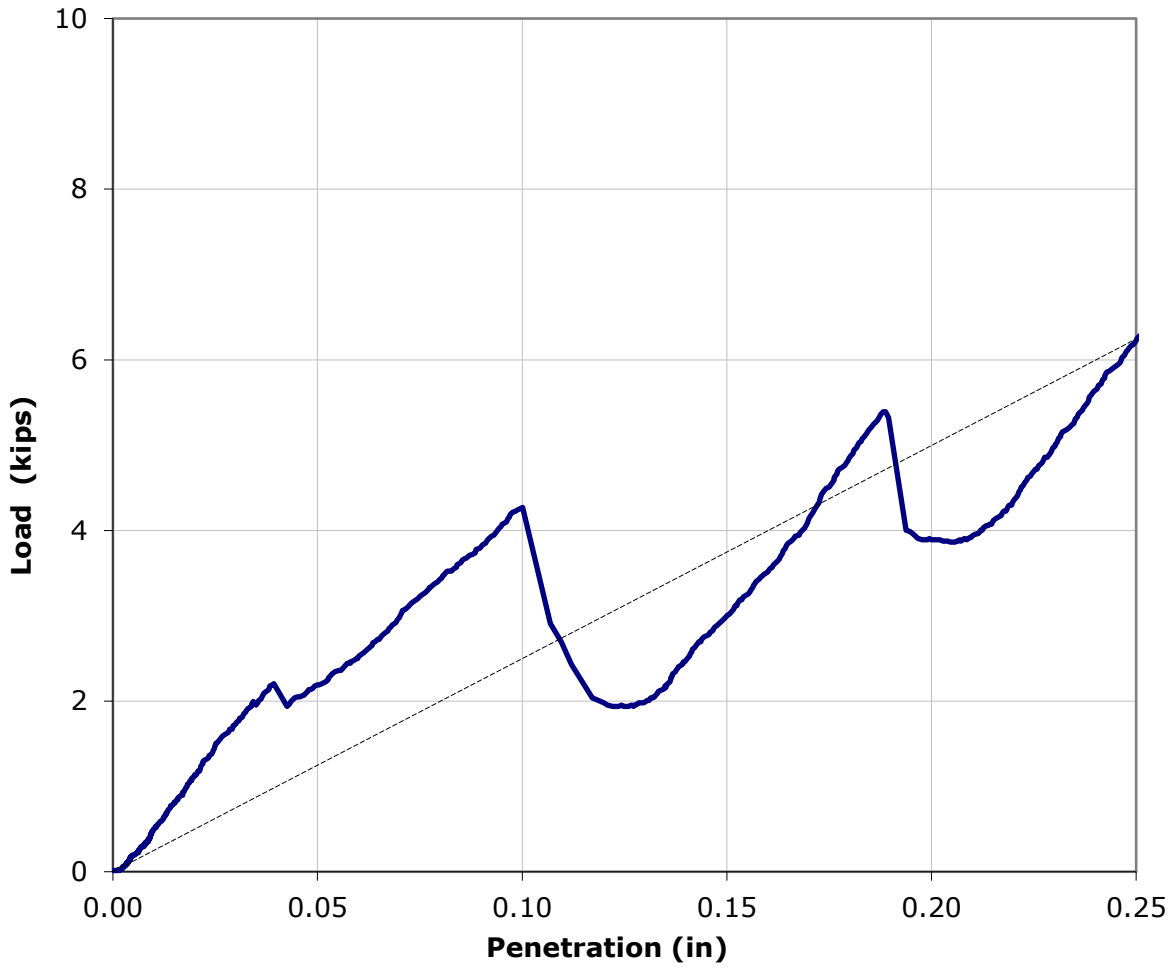
Moisture Condition:	as-received	Maximum Load, lbs:	3806
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	15.3



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/23/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-001
Depth, ft:	230.97-232.61
Visual Description:	---

Punch Penetration Index Test

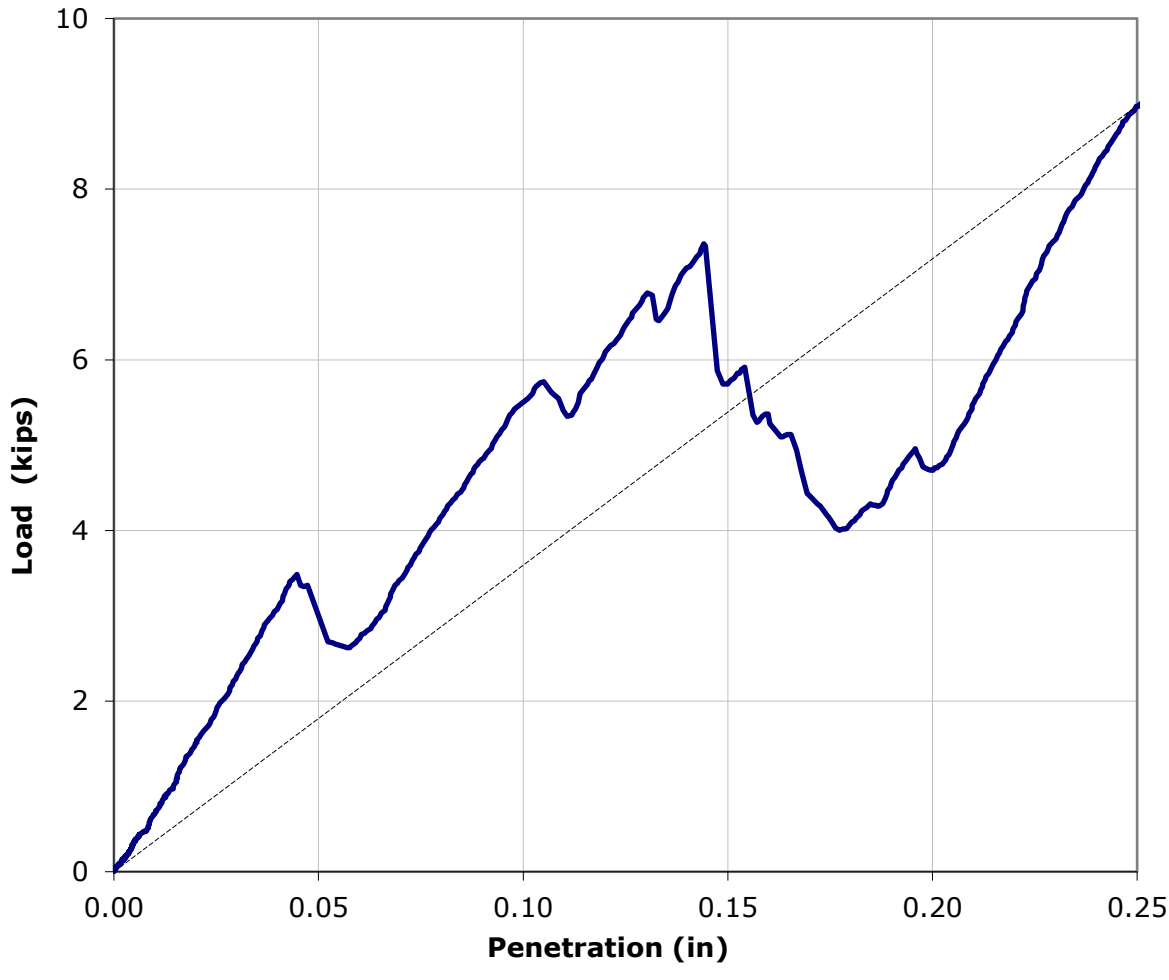
Moisture Condition:	as-received	Maximum Load, lbs:	6250
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	25.0



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/23/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-010
Depth, ft:	296.59-300.20
Visual Description:	---

Punch Penetration Index Test

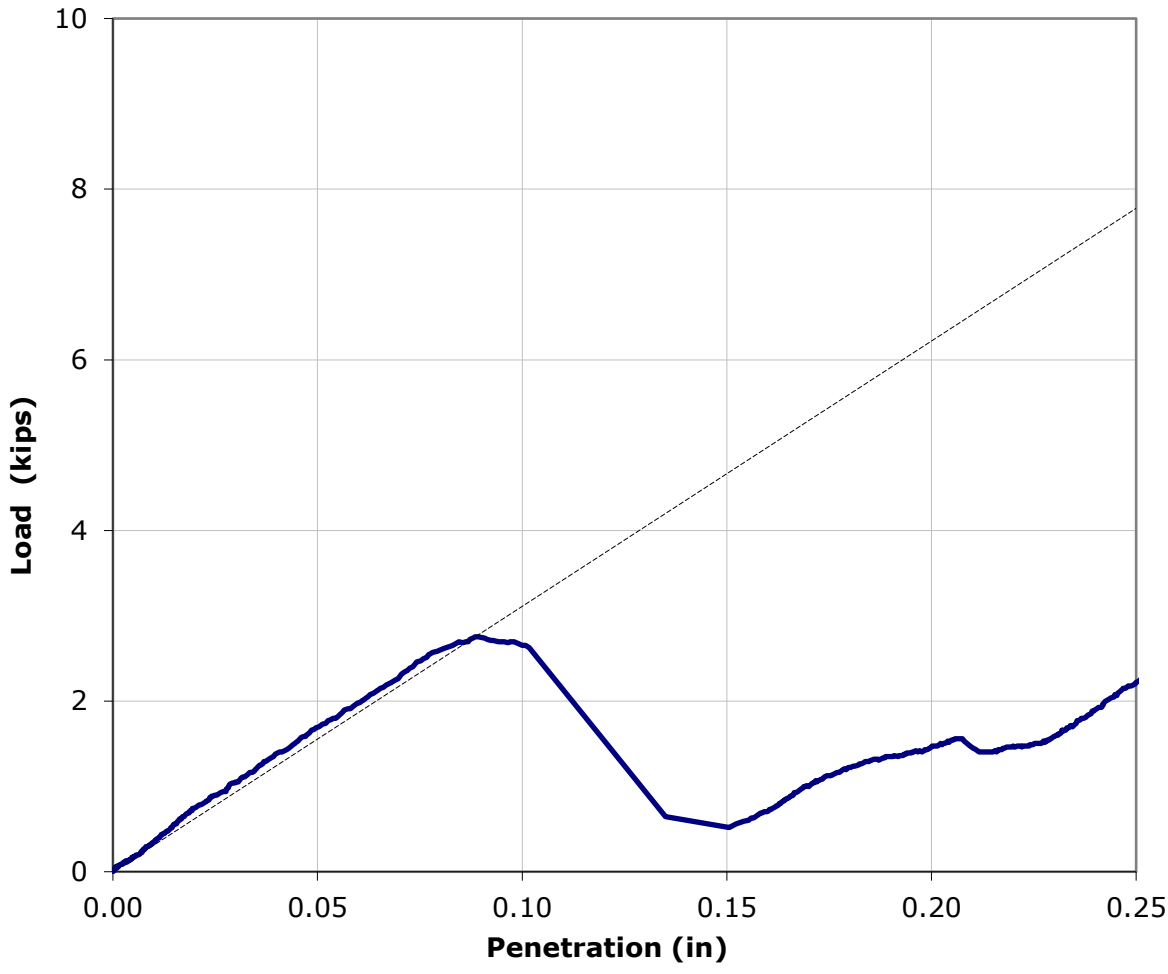
Moisture Condition:	as-received	Maximum Load, lbs:	8974
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	35.9



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/23/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-013
Depth, ft:	312.99-313.98
Visual Description:	---

Punch Penetration Index Test

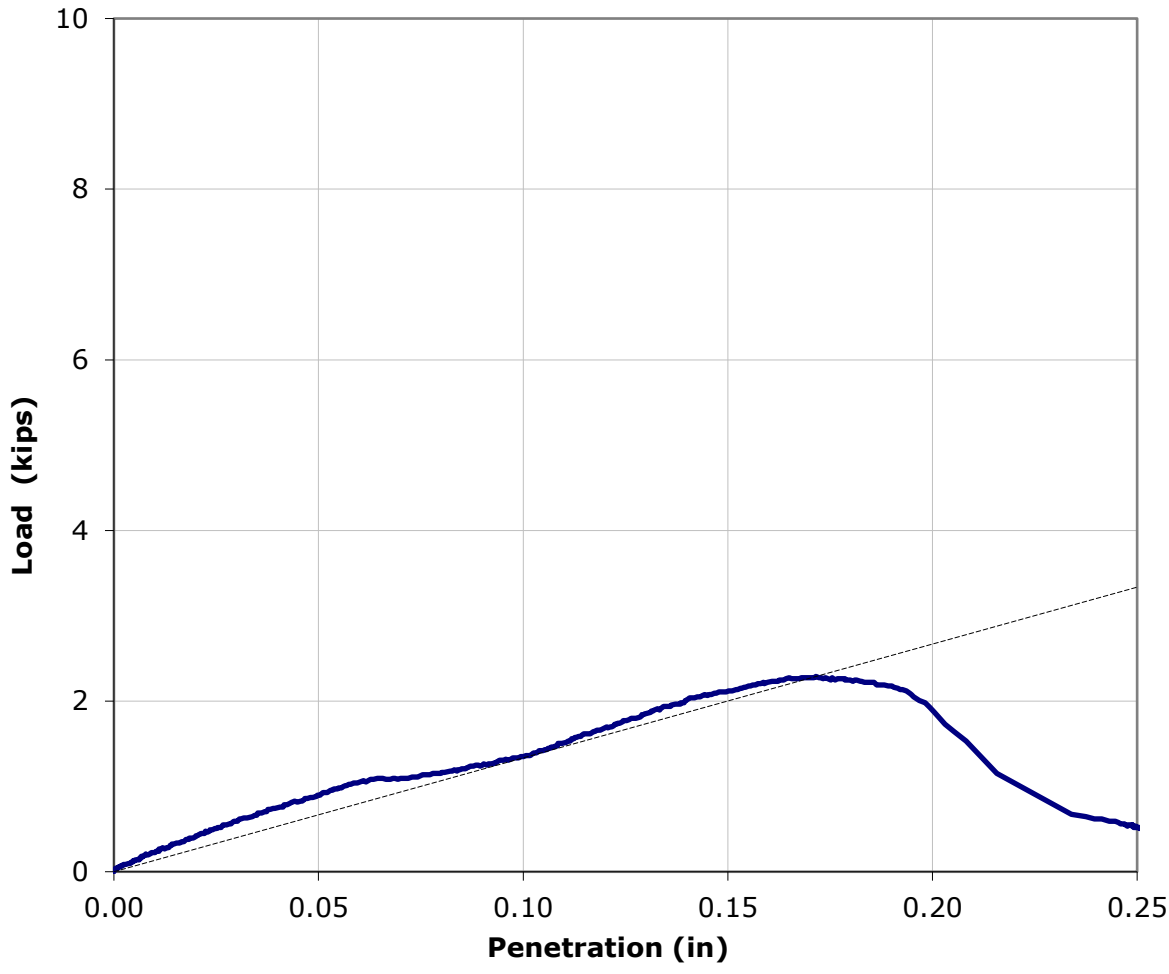
Moisture Condition:	as-received	Maximum Load, lbs:	2753
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	31.1



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/24/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-25
Sample ID:	LRB-002
Depth, ft:	308.73-309.71
Visual Description:	---

Punch Penetration Index Test

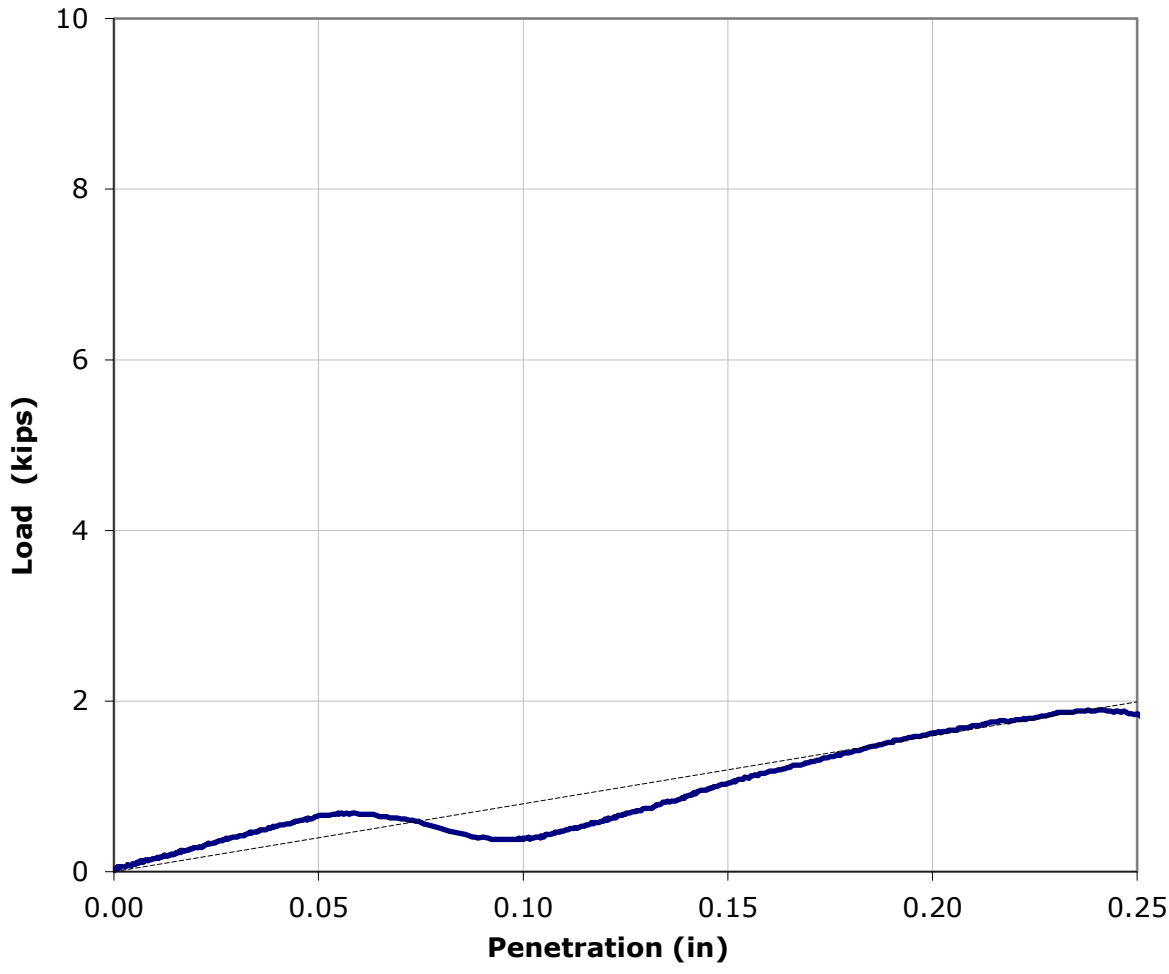
Moisture Condition:	as-received	Maximum Load, lbs:	2289
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	13.3



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/24/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-27
Sample ID:	LRB-004
Depth, ft:	310.04-310.70
Visual Description:	---

Punch Penetration Index Test

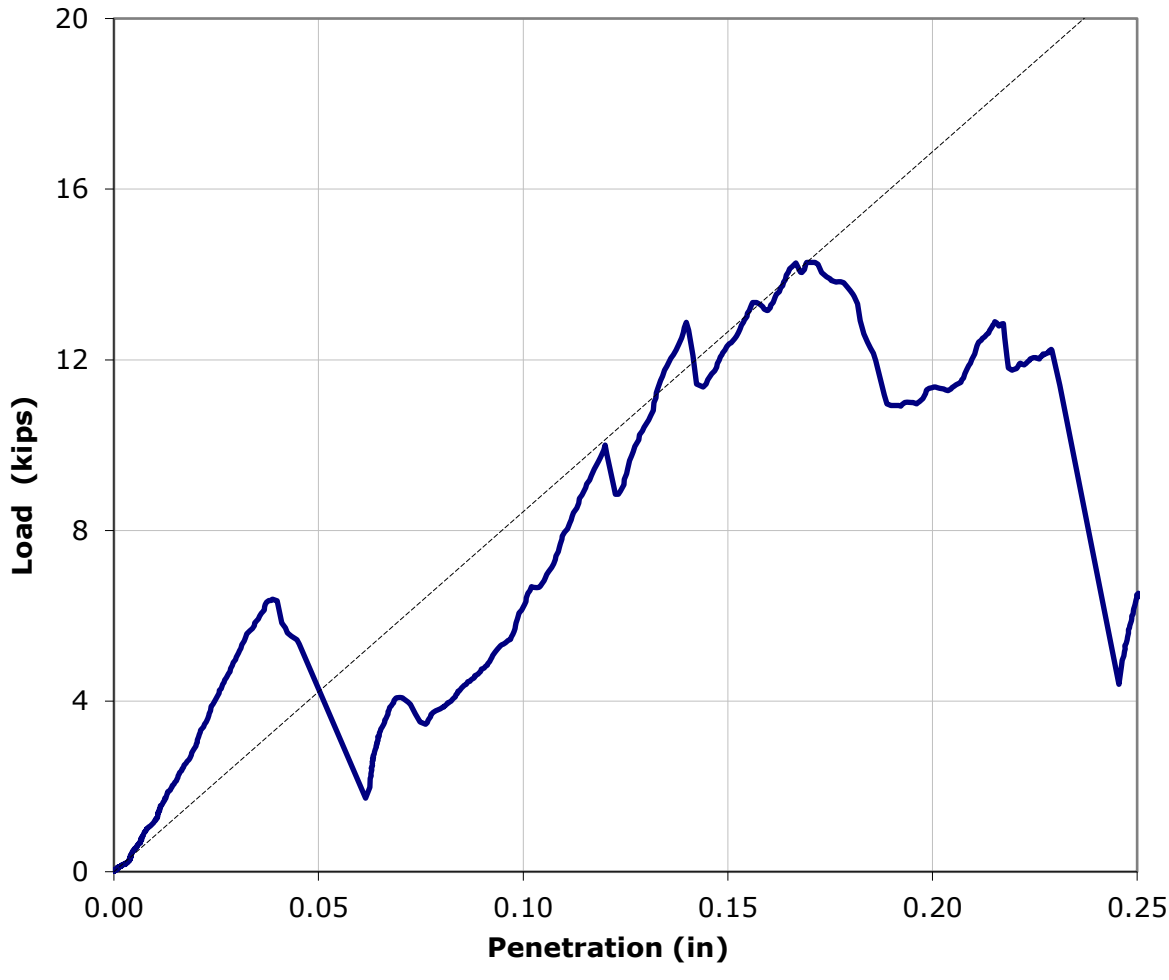
Moisture Condition:	as-received	Maximum Load, lbs:	1896
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	8.0



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/24/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-27
Sample ID:	LRB-006
Depth, ft:	321.52-322.16
Visual Description:	---

Punch Penetration Index Test

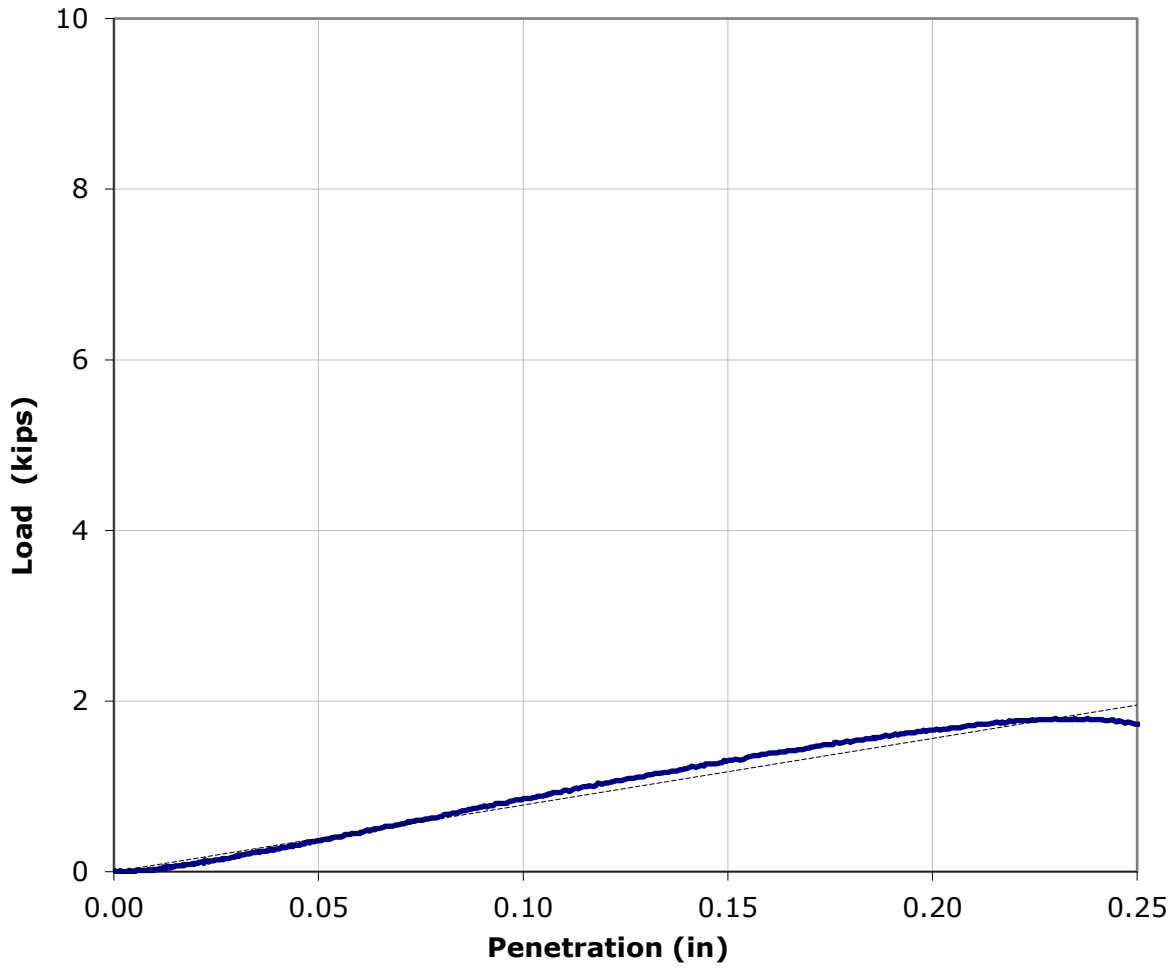
Moisture Condition:	as-received	Maximum Load, lbs:	14283
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	84.4



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/24/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-28
Sample ID:	LRB-007
Depth, ft:	215.55-217.85
Visual Description:	---

Punch Penetration Index Test

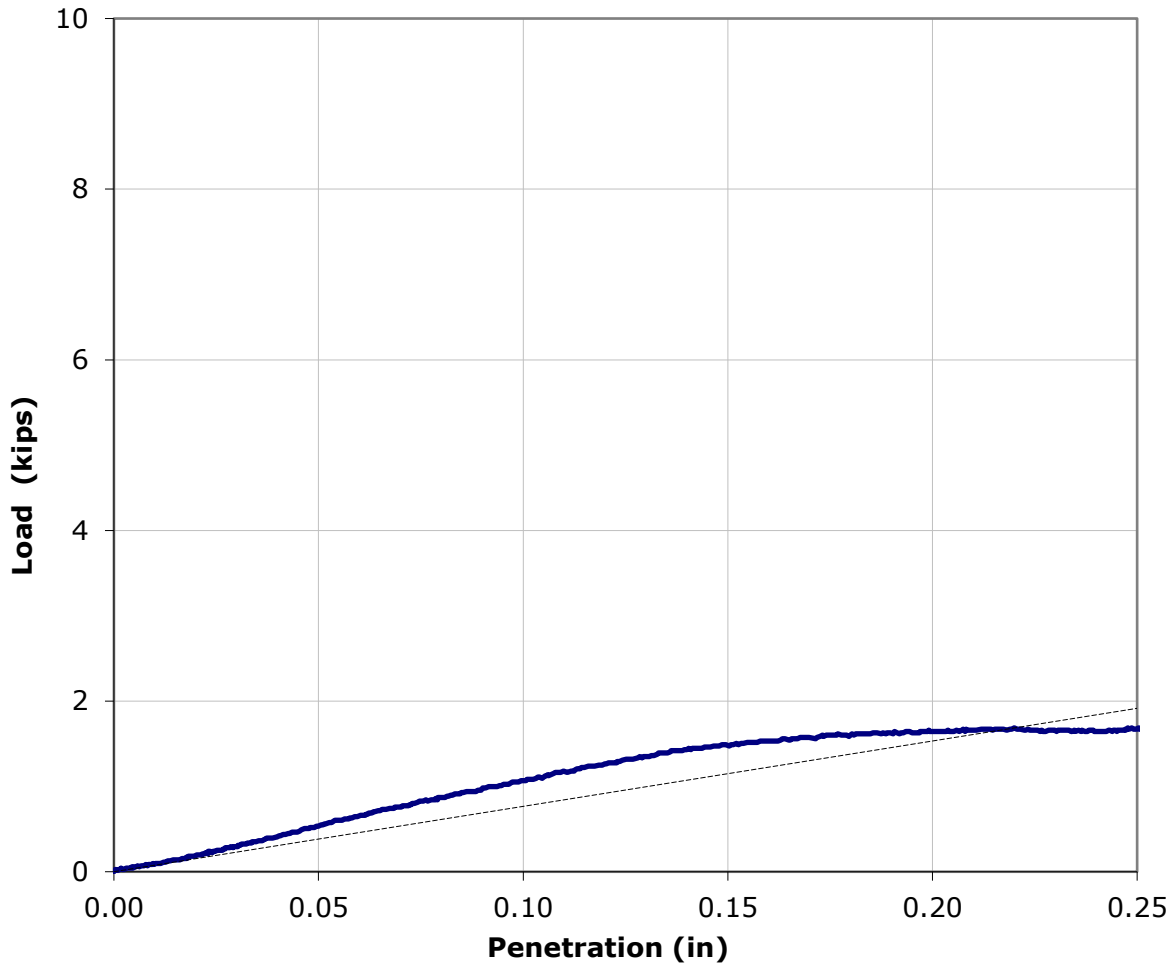
Moisture Condition:	as-received	Maximum Load, lbs:	1798
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	7.8



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/24/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-28
Sample ID:	LRB-010
Depth, ft:	239.83-241.14
Visual Description:	---

Punch Penetration Index Test

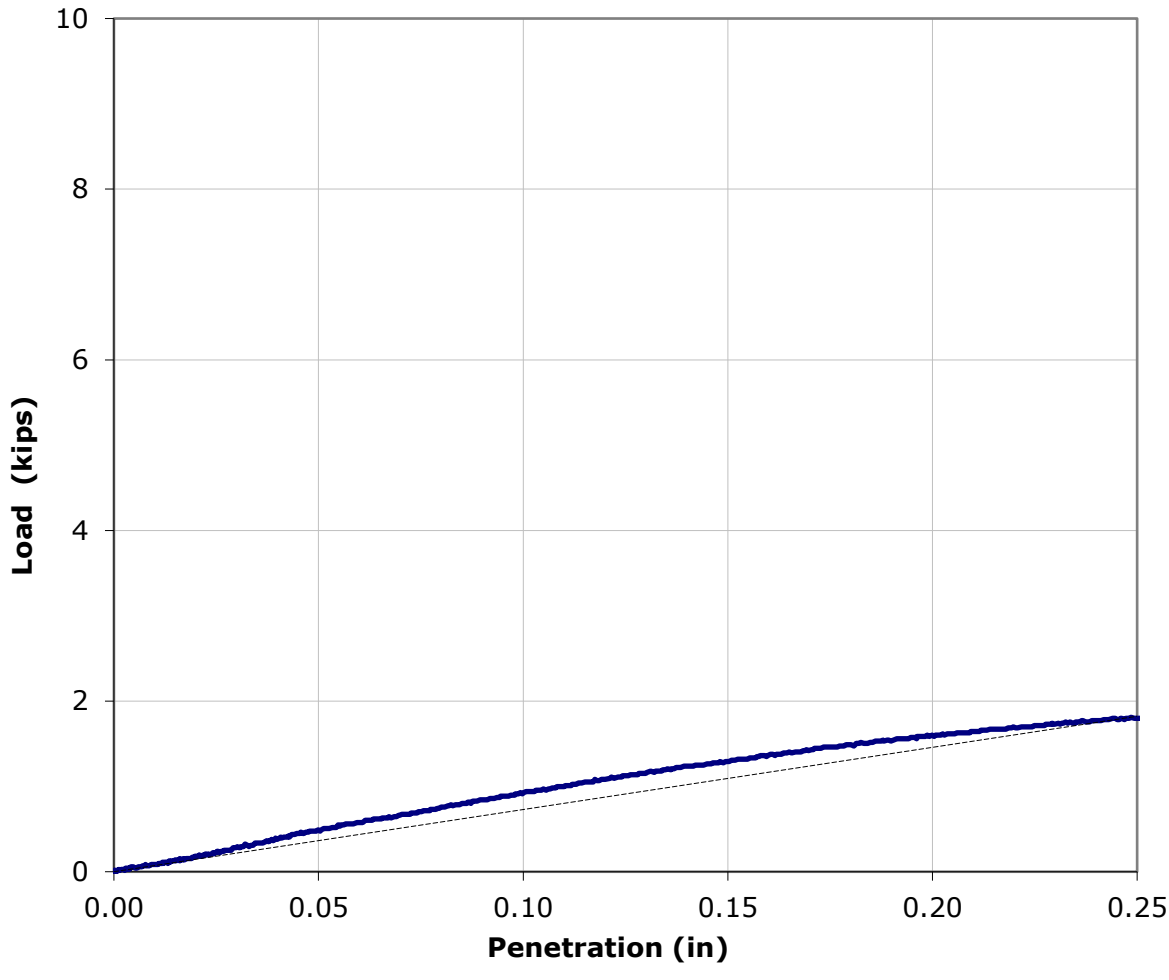
Moisture Condition:	as-received	Maximum Load, lbs:	1685
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	7.7



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/27/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-31
Sample ID:	LRB-004
Depth, ft:	180.12-182.09
Visual Description:	---

Punch Penetration Index Test

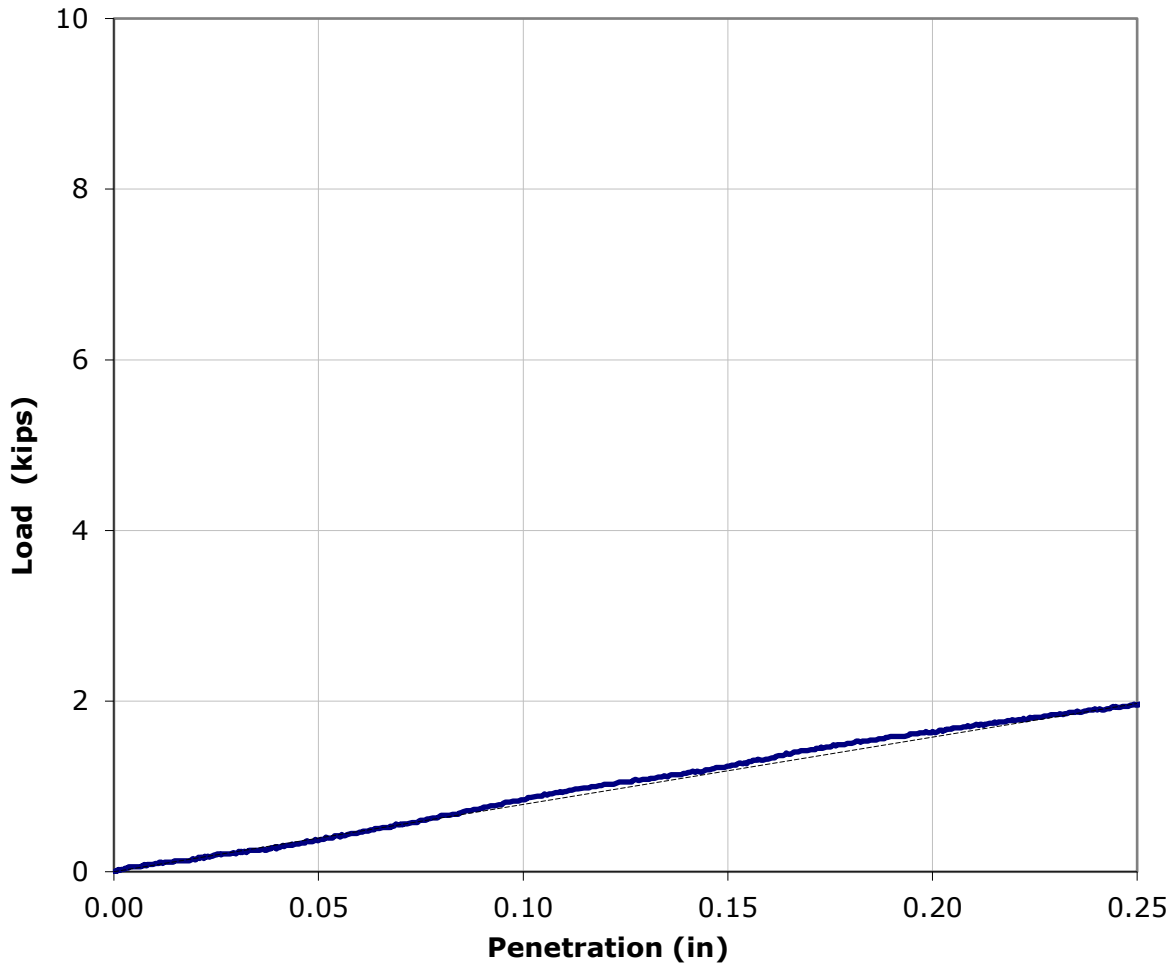
Moisture Condition:	as-received	Maximum Load, lbs:	1812
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	7.3



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/27/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-31
Sample ID:	LRB-005
Depth, ft:	195.87-197.83
Visual Description:	---

Punch Penetration Index Test

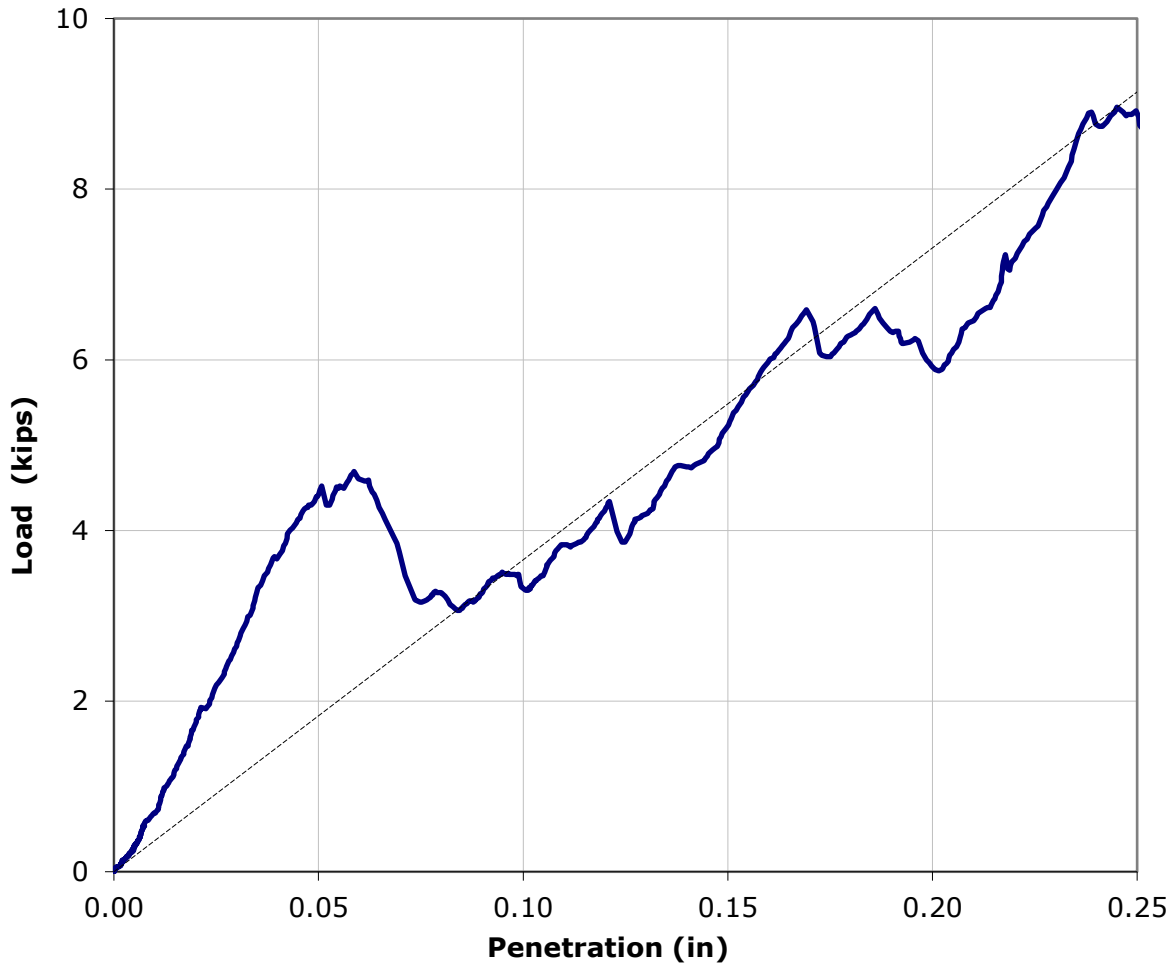
Moisture Condition:	as-received	Maximum Load, lbs:	1966
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	7.9



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/27/2020
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-31
Sample ID:	LRB-010
Depth, ft:	247.70-249.34
Visual Description:	---

Punch Penetration Index Test

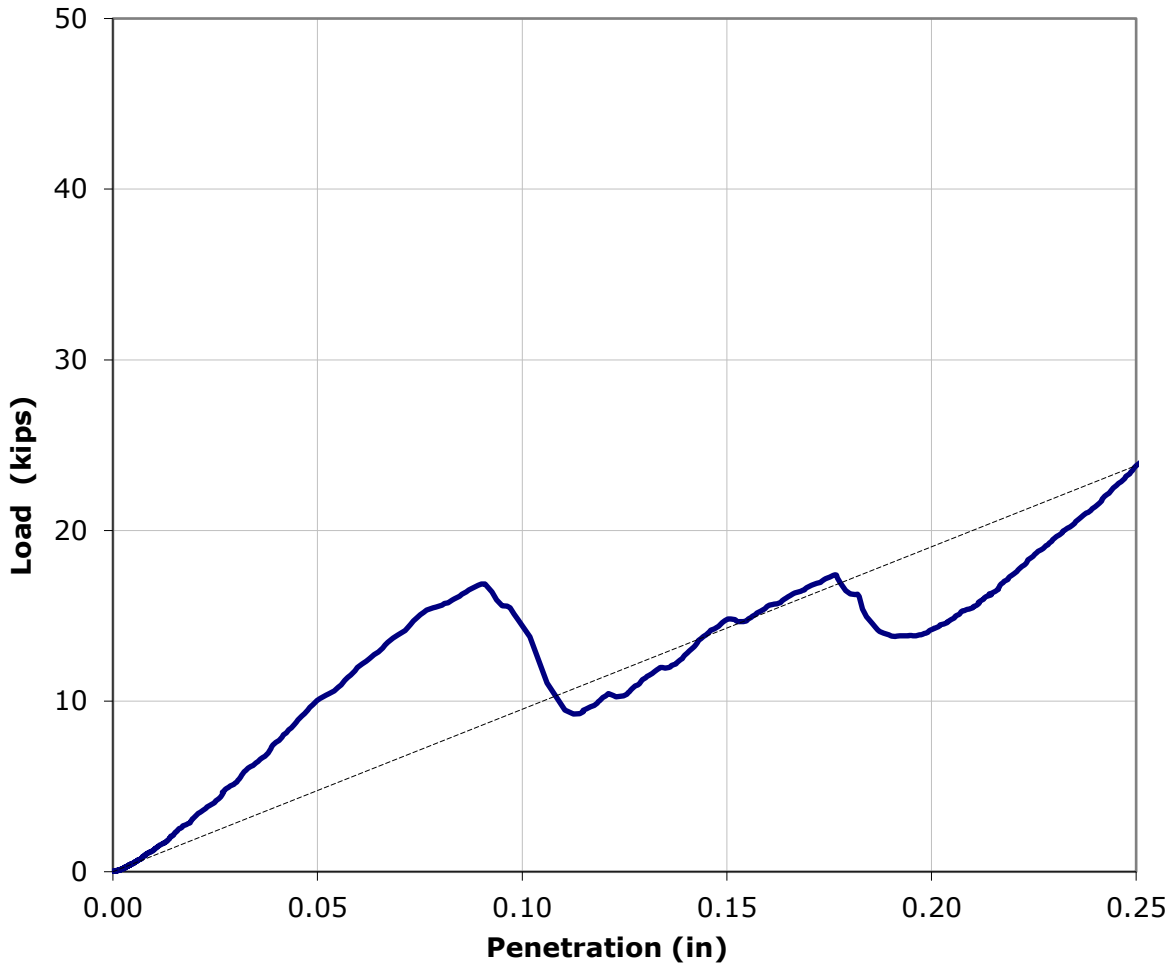
Moisture Condition:	as-received	Maximum Load, lbs:	8960
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	36.6



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	11/4/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-32
Sample ID:	LRB-002
Depth, ft:	122.05
Visual Description:	---

Punch Penetration Index Test

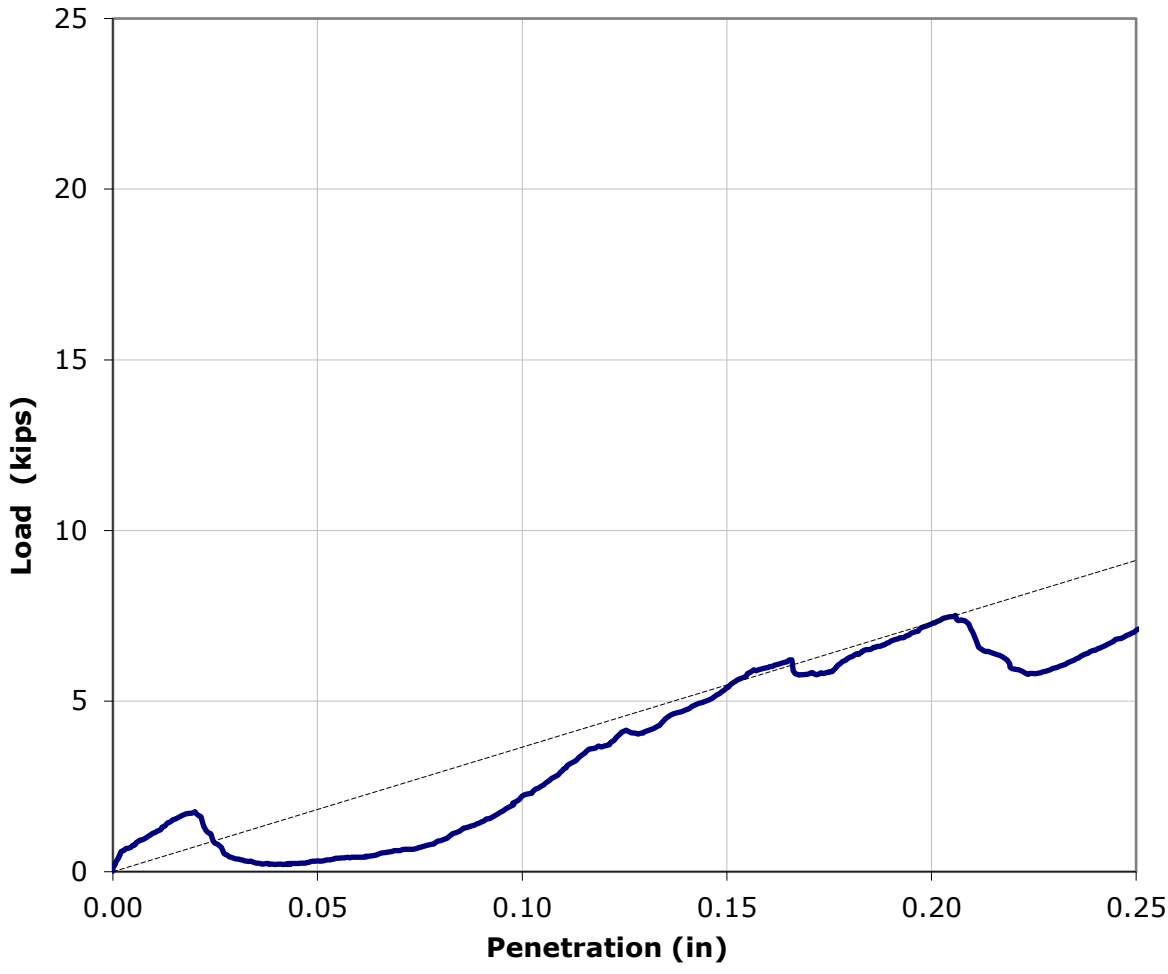
Moisture Condition:	as-received	Maximum Load, lbs:	23804
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	95.2



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-33
Sample ID:	LRB-004
Depth, ft:	135.17
Visual Description:	---

Punch Penetration Index Test

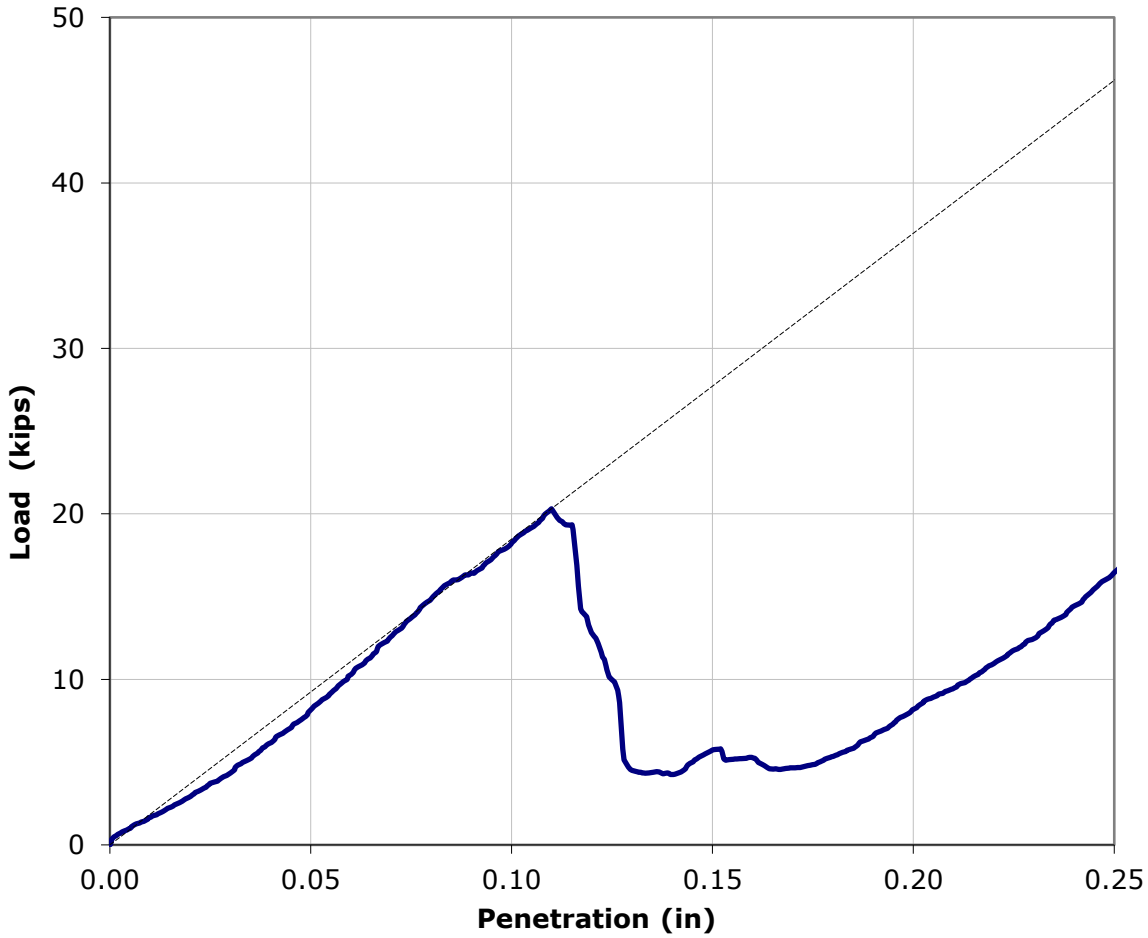
Moisture Condition:	as-received	Maximum Load, lbs:	7513
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	36.5



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-33
Sample ID:	LRB-006
Depth, ft:	184.05
Visual Description:	---

Punch Penetration Index Test

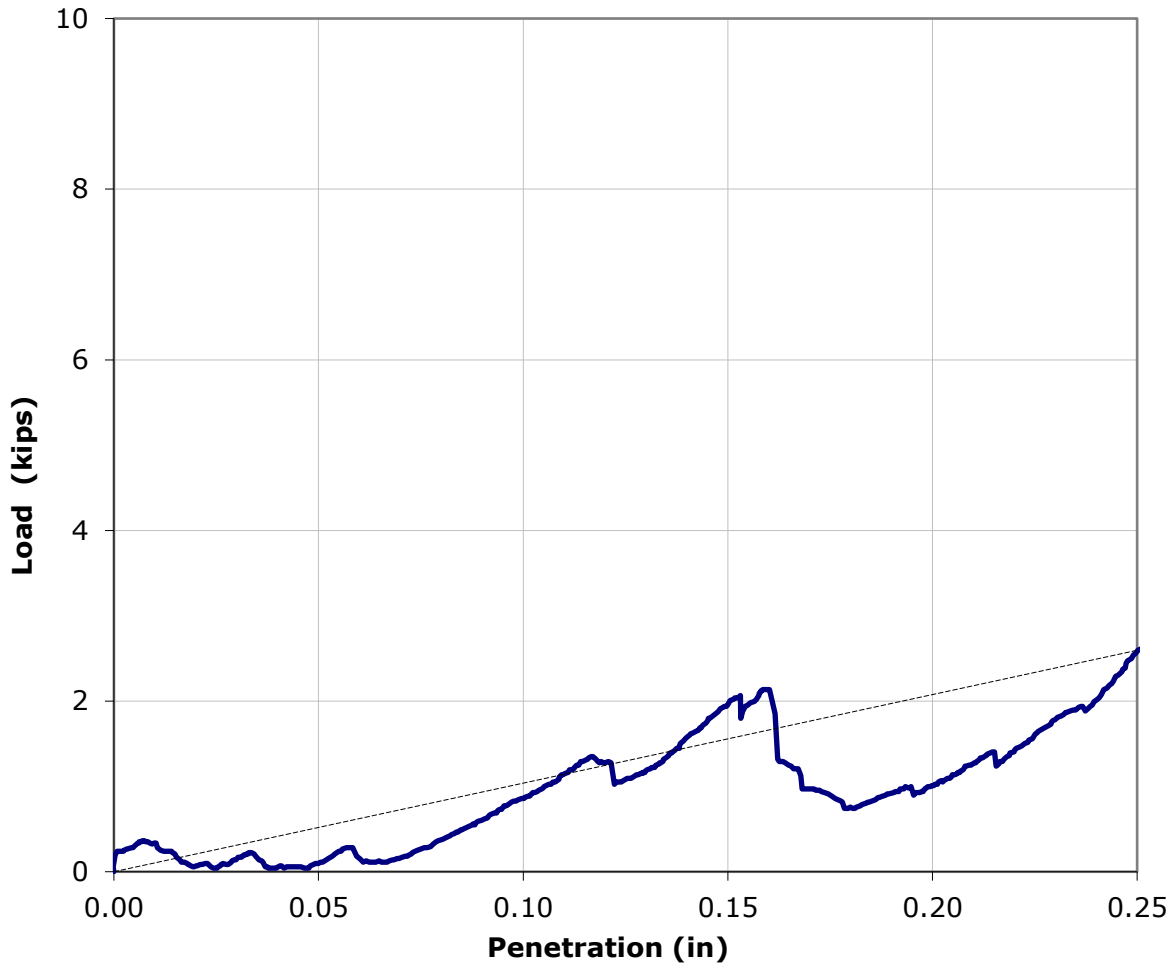
Moisture Condition:	as-received	Maximum Load, lbs:	20335
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	185



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/22/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-37
Sample ID:	LRB-007
Depth, ft:	225.8-226.9
Visual Description:	---

Punch Penetration Index Test

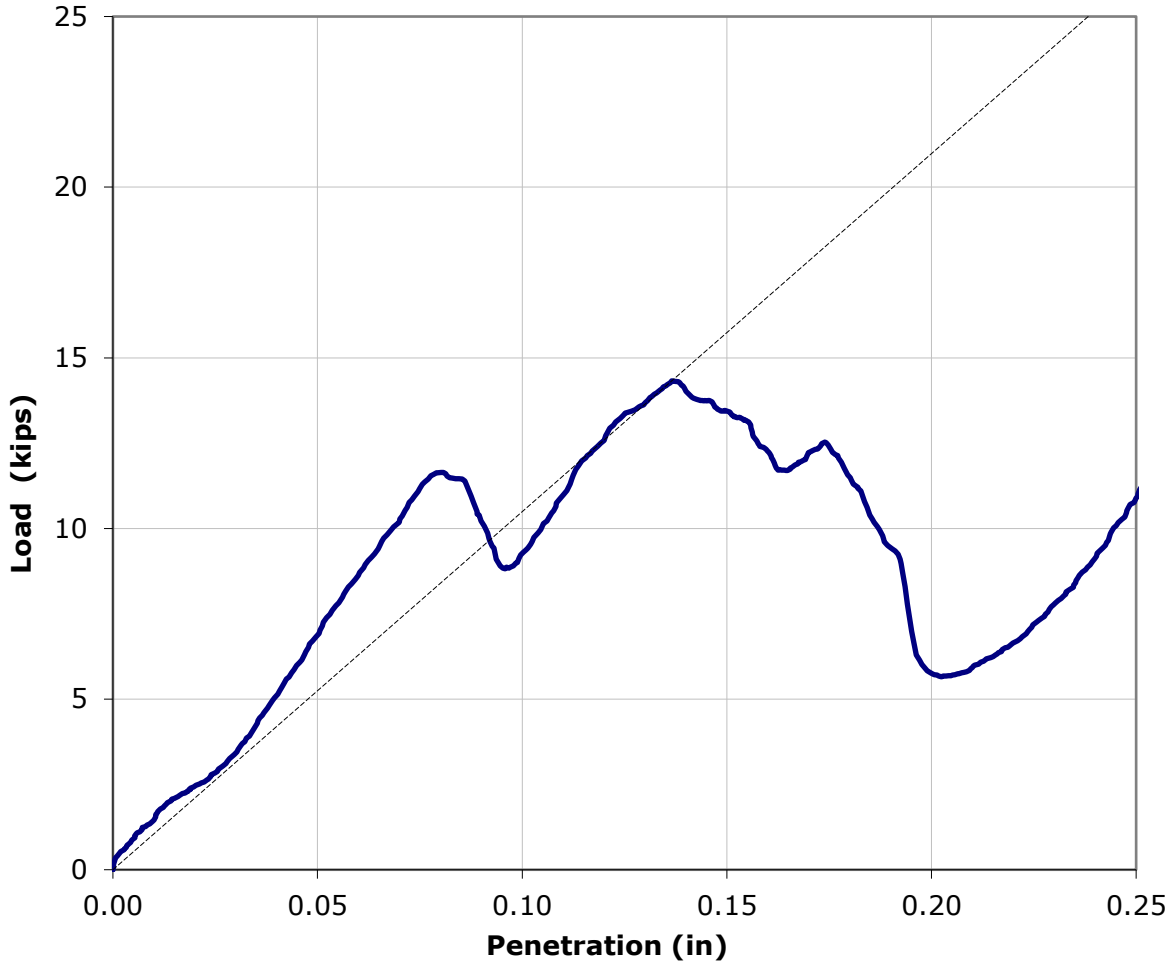
Moisture Condition:	as-received	Maximum Load, lbs:	2598
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	10.4



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/22/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-38
Sample ID:	LRB-003
Depth, ft:	145.5-146
Visual Description:	---

Punch Penetration Index Test

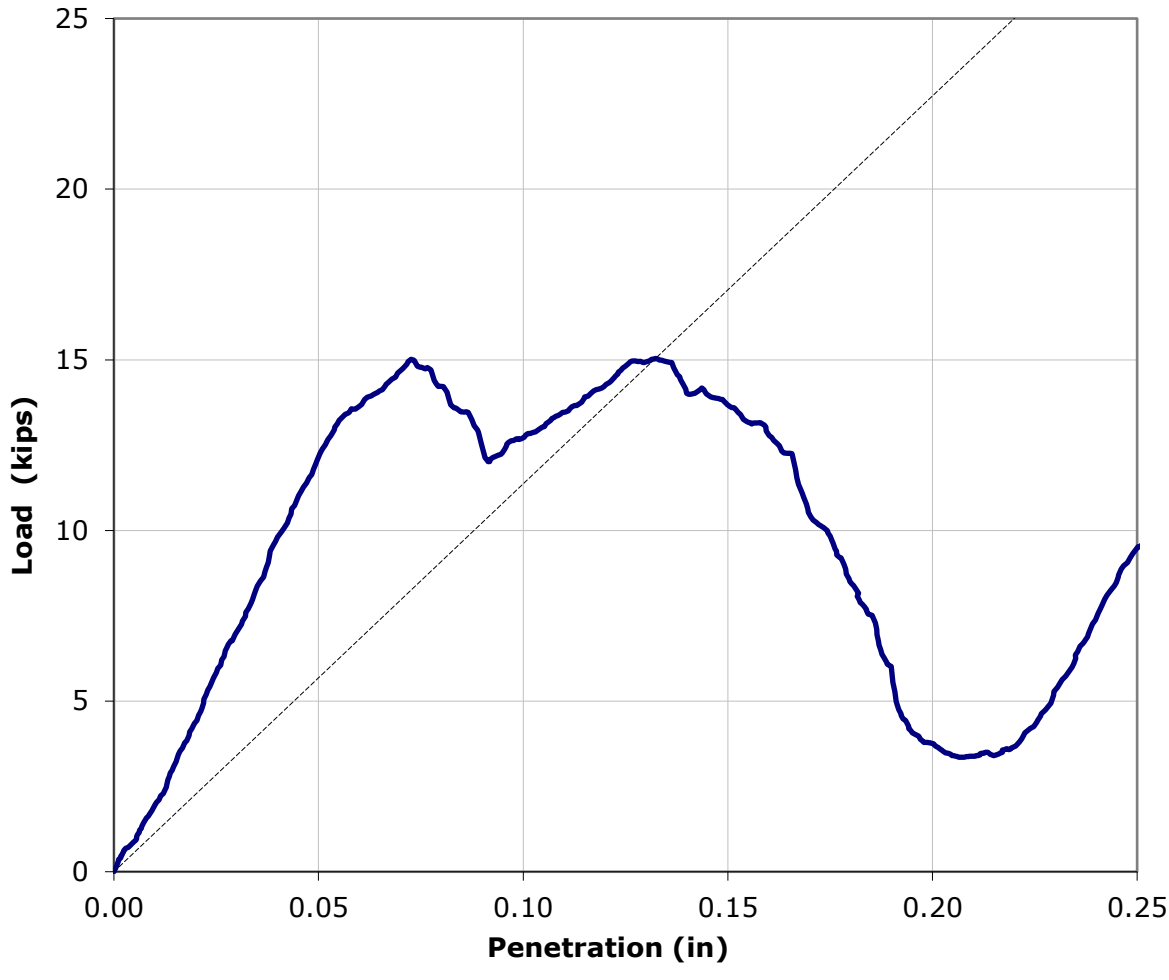
Moisture Condition:	as-received	Maximum Load, lbs:	14325
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	105



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/23/2019
Tested By:	tlm
Checked By:	smd
Boring ID:	BH19-38
Sample ID:	LRB-009
Depth, ft:	190.1-190.4
Visual Description:	---

Punch Penetration Index Test

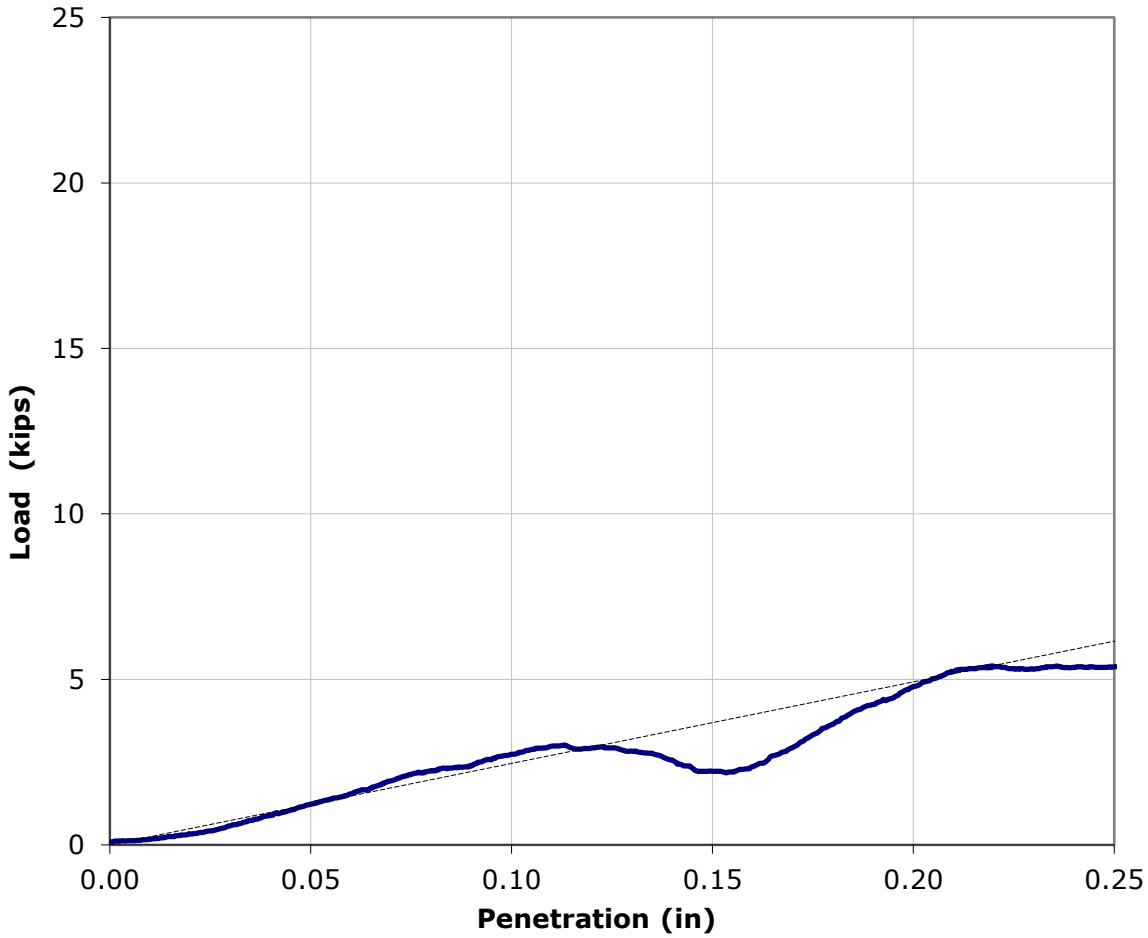
Moisture Condition:	as-received	Maximum Load, lbs:	15041
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	114



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/18/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	PZ19-42
Sample ID:	SB-003
Depth, ft:	20
Visual Description:	---

Punch Penetration Index Test

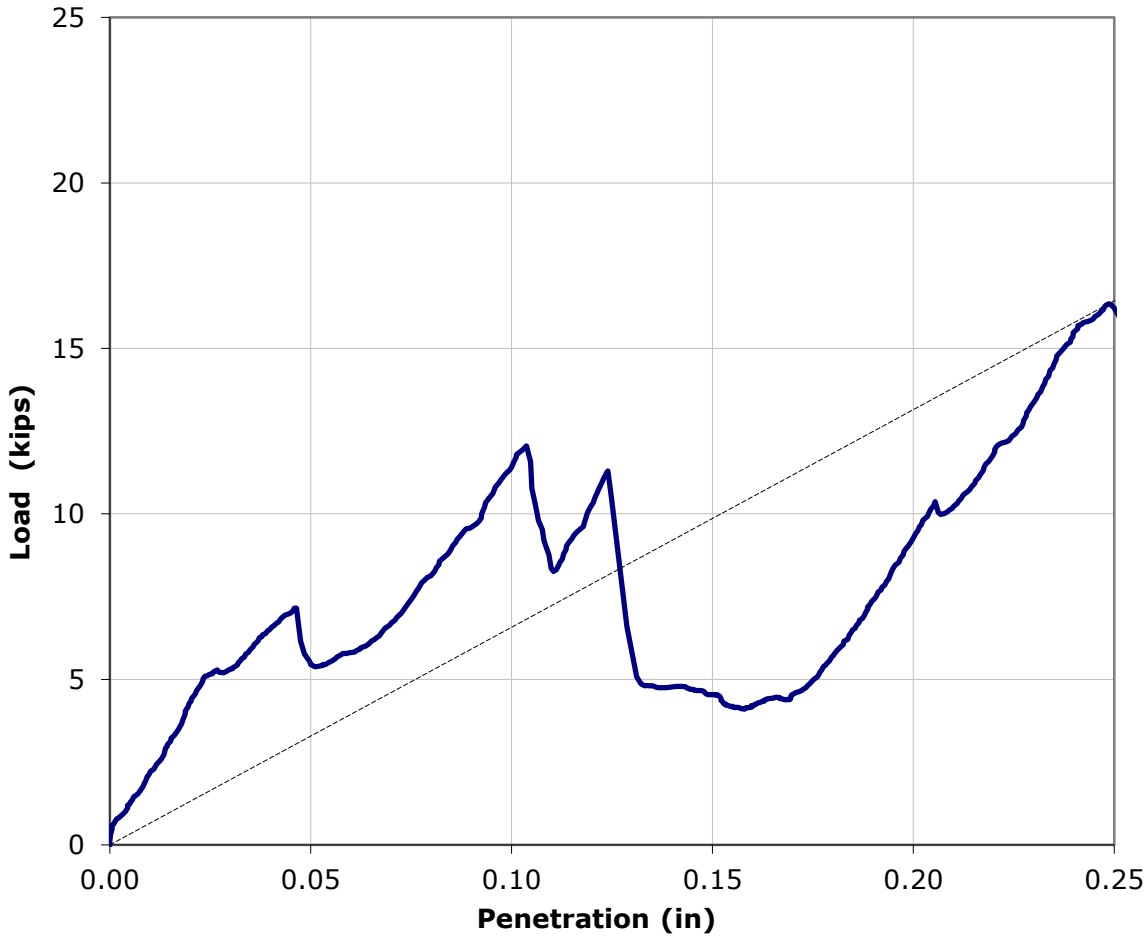
Moisture Condition:	as-received	Maximum Load, lbs:	5589
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	24.6



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/18/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	PZ19-42
Sample ID:	SB-003
Depth, ft:	30
Visual Description:	---

Punch Penetration Index Test

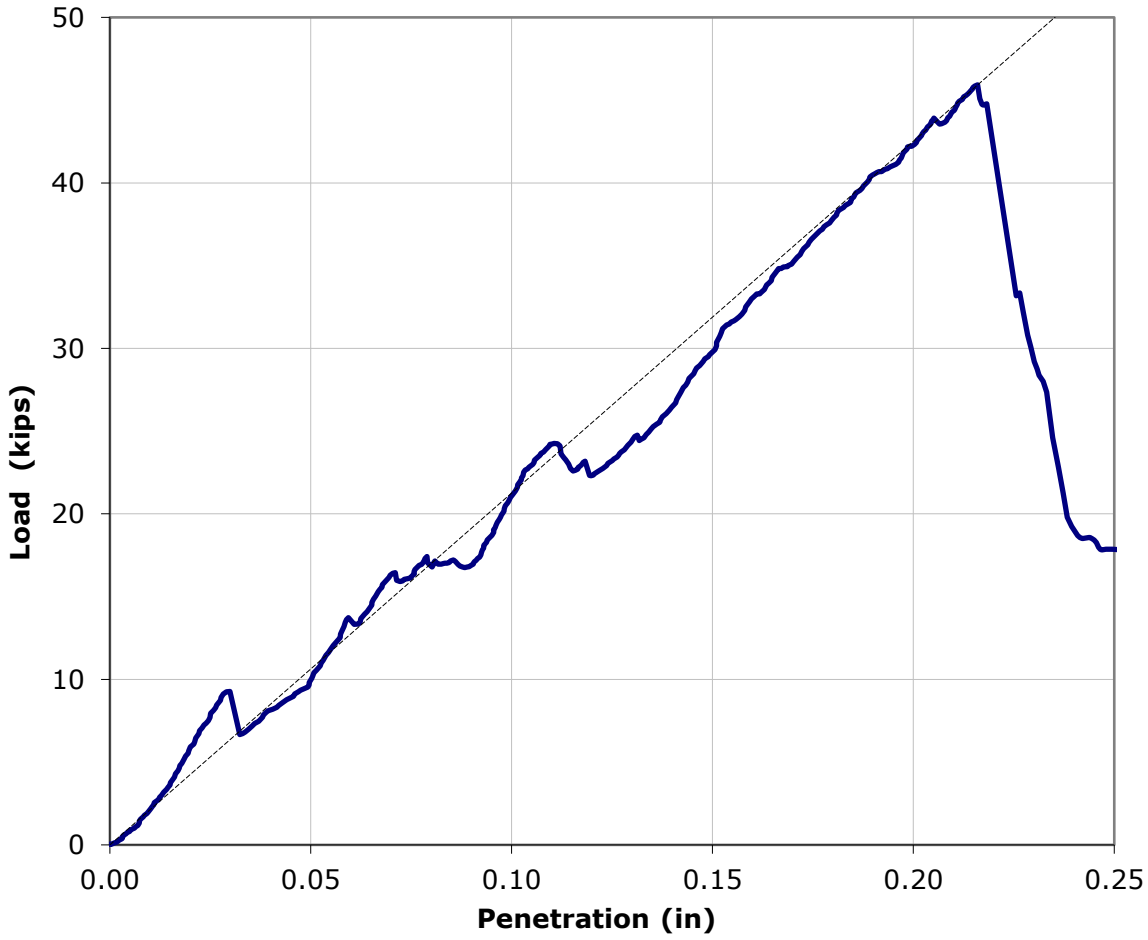
Moisture Condition:	as-received	Maximum Load, lbs:	16347
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	65.8



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/18/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	PZ19-42
Sample ID:	SB-004
Depth, ft:	45
Visual Description:	---

Punch Penetration Index Test

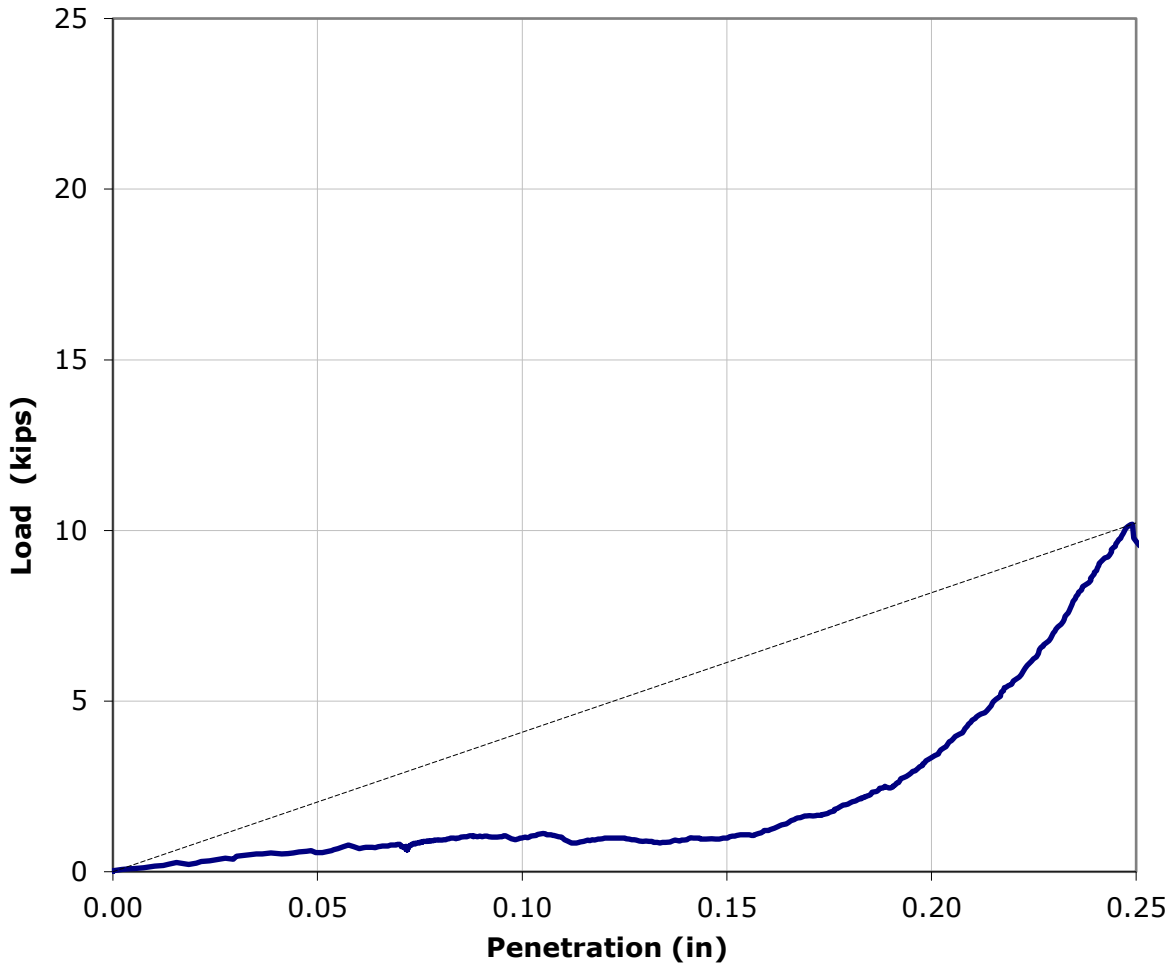
Moisture Condition:	as-received	Maximum Load, lbs:	45937
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	213



Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/18/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	PZ19-42
Sample ID:	SB-004
Depth, ft:	50
Visual Description:	---

Punch Penetration Index Test

Moisture Condition:	as-received	Maximum Load, lbs:	10182
Penetration Rate, in/sec:	0.001	Peak Slope Index, kips/in:	40.9



Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	11/07/19	Checked By:	smd
Depth :	---	Test Id:	527320		

Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method C

Boring ID	Sample Number	Depth	Bulk Density, pcf	Compressive strength, psi	Failure Type	Meets ASTM D4543	Note(s)
BH19-08	LRB-006	32.6 ft	153	6637	3	No	2,*
BH19-09	LRB-003	26.5 ft	149	5766	1	No	2,*
BH19-09	LRB-011	53.5 ft	159	13429	1	No	2,*
BH19-15	LRB-004	166.26 - 166.72 ft	165	16259	3	Yes	---
BH19-16	LRB-010	270.44 - 270.90 ft	168	14422	2	No	2,*
BH19-32	LRB-005	126.67 - 127.66 ft	166	11779	1	No	2,*
BH19-32	LRB-009	169.0- 169.9 ft	141	438	1	No	2,*

Notes: Density determined on core samples by measuring dimensions and weight and then calculating.

All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.

The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

1: Best effort end preparation. See Tolerance report for details.
2: The as-received core did not meet the ASTM side straightness tolerance due to irregularities in the sample as cored.
3: Specimen L/D < 2.
4: The as-received core did not meet the ASTM minimum diameter tolerance of 1.875 inches.
5: Specimen diameter is less than 10 times maximum particle size.
6: Specimen diameter is less than 6 times maximum particle size.

*Because the indicated tested specimens did not meet the ASTM D4543 standard tolerances, the results reported here may differ from those for a test specimen within tolerances.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	jck
Sample ID:	---	Test Date:	08/29/19	Checked By:	smd
Depth :	---	Test Id:	518413		

Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method C

Boring ID	Sample Number	Depth	Bulk Density, pcf	Compressive strength, psi	Failure Type	Meets ASTM D4543	Note(s)
BH19-35	LRB-003	176.84 ft	149	19609	1	No	1 , 2,*
BH19-38	LRB-002	144.5-144.7 ft	157	12209	2	Yes	---

Notes: Density determined on core samples by measuring dimensions and weight and then calculating.

All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.

The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

1: Best effort end preparation. See Tolerance report for details.
2: The as-received core did not meet the ASTM side straightness tolerance due to irregularities in the sample as cored.
3: Specimen L/D < 2.
4: The as-received core did not meet the ASTM minimum diameter tolerance of 1.875 inches.
5: Specimen diameter is less than 10 times maximum particle size.
6: Specimen diameter is less than 6 times maximum particle size.

*Because the indicated tested specimens did not meet the ASTM D4543 standard tolerances, the results reported here may differ from those for a test specimen within tolerances.

Client:	WSP	Test Date:	8/27/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-08		
Sample ID:	LRB-006		
Depth:	32.6 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.31	5.31	5.31
Specimen Diameter, in:	2.39	2.40	2.40
Specimen Mass, g:	963.45		
Bulk Density, lb/ft^3	153	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.2	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00090	-0.00080	-0.00060	-0.00050	-0.00040	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010
Diameter 2, in (rotated 90°)	-0.00050	-0.00040	-0.00030	-0.00020	-0.00010	-0.00010	-0.00020	0.00000	0.00000	0.00010	0.00010	0.00000	0.00000	-0.00010	-0.00010

Difference between max and min readings, in:

0° = 0.00100 90° = 0.00060

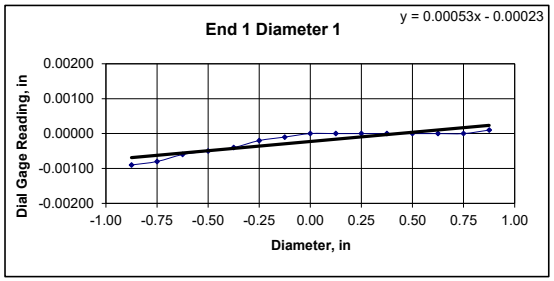
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00080	-0.00080	-0.00060	-0.00050	-0.00040	-0.00020	-0.00020	0.00000	0.00000	0.00000	0.00000	0.00010	0.00000	0.00000	0.00010
Diameter 2, in (rotated 90°)	-0.00050	-0.00030	-0.00030	-0.00020	-0.00010	-0.00010	-0.00010	0.00000	0.00000	0.00010	0.00000	0.00000	0.00010	0.00000	0.00000

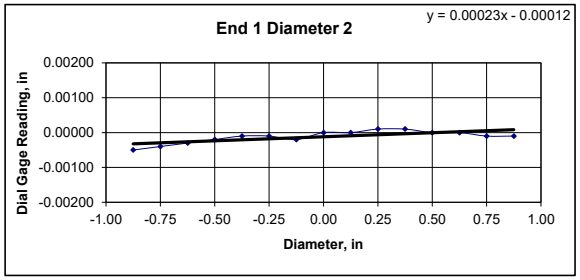
Difference between max and min readings, in:

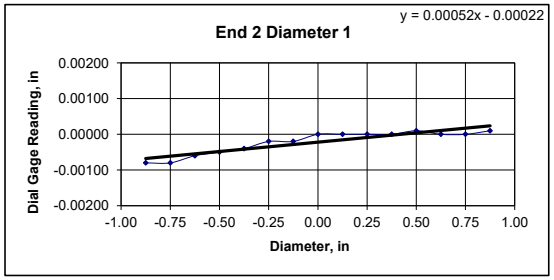
0° = 0.0009 90° = 0.0006

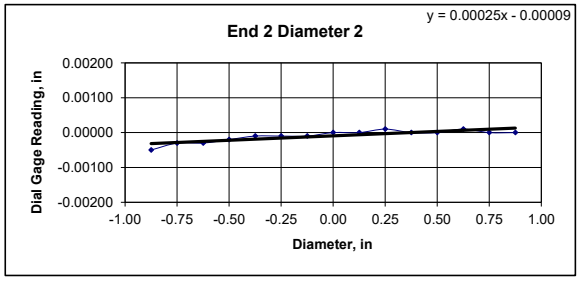
Maximum difference must be < 0.0020 in. Difference = ± 0.00050

Flatness Tolerance Met? YES









DIAMETER 1

End 1:
- Slope of Best Fit Line: 0.00053
- Angle of Best Fit Line: 0.03028

End 2:
- Slope of Best Fit Line: 0.00052
- Angle of Best Fit Line: 0.02996

Maximum Angular Difference: 0.00033

Parallelism Tolerance Met? YES

Spherically Seated

DIAMETER 2

End 1:
- Slope of Best Fit Line: 0.00023
- Angle of Best Fit Line: 0.01326

End 2:
- Slope of Best Fit Line: 0.00025
- Angle of Best Fit Line: 0.01457

Maximum Angular Difference: 0.00131

Parallelism Tolerance Met? YES

Spherically Seated

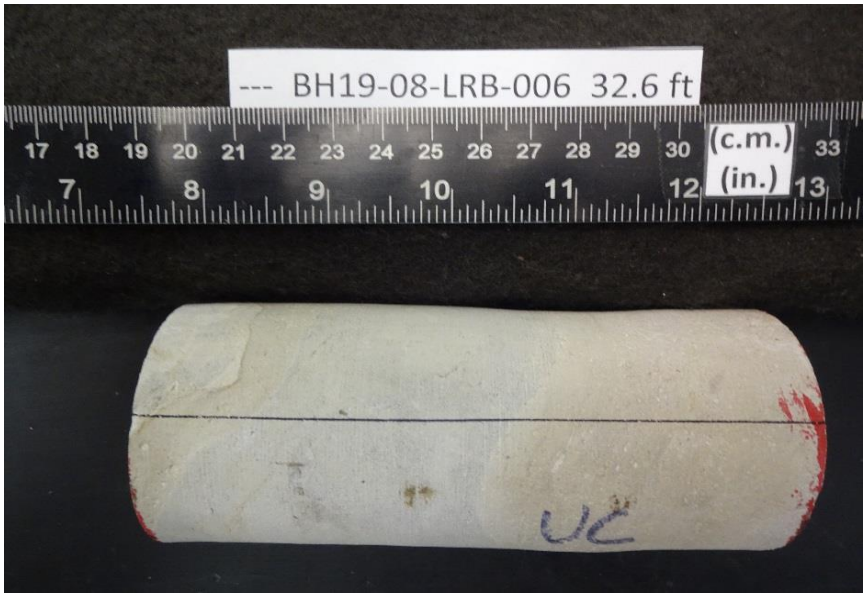
PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00100	2.395	0.00042	0.024	YES
Diameter 2, in (rotated 90°)	0.00060	2.395	0.00025	0.014	YES
END 2					
Diameter 1, in	0.00090	2.395	0.00038	0.022	YES
Diameter 2, in (rotated 90°)	0.00060	2.395	0.00025	0.014	YES

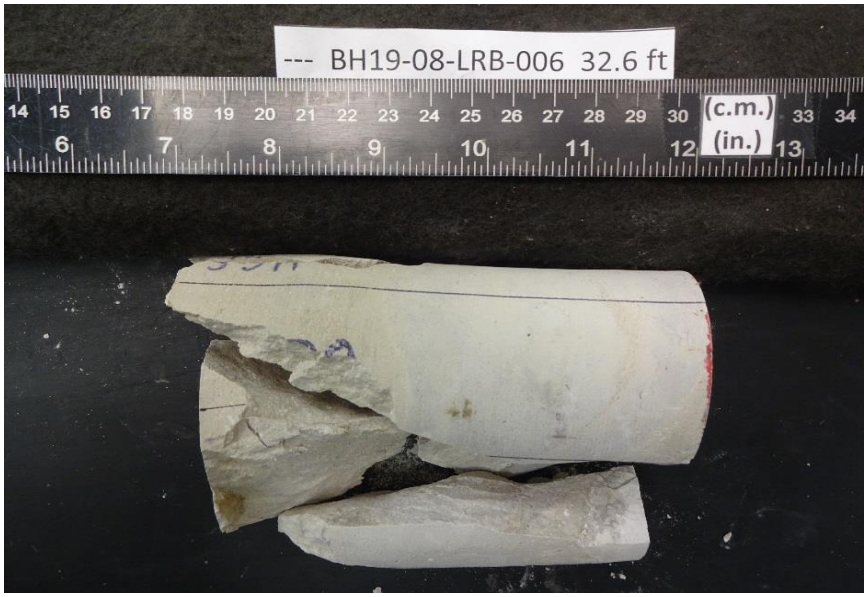
Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/28/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-08
Sample ID:	LRB-006
Depth, ft:	32.6



After cutting and grinding



After break

Client:	WSP	Test Date:	8/30/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-09		
Sample ID:	LRB-011		
Depth:	53.5 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.40	5.40	5.40
Specimen Diameter, in:	2.39	2.40	2.40
Specimen Mass, g:	1017.29		
Bulk Density, lb/ft^3	159	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00030	-0.00030	-0.00040	-0.00050
Diameter 2, in (rotated 90°)	0.00000	-0.00020	-0.00020	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010

Difference between max and min readings, in:

0° = 0.00050 90° = 0.00030

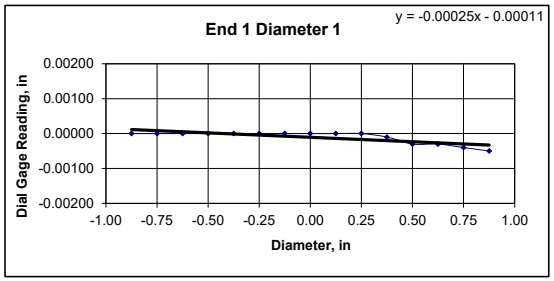
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00020	0.00020	0.00020	0.00010	0.00010	0.00010	0.00010	0.00000	0.00000	0.00000	0.00000	-0.00020	-0.00020	-0.00030	-0.00040
Diameter 2, in (rotated 90°)	-0.00010	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010

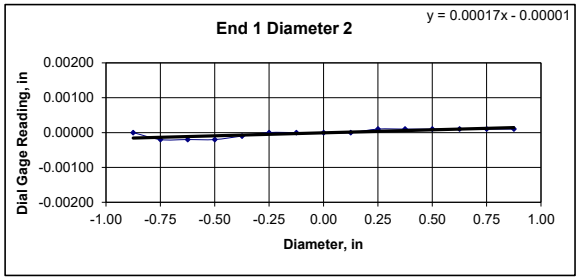
Difference between max and min readings, in:

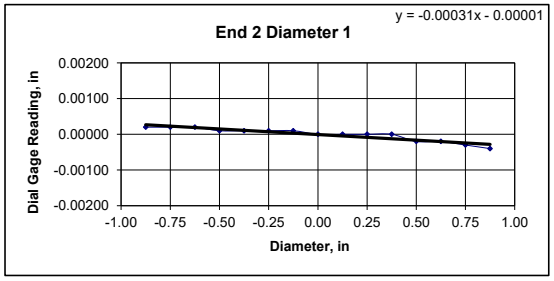
0° = 0.0006 90° = 0.0003

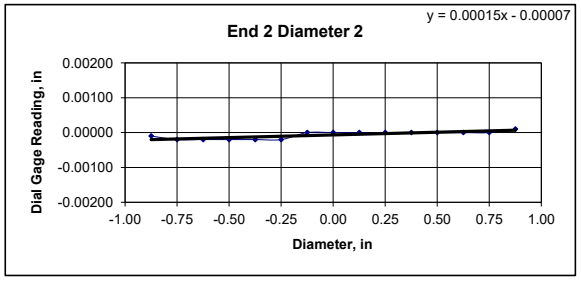
Maximum difference must be < 0.0020 in. Difference = ± 0.00030

Flatness Tolerance Met? YES









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00025
Angle of Best Fit Line: 0.01457

End 2:
Slope of Best Fit Line 0.00031
Angle of Best Fit Line: 0.01801

Maximum Angular Difference: 0.00344

Parallelism Tolerance Met? YES
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00017
Angle of Best Fit Line: 0.00982

End 2:
Slope of Best Fit Line 0.00015
Angle of Best Fit Line: 0.00884

Maximum Angular Difference: 0.00098

Parallelism Tolerance Met? YES
Spherically Seated

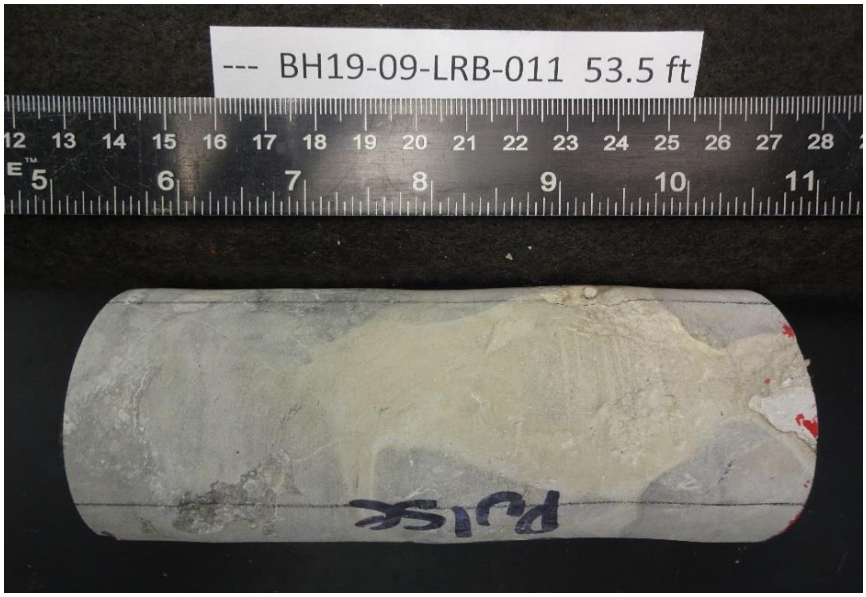
PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00050	2.395	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00030	2.395	0.00013	0.007	YES
END 2					
Diameter 1, in	0.00060	2.395	0.00025	0.014	YES
Diameter 2, in (rotated 90°)	0.00030	2.395	0.00013	0.007	YES

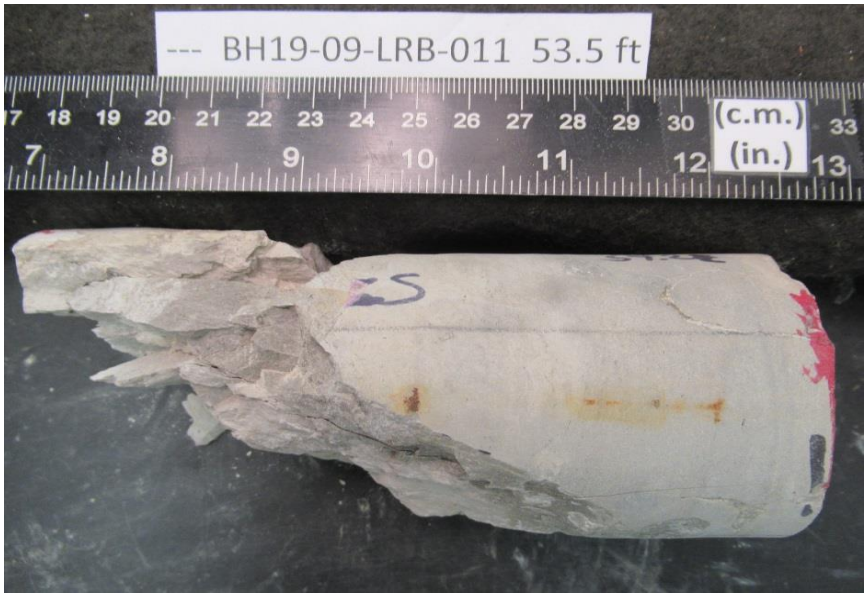
Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/11/2019
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-09
Sample ID:	LRB-011
Depth, ft:	53.5



After cutting and grinding



After break

Client:	WSP	Test Date:	8/30/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-9		
Sample ID:	LRB-003		
Depth:	26.5 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.38	5.37	5.38
Specimen Diameter, in:	2.39	2.39	2.39
Specimen Mass, g:	945.68		
Bulk Density, lb/ft^3	149	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.2	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? NO

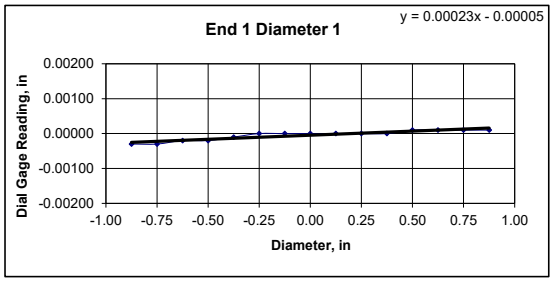
END FLATNESS AND PARALLELISM (Procedure FP1)

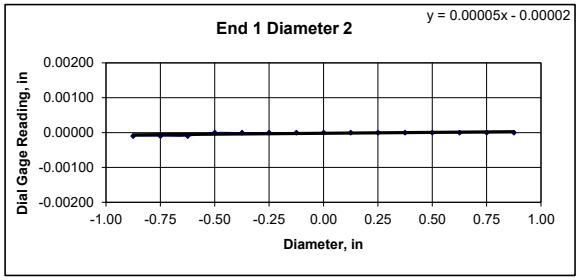
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00030	-0.00030	-0.00020	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00010	0.00010
Diameter 2, in (rotated 90°)	-0.00010	-0.00010	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

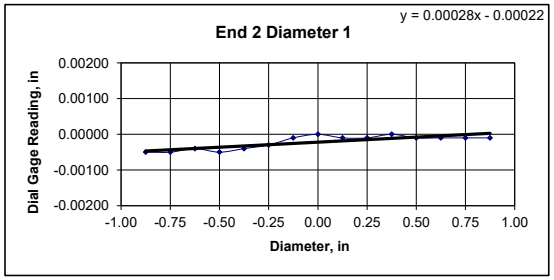
Difference between max and min readings, in:
0° = 0.00040 90° = 0.00010

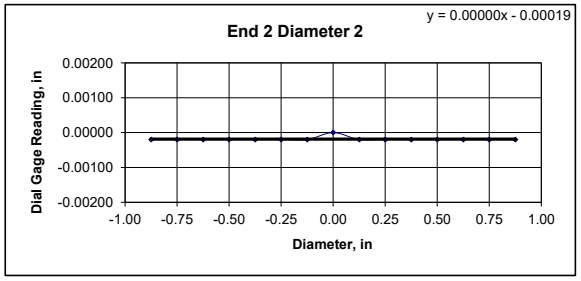
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00050	-0.00050	-0.00040	-0.00050	-0.00040	-0.00030	-0.00010	0.00000	-0.00010	-0.00010	0.00000	-0.00010	-0.00010	-0.00010	-0.00010
Diameter 2, in (rotated 90°)	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020	0.00000	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020	-0.00020

Difference between max and min readings, in:
0° = 0.0005 90° = 0.0002
Maximum difference must be < 0.0020 in. Difference = ± 0.00025
Flatness Tolerance Met? YES









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00023
Angle of Best Fit Line: 0.01342

End 2:
Slope of Best Fit Line 0.00028
Angle of Best Fit Line: 0.01621

Maximum Angular Difference: 0.00278

Parallelism Tolerance Met? YES
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00005
Angle of Best Fit Line: 0.00295

End 2:
Slope of Best Fit Line 0.00000
Angle of Best Fit Line: 0.00000

Maximum Angular Difference: 0.00295

Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00040	2.390	0.00017	0.010	YES
Diameter 2, in (rotated 90°)	0.00010	2.390	0.00004	0.002	YES
END 2					
Diameter 1, in	0.00050	2.390	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00020	2.390	0.00008	0.005	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/11/2019
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-09
Sample ID:	LBR-003
Depth, ft:	26.5

After cutting and grinding

After break

Client:	WSP	Test Date:	7/26/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-15		
Sample ID:	LRB-004		
Depth:	166.26-166.72 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.11	5.11	5.11
Specimen Diameter, in:	2.39	2.39	2.39
Specimen Mass, g:	997.45		
Bulk Density, lb/ft^3	165	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.1	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? YES

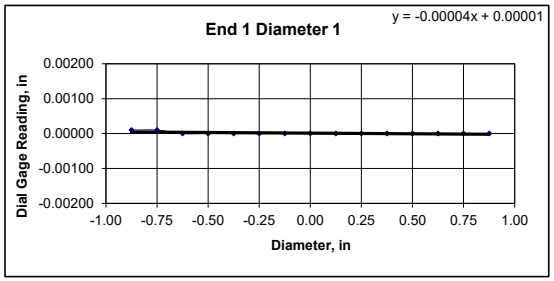
END FLATNESS AND PARALLELISM (Procedure FP1)

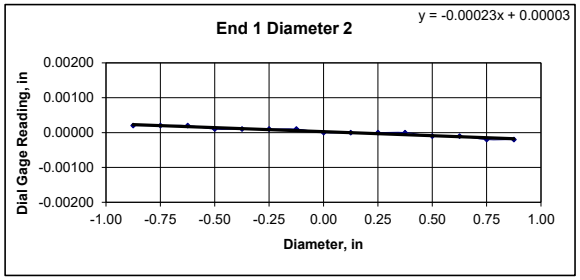
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00010	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Diameter 2, in (rotated 90°)	0.00020	0.00020	0.00020	0.00010	0.00010	0.00010	0.00010	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00020	-0.00020

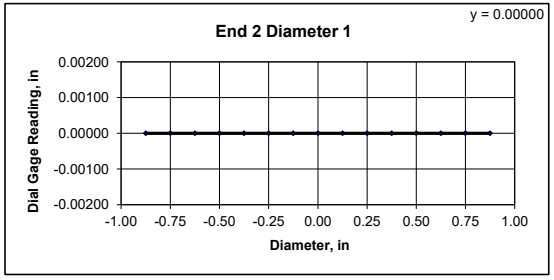
Difference between max and min readings, in:
0° = 0.00010 90° = 0.00040

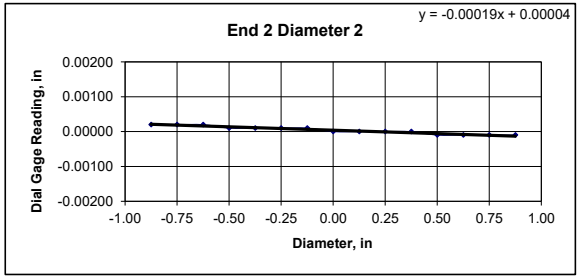
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Diameter 2, in (rotated 90°)	0.00020	0.00020	0.00020	0.00010	0.00010	0.00010	0.00010	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00010	-0.00010

Difference between max and min readings, in:
0° = 0 90° = 0.0003
Maximum difference must be < 0.0020 in. Difference = ± 0.00020
Flatness Tolerance Met? YES









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00004
Angle of Best Fit Line: 0.00213

End 2:
Slope of Best Fit Line 0.00000
Angle of Best Fit Line: 0.00000

Maximum Angular Difference: 0.00213

Parallelism Tolerance Met? YES
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00023
Angle of Best Fit Line: 0.01326

End 2:
Slope of Best Fit Line 0.00019
Angle of Best Fit Line: 0.01113

Maximum Angular Difference: 0.00213

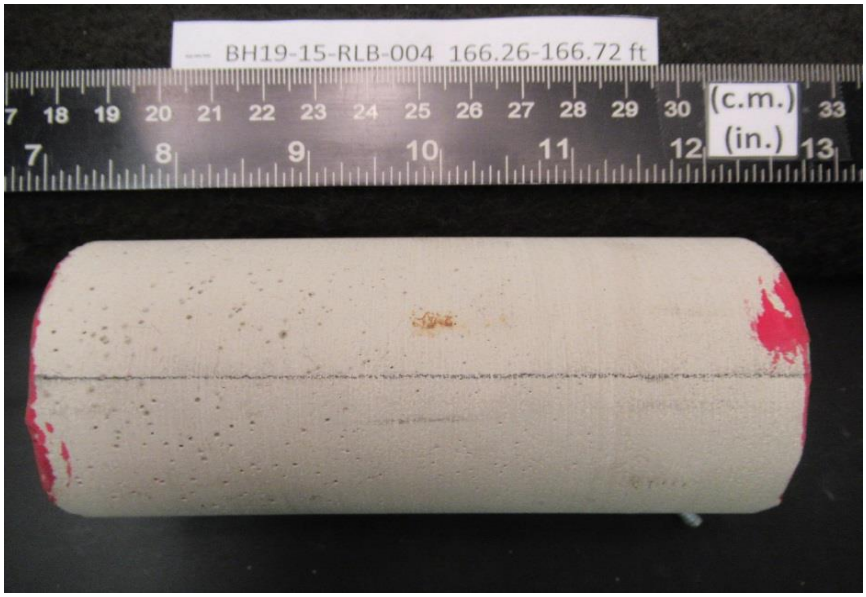
Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00010	2.390	0.00004	0.002	YES
Diameter 2, in (rotated 90°)	0.00040	2.390	0.00017	0.010	YES
END 2					
Diameter 1, in	0.00000	2.390	0.00000	0.000	YES
Diameter 2, in (rotated 90°)	0.00030	2.390	0.00013	0.007	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/9/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-15
Sample ID:	LRB-004
Depth, ft:	166.26-166.72



After cutting and grinding

After break

Client:	WSP	Test Date:	7/26/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-16		
Sample ID:	LRB-010		
Depth:	270.44-270.90 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.18	5.17	5.18
Specimen Diameter, in:	2.39	2.39	2.39
Specimen Mass, g:	1025.08		
Bulk Density, lb/ft^3	168	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.2	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

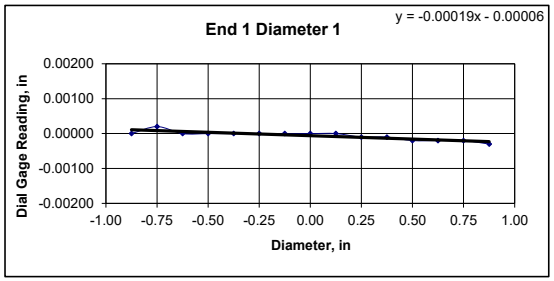
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00020	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00020	-0.00020	-0.00020	-0.00030
Diameter 2, in (rotated 90°)	-0.00060	-0.00070	-0.00050	-0.00030	-0.00030	-0.00010	0.00000	0.00000	0.00010	0.00020	0.00020	0.00020	0.00030	0.00040	0.00040

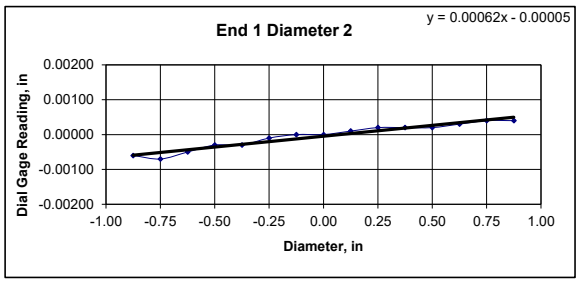
Difference between max and min readings, in:
0° = 0.00050 90° = 0.00110

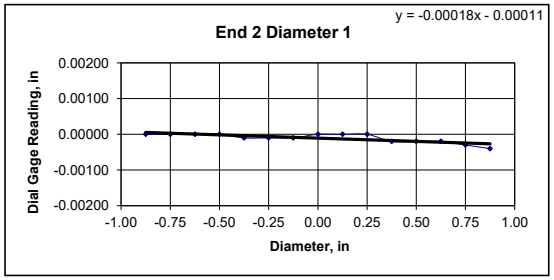
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00010	0.00000	0.00000	0.00000	-0.00020	-0.00020	-0.00020	-0.00030	-0.00040
Diameter 2, in (rotated 90°)	-0.00050	-0.00050	-0.00040	-0.00030	-0.00010	0.00000	0.00000	0.00000	0.00010	0.00020	0.00020	0.00020	0.00030	0.00040	0.00050

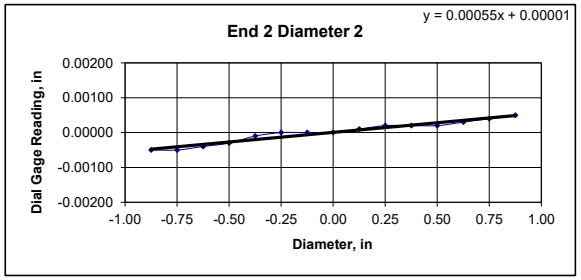
Difference between max and min readings, in:
0° = 0.0004 90° = 0.001

Maximum difference must be < 0.0020 in. Difference = ± 0.00055
Flatness Tolerance Met? YES









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00019
Angle of Best Fit Line: 0.01113

End 2:
Slope of Best Fit Line 0.00018
Angle of Best Fit Line: 0.01048

Maximum Angular Difference: 0.00065

Parallelism Tolerance Met? YES
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00062
Angle of Best Fit Line: 0.03569

End 2:
Slope of Best Fit Line 0.00055
Angle of Best Fit Line: 0.03159

Maximum Angular Difference: 0.00409

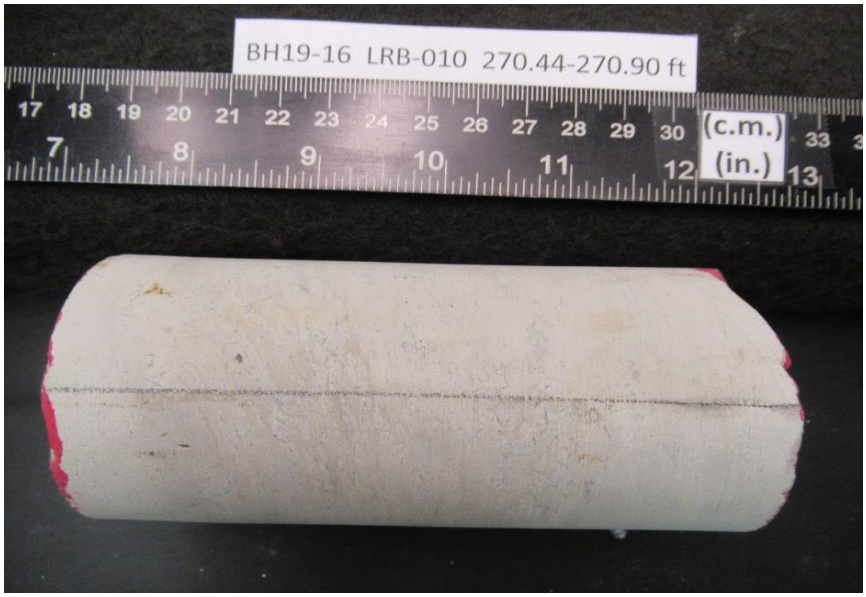
Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00050	2.390	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00110	2.390	0.00046	0.026	YES
END 2					
Diameter 1, in	0.00040	2.390	0.00017	0.010	YES
Diameter 2, in (rotated 90°)	0.00100	2.390	0.00042	0.024	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/9/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-16
Sample ID:	LRB-010
Depth, ft:	270.44-270.90



After cutting and grinding

After break

Client:	WSP	Test Date:	11/7/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-32		
Sample ID:	LRB-005		
Depth:	126.67-127.66 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	7.93	7.93	7.93
Specimen Diameter, in:	3.89	3.90	3.90
Specimen Mass, g:	4119.4		
Bulk Density, lb/ft^3	166	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.0	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

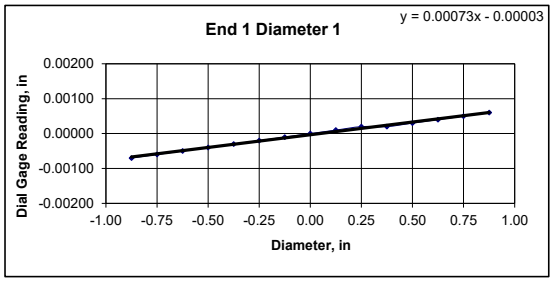
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00070	-0.00060	-0.00050	-0.00040	-0.00030	-0.00020	-0.00010	0.00000	0.00010	0.00020	0.00020	0.00030	0.00040	0.00050	0.00060
Diameter 2, in (rotated 90°)	0.00070	0.00060	0.00050	0.00040	0.00030	0.00020	0.00000	0.00000	-0.00020	-0.00030	-0.00040	-0.00050	-0.00060	-0.00060	-0.00070

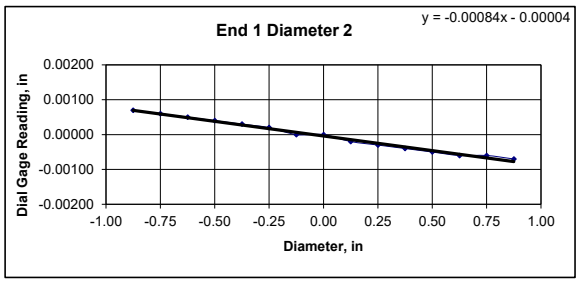
Difference between max and min readings, in:
0° = 0.00130 90° = 0.00140

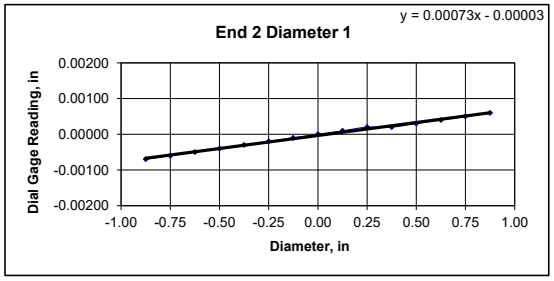
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00070	-0.00060	-0.00050	-0.00040	-0.00030	-0.00020	-0.00010	0.00000	0.00010	0.00020	0.00020	0.00030	0.00040	0.00050	0.00060
Diameter 2, in (rotated 90°)	0.00070	0.00060	0.00050	0.00040	0.00030	0.00020	0.00000	0.00000	-0.00020	-0.00030	-0.00040	-0.00050	-0.00060	-0.00060	-0.00070

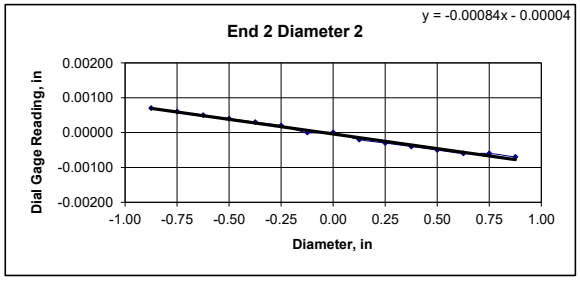
Difference between max and min readings, in:
0° = 0.0013 90° = 0.0014

Maximum difference must be < 0.0020 in. Difference = ± 0.00070
Flatness Tolerance Met? YES









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00073
Angle of Best Fit Line: 0.04174

End 2:
Slope of Best Fit Line 0.00073
Angle of Best Fit Line: 0.04174

Maximum Angular Difference: 0.00000

Parallelism Tolerance Met? YES
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00084
Angle of Best Fit Line: 0.04813

End 2:
Slope of Best Fit Line 0.00084
Angle of Best Fit Line: 0.04813

Maximum Angular Difference: 0.00000

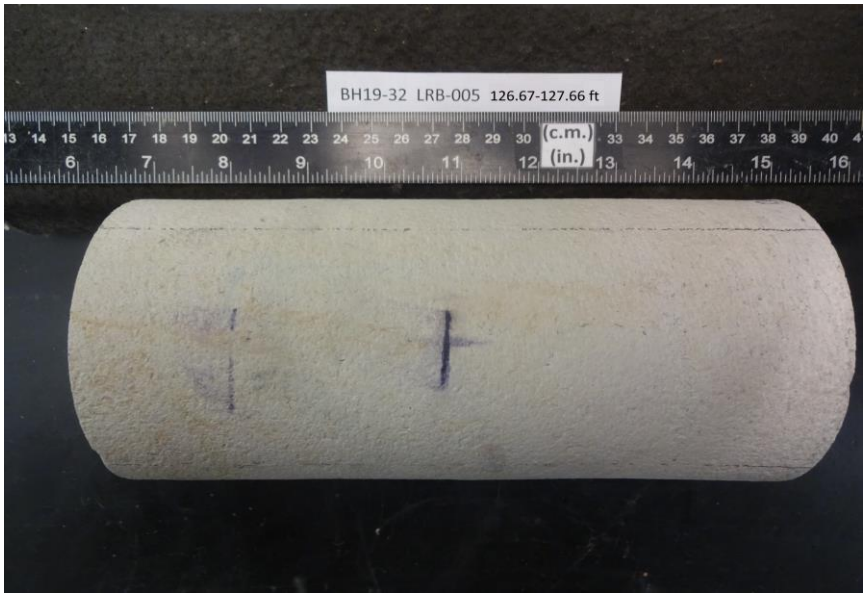
Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00130	3.895	0.00033	0.019	YES
Diameter 2, in (rotated 90°)	0.00140	3.895	0.00036	0.021	YES
END 2					
Diameter 1, in	0.00130	3.895	0.00033	0.019	YES
Diameter 2, in (rotated 90°)	0.00140	3.895	0.00036	0.021	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	11/7/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-32
Sample ID:	LRB-005
Depth:	126.67-127.66



After cutting and grinding

After break

Client:	WSP	Test Date:	11/7/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	tlm
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-32		
Sample ID:	LRB-009		
Depth:	169.0-169.9 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	7.47	7.48	7.48
Specimen Diameter, in:	3.81	3.82	3.82
Specimen Mass, g:	3162.5		
Bulk Density, lb/ft^3	141	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.0	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

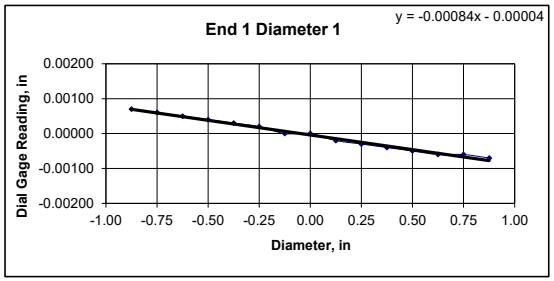
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00070	0.00060	0.00050	0.00040	0.00030	0.00020	0.00000	0.00000	-0.00020	-0.00030	-0.00040	-0.00050	-0.00060	-0.00060	-0.00070
Diameter 2, in (rotated 90°)	-0.00070	-0.00060	-0.00050	-0.00040	-0.00030	-0.00020	-0.00010	0.00000	0.00010	0.00020	0.00020	0.00030	0.00040	0.00050	0.00060

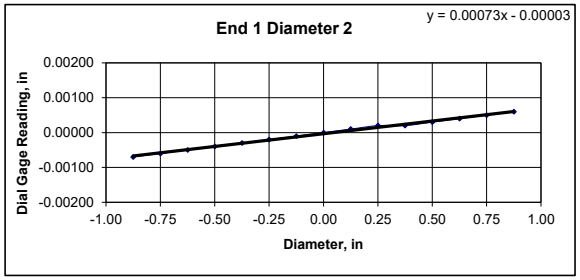
Difference between max and min readings, in:
0° = 0.00140 90° = 0.00130

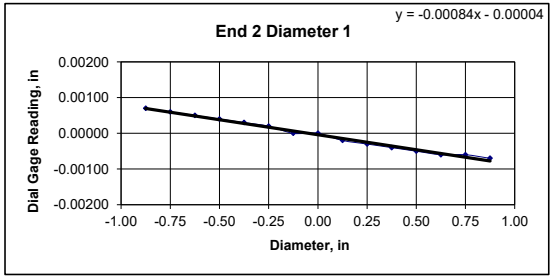
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00070	0.00060	0.00050	0.00040	0.00030	0.00020	0.00000	0.00000	-0.00020	-0.00030	-0.00040	-0.00050	-0.00060	-0.00060	-0.00070
Diameter 2, in (rotated 90°)	-0.00070	-0.00060	-0.00050	-0.00040	-0.00030	-0.00020	-0.00010	0.00000	0.00010	0.00020	0.00020	0.00030	0.00040	0.00050	0.00060

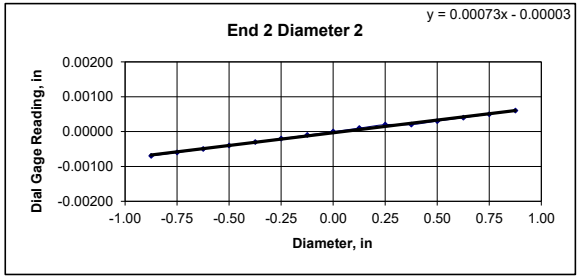
Difference between max and min readings, in:
0° = 0.0014 90° = 0.0013

Maximum difference must be < 0.0020 in. Difference = ± 0.00070
Flatness Tolerance Met? YES









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00084
Angle of Best Fit Line: 0.04813

End 2:
Slope of Best Fit Line 0.00084
Angle of Best Fit Line: 0.04813

Maximum Angular Difference: 0.00000

Parallelism Tolerance Met? YES
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00073
Angle of Best Fit Line: 0.04174

End 2:
Slope of Best Fit Line 0.00073
Angle of Best Fit Line: 0.04174

Maximum Angular Difference: 0.00000

Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00140	3.815	0.00037	0.021	YES
Diameter 2, in (rotated 90°)	0.00130	3.815	0.00034	0.020	YES
END 2					
Diameter 1, in	0.00140	3.815	0.00037	0.021	YES
Diameter 2, in (rotated 90°)	0.00130	3.815	0.00034	0.020	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	11/7/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-32
Sample ID:	LRB-009
Depth, ft:	169.0-169.9 ft

After cutting and grinding

After break

Client:	WSP	Test Date:	8/30/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH-19-35		
Sample ID:	LRB-003		
Depth:	176.84 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	7.99	7.97	7.98
Specimen Diameter, in:	3.96	3.94	3.95
Specimen Mass, g:	3823		
Bulk Density, lb/ft^3	149	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.0	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	0.00000	0.00010	0.00010	0.00020	0.00020	0.00000	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Diameter 2, in (rotated 90°)	0.00520	0.00380	0.00290	0.00220	0.00150	0.00080	0.00050	-0.00010	-0.00090	-0.00200	-0.00280	-0.00410	-0.00510	-0.00550	-0.00620

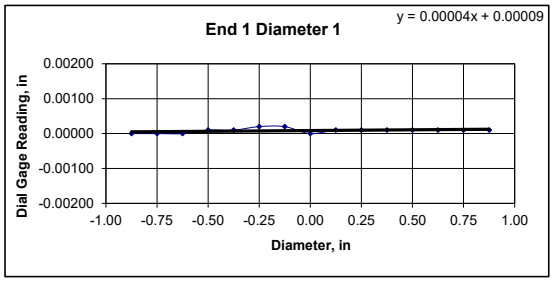
Difference between max and min readings, in: 0° = 0.00020, 90° = 0.01140

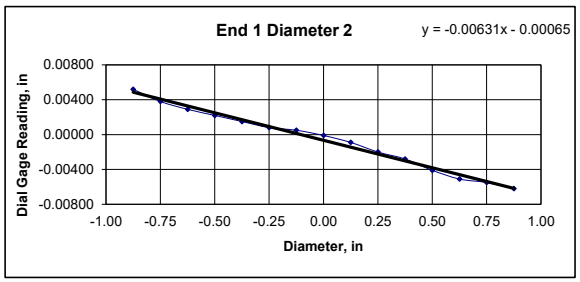
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00030	-0.00030	-0.00040	-0.00060	-0.00070	-0.00040	-0.00020	-0.00010	-0.00010	-0.00020	-0.00060	-0.00120	-0.00120	-0.00120	-0.00110
Diameter 2, in (rotated 90°)	0.00440	0.00370	0.00270	0.00210	0.00150	0.00100	0.00060	0.00000	-0.00220	-0.00370	-0.00540	-0.00650	-0.00660	-0.00690	-0.00790

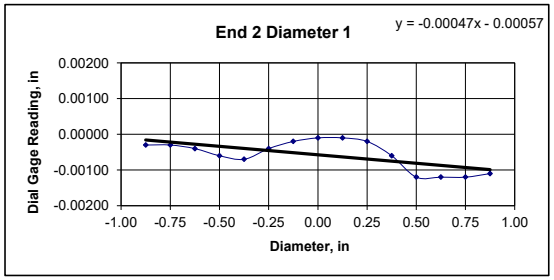
Difference between max and min readings, in: 0° = 0.0011, 90° = 0.0123

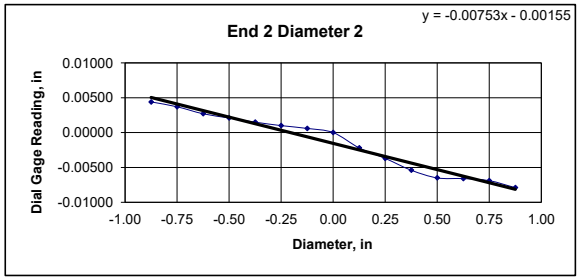
Maximum difference must be < 0.0020 in. Difference = ± 0.00615

Flatness Tolerance Met? NO









DIAMETER 1

End 1:
- Slope of Best Fit Line: 0.00004
- Angle of Best Fit Line: 0.00246

End 2:
- Slope of Best Fit Line: 0.00047
- Angle of Best Fit Line: 0.02717

Maximum Angular Difference: 0.02472

Parallelism Tolerance Met? NO

Spherically Seated

DIAMETER 2

End 1:
- Slope of Best Fit Line: 0.00631
- Angle of Best Fit Line: 0.36129

End 2:
- Slope of Best Fit Line: 0.00753
- Angle of Best Fit Line: 0.43135

Maximum Angular Difference: 0.07006

Parallelism Tolerance Met? NO

Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00020	3.950	0.00005	0.003	YES
Diameter 2, in (rotated 90°)	0.01140	3.950	0.00289	0.165	YES
END 2					
Diameter 1, in	0.00110	3.950	0.00028	0.016	YES
Diameter 2, in (rotated 90°)	0.01230	3.950	0.00311	0.178	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

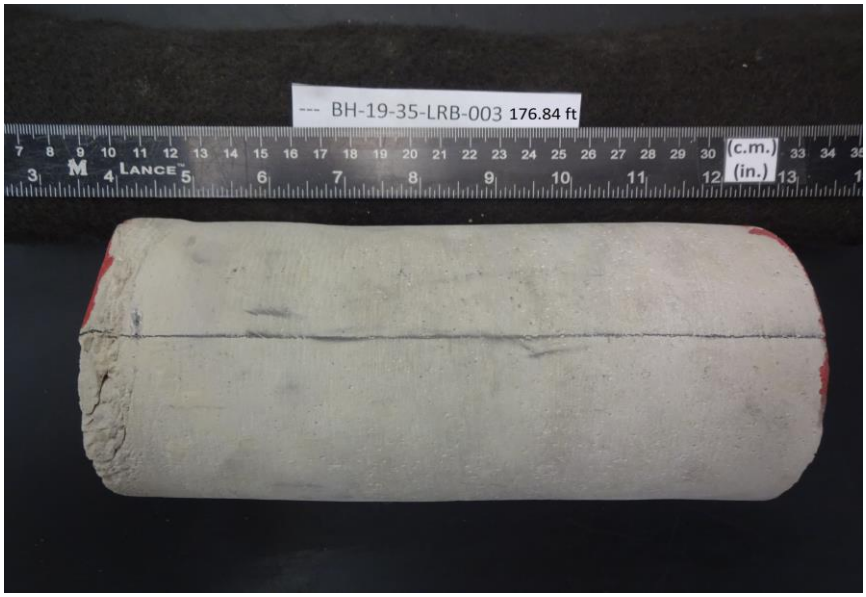
Client:	WSP	Test Date:	9/6/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH-19-35	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-003		
Depth (ft):	176.84		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS		
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/6/2019
Tested By:	cmh
Checked By:	smd
Boring ID:	BH-19-35
Sample ID:	LRB-003
Depth, ft:	176.84



After cutting and grinding

After break

Client:	WSP	Test Date:	8/19/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-38		
Sample ID:	LRB-002		
Depth:	144.5-144.7 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.47	5.47	5.47
Specimen Diameter, in:	2.40	2.40	2.40
Specimen Mass, g:	1023.16		
Bulk Density, lb/ft^3	157	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? YES

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00030	-0.00030	-0.00020	-0.00020	-0.00020	-0.00020	-0.00010	0.00000	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00020
Diameter 2, in (rotated 90°)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00020

Difference between max and min readings, in:

0° = 0.00050 90° = 0.00020

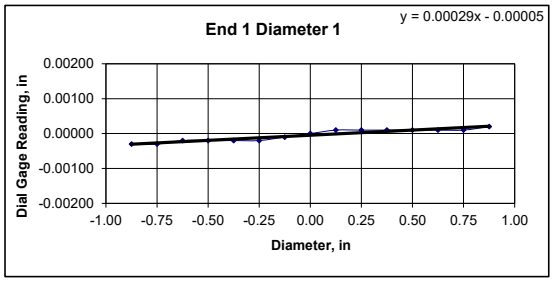
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00030	-0.00030	-0.00030	-0.00030	-0.00020	-0.00010	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00020
Diameter 2, in (rotated 90°)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00020	-0.00030

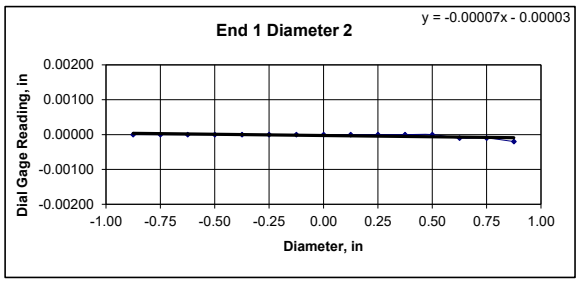
Difference between max and min readings, in:

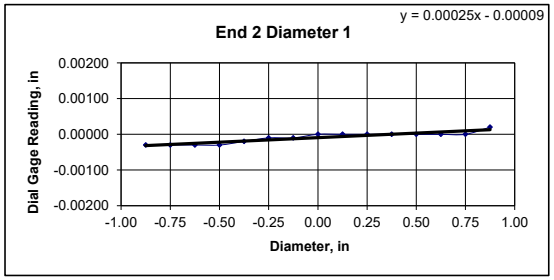
0° = 0.0005 90° = 0.0003

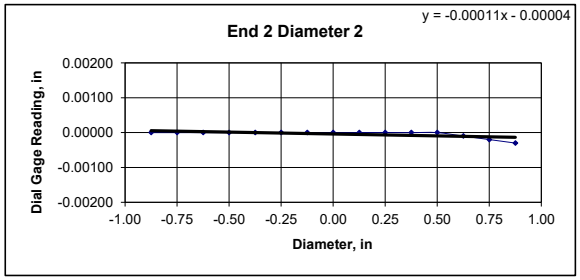
Maximum difference must be < 0.0020 in. Difference = ± 0.00025

Flatness Tolerance Met? YES









DIAMETER 1

End 1:
- Slope of Best Fit Line: 0.00029
- Angle of Best Fit Line: 0.01686

End 2:
- Slope of Best Fit Line: 0.00025
- Angle of Best Fit Line: 0.01457

Maximum Angular Difference: 0.00229

Parallelism Tolerance Met? YES

Spherically Seated

DIAMETER 2

End 1:
- Slope of Best Fit Line: 0.00007
- Angle of Best Fit Line: 0.00409

End 2:
- Slope of Best Fit Line: 0.00011
- Angle of Best Fit Line: 0.00622

Maximum Angular Difference: 0.00213

Parallelism Tolerance Met? YES

Spherically Seated

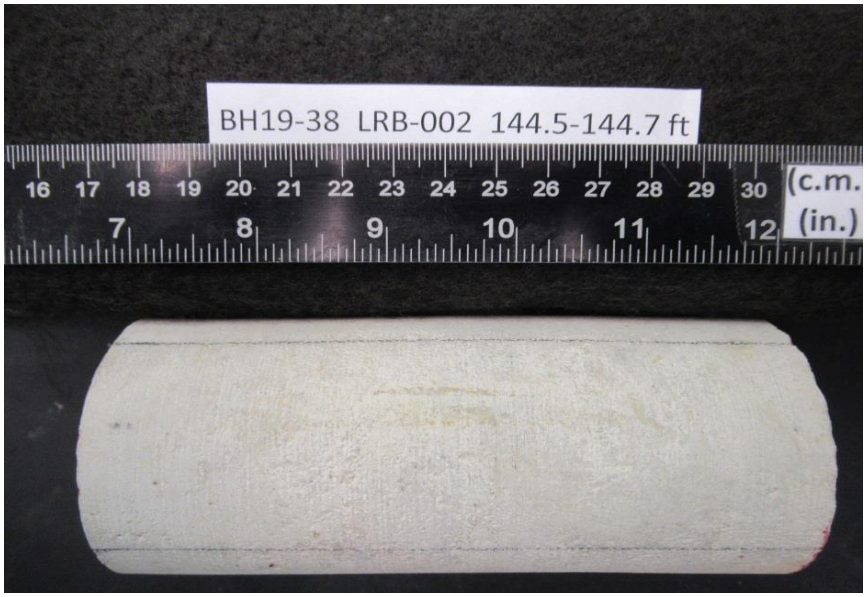
PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00050	2.400	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00020	2.400	0.00008	0.005	YES
END 2					
Diameter 1, in	0.00050	2.400	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00030	2.400	0.00013	0.007	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	8/29/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-38
Sample ID:	LRB-002
Depth, ft:	144.5-144.7



After cutting and grinding

After break

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	jck
Sample ID:	---	Test Date:	12/11/19	Checked By:	smd
Depth :	---	Test Id:	532803		

Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method C

Boring ID	Sample Number	Depth	Bulk Density, pcf	Compressive strength, psi	Failure Type	Meets ASTM D4543	Note(s)
BH19-19	LRB-006	136.81 - 137.60 ft	148	175	1	No	1 , 2,*
BH19-36	LRB-005	211.61 - 212.27 ft	144	543	1	No	1 , 2,*

Notes: Density determined on core samples by measuring dimensions and weight and then calculating.

All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.

The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

1: Best effort end preparation. See Tolerance report for details.
2: The as-received core did not meet the ASTM side straightness tolerance due to irregularities in the sample as cored.
3: Specimen L/D < 2.
4: The as-received core did not meet the ASTM minimum diameter tolerance of 1.875 inches.
5: Specimen diameter is less than 10 times maximum particle size.
6: Specimen diameter is less than 6 times maximum particle size.

*Because the indicated tested specimens did not meet the ASTM D4543 standard tolerances, the results reported here may differ from those for a test specimen within tolerances.

Client:	WSP	Test Date:	12/11/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-19		
Sample ID:	LRB-006		
Depth:	136.81-137.60 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	7.88	7.75	7.82
Specimen Diameter, in:	3.97	3.96	3.97
Specimen Mass, g:	3747		
Bulk Density, lb/ft^3	148	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.0	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? **NO**

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.02320	-0.01930	-0.01650	-0.01200	-0.00880	-0.00630	-0.00350	-0.00080	0.00220	0.00710	0.01090	0.01370	0.01610	0.01920	0.02120
Diameter 2, in (rotated 90°)	-0.00490	-0.00170	-0.00020	0.00120	0.00050	0.00050	0.00050	0.00040	0.00060	0.00060	0.00010	-0.00040	-0.00060	-0.00180	-0.00290

Difference between max and min readings, in:

0° = 0.04440 90° = 0.00610

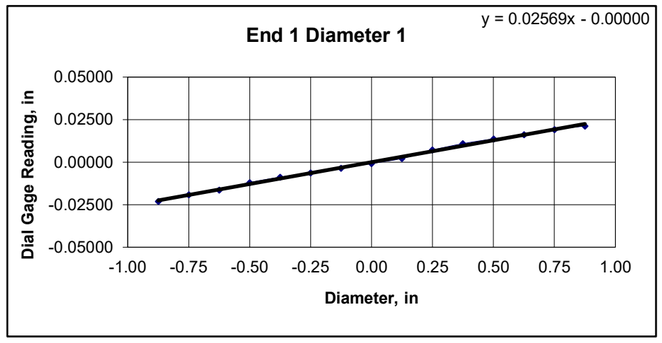
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.02030	-0.01860	-0.01570	-0.01210	-0.00910	-0.00650	-0.00400	-0.00040	0.00330	0.00570	0.00810	0.01070	0.01380	0.01650	0.01820
Diameter 2, in (rotated 90°)	0.00140	0.00100	-0.00020	0.00050	0.00060	0.00060	0.00050	0.00020	0.00000	0.00020	0.00010	0.00030	-0.00020	-0.00050	-0.00140

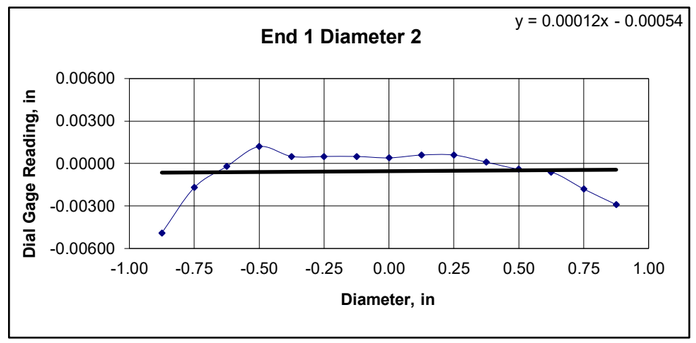
Difference between max and min readings, in:

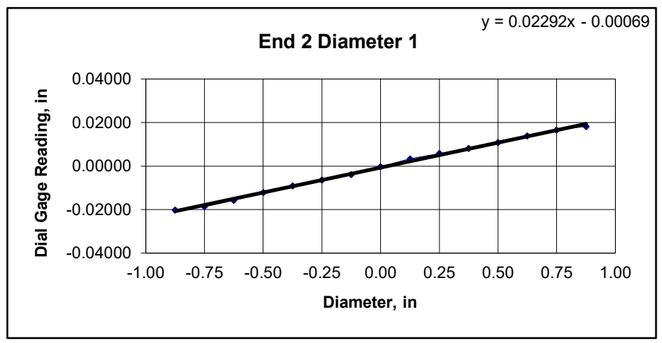
0° = 0.0385 90° = 0.0028

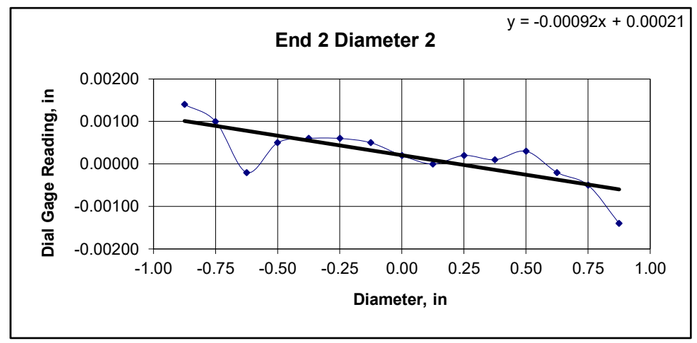
Maximum difference must be < 0.0020 in. Difference = ± 0.02220

Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:

Slope of Best Fit Line	0.02569
Angle of Best Fit Line:	1.47169

End 2:

Slope of Best Fit Line	0.02292
Angle of Best Fit Line:	1.31283

Maximum Angular Difference: 0.15886

Parallelism Tolerance Met? **NO**

Spherically Seated

DIAMETER 2

End 1:

Slope of Best Fit Line	0.00012
Angle of Best Fit Line:	0.00671

End 2:

Slope of Best Fit Line	0.00092
Angle of Best Fit Line:	0.05271

Maximum Angular Difference: 0.04600

Parallelism Tolerance Met? **NO**

Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.04440	3.965	0.01120	0.642	NO
Diameter 2, in (rotated 90°)	0.00610	3.965	0.00154	0.088	YES
END 2					
Diameter 1, in	0.03850	3.965	0.00971	0.556	NO
Diameter 2, in (rotated 90°)	0.00280	3.965	0.00071	0.040	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? **NO**

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	12/11/2019
Tested By:	cmh
Checked By:	jsc
Boring ID:	BH19-19
Sample ID:	LRB-006
Depth, ft:	136.81-137.60

After cutting and grinding

After break

Client:	WSP	Test Date:	12/10/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-36		
Sample ID:	LRB-005		
Depth:	211.61-212.27 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.70	8.63	8.67
Specimen Diameter, in:	3.79	3.78	3.79
Specimen Mass, g:	3704		
Bulk Density, lb/ft^3	144	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **NO**

END FLATNESS AND PARALLELISM (Procedure FP1)

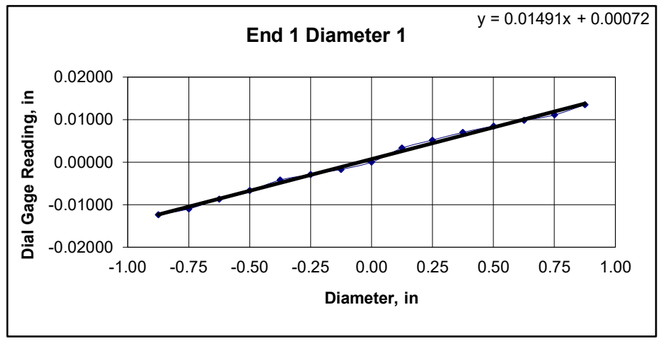
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.01240	-0.01100	-0.00870	-0.00670	-0.00420	-0.00290	-0.00170	0.00000	0.00330	0.00520	0.00700	0.00850	0.00980	0.01110	0.01350
Diameter 2, in (rotated 90°)	-0.00570	-0.00530	-0.00390	-0.00250	-0.00230	-0.00210	-0.00160	0.00010	0.00070	0.00100	0.00220	0.00310	0.00360	0.00420	0.00490

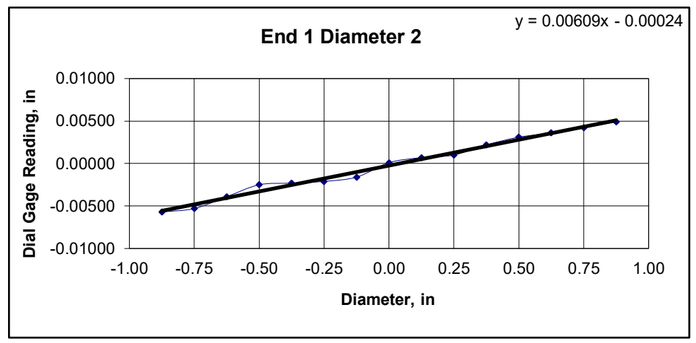
Difference between max and min readings, in:
0° = 0.02590 90° = 0.01060

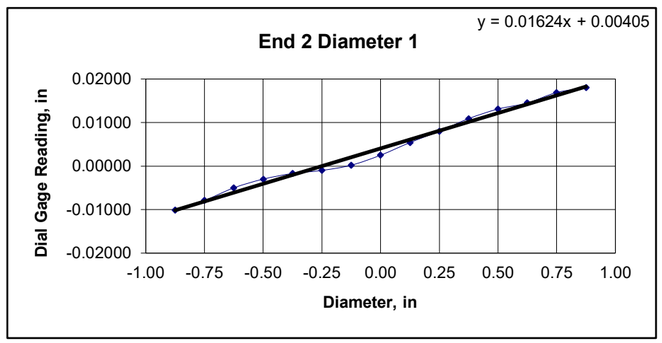
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.01010	-0.00790	-0.00500	-0.00300	-0.00170	-0.00100	0.00020	0.00250	0.00540	0.00800	0.01090	0.01310	0.01450	0.01690	0.01800
Diameter 2, in (rotated 90°)	-0.00170	-0.00370	-0.00140	-0.00160	-0.00160	-0.00090	-0.00060	-0.00040	0.00000	-0.00010	-0.00020	-0.00020	0.00000	0.00010	0.00020

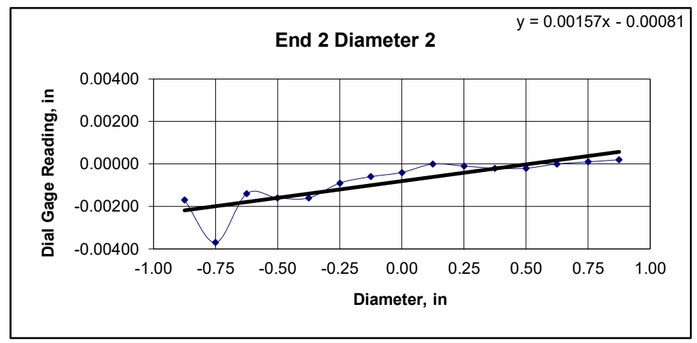
Difference between max and min readings, in:
0° = 0.0281 90° = 0.0039

Maximum difference must be < 0.0020 in. Difference = ± 0.01405
Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.01491
Angle of Best Fit Line: 0.85446

End 2:
Slope of Best Fit Line 0.01624
Angle of Best Fit Line: 0.93040

Maximum Angular Difference: 0.07594

Parallelism Tolerance Met? **NO**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00609
Angle of Best Fit Line: 0.34885

End 2:
Slope of Best Fit Line 0.00157
Angle of Best Fit Line: 0.09020

Maximum Angular Difference: 0.25865

Parallelism Tolerance Met? **NO**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.02590	3.785	0.00684	0.392	NO
Diameter 2, in (rotated 90°)	0.01060	3.785	0.00280	0.160	YES
END 2					
Diameter 1, in	0.02810	3.785	0.00742	0.425	NO
Diameter 2, in (rotated 90°)	0.00390	3.785	0.00103	0.059	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? **NO**

Client:	WSP	Test Date:	12/10/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-36	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-005		
Depth (ft):	211.61-212.27		
Visual Description:	See photographs		

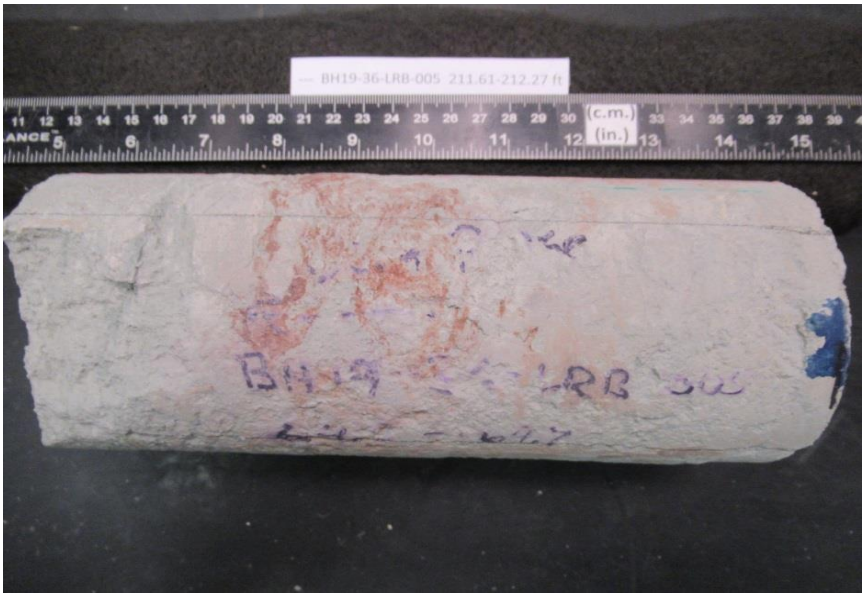
BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS

END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	NO
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	NO

End Flatness Tolerance Met? NO

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	12/11/2019
Tested By:	jck
Checked By:	jsc
Boring ID:	BH19-36
Sample ID:	LRB-005
Depth, ft:	211.61-212.27



After cutting and grinding

After break

GeoTesting EXPRESS

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	01/29/20	Checked By:	smd
Depth :	---	Test Id:	537820		

Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method C

Boring ID	Sample Number	Depth	Bulk Density, pcf	Compressive strength, psi	Failure Type	Meets ASTM D4543	Note(s)
BH19-23	LRB-004	173.56 - 175.20 ft	134	1262	1	Yes	---
BH19-23	LRB-012	235.56 - 237.86 ft	144	3903	1	No	1,*
BH19-24A	LRB-001	230.97 - 232.61 ft	139	1657	1	No	1,*
BH19-24A	LRB-003	243.11 - 244.42 ft	142	497	1	No	1 , 2,*
BH19-24A	LRB-006	269.69 - 271.98 ft	139	1949	1	Yes	---
BH19-24A	LRB-009	288.06 - 289.70 ft	140	1612	1	No	1,*
BH19-24A	LRB-010	296.59 - 300.20 ft	142	2845	1	No	1,*

Notes: Density determined on core samples by measuring dimensions and weight and then calculating.

All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.

The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

1: Best effort end preparation. See Tolerance report for details.
2: The as-received core did not meet the ASTM side straightness tolerance due to irregularities in the sample as cored.
3: Specimen L/D < 2.
4: The as-received core did not meet the ASTM minimum diameter tolerance of 1.875 inches.
5: Specimen diameter is less than 10 times maximum particle size.
6: Specimen diameter is less than 6 times maximum particle size.

*Because the indicated tested specimens did not meet the ASTM D4543 standard tolerances, the results reported here may differ from those for a test specimen within tolerances.

Client:	WSP				
Project:	Line 5 Replacement and Tunnel Project				
Location:	Straits of Mackinac			Project No:	GTX-310187
Boring ID:	---	Sample Type:	---	Tested By:	tlm
Sample ID:	---	Test Date:	01/29/20	Checked By:	smd
Depth :	---	Test Id:	538357		

Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method C

Boring ID	Sample Number	Depth	Bulk Density, pcf	Compressive strength, psi	Failure Type	Meets ASTM D4543	Note(s)
BH19-26	LRB-003	328.74 - 330.05 ft	137	652	1	No	1 , 2,*
BH19-27	LRB-003	302.17 - 304.46 ft	131	763	1	No	1 , 2,*
BH19-28	LRB-010	239.83 - 241.14 ft	134	522	3	No	1,*
BH19-31	LRB-011	261.48 - 262.47 ft	136	904	2	No	1,*

Notes: Density determined on core samples by measuring dimensions and weight and then calculating.

All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.

The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.

Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure (See attached photographs)

1: Best effort end preparation. See Tolerance report for details.
2: The as-received core did not meet the ASTM side straightness tolerance due to irregularities in the sample as cored.
3: Specimen L/D < 2.
4: The as-received core did not meet the ASTM minimum diameter tolerance of 1.875 inches.
5: Specimen diameter is less than 10 times maximum particle size.
6: Specimen diameter is less than 6 times maximum particle size.

*Because the indicated tested specimens did not meet the ASTM D4543 standard tolerances, the results reported here may differ from those for a test specimen within tolerances.

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-23		
Sample ID:	LRB-004		
Depth:	173.56-175.20 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.83	8.83	8.83
Specimen Diameter, in:	3.95	3.95	3.95
Specimen Mass, g:	3818.9		
Bulk Density, lb/ft^3	134	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.2	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **YES**

END FLATNESS AND PARALLELISM (Procedure FP1)

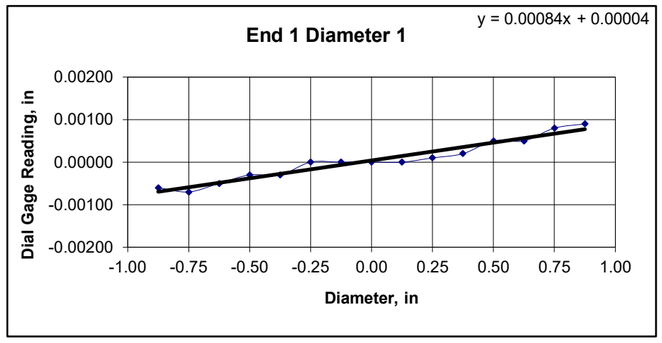
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00060	-0.00070	-0.00050	-0.00030	-0.00030	0.00000	0.00000	0.00000	0.00000	0.00010	0.00020	0.00050	0.00050	0.00080	0.00090
Diameter 2, in (rotated 90°)	0.00080	0.00070	0.00070	0.00060	0.00040	0.00020	0.00010	0.00000	-0.00030	-0.00040	-0.00040	-0.00050	-0.00070	-0.00080	-0.00090

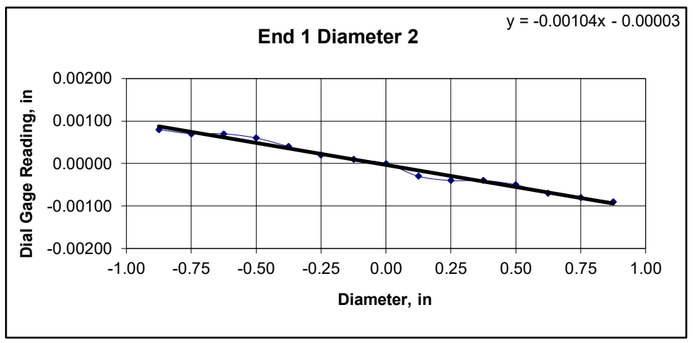
Difference between max and min readings, in:
0° = 0.00160 90° = 0.00170

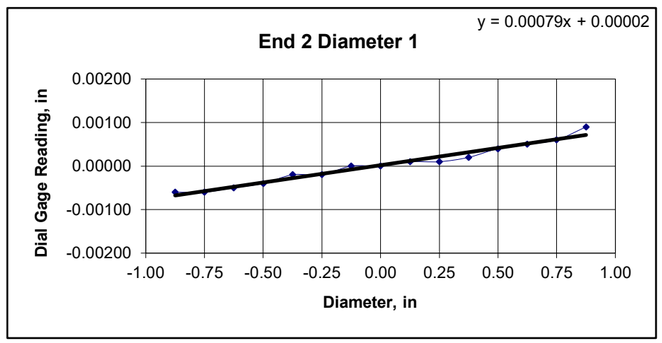
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00060	-0.00060	-0.00050	-0.00040	-0.00020	-0.00020	0.00000	0.00000	0.00010	0.00010	0.00020	0.00040	0.00050	0.00060	0.00090
Diameter 2, in (rotated 90°)	0.00080	0.00070	0.00080	0.00030	0.00010	0.00010	0.00000	0.00000	-0.00030	-0.00030	-0.00040	-0.00050	-0.00070	-0.00080	-0.00090

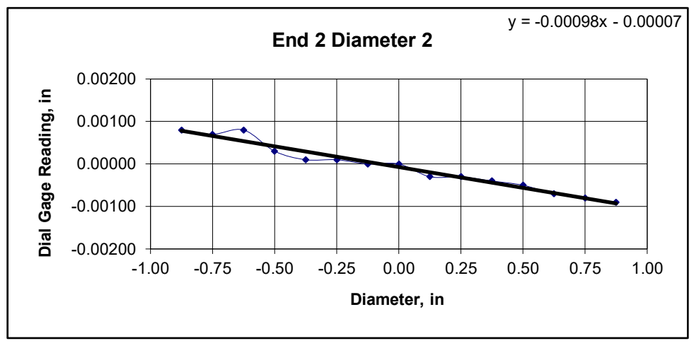
Difference between max and min readings, in:
0° = 0.0015 90° = 0.0017

Maximum difference must be < 0.0020 in. Difference = ± 0.00085
Flatness Tolerance Met? **YES**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00084
Angle of Best Fit Line: 0.04813

End 2:
Slope of Best Fit Line 0.00079
Angle of Best Fit Line: 0.04551

Maximum Angular Difference: 0.00262

Parallelism Tolerance Met? **YES**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00104
Angle of Best Fit Line: 0.05942

End 2:
Slope of Best Fit Line 0.00098
Angle of Best Fit Line: 0.05599

Maximum Angular Difference: 0.00344

Parallelism Tolerance Met? **YES**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00160	3.950	0.00041	0.023	YES
Diameter 2, in (rotated 90°)	0.00170	3.950	0.00043	0.025	YES
END 2					
Diameter 1, in	0.00150	3.950	0.00038	0.022	YES
Diameter 2, in (rotated 90°)	0.00170	3.950	0.00043	0.025	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? **YES**

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-23
Sample ID:	LRB-004
Depth, ft:	173.56-175.20

After cutting and grinding

After break

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-23		
Sample ID:	LRB-012		
Depth:	235.56-237.86 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	9.04	9.04	9.04
Specimen Diameter, in:	3.96	3.96	3.96
Specimen Mass, g:	4211		
Bulk Density, lb/ft^3	144	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **YES**

END FLATNESS AND PARALLELISM (Procedure FP1)

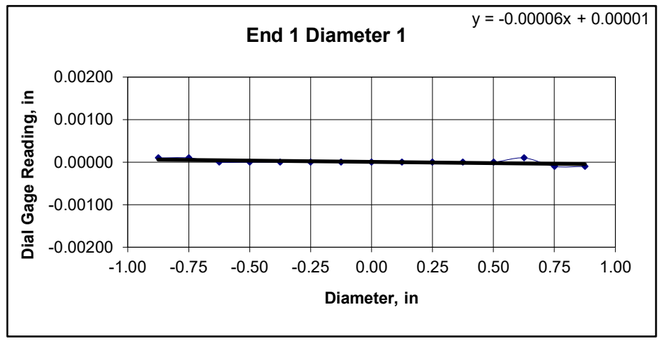
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00010	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	-0.00010	-0.00010
Diameter 2, in (rotated 90°)	0.00150	0.00140	0.00110	0.00090	0.00090	0.00070	0.00050	0.00000	0.00000	0.00000	-0.00030	-0.00060	-0.00070	-0.00090	-0.00110

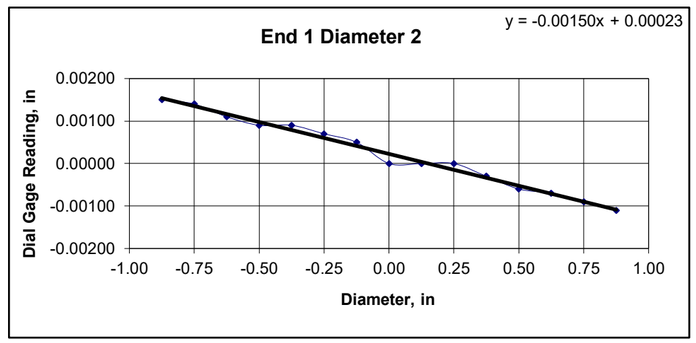
Difference between max and min readings, in:
0° = 0.00020 90° = 0.00260

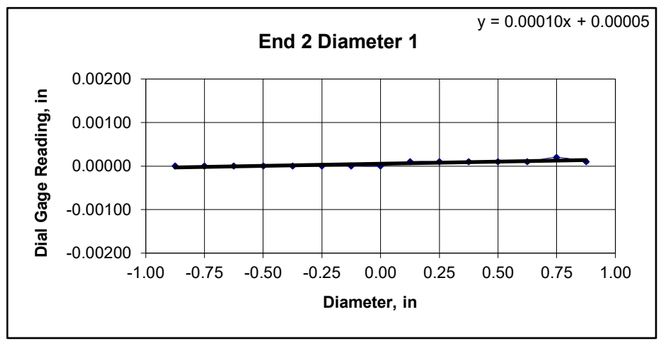
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00010	0.00010	0.00010	0.00020	0.00010
Diameter 2, in (rotated 90°)	0.00120	0.00110	0.00090	0.00080	0.00040	0.00040	0.00030	0.00000	-0.00030	-0.00050	-0.00060	-0.00100	-0.00100	-0.00110	-0.00120

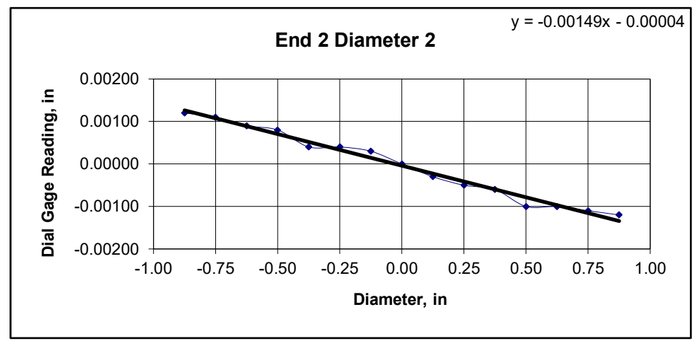
Difference between max and min readings, in:
0° = 0.0002 90° = 0.0024

Maximum difference must be < 0.0020 in. Difference = ± 0.00130
Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00006
Angle of Best Fit Line: 0.00344

End 2:
Slope of Best Fit Line 0.00010
Angle of Best Fit Line: 0.00557

Maximum Angular Difference: 0.00213

Parallelism Tolerance Met? **YES**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00150
Angle of Best Fit Line: 0.08594

End 2:
Slope of Best Fit Line 0.00149
Angle of Best Fit Line: 0.08529

Maximum Angular Difference: 0.00065

Parallelism Tolerance Met? **YES**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00020	3.960	0.00005	0.003	YES
Diameter 2, in (rotated 90°)	0.00260	3.960	0.00066	0.038	YES
END 2					
Diameter 1, in	0.00020	3.960	0.00005	0.003	YES
Diameter 2, in (rotated 90°)	0.00240	3.960	0.00061	0.035	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? **YES**

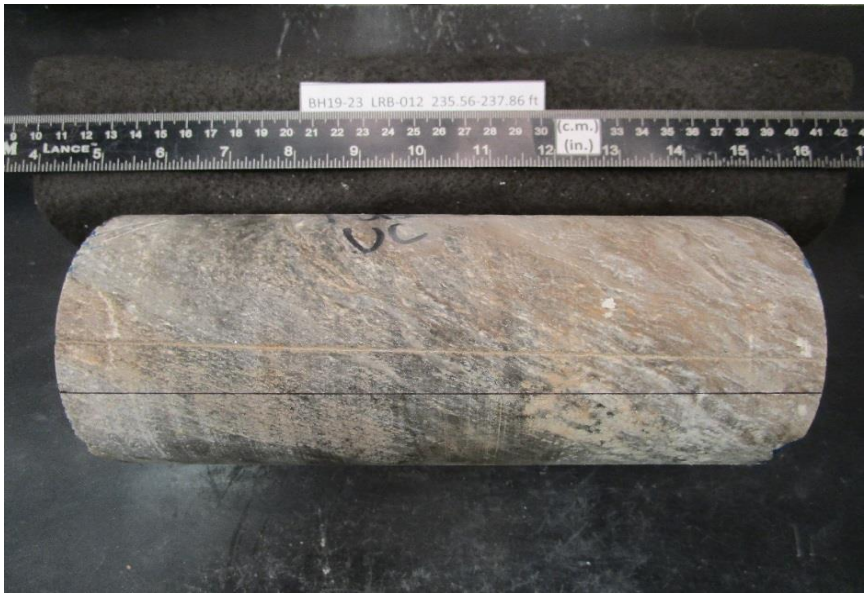
Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-23	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-012		
Depth (ft):	235.56-237.86		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS		
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-23
Sample ID:	LRB-012
Depth, ft:	235.56-237.86



After cutting and grinding

After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A		
Sample ID:	LRB-001		
Depth:	230.97-232.61 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.92	8.92	8.92
Specimen Diameter, in:	3.90	3.91	3.91
Specimen Mass, g:	3901		
Bulk Density, lb/ft^3	139	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **YES**

END FLATNESS AND PARALLELISM (Procedure FP1)

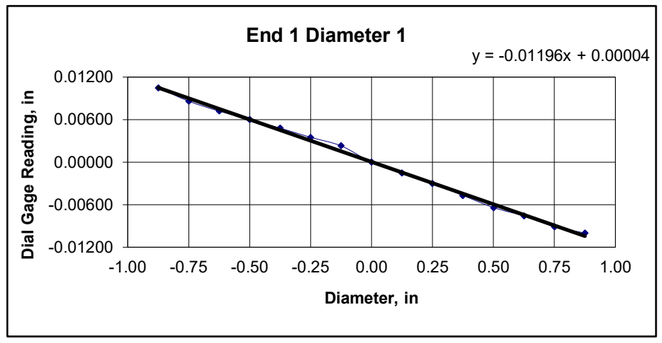
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.01050	0.00860	0.00720	0.00600	0.00480	0.00350	0.00230	0.00000	-0.00150	-0.00300	-0.00470	-0.00640	-0.00760	-0.00910	-0.01000
Diameter 2, in (rotated 90°)	0.00190	0.00170	0.00140	0.00120	0.00090	0.00050	0.00040	0.00000	-0.00060	-0.00080	-0.00090	-0.00130	-0.00150	-0.00160	-0.00210

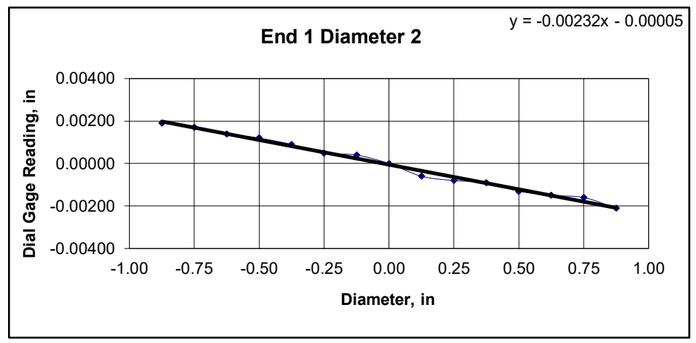
Difference between max and min readings, in:
0° = 0.02050 90° = 0.00400

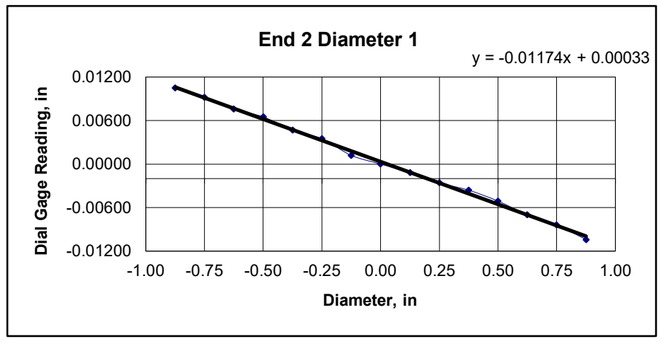
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.01050	0.00920	0.00760	0.00650	0.00470	0.00350	0.00120	0.00000	-0.00120	-0.00260	-0.00360	-0.00510	-0.00700	-0.00840	-0.01040
Diameter 2, in (rotated 90°)	0.00130	0.00120	0.00100	0.00100	0.00080	0.00030	-0.00010	0.00000	0.00000	-0.00030	-0.00040	-0.00040	-0.00040	-0.00100	-0.00100

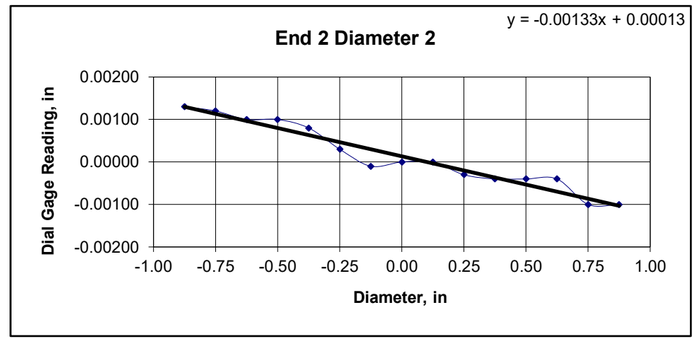
Difference between max and min readings, in:
0° = 0.0209 90° = 0.0023

Maximum difference must be < 0.0020 in. Difference = ± 0.01045
Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.01196
Angle of Best Fit Line: 0.68522

End 2:
Slope of Best Fit Line 0.01174
Angle of Best Fit Line: 0.67246

Maximum Angular Difference: 0.01277

Parallelism Tolerance Met? **NO**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00232
Angle of Best Fit Line: 0.13309

End 2:
Slope of Best Fit Line 0.00133
Angle of Best Fit Line: 0.07629

Maximum Angular Difference: 0.05680

Parallelism Tolerance Met? **NO**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.02050	3.905	0.00525	0.301	NO
Diameter 2, in (rotated 90°)	0.00400	3.905	0.00102	0.059	YES
END 2					
Diameter 1, in	0.02090	3.905	0.00535	0.307	NO
Diameter 2, in (rotated 90°)	0.00230	3.905	0.00059	0.034	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? **NO**

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-001		
Depth (ft):	230.97-232.61		
Visual Description:	See photographs		

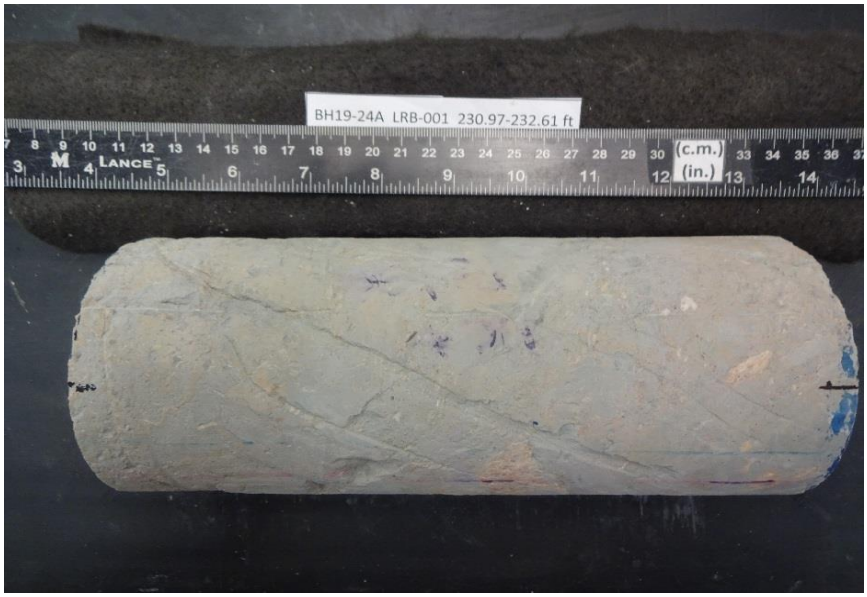
BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS

END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? NO

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-001
Depth, ft:	230.97-232.61



After cutting and grinding

After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A		
Sample ID:	LRB-003		
Depth:	243.11-244.42 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.80	8.81	8.81
Specimen Diameter, in:	3.94	3.95	3.95
Specimen Mass, g:	4025		
Bulk Density, lb/ft^3	142	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.2	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **NO**

END FLATNESS AND PARALLELISM (Procedure FP1)

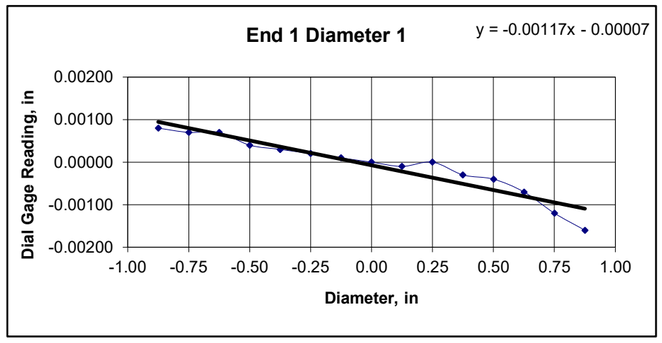
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00080	0.00070	0.00070	0.00040	0.00030	0.00020	0.00010	0.00000	-0.00010	0.00000	-0.00030	-0.00040	-0.00070	-0.00120	-0.00160
Diameter 2, in (rotated 90°)	0.00990	0.00900	0.00790	0.00650	0.00520	0.00360	0.00280	0.00000	-0.00050	-0.00160	-0.00210	-0.00300	-0.00450	-0.00610	-0.00840

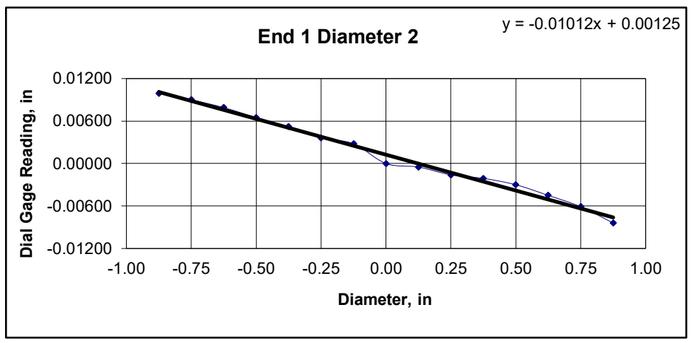
Difference between max and min readings, in:
0° = 0.00240 90° = 0.01830

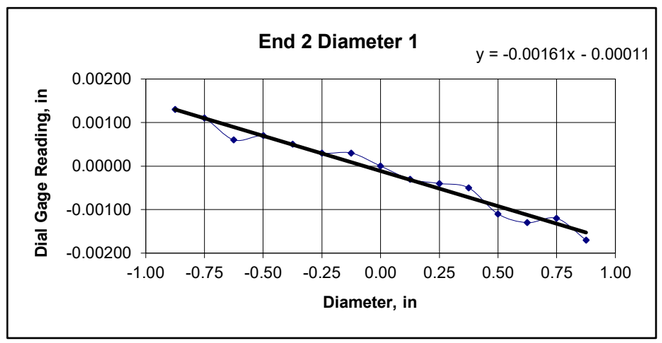
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00130	0.00110	0.00060	0.00070	0.00050	0.00030	0.00030	0.00000	-0.00030	-0.00040	-0.00050	-0.00110	-0.00130	-0.00120	-0.00170
Diameter 2, in (rotated 90°)	0.00950	0.00840	0.00750	0.00620	0.00520	0.00380	0.00260	0.00000	-0.00050	-0.00140	-0.00210	-0.00270	-0.00320	-0.00400	-0.00440

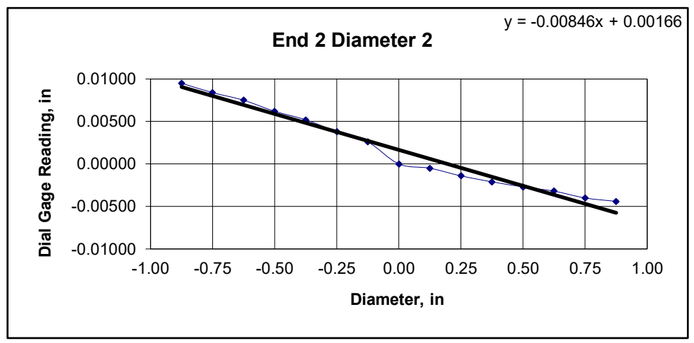
Difference between max and min readings, in:
0° = 0.003 90° = 0.0139

Maximum difference must be < 0.0020 in. Difference = ± 0.00915
Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00117
Angle of Best Fit Line: 0.06679

End 2:
Slope of Best Fit Line 0.00161
Angle of Best Fit Line: 0.09249

Maximum Angular Difference: 0.02570

Parallelism Tolerance Met? **NO**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.01012
Angle of Best Fit Line: 0.57998

End 2:
Slope of Best Fit Line 0.00846
Angle of Best Fit Line: 0.48487

Maximum Angular Difference: 0.09510

Parallelism Tolerance Met? **NO**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00240	3.945	0.00061	0.035	YES
Diameter 2, in (rotated 90°)	0.01830	3.945	0.00464	0.266	NO
END 2					
Diameter 1, in	0.00300	3.945	0.00076	0.044	YES
Diameter 2, in (rotated 90°)	0.01390	3.945	0.00352	0.202	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? **NO**

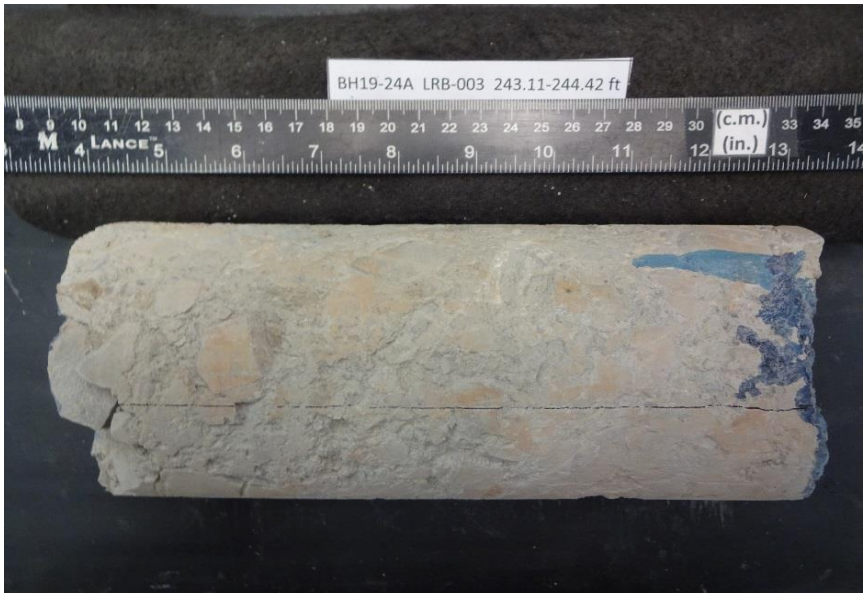
Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-003		
Depth (ft):	243.11-244.42		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS		
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-003
Depth, ft:	243.11-244.42



After cutting and grinding

After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A		
Sample ID:	LRB-006		
Depth:	269.69-271.98 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	9.40	9.42	9.41
Specimen Diameter, in:	3.93	3.94	3.94
Specimen Mass, g:	4183		
Bulk Density, lb/ft^3	139	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.4	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? YES

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00010	0.00000
Diameter 2, in (rotated 90°)	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00010	0.00000	0.00000	0.00000	0.00010	0.00010	0.00000	0.00000	-0.00010

Difference between max and min readings, in:

0° = 0.00010 90° = 0.00020

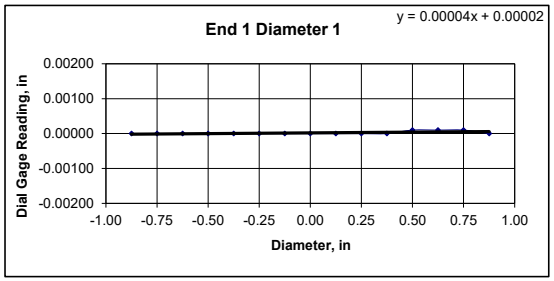
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00000	0.00000	-0.00010	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	0.00000	0.00000	0.00000	0.00000
Diameter 2, in (rotated 90°)	0.00000	0.00000	-0.00020	-0.00010	-0.00020	-0.00010	0.00000	0.00000	0.00000	-0.00010	0.00000	-0.00020	-0.00010	-0.00030	-0.00010

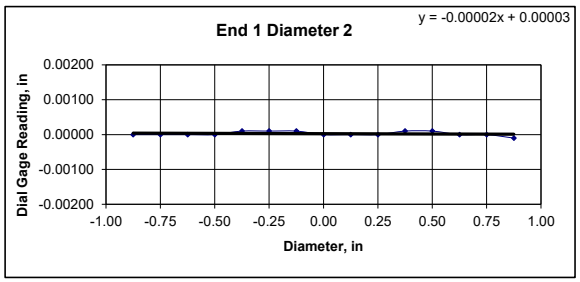
Difference between max and min readings, in:

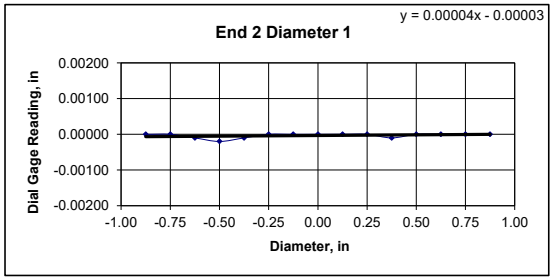
0° = 0.0002 90° = 0.0003

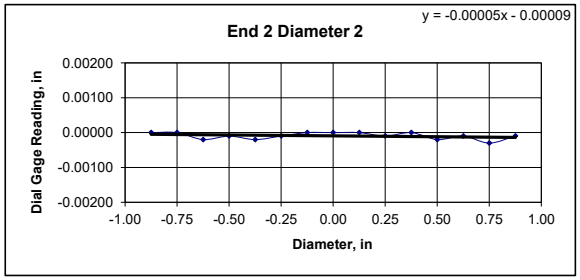
Maximum difference must be < 0.0020 in. Difference = ± 0.00015

Flatness Tolerance Met? YES









DIAMETER 1

End 1:
- Slope of Best Fit Line: 0.00004
- Angle of Best Fit Line: 0.00246

End 2:
- Slope of Best Fit Line: 0.00004
- Angle of Best Fit Line: 0.00213

Maximum Angular Difference: 0.00033

Parallelism Tolerance Met? YES

Spherically Seated

DIAMETER 2

End 1:
- Slope of Best Fit Line: 0.00002
- Angle of Best Fit Line: 0.00098

End 2:
- Slope of Best Fit Line: 0.00005
- Angle of Best Fit Line: 0.00295

Maximum Angular Difference: 0.00196

Parallelism Tolerance Met? YES

Spherically Seated

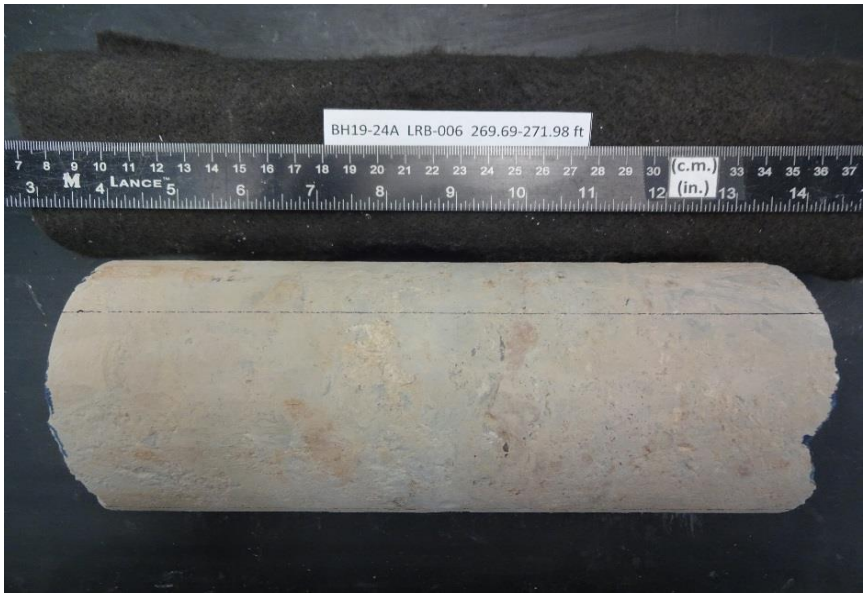
PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00010	3.935	0.00003	0.001	YES
Diameter 2, in (rotated 90°)	0.00020	3.935	0.00005	0.003	YES
END 2					
Diameter 1, in	0.00020	3.935	0.00005	0.003	YES
Diameter 2, in (rotated 90°)	0.00030	3.935	0.00008	0.004	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-006
Depth, ft:	269.69-271.98



After cutting and grinding

After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A		
Sample ID:	LRB-009		
Depth:	288.06-289.70 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.85	8.87	8.86
Specimen Diameter, in:	3.92	3.92	3.92
Specimen Mass, g:	3935		
Bulk Density, lb/ft^3	140	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? YES

END FLATNESS AND PARALLELISM (Procedure FP1)

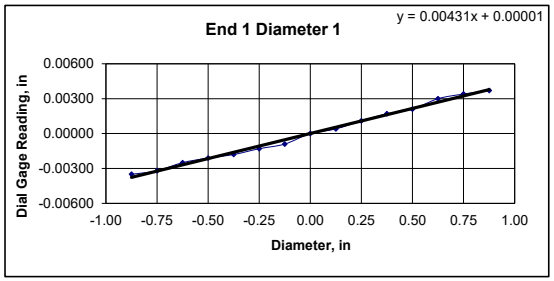
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00350	-0.00320	-0.00250	-0.00210	-0.00180	-0.00130	-0.00090	0.00000	0.00040	0.00110	0.00170	0.00210	0.00300	0.00340	0.00370
Diameter 2, in (rotated 90°)	0.00760	0.00690	0.00570	0.00440	0.00330	0.00230	0.00140	0.00000	-0.00090	-0.00180	-0.00270	-0.00440	-0.00600	-0.00680	-0.00780

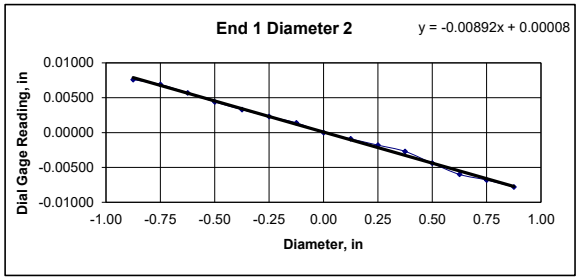
Difference between max and min readings, in:
0° = 0.00720 90° = 0.01540

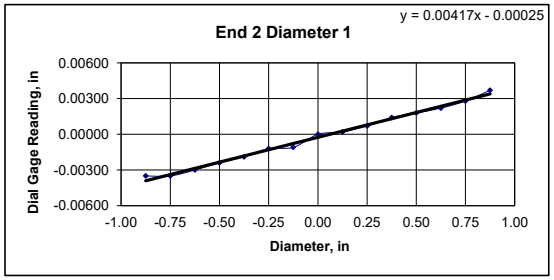
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00350	-0.00350	-0.00300	-0.00240	-0.00190	-0.00120	-0.00110	0.00000	0.00020	0.00070	0.00140	0.00180	0.00220	0.00280	0.00370
Diameter 2, in (rotated 90°)	0.00750	0.00660	0.00580	0.00450	0.00300	0.00190	0.00110	0.00000	-0.00080	-0.00180	-0.00310	-0.00370	-0.00450	-0.00570	-0.00690

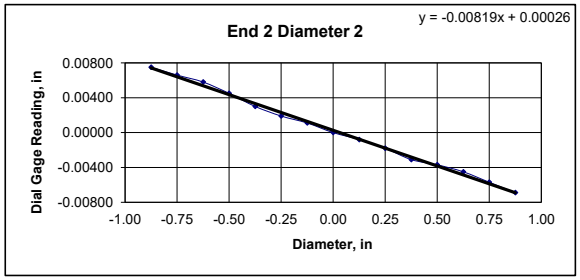
Difference between max and min readings, in:
0° = 0.0072 90° = 0.0144

Maximum difference must be < 0.0020 in. Difference = ± 0.00770
Flatness Tolerance Met? NO









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00431
Angle of Best Fit Line: 0.24703

End 2:
Slope of Best Fit Line 0.00417
Angle of Best Fit Line: 0.23900

Maximum Angular Difference: 0.00802

Parallelism Tolerance Met? NO
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00892
Angle of Best Fit Line: 0.51106

End 2:
Slope of Best Fit Line 0.00819
Angle of Best Fit Line: 0.46900

Maximum Angular Difference: 0.04207

Parallelism Tolerance Met? NO
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00720	3.920	0.00184	0.105	YES
Diameter 2, in (rotated 90°)	0.01540	3.920	0.00393	0.225	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? YES

END 2					
Diameter 1, in	0.00720	3.920	0.00184	0.105	YES
Diameter 2, in (rotated 90°)	0.01440	3.920	0.00367	0.210	YES

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-009		
Depth (ft):	288.06-289.70		
Visual Description:	See photographs		

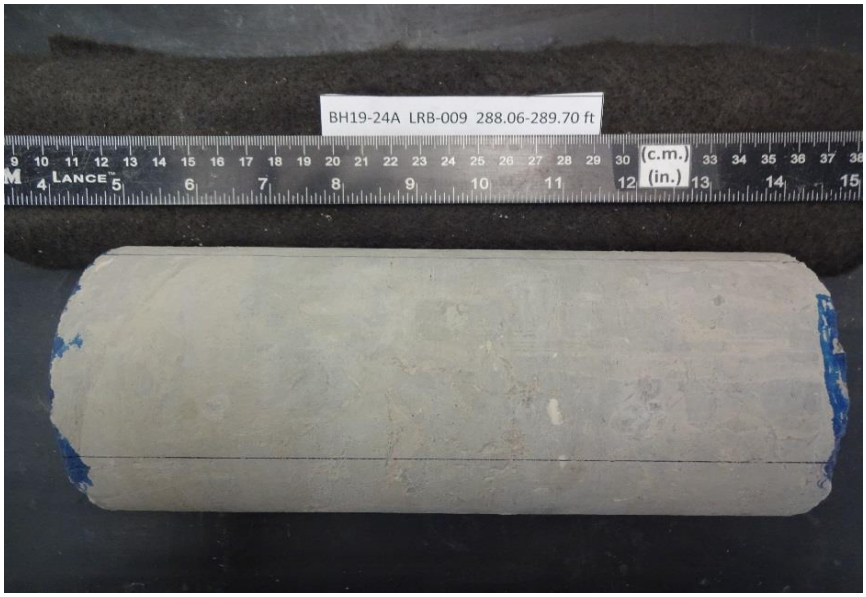
BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS

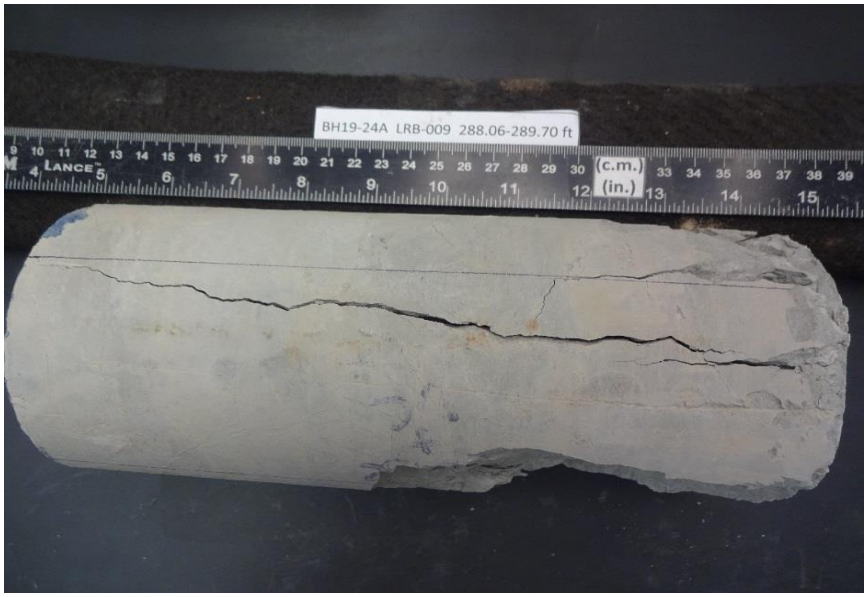
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-009
Depth, ft:	288.06-289.70



After cutting and grinding



After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A		
Sample ID:	LRB-010		
Depth:	296.59-300.20 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	9.38	9.38	9.38
Specimen Diameter, in:	3.93	3.94	3.94
Specimen Mass, g:	4264		
Bulk Density, lb/ft^3	142	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.4	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? YES

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00140	-0.00130	-0.00110	-0.00090	-0.00060	-0.00030	-0.00010	0.00000	0.00020	0.00050	0.00060	0.00110	0.00130	0.00140	0.00160
Diameter 2, in (rotated 90°)	0.00100	0.00090	0.00080	0.00070	0.00060	0.00030	0.00010	0.00000	0.00030	0.00030	0.00010	-0.00010	-0.00030	-0.00040	-0.00060

Difference between max and min readings, in:

0° = 0.00300 90° = 0.00160

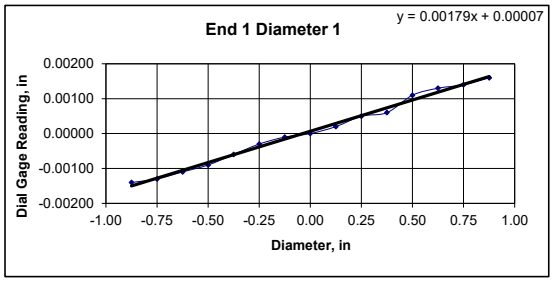
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00090	-0.00080	-0.00070	-0.00050	-0.00050	-0.00040	-0.00020	0.00000	0.00020	0.00040	0.00070	0.00090	0.00100	0.00120	0.00150
Diameter 2, in (rotated 90°)	0.00100	0.00070	0.00060	0.00050	0.00050	0.00050	0.00040	0.00000	0.00000	-0.00020	-0.00010	-0.00020	-0.00030	-0.00080	-0.00100

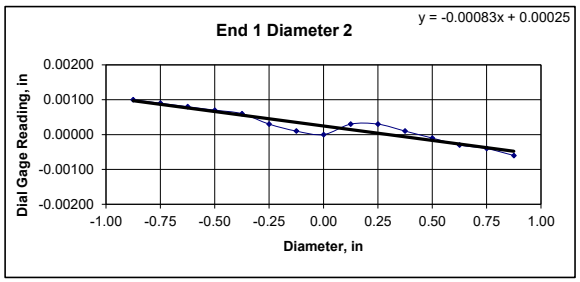
Difference between max and min readings, in:

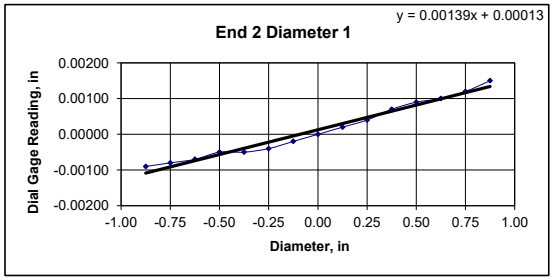
0° = 0.0024 90° = 0.002

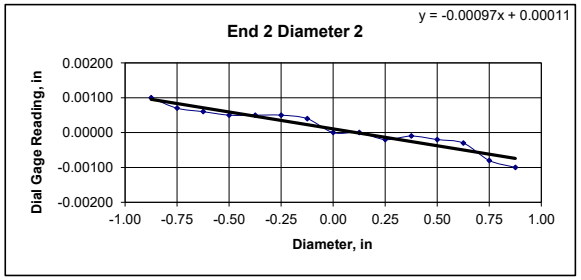
Maximum difference must be < 0.0020 in. Difference = ± 0.00150

Flatness Tolerance Met? NO









DIAMETER 1

End 1:
- Slope of Best Fit Line: 0.00179
- Angle of Best Fit Line: 0.10264

End 2:
- Slope of Best Fit Line: 0.00139
- Angle of Best Fit Line: 0.07940

Maximum Angular Difference: 0.02325

Parallelism Tolerance Met? NO

Spherically Seated

DIAMETER 2

End 1:
- Slope of Best Fit Line: 0.00083
- Angle of Best Fit Line: 0.04747

End 2:
- Slope of Best Fit Line: 0.00097
- Angle of Best Fit Line: 0.05550

Maximum Angular Difference: 0.00802

Parallelism Tolerance Met? NO

Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00300	3.935	0.00076	0.044	YES
Diameter 2, in (rotated 90°)	0.00160	3.935	0.00041	0.023	YES
END 2					
Diameter 1, in	0.00240	3.935	0.00061	0.035	YES
Diameter 2, in (rotated 90°)	0.00200	3.935	0.00051	0.029	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-24A	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-010		
Depth (ft):	296.59-300.20		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS		
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-24A
Sample ID:	LRB-010
Depth, ft:	296.59-300.20

After cutting and grinding

After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-26		
Sample ID:	LRB-003		
Depth:	328.74-330.05 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	7.95	7.97	7.96
Specimen Diameter, in:	3.94	3.91	3.93
Specimen Mass, g:	3468.6		
Bulk Density, lb/ft^3	137	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.0	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.01210	0.00960	0.00820	0.00680	0.00520	0.00390	0.00280	0.00000	-0.00160	-0.00300	-0.00450	-0.00660	-0.00870	-0.01070	-0.01380
Diameter 2, in (rotated 90°)	-0.00300	-0.00270	-0.00230	-0.00200	-0.00140	-0.00090	-0.00060	0.00000	0.00060	0.00090	0.00130	0.00190	0.00230	0.00300	0.00330

Difference between max and min readings, in:

0° = 0.02590 90° = 0.00630

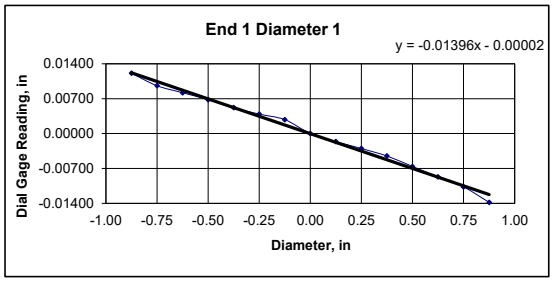
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.01380	0.01170	0.00980	0.00870	0.00680	0.00560	0.00450	0.00000	-0.00010	-0.00340	-0.00440	-0.00520	-0.00580	-0.00660	-0.00740
Diameter 2, in (rotated 90°)	-0.00420	-0.00400	-0.00330	-0.00310	-0.00230	-0.00170	-0.00130	0.00000	0.00030	0.00030	0.00240	0.00210	0.00210	0.00240	0.00310

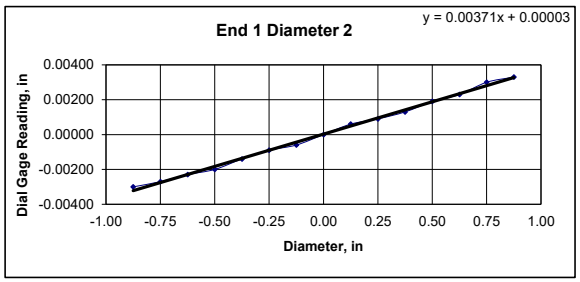
Difference between max and min readings, in:

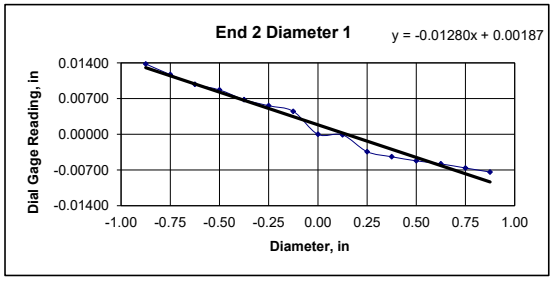
0° = 0.0212 90° = 0.0073

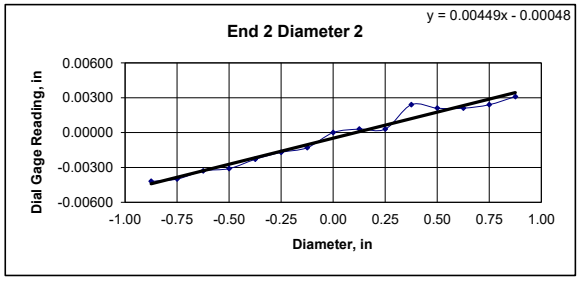
Maximum difference must be < 0.0020 in. Difference = ± 0.01295

Flatness Tolerance Met? NO









DIAMETER 1

End 1:
- Slope of Best Fit Line: 0.01396
- Angle of Best Fit Line: 0.79963

End 2:
- Slope of Best Fit Line: 0.01280
- Angle of Best Fit Line: 0.73335

Maximum Angular Difference: 0.06629

Parallelism Tolerance Met? NO

Spherically Seated

DIAMETER 2

End 1:
- Slope of Best Fit Line: 0.00371
- Angle of Best Fit Line: 0.21248

End 2:
- Slope of Best Fit Line: 0.00449
- Angle of Best Fit Line: 0.25701

Maximum Angular Difference: 0.04453

Parallelism Tolerance Met? NO

Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.02590	3.925	0.00660	0.378	NO
Diameter 2, in (rotated 90°)	0.00630	3.925	0.00161	0.092	YES
END 2					
Diameter 1, in	0.02120	3.925	0.00540	0.309	NO
Diameter 2, in (rotated 90°)	0.00730	3.925	0.00186	0.107	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? NO

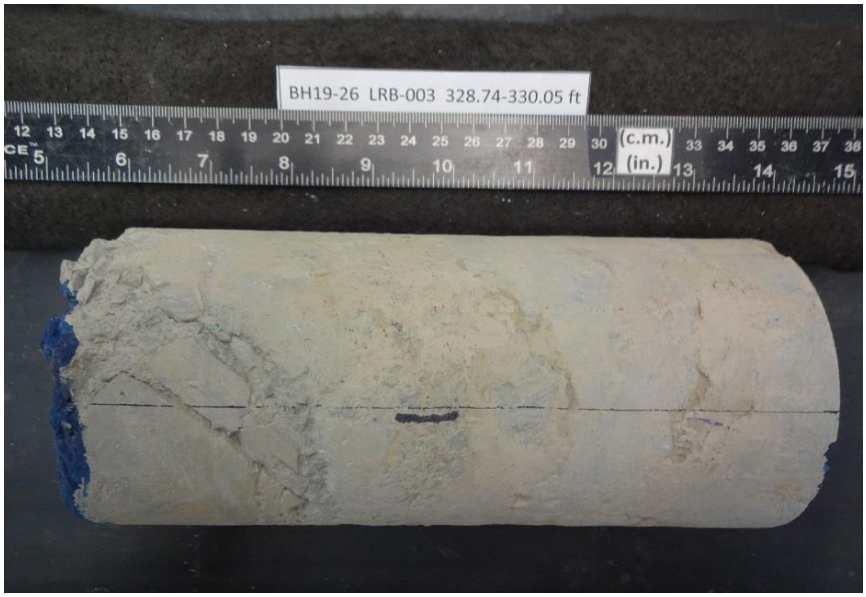
Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-26	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-003		
Depth (ft):	328.74-330.05		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS		
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-26
Sample ID:	LRB-003
Depth, ft:	328.74-330.05



After cutting and grinding

After break

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-27		
Sample ID:	LRB-003		
Depth:	302.17-304.46 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.84	8.84	8.84
Specimen Diameter, in:	3.92	3.93	3.93
Specimen Mass, g:	3685.1		
Bulk Density, lb/ft^3	131	**Minimum Diameter Tolerence Met?**	YES
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	YES

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:

Is the maximum gap ≤ 0.02 in.? NO

Maximum difference must be < 0.020 in.

Straightness Tolerance Met? NO

END FLATNESS AND PARALLELISM (Procedure FP1)

END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00360	0.00330	0.00250	0.00180	0.00130	0.00110	0.00030	0.00000	-0.00100	-0.00130	-0.00210	-0.00320	-0.00380	-0.00390	-0.00450
Diameter 2, in (rotated 90°)	-0.00140	-0.00140	-0.00110	-0.00100	-0.00060	-0.00040	-0.00030	0.00000	0.00030	0.00060	0.00100	0.00120	0.00150	0.00180	0.00180

Difference between max and min readings, in:

0° = 0.00810 90° = 0.00320

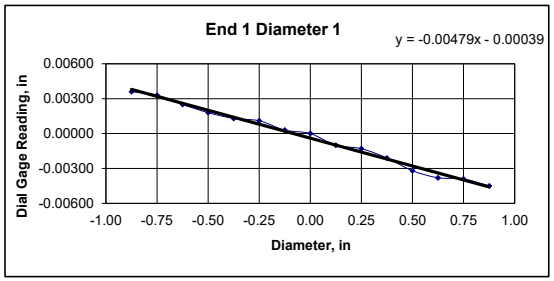
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00380	0.00340	0.00320	0.00280	0.00230	0.00170	0.00150	0.00000	-0.00020	-0.00070	-0.00130	-0.00200	-0.00230	-0.00240	-0.00310
Diameter 2, in (rotated 90°)	-0.00110	-0.00120	-0.00090	-0.00060	-0.00050	-0.00030	-0.00020	0.00000	0.00030	0.00090	0.00140	0.00190	0.00240	0.00270	0.00300

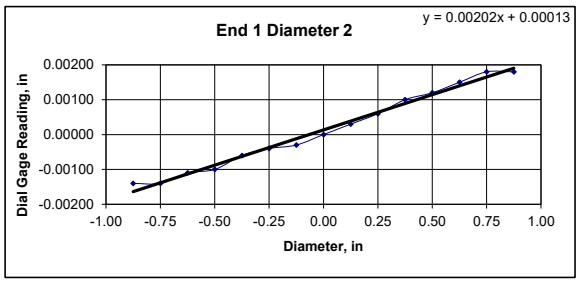
Difference between max and min readings, in:

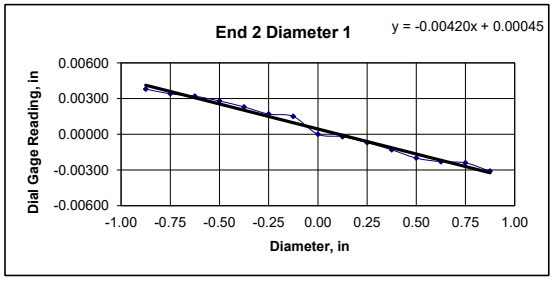
0° = 0.0069 90° = 0.0042

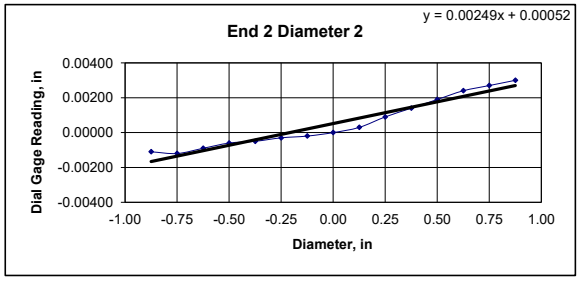
Maximum difference must be < 0.0020 in. Difference = ± 0.00405

Flatness Tolerance Met? NO









DIAMETER 1

End 1:

Slope of Best Fit Line 0.00479

Angle of Best Fit Line: 0.27453

End 2:

Slope of Best Fit Line 0.00420

Angle of Best Fit Line: 0.24080

Maximum Angular Difference: 0.03372

Parallelism Tolerance Met? NO

Spherically Seated

DIAMETER 2

End 1:

Slope of Best Fit Line 0.00202

Angle of Best Fit Line: 0.11590

End 2:

Slope of Best Fit Line 0.00249

Angle of Best Fit Line: 0.14275

Maximum Angular Difference: 0.02685

Parallelism Tolerance Met? NO

Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00810	3.925	0.00206	0.118	YES
Diameter 2, in (rotated 90°)	0.00320	3.925	0.00082	0.047	YES
END 2					
Diameter 1, in	0.00690	3.925	0.00176	0.101	YES
Diameter 2, in (rotated 90°)	0.00420	3.925	0.00107	0.061	YES

Maximum angle of departure must be ≤ 0.25°

Perpendicularity Tolerance Met? YES

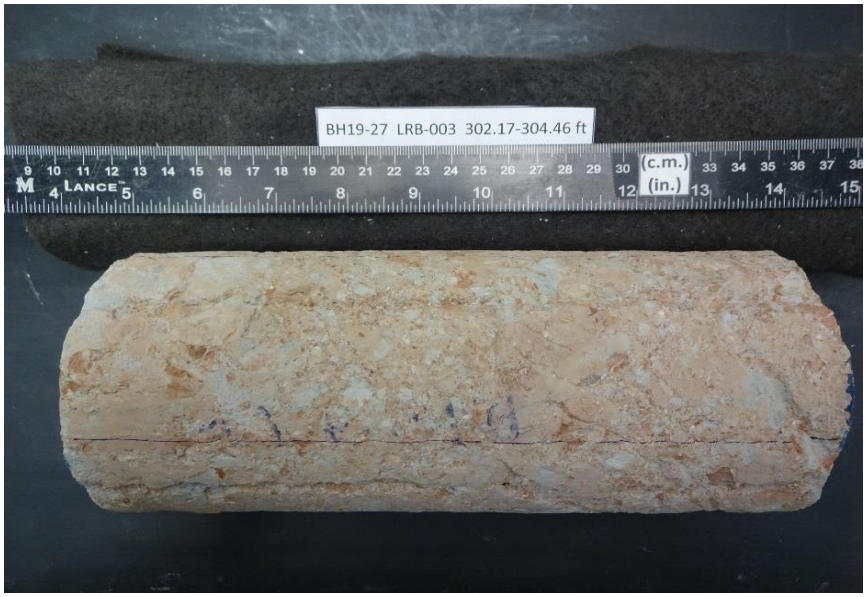
Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-27	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-003		
Depth (ft):	302.17-304.46 ft		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS		
END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	YES
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	YES

End Flatness Tolerance Met? YES

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-27
Sample ID:	LRB-003
Depth, ft:	302.17-304.46



After cutting and grinding

After break

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-28		
Sample ID:	LRB-010		
Depth:	239.83-241.14 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.20	8.20	8.20
Specimen Diameter, in:	3.93	3.94	3.94
Specimen Mass, g:	3518		
Bulk Density, lb/ft^3	134	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.1	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **YES**

END FLATNESS AND PARALLELISM (Procedure FP1)

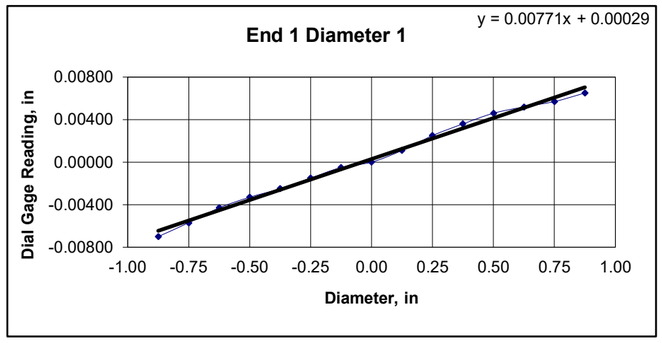
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00700	-0.00570	-0.00430	-0.00330	-0.00250	-0.00150	-0.00050	0.00000	0.00110	0.00250	0.00360	0.00460	0.00520	0.00570	0.00650
Diameter 2, in (rotated 90°)	-0.00220	-0.00190	-0.00160	-0.00150	-0.00100	-0.00100	-0.00050	0.00000	0.00050	0.00050	0.00040	0.00040	0.00070	0.00100	0.00390

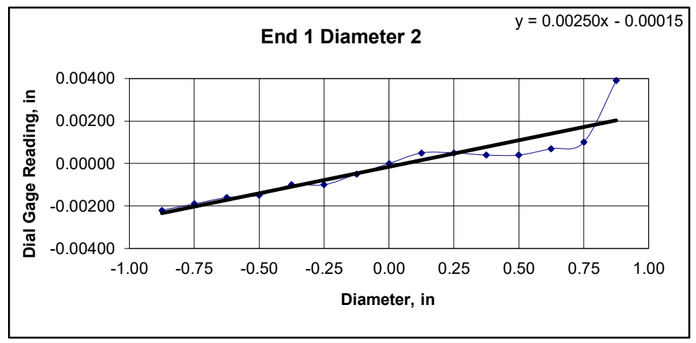
Difference between max and min readings, in:
0° = 0.01350 90° = 0.00610

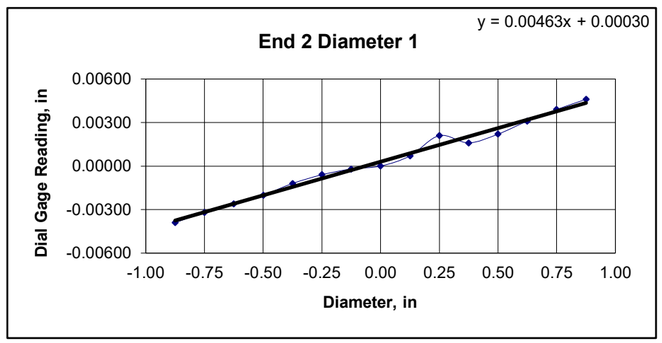
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00390	-0.00320	-0.00260	-0.00200	-0.00120	-0.00060	-0.00020	0.00000	0.00070	0.00210	0.00160	0.00220	0.00310	0.00390	0.00460
Diameter 2, in (rotated 90°)	-0.00240	-0.00230	-0.00180	-0.00110	-0.00080	-0.00050	-0.00030	0.00000	0.00030	0.00040	0.00060	0.00060	0.00080	0.00110	0.00120

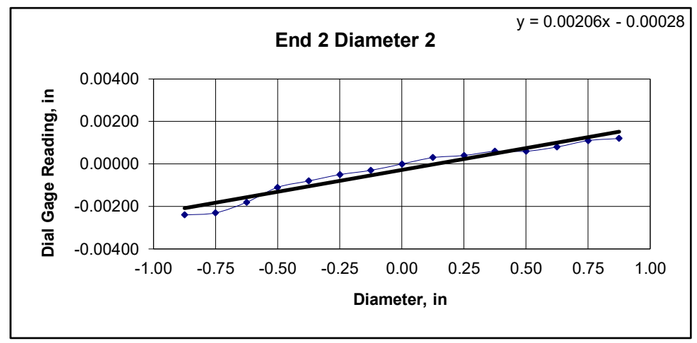
Difference between max and min readings, in:
0° = 0.0085 90° = 0.0036

Maximum difference must be < 0.0020 in. Difference = ± 0.00675
Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00771
Angle of Best Fit Line: 0.44182

End 2:
Slope of Best Fit Line 0.00463
Angle of Best Fit Line: 0.26536

Maximum Angular Difference: 0.17646

Parallelism Tolerance Met? **NO**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00250
Angle of Best Fit Line: 0.14308

End 2:
Slope of Best Fit Line 0.00206
Angle of Best Fit Line: 0.11787

Maximum Angular Difference: 0.02521

Parallelism Tolerance Met? **NO**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.01350	3.935	0.00343	0.197	YES
Diameter 2, in (rotated 90°)	0.00610	3.935	0.00155	0.089	YES
END 2					
Diameter 1, in	0.00850	3.935	0.00216	0.124	YES
Diameter 2, in (rotated 90°)	0.00360	3.935	0.00091	0.052	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? **YES**

Client:	WSP	Test Date:	1/24/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-28	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-010		
Depth (ft):	239.83-241.14		
Visual Description:	See photographs		

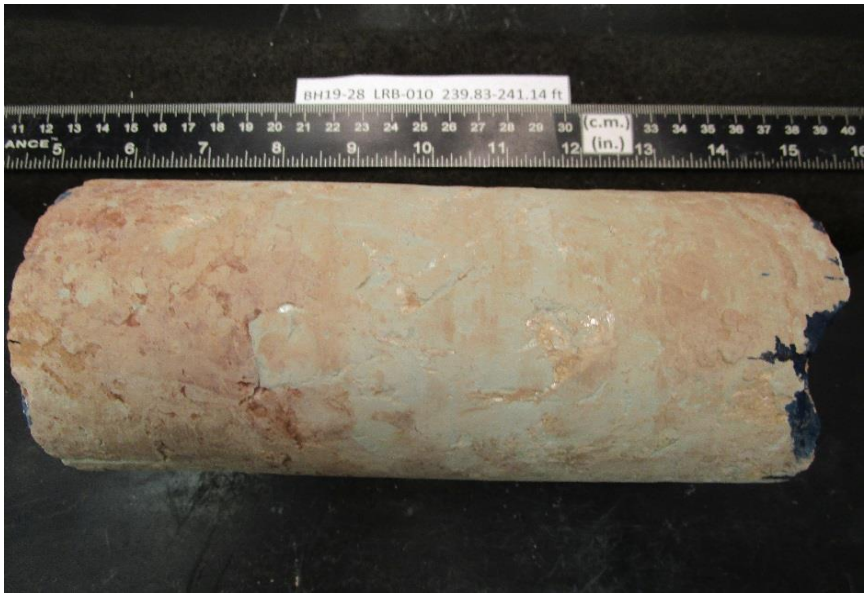
BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS

END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	NO
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	NO

End Flatness Tolerance Met? NO

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-28
Sample ID:	LRB-010
Depth, ft:	239.83-241.14



After cutting and grinding

After break

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-31		
Sample ID:	LRB-011		
Depth:	261.48-262.47 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	8.92	8.93	8.93
Specimen Diameter, in:	3.95	3.95	3.95
Specimen Mass, g:	3899		
Bulk Density, lb/ft^3	136	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.3	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **YES**

END FLATNESS AND PARALLELISM (Procedure FP1)

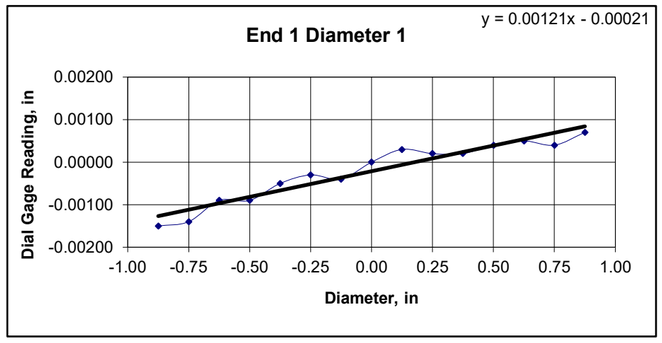
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00150	-0.00140	-0.00090	-0.00090	-0.00050	-0.00030	-0.00040	0.00000	0.00030	0.00020	0.00020	0.00040	0.00050	0.00040	0.00070
Diameter 2, in (rotated 90°)	-0.00310	-0.00230	-0.00180	-0.00140	-0.00090	-0.00060	-0.00020	0.00000	0.00070	0.00120	0.00140	0.00150	0.00180	0.00220	0.00260

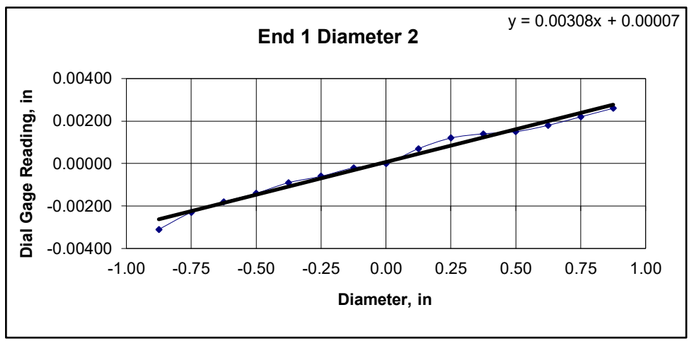
Difference between max and min readings, in:
0° = 0.00220 90° = 0.00570

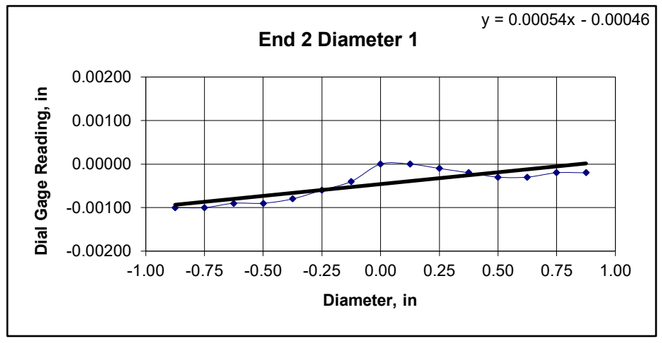
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00100	-0.00100	-0.00090	-0.00090	-0.00080	-0.00060	-0.00040	0.00000	0.00000	-0.00010	-0.00020	-0.00030	-0.00030	-0.00020	-0.00020
Diameter 2, in (rotated 90°)	-0.00250	-0.00230	-0.00190	-0.00120	-0.00100	-0.00060	-0.00020	0.00000	0.00020	0.00050	0.00080	0.00130	0.00150	0.00160	0.00170

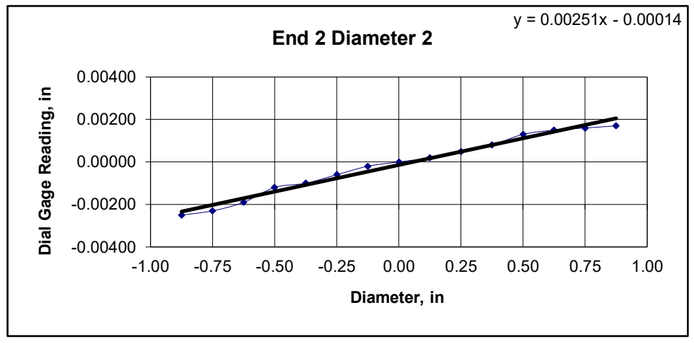
Difference between max and min readings, in:
0° = 0.001 90° = 0.0042

Maximum difference must be < 0.0020 in. Difference = ± 0.00285
Flatness Tolerance Met? **NO**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00121
Angle of Best Fit Line: 0.06908

End 2:
Slope of Best Fit Line 0.00054
Angle of Best Fit Line: 0.03110

Maximum Angular Difference: 0.03798

Parallelism Tolerance Met? **NO**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00308
Angle of Best Fit Line: 0.17663

End 2:
Slope of Best Fit Line 0.00251
Angle of Best Fit Line: 0.14373

Maximum Angular Difference: 0.03290

Parallelism Tolerance Met? **NO**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00220	3.950	0.00056	0.032	YES
Diameter 2, in (rotated 90°)	0.00570	3.950	0.00144	0.083	YES
END 2					
Diameter 1, in	0.00100	3.950	0.00025	0.015	YES
Diameter 2, in (rotated 90°)	0.00420	3.950	0.00106	0.061	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? **YES**

Client:	WSP	Test Date:	1/22/2020
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	cmh
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-31	Reliable dial gauge measurements could not be performed on this rock type. Tolerance measurements were performed using a machinist straightedge and feeler gauges to ASTM specifications.	
Sample ID:	LRB-011		
Depth (ft):	261.48-262.47		
Visual Description:	See photographs		

BEST EFFORT END FLATNESS TOLERANCES OF ROCK CORE SPECIMENS TO ASTM D4543

END FLATNESS

END 1		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	NO
END 2		
Diameter 1	Is the maximum gap $\leq \pm 0.001$ in.?	NO
Diameter 2 (rotated 90°)	Is the maximum gap $\leq \pm 0.001$ in.?	NO

End Flatness Tolerance Met? NO

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	cmh
Checked By:	smd
Boring ID:	BH19-31
Sample ID:	LRB-011
Depth, ft:	261.48-262.47

After cutting and grinding

After break

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/18/2019
Tested By:	jck
Checked By:	jsc

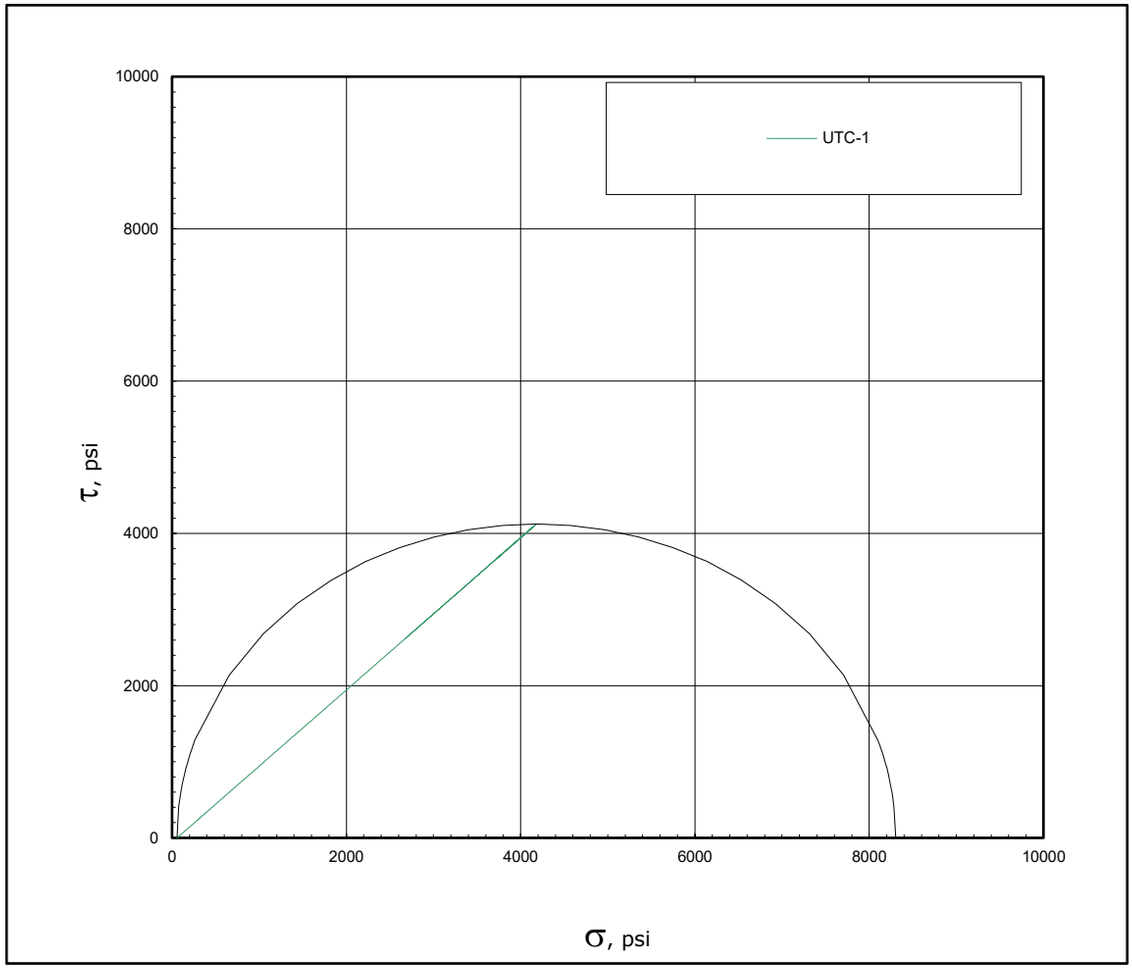
Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method A

Boring ID	Sample ID	Depth, m	Specimen Diameter, in.	Specimen Length, in.	Length to Diameter Ratio	Bulk Density, lb/ft^3	Confining Stress, psi	Peak Shear Strength, psi	Peak Compressive Strength, psi	Failure Type	In conformance with ASTM D 4543
BH19-09	LRB-012	62.43-62.86	2.40	5.05	2.1	158	57	4124	8,248	1	YES

Notes:
Density determined on core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure (See attached photographs)

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/18/2019
Tested By:	jck
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-012
Depth, ft:	62.43-62.86
Test No.:	UTC-1
Sample Type:	rock core
Sample Description:	See Photographs

Triaxial Compressive Strength of Undrained Rock Core Specimens by ASTM D7012 - Method A



	UTC-1	---	---
Confining Stress, σ_3, psi	57	---	---
Maximum Total Stress, σ_1, psi	8,305	---	---
Peak Deviator Stress, σ, psi	8,248	---	---
Failure Type	Intact material failure	---	---

Notes: All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.

The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.

Client:	WSP	Test Date:	9/17/2019
Project Name:	Line 5 Replacement and Tunnel Project	Tested By:	jck
Project Location:	Straits of Mackinac	Checked By:	smd
GTX #:	310187		
Boring ID:	BH19-09		
Sample ID:	LRB-012		
Depth:	62.43-62.86 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY

	1	2	Average
Specimen Length, in:	5.04	5.05	5.05
Specimen Diameter, in:	2.39	2.40	2.40
Specimen Mass, g:	947.08		
Bulk Density, lb/ft^3	158	**Minimum Diameter Tolerence Met?**	**YES**
Length to Diameter Ratio:	2.1	**Length to Diameter Ratio Tolerance Met?**	**YES**

DEVIATION FROM STRAIGHTNESS (Procedure S1)

Maximum gap between side of core and reference surface plate:
Is the maximum gap ≤ 0.02 in.? YES

Maximum difference must be < 0.020 in.
Straightness Tolerance Met? **YES**

END FLATNESS AND PARALLELISM (Procedure FP1)

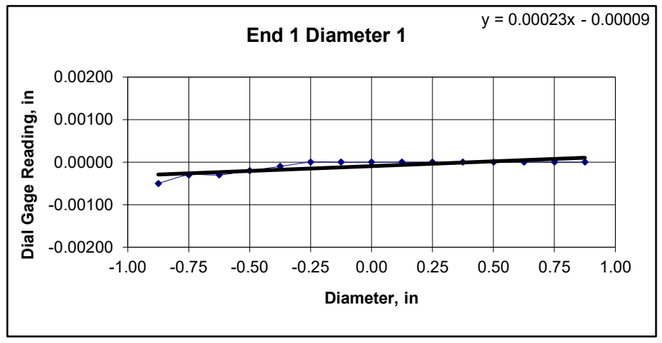
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00050	-0.00030	-0.00030	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Diameter 2, in (rotated 90°)	-0.00050	-0.00030	-0.00030	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

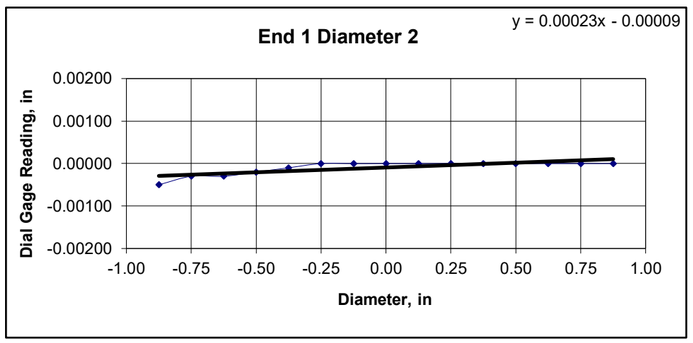
Difference between max and min readings, in:
0° = 0.00050 90° = 0.00050

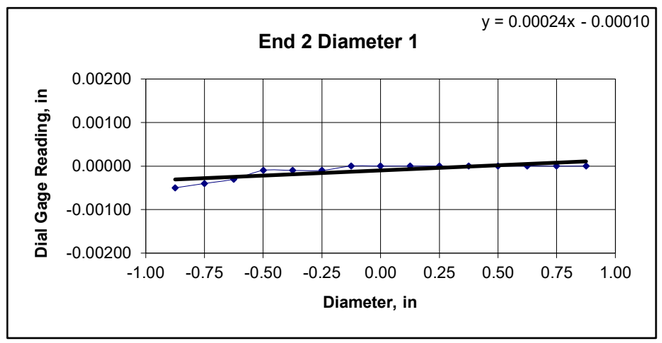
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00050	-0.00040	-0.00030	-0.00010	-0.00010	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Diameter 2, in (rotated 90°)	-0.00050	-0.00040	-0.00030	-0.00020	-0.00020	0.00000	0.00000	0.00000	0.00000	0.00020	0.00000	0.00020	0.00000	0.00000	0.00000

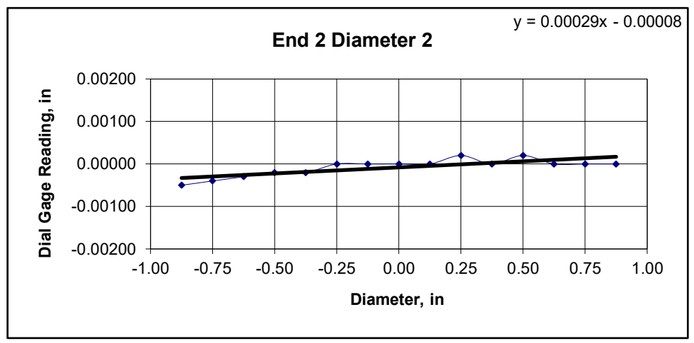
Difference between max and min readings, in:
0° = 0.0005 90° = 0.0007

Maximum difference must be < 0.0020 in. Difference = ± 0.00035
Flatness Tolerance Met? **YES**









DIAMETER 1

End 1:
Slope of Best Fit Line 0.00023
Angle of Best Fit Line: 0.01293

End 2:
Slope of Best Fit Line 0.00024
Angle of Best Fit Line: 0.01359

Maximum Angular Difference: 0.00065

Parallelism Tolerance Met? **YES**
Spherically Seated

DIAMETER 2

End 1:
Slope of Best Fit Line 0.00023
Angle of Best Fit Line: 0.01293

End 2:
Slope of Best Fit Line 0.00029
Angle of Best Fit Line: 0.01637

Maximum Angular Difference: 0.00344

Parallelism Tolerance Met? **YES**
Spherically Seated

PERPENDICULARITY (Procedure P1) (Calculated from End Flatness and Parallelism measurements above)

END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?
Diameter 1, in	0.00050	2.395	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00050	2.395	0.00021	0.012	YES
END 2					
Diameter 1, in	0.00050	2.395	0.00021	0.012	YES
Diameter 2, in (rotated 90°)	0.00070	2.395	0.00029	0.017	YES

Maximum angle of departure must be ≤ 0.25°
Perpendicularity Tolerance Met? **YES**

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/18/2019
Tested By:	jck
Checked By:	smd
Boring ID:	BH19-09
Sample ID:	LRB-012
Depth, ft:	62.43-62.86

After cutting and grinding

After break

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/30/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-16
Sample ID:	LRB-009
Depth, ft:	264.5-269.5

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	1.20
2	2.20
Average	1.7

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	7/30/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-16
Sample ID:	LRB-009
Depth, ft:	264.5-269.5

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	3.30
2	2.70
Average	3.00

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

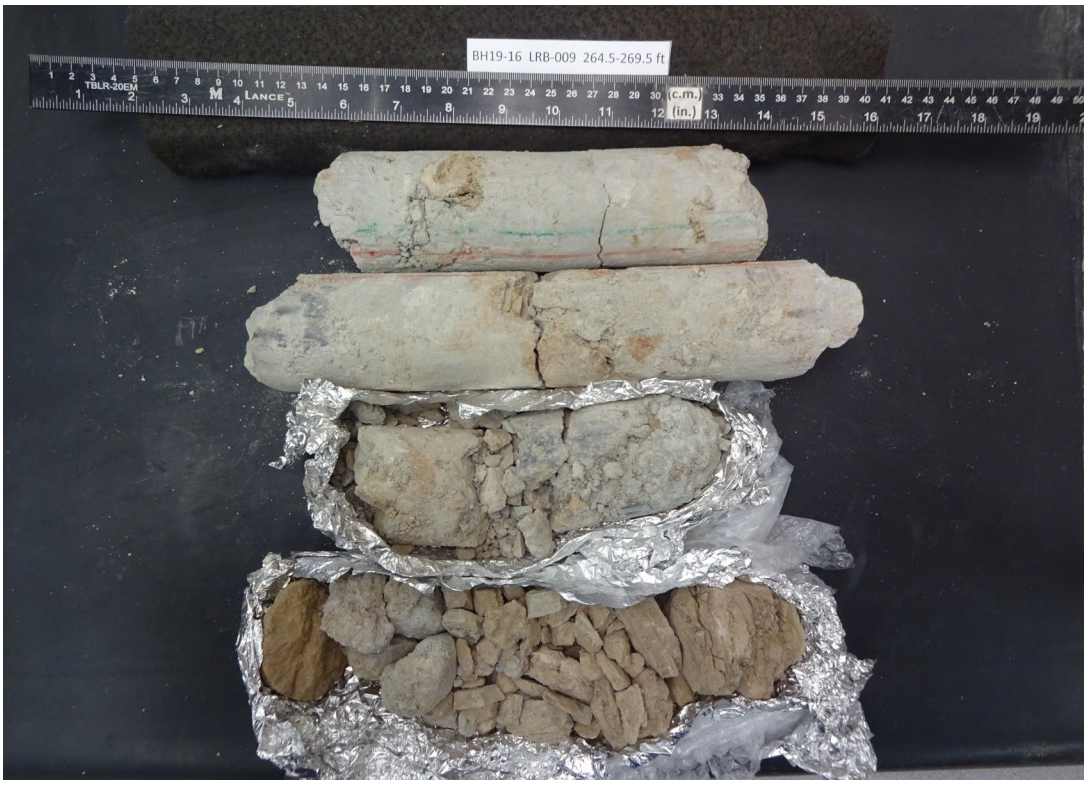
Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-16
Sample ID:	LRB-009
Depth, ft:	264.5-269.5

Rock Drillability - Sample As-Received



Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-17
Sample ID:	LRB-005 (A,D)
Depth, ft:	333-338

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.20
2	0.10
Average	0.15

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-17
Sample ID:	LRB-005 (A,D)
Depth, ft:	333-338

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	2.70
2	2.50
Average	2.60

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-17
Sample ID:	LRB-005 (A,D)
Depth, ft:	333-338

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-21
Sample ID:	LRB-001
Depth, ft:	55.77-56.76

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.60
2	1.00
Average	0.8

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-21
Sample ID:	LRB-001
Depth, ft:	55.77-56.76

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	3.20
2	2.20
Average	2.70

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-21
Sample ID:	LRB-001
Depth:	55.77-56.76

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24A
Sample ID:	LRB-010
Depth, ft:	269.59-300.20

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	1.60
2	1.50
Average	1.55

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24A
Sample ID:	LRB-010
Depth, ft:	269.59-300.20

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.50
2	0.40
Average	0.45

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-24A
Sample ID:	LRB-010
Depth:	269.59-300.20

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LRB-003
Depth, ft:	302.17-304.46

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	1.10
2	1.40
Average	1.25

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LRB-003
Depth, ft:	302.17-304.46

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	1.70
2	1.20
Average	1.45

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LRB-003
Depth:	302.17-304.46

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LRB-002
Depth, ft:	180.77-182.41

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	1.60
2	1.70
Average	1.65

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/5/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LRB-002
Depth, ft:	180.77-182.41

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	2.80
2	3.30
Average	3.05

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-28
Sample ID:	LRB-002
Depth:	180.77-182.41

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/6/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LRB-007
Depth, ft:	215.55-217.85

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	1.60
2	2.80
Average	2.20

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/6/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LRB-007
Depth, ft:	215.55-217.85

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	2.90
2	2.10
Average	2.50

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-28
Sample ID:	LRB-007
Depth:	215.55-217.85

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/6/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-31
Sample ID:	LRB-005
Depth, ft:	195.87-197.83

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.70
2	0.50
Average	0.6

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/6/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-31
Sample ID:	LRB-005
Depth, ft:	195.87-197.83

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	2.20
2	1.60
Average	1.90

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-31
Sample ID:	LRB-005
Depth:	195.87-197.83

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	10/31/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-32
Sample ID:	LRB-008
Depth, ft:	164.96-166.66

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.50
2	1.30
Average	0.9

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	10/31/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-32
Sample ID:	LRB-008
Depth, ft:	164.96-166.66

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.80
2	2.20
Average	1.50

Sample Classification: Very Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-32
Sample ID:	LRB-008
Depth, ft:	164.96-166.66

Rock Drillability - Sample As-Received

No as-received photo available

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-33
Sample ID:	LRB-006
Depth, ft:	184.05

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.30
2	0.20
Average	0.25

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-33
Sample ID:	LRB-006
Depth, ft:	184.05

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.30
2	0.20
Average	0.25

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-33
Sample ID:	LRB-006
Depth, ft:	184.05

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-37
Sample ID:	LRB-003 (A,B)
Depth, ft:	193-200

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.10
2	0.20
Average	0.15

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/3/2019
Tested By:	jw
Checked By:	jsc
Boring ID:	BH19-37
Sample ID:	LRB-003 (A,B)
Depth, ft:	193-200

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.20
2	0.10
Average	0.15

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-37
Sample ID:	LRB-003 (A,B)
Depth, ft:	193-200

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/5/2019
Tested By:	tlm/jw
Checked By:	jsc
Boring ID:	BH19-38
Sample ID:	LRB-006 (A-C)
Depth, ft:	146.3-154.7

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.50
2	0.60
Average	0.55

Sample Classification: Extremely Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/5/2019
Tested By:	tlm/jw
Checked By:	jsc
Boring ID:	BH19-38
Sample ID:	LRB-006 (A-C)
Depth, ft:	146.3-154.7

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.20
2	0.20
Average	0.20

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-38
Sample ID:	LRB-006 (A-C)
Depth, ft:	146.3-154.7

Rock Drillability - Sample As-Received

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	10/31/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-32
Sample ID:	LRB-005
Depth, ft:	126.67-127.66

Rock Drillability Tests (1) (2)

Test Results:

Sievers J-Value, (0.1 mm)	Abrasion Value Steel Cutters, (mg)
66.7	0.75
Very Low	**Extremely Low**

Calculated Indices:

	Cutter Life Index
Assessed value	77.8
Classification Category	**Extremely High**

NTNU/SINTEF Rock Drillability Tests Classification:

Classification of Indices according to "13A-98 Drillability Test Methods," Dept. of Civil and Transport Engineering, NTNU.

Category	Cutter Life Index
Extremely Low	≤ 5
Very Low	5.0-5.9
Low	6.0 - 7.9
Medium	8.0 - 14.9
High	15 - 34
Very High	35 - 74
Extremely High	≥ 75

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Samples were delivered to GTX by client.
4. Testing was done on best representative rock specimens from samples provided.
5. Samples were stored at $20^{\circ} \pm 5^{\circ}$ C for a minimum of 48 hrs before testing.
6. Assessed values were measured by NTNU/SINTEF's Hard Rock Tunnel Boring Drillability Test Methods figures.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	10/31/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-32
Sample ID:	LRB-005
Depth, ft:	126.67-127.66

Rock Drillability - Sievers' J-Value

Individual Test Results

Test Number	Sievers' J-Value SJ (1/10 mm)
1	66.4
2	68.5
3	62.1
4	66.0
5	70.7
Average	66.7

Sample Classification: Very Low

Sievers' J-Value Reference Classification Chart

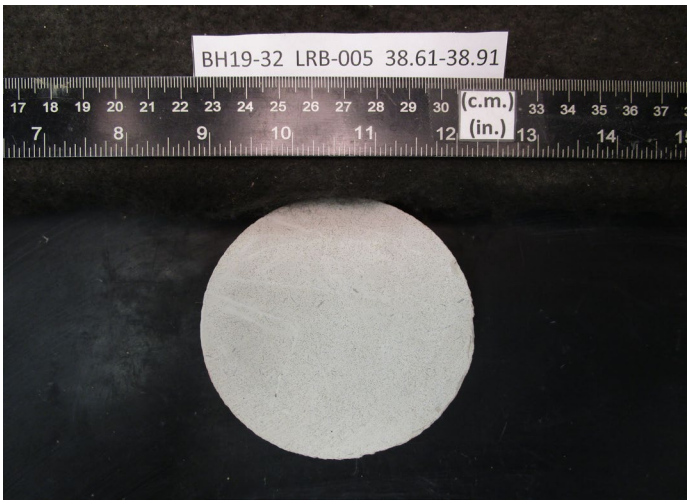
Category	SJ-Value (1/10 mm)
Extremely High	≤ 2.0
Very High	2.1 - 3.9
High	4.0 - 6.9
Medium	7.0 - 18.9
Low	19.0 - 55.9
Very Low	56.0 - 85.9
Extremely Low	≥ 86.0

Notes:

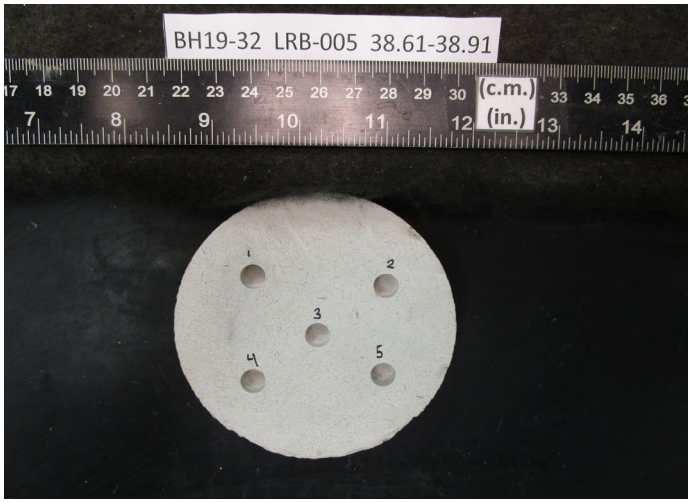
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. The standard number of Sievers' J drillings performed on each sample is 4 to 8, depending on the variation in the texture of the sample. Drilling locations were selected to be tested on 60% hard and 40% softer layers found in the sample. Soft/hard combinations at drill locations are avoided as best as possible to try to give a more accurate representation of the rock. This is however impossible in samples which have alternating soft and hard layered mineral composition. The average Sievers' J value is regarded as representative for the tested rock.
4. Test was performed at 197 RPM.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	10/31/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-32
Sample ID:	LRB-005
Depth, ft:	126.67-127.66

Rock Drillability - Sievers' J-Value Sample



Sample before testing



After testing showing drill locations

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/15/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-32
Sample ID:	LRB-005
Depth, ft:	126.67-127.66

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.70
2	0.80
Average	0.75

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability Tests (1) (2)

Test Results:

Brittleness Value S_{20}, (%)	Flakiness, (f)	Compaction Index	Density, (g/cm^3)	Sievers J-Value, (0.1 mm)	Abrasion Value, (mg)	Abrasion Value Steel Cutters, (mg)
61.93	1.38	1	2.70	56.76	1.35	0.40
Very High	---	---	---	**Very Low**	**Very Low**	**Extremely Low**

Calculated Indices:

	Drilling Rate Index	Bit Wear Index	Cutter Life Index
Assessed value	71	11	93.1
Classification Category	**Very High**	**Very Low**	**Extremely High**

NTNU/SINTEF Rock Drillability Tests Classifications:

Classification of Indices according to "13A-98 Drillability Test Methods," Dept. of Civil and Transport Engineering, NTNU.

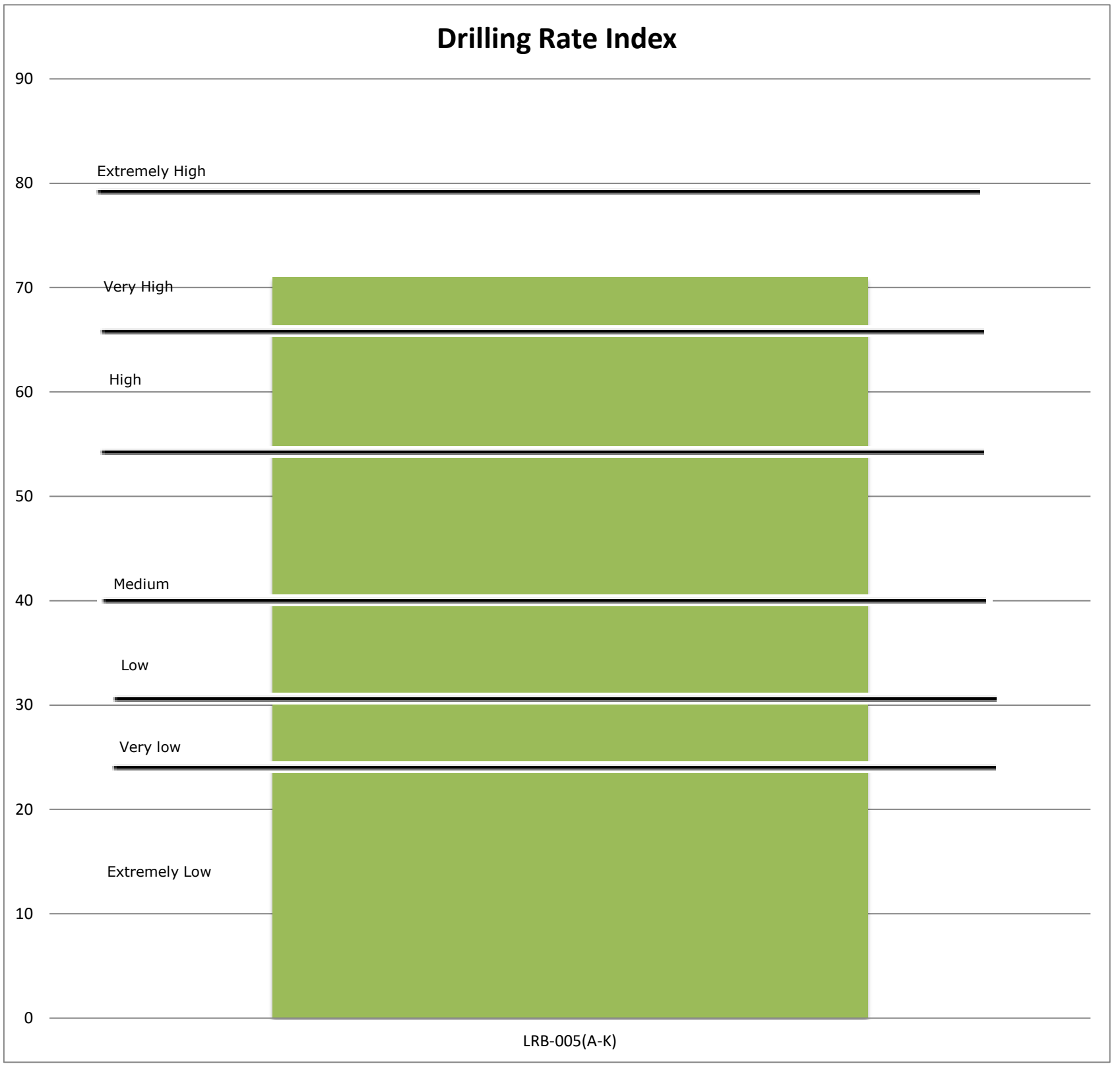
Category	Drilling Rate Index	Bit Wear Index	Cutter Life Index
Extremely Low	$\leq$ 25	$\leq$ 10	$\leq$ 5
Very Low	26 - 32	11-20	5.0-5.9
Low	33 - 42	21 - 30	6.0 - 7.9
Medium	43 - 57	31 - 44	8.0 - 14.9
High	58 - 69	45 - 55	15 - 34
Very High	70 - 82	56 - 69	35 - 74
Extremely High	$\geq$ 83	$\geq$ 70	$\geq$ 75

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Samples were delivered to GTX by client.
4. Testing was done on best representative rock specimens from samples provided.
5. Samples were stored at 20° $\pm$ 5° C for a minimum of 48 hrs before testing.
6. Assessed values were measured by NTNU/SINTEF's Hard Rock Tunnel Boring Drillability Test Methods figures.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43728
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

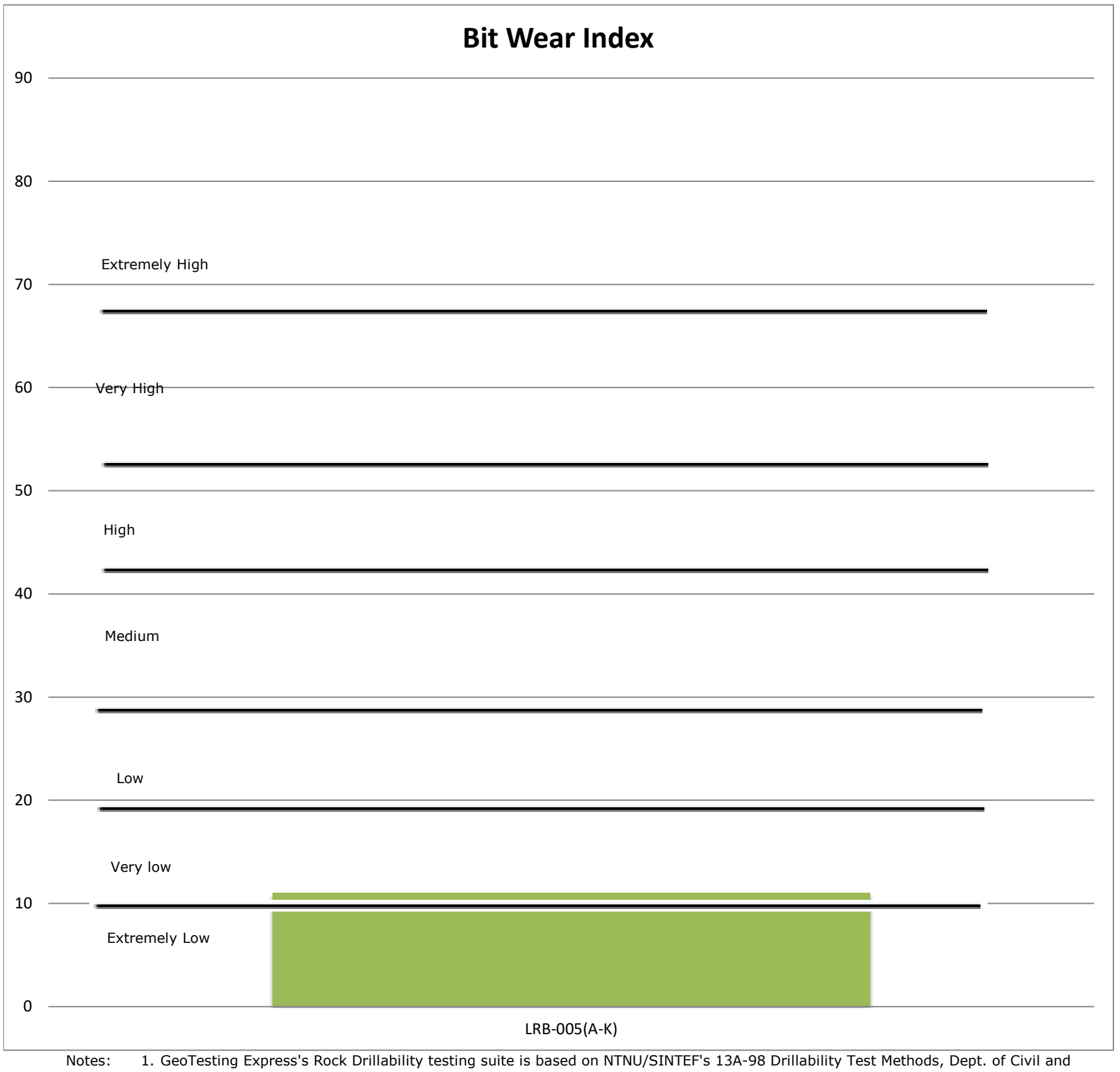
Rock Drillability Tests



Notes:
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43728
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

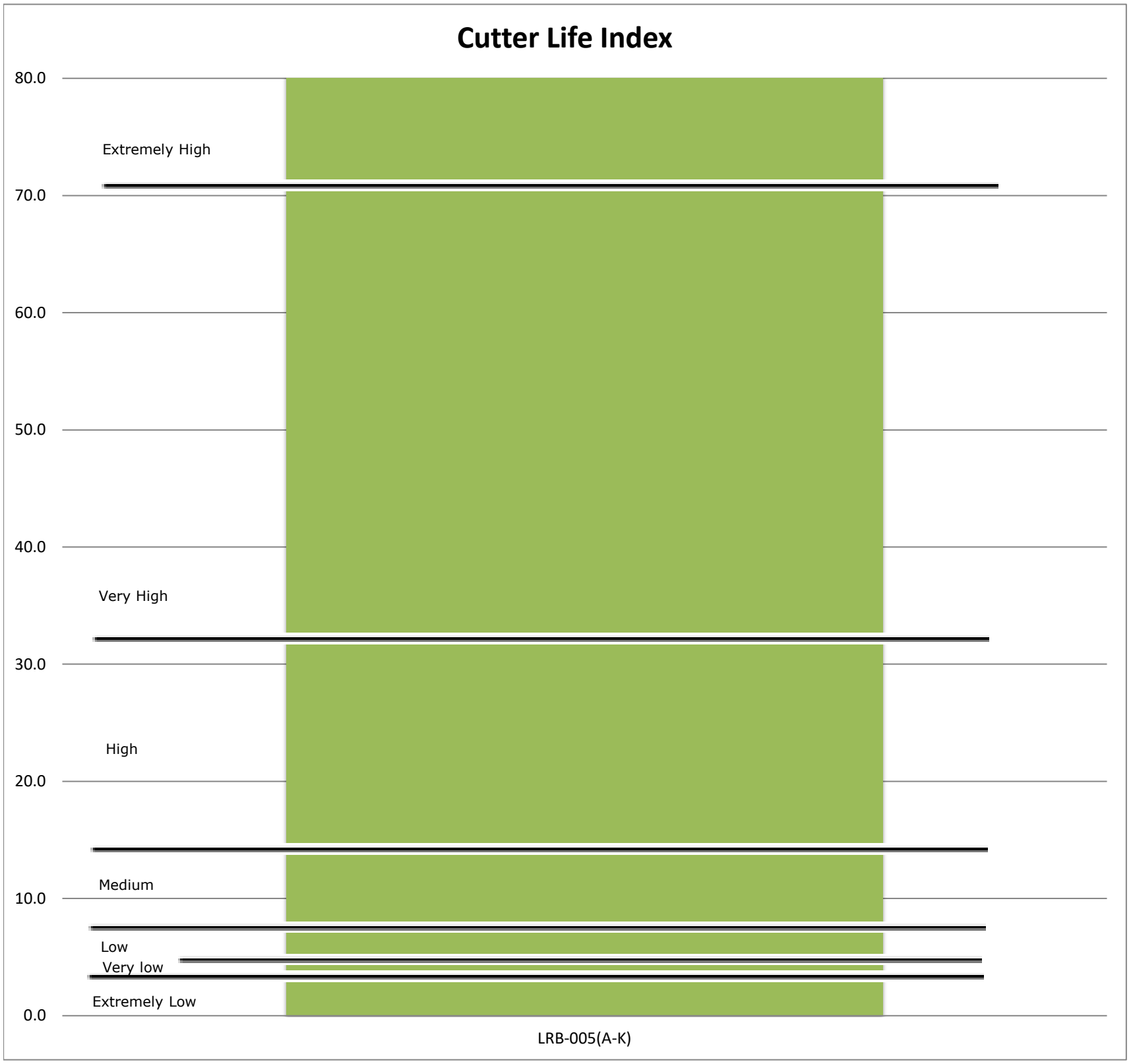
Rock Drillability Tests



Notes:
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43728
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability Tests



Notes:
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, in:	129.4-134.7

Rock Drillability - Sample As-Received

(* indicates location of Sievers' J-Value sampling)

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability - Brittleness Value

Individual Test Results

Test Number	Brittleness Value, S_{20} (%)
1	62.08
2	59.57
3	64.13
Average	61.93

Sample classification: Very High

Brittleness Value Reference Classification Chart

Category	Brittleness Value, S_{20} (%)
Extremely Low	$\leq$ 29.0
Very Low	29.1 - 34.9
Low	35.0 - 40.9
Medium	41.0 - 50.9
High	51.0 - 59.9
Very High	60.0 - 65.9
Extremely High	$\geq$ 66.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. The Brittleness Value test is performed on three extractions from one representative and homogenized sample of crushed and sieved rock material. When there is not enough material provided to perform the three tests, one or two tests may be performed.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability - Sievers' J-Value

Individual Test Results

Test Number	Sievers' J-Value SJ (1/10 mm)
1	62.95
2	55.60
3	51.70
4	60.25
5	53.30
Average	56.76

Sample Classification: Very Low

Sievers' J-Value Reference Classification Chart

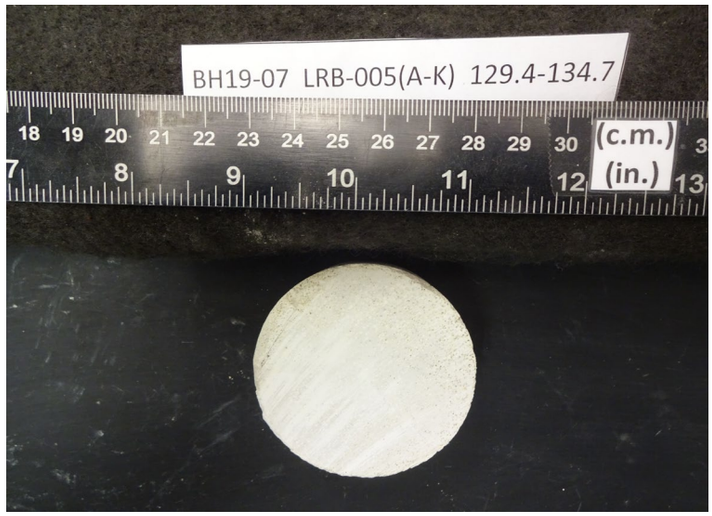
Category	SJ-Value (1/10 mm)
Extremely High	$\leq$ 2.0
Very High	2.1 - 3.9
High	4.0 - 6.9
Medium	7.0 - 18.9
Low	19.0 - 55.9
Very Low	56.0 - 85.9
Extremely Low	$\geq$ 86.0

Notes:

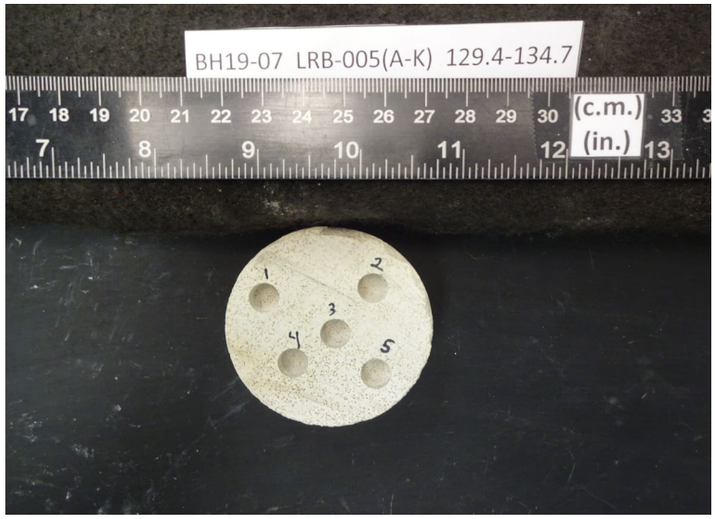
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. The standard number of Sievers' J drillings performed on each sample is 4 to 8, depending on the variation in the texture of the sample. Drilling locations were selected to be tested on 60% hard and 40% softer layers found in the sample. Soft/hard combinations at drill locations are avoided as best as possible to try to give a more accurate representation of the rock. This is however impossible in samples which have alternating soft and hard layered mineral composition. The average Sievers' J value is regarded as representative for the tested rock.
4. Test was performed at 197 RPM.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability - Sievers' J-Value Sample



Sample before testing



After testing showing drill locations

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norwav.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	1.70
2	1.00
Average	1.35

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-07
Sample ID:	LRB-005(A-K)
Depth, ft:	129.4-134.7

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.40
2	0.40
Average	0.40

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability Tests (1) (2)

Test Results:

Brittleness Value S_{20}, (%)	Flakiness, (f)	Compaction Index	Density, (g/cm^3)	Sievers J-Value, (0.1 mm)	Abrasion Value, (mg)	Abrasion Value Steel Cutters, (mg)
42.83	1.31	0	2.58	4.38	1.15	0.25
Medium	---	---	---	**High**	**Very Low**	**Extremely Low**

Calculated Indices:

	Drilling Rate Index	Bit Wear Index	Cutter Life Index
Assessed value	39	28	41.6
Classification Category	**Low**	**Low**	**Very High**

NTNU/SINTEF Rock Drillability Tests Classifications:

Classification of Indices according to "13A-98 Drillability Test Methods," Dept. of Civil and Transport Engineering, NTNU.

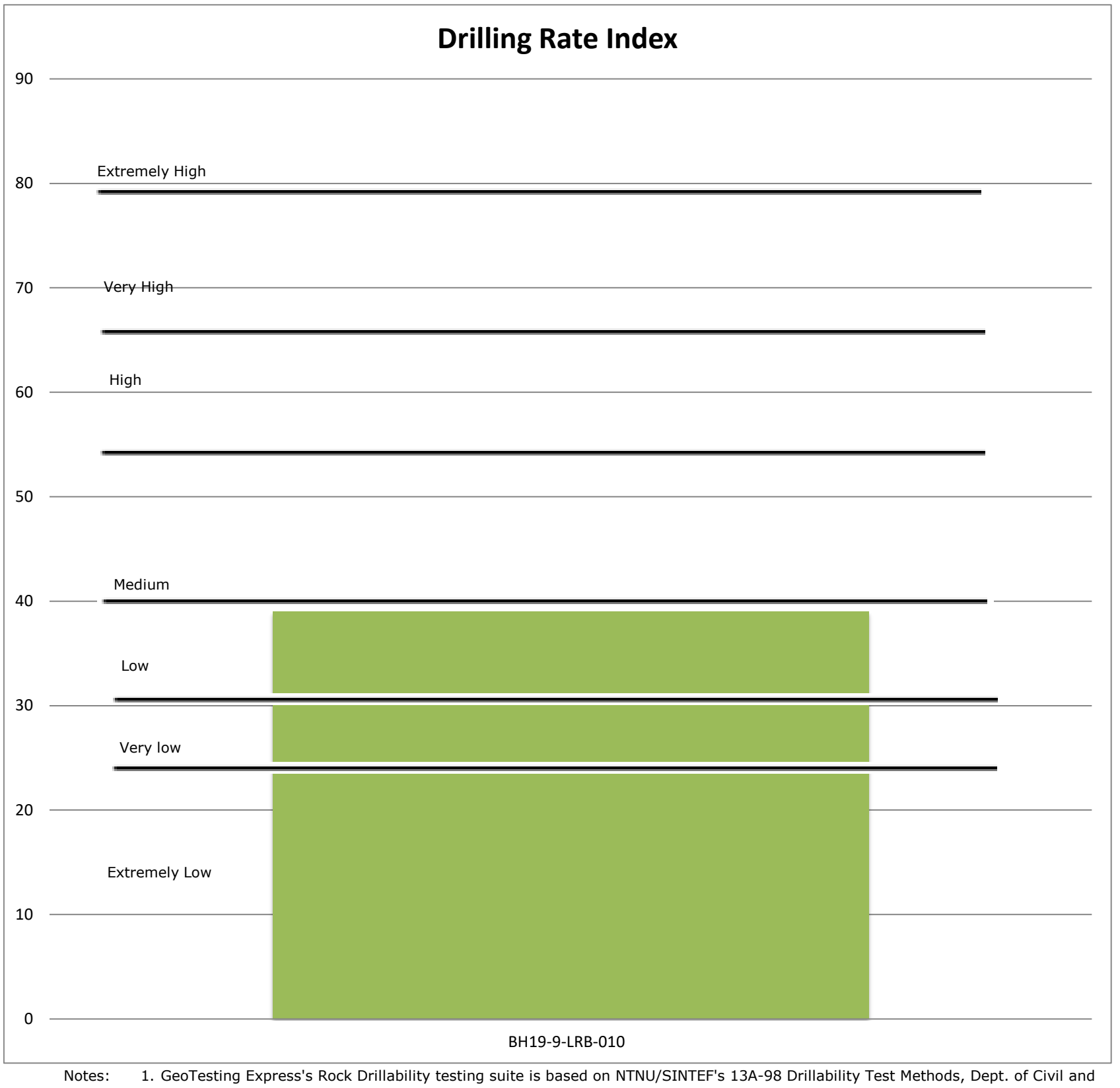
Category	Drilling Rate Index	Bit Wear Index	Cutter Life Index
Extremely Low	$\leq$ 25	$\leq$ 10	$\leq$ 5
Very Low	26 - 32	11-20	5.0-5.9
Low	33 - 42	21 - 30	6.0 - 7.9
Medium	43 - 57	31 - 44	8.0 - 14.9
High	58 - 69	45 - 55	15 - 34
Very High	70 - 82	56 - 69	35 - 74
Extremely High	$\geq$ 83	$\geq$ 70	$\geq$ 75

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Samples were delivered to GTX by client.
4. Testing was done on best representative rock specimens from samples provided.
5. Samples were stored at 20° $\pm$ 5° C for a minimum of 48 hrs before testing.
6. Assessed values were measured by NTNU/SINTEF's Hard Rock Tunnel Boring Drillability Test Methods figures.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43728
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

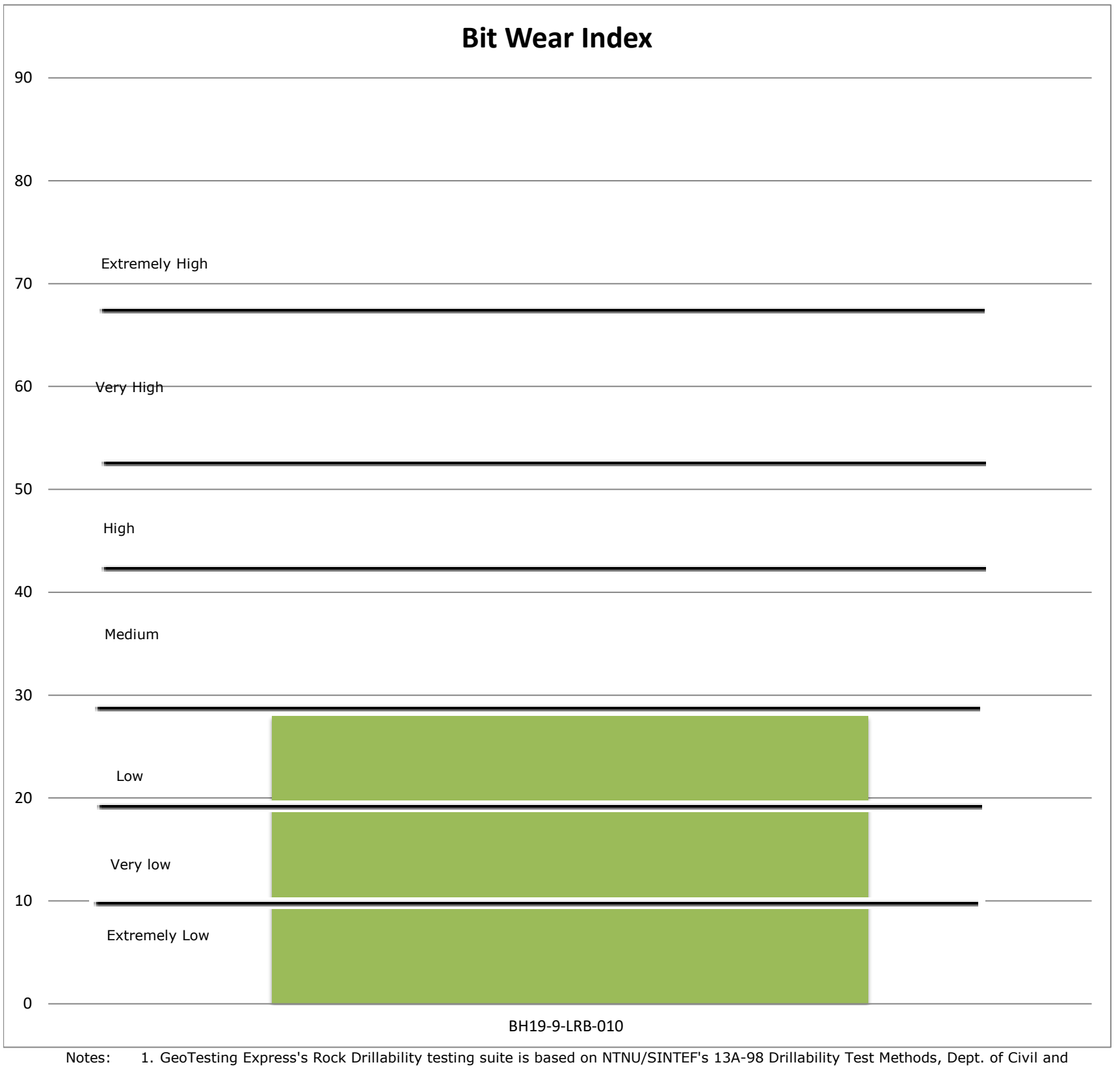
Rock Drillability Tests



Notes:
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43728
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

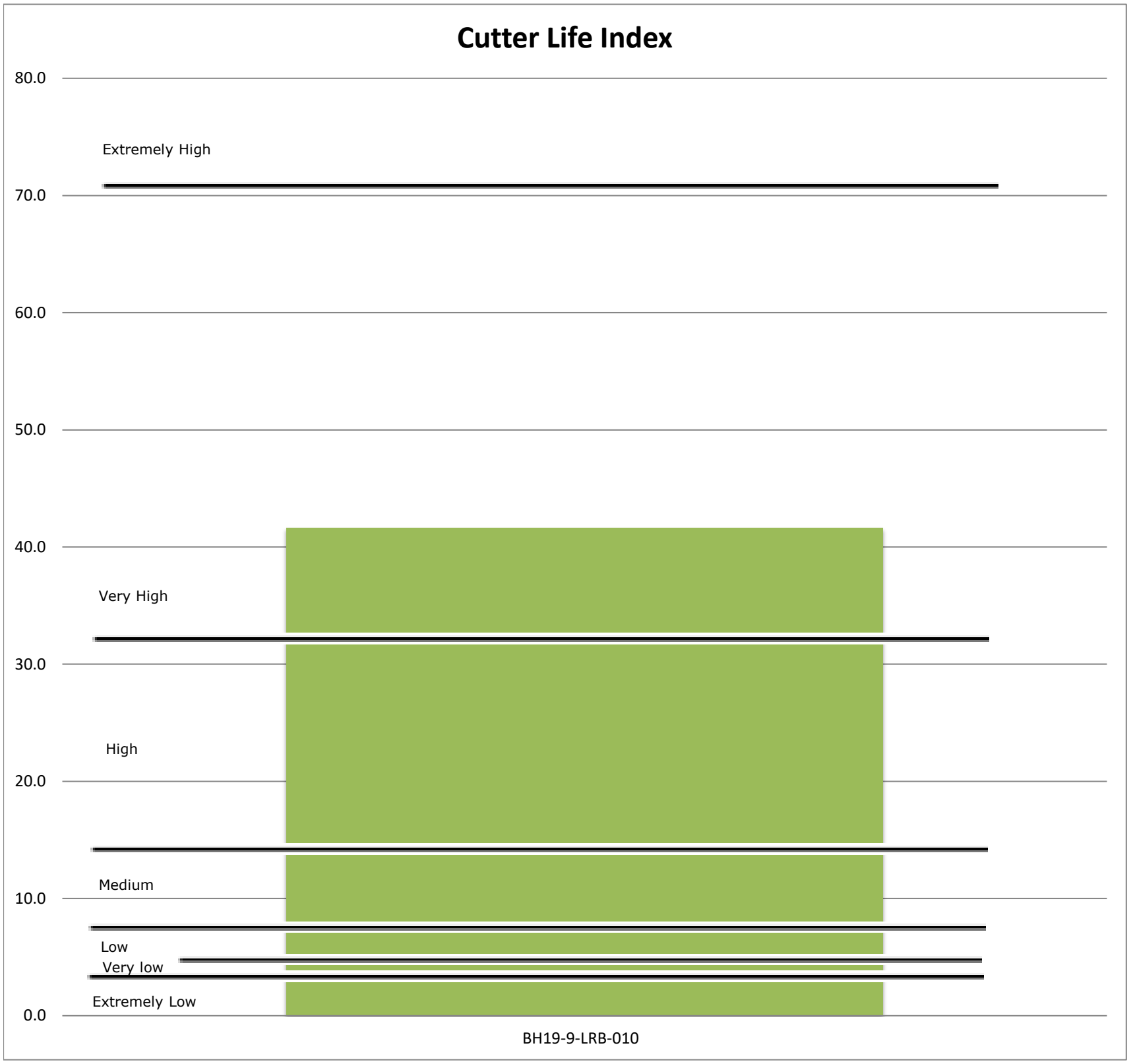
Rock Drillability Tests



Notes:
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43728
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability Tests



Notes:
1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability - Sample As-Received

(* indicates location of Sievers' J-Value sampling)

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability - Brittleness Value

Individual Test Results

Test Number	Brittleness Value, S_{20} (%)
1	43.37
2	43.08
3	42.06
Average	42.83

Sample classification: Medium

Brittleness Value Reference Classification Chart

Category	Brittleness Value, S_{20} (%)
Extremely Low	$\leq$ 29.0
Very Low	29.1 - 34.9
Low	35.0 - 40.9
Medium	41.0 - 50.9
High	51.0 - 59.9
Very High	60.0 - 65.9
Extremely High	$\geq$ 66.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. The Brittleness Value test is performed on three extractions from one representative and homogenized sample of crushed and sieved rock material. When there is not enough material provided to perform the three tests, one or two tests may be performed.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability - Sievers' J-Value

Individual Test Results

Test Number	Sievers' J-Value SJ (1/10 mm)
1	8.85
2	3.00
3	1.55
4	4.55
5	3.95
Average	4.38

Sample Classification: High

Sievers' J-Value Reference Classification Chart

Category	SJ-Value (1/10 mm)
Extremely High	≤ 2.0
Very High	2.1 - 3.9
High	4.0 - 6.9
Medium	7.0 - 18.9
Low	19.0 - 55.9
Very Low	56.0 - 85.9
Extremely Low	≥ 86.0

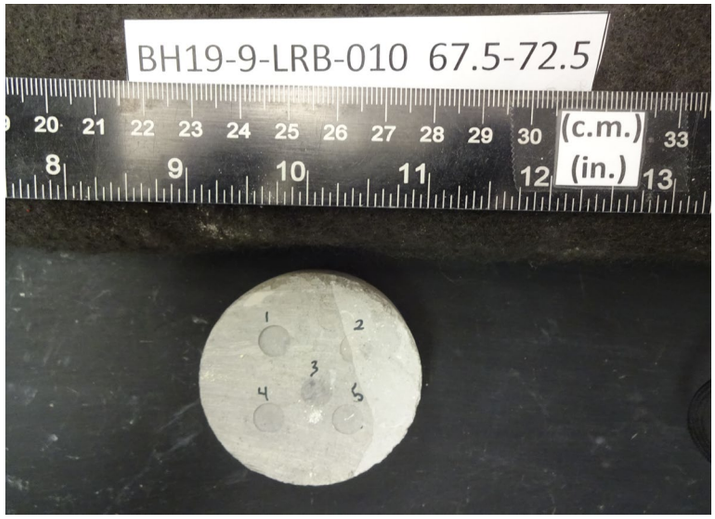
Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. The standard number of Sievers' J drillings performed on each sample is 4 to 8, depending on the variation in the texture of the sample. Drilling locations were selected to be tested on 60% hard and 40% softer layers found in the sample. Soft/hard combinations at drill locations are avoided as best as possible to try to give a more accurate representation of the rock. This is however impossible in samples which have alternating soft and hard layered mineral composition. The average Sievers' J value is regarded as representative for the tested rock.
4. Test was performed at 197 RPM.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability - Sievers' J-Value Sample

Sample before testing



After testing showing drill locations

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norwav.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability - Abrasion Value (AV)

Individual Test Results

Test Number	Abrasion Value AV (mg)
1	0.90
2	1.40
Average	1.15

Sample Classification: Very Low

Abrasion Value Reference Classification Chart

Category	AV (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 10.9
Medium	11.0 - 27.9
High	28.0 - 41.9
Very High	42.0 - 57.9
Extremely High	≥ 58.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AV test pieces are comprised of tungsten carbide. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 5 mins for a total of 100 revolutions

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/20/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-09
Sample ID:	LRB-010
Depth, ft:	67.5-72.5

Rock Drillability - Abrasion Value Cutter Steel (AVS)

Individual Test Results

Test Number	Abrasion Value Cutter Steel AVS (mg)
1	0.20
2	0.30
Average	0.25

Sample Classification: Extremely Low

Abrasion Value Cutter Steel Reference Classification Chart

Category	AVS (mg)
Extremely Low	≤ 1.0
Very Low	1.1 - 3.9
Low	4.0 - 12.9
Medium	13.0 - 25.9
High	26.0 - 35.9
Very High	36.0 - 43.9
Extremely High	≥ 44.0

Notes:

1. GeoTesting Express's Rock Drillability testing suite is based on NTNU/SINTEF's 13A-98 Drillability Test Methods, Dept. of Civil and Transportation Engineering and performed in accordance with Dahl, Filip, 2003, The Suggested DRI, BWI, CLI Standard.
2. The trademarked acronyms and terms DRI™, BWI™, CLI™ BWI™, SAT™, Bit Wear Index™, Cutter Life Index™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
3. Abrasion test material was taken from the extractions used for the Brittleness Value test. The AVS test pieces are comprised of cutter ring steel. Grain size, shape and binding are some factors that are believed to have substantial influence on the abrasiveness of the rock.
4. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-21
Sample ID:	LSB-002
Depth, ft:	39.24-39.69

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	3.1
2	3.9
Average	3.5

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

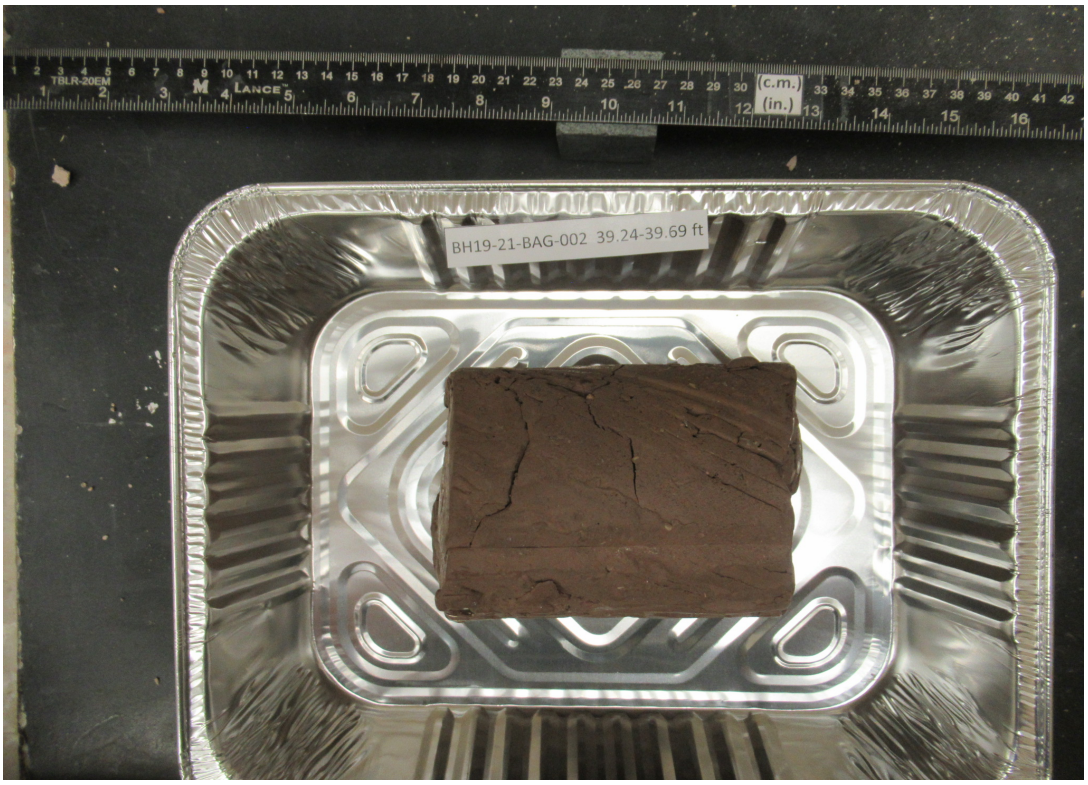
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-21
Sample ID:	LSB-002
Depth, ft:	39.24-39.69

Soil Abrasivity Test - Sample As-Received

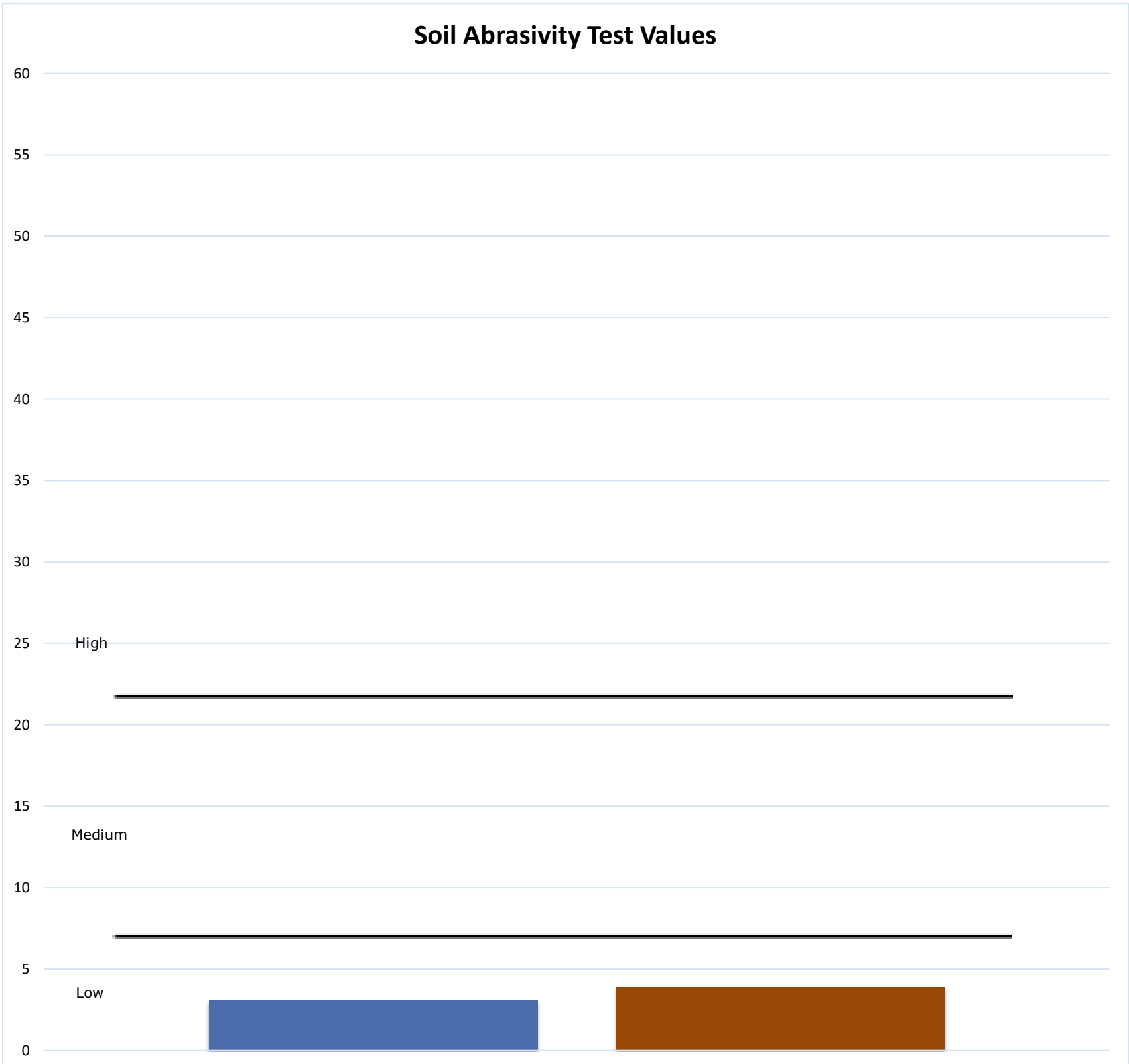


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-21
Sample ID:	LSB-002
Depth, ft:	39.24-39.69

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-21
Sample ID:	LSB-004
Depth, ft:	48.09-48.56

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.2
2	1.4
Average	1.3

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

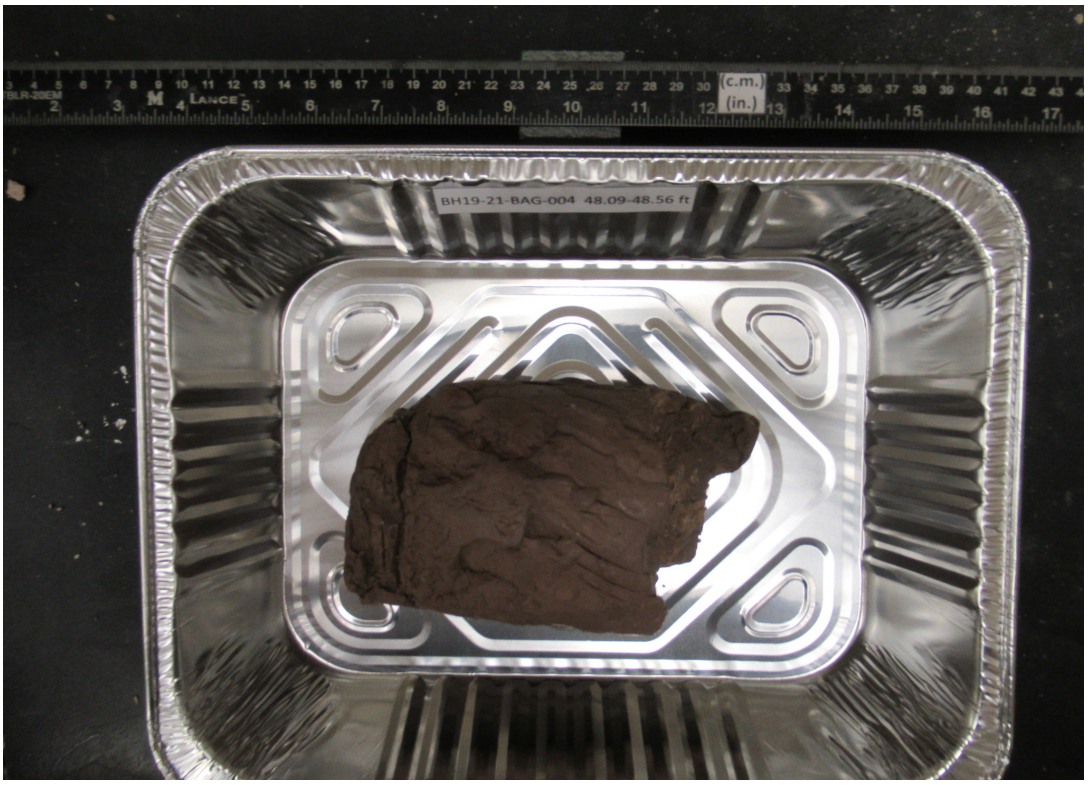
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-21
Sample ID:	LSB-004
Depth, ft:	48.09-48.56

Soil Abrasivity Test - Sample As-Received

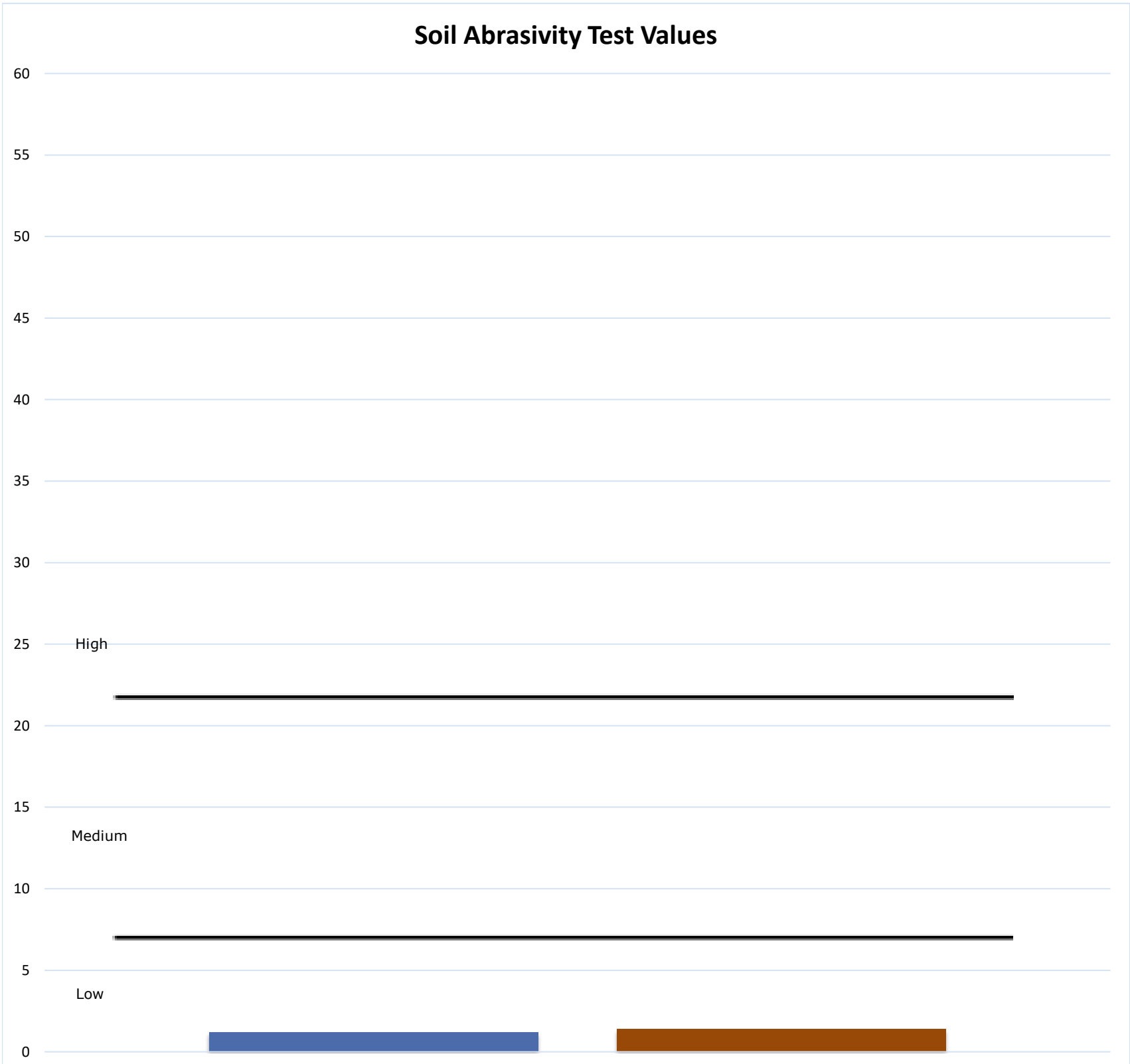


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-21
Sample ID:	LSB-004
Depth, ft:	48.09-48.56

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-23
Sample ID:	LSB-001
Depth, ft:	29.39-29.95

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	2.2
2	3.4
Average	2.8

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-23
Sample ID:	LSB-001
Depth, ft:	29.39-29.95

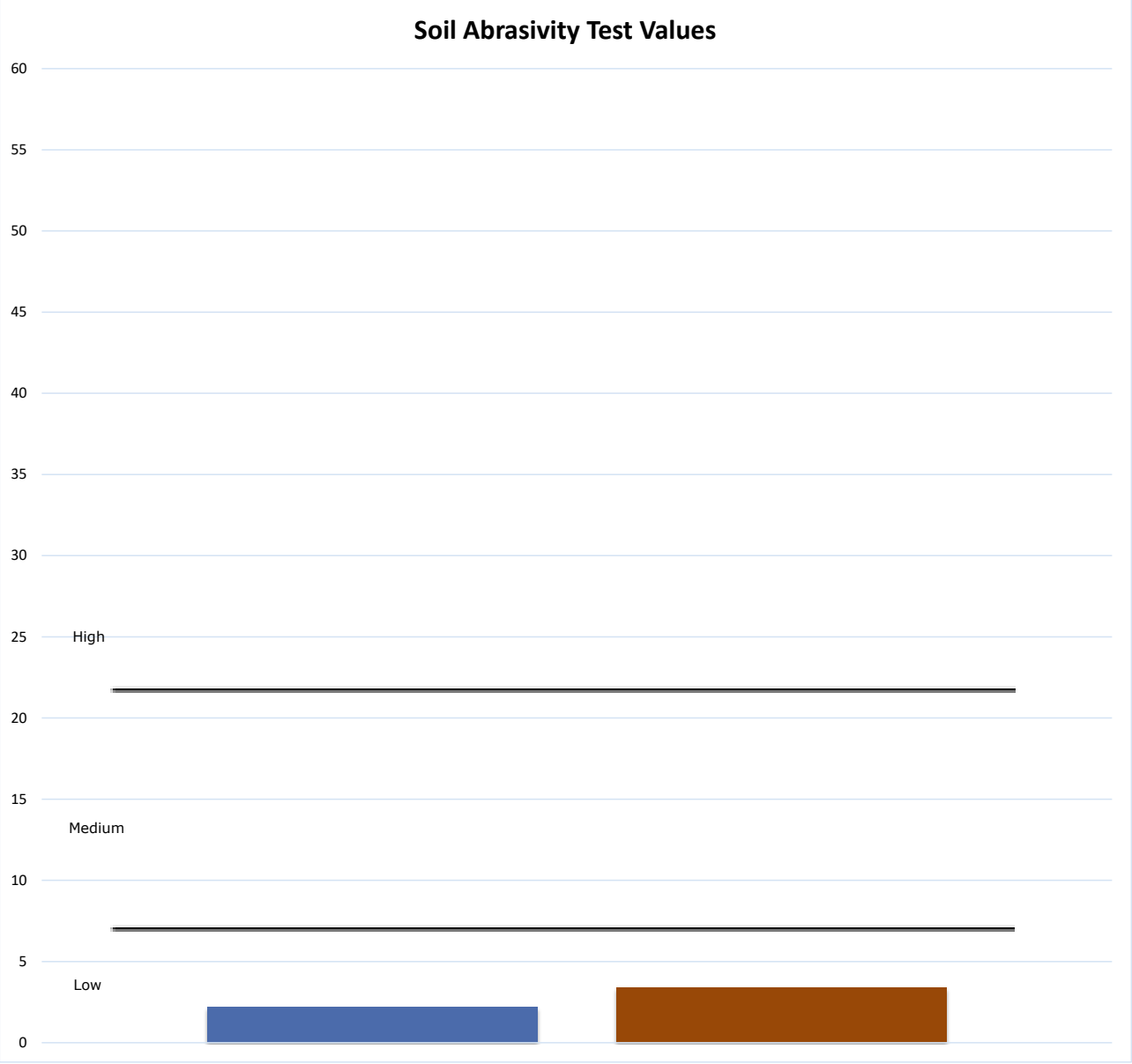
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-23
Sample ID:	LSB-001
Depth, ft:	29.39-29.95

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-23
Sample ID:	LSB-002
Depth, ft:	68.01-68.64

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	42.2
2	41.5
Average	41.8

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-23
Sample ID:	LSB-002
Depth, ft:	68.01-68.64

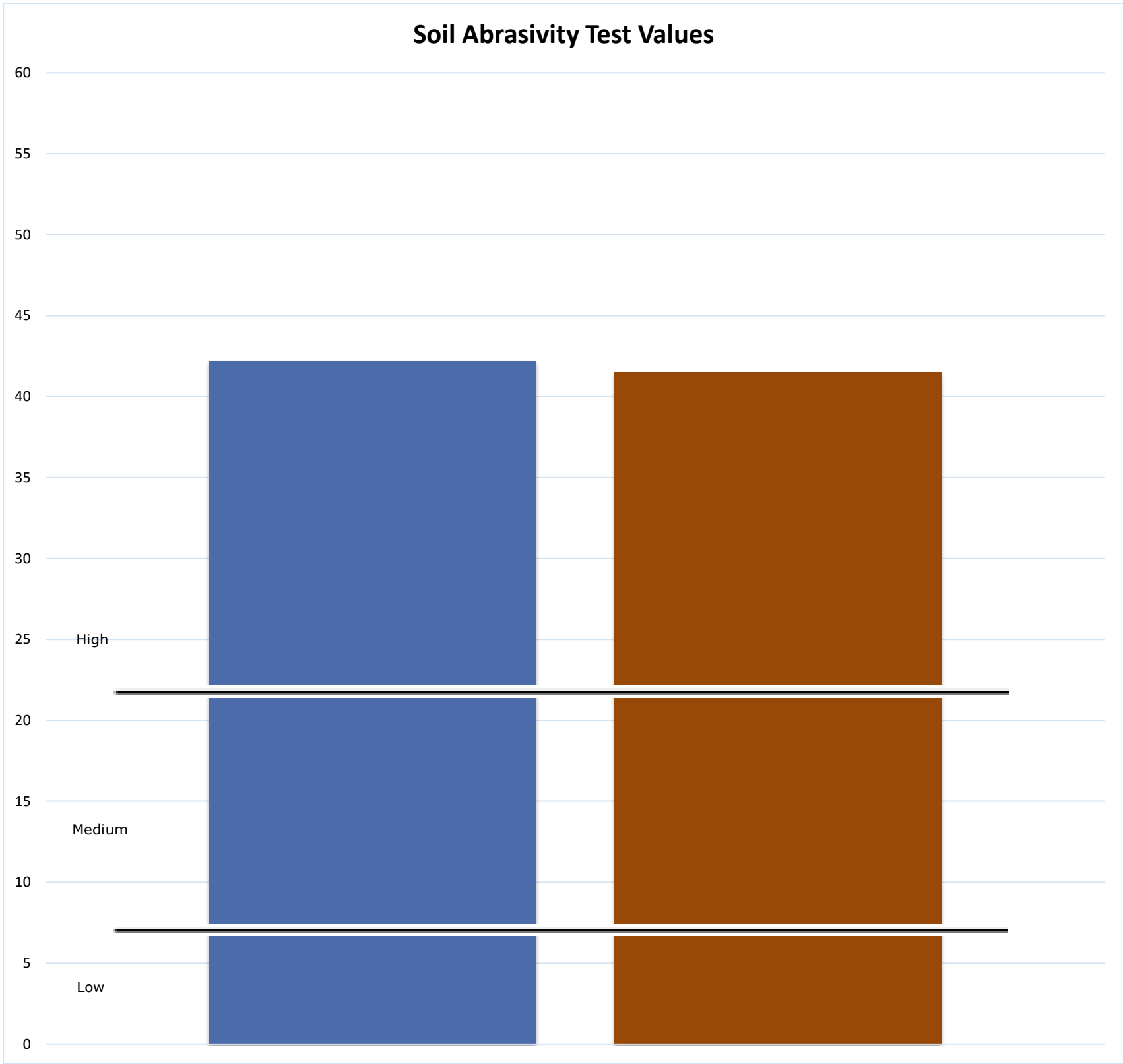
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-23
Sample ID:	LSB-002
Depth, ft:	68.01-68.64

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-23
Sample ID:	LSB-003
Depth, ft:	94.26-94.78

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	29.3
2	31.5
Average	30.4

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-23
Sample ID:	LSB-003
Depth, ft:	94.26-94.78

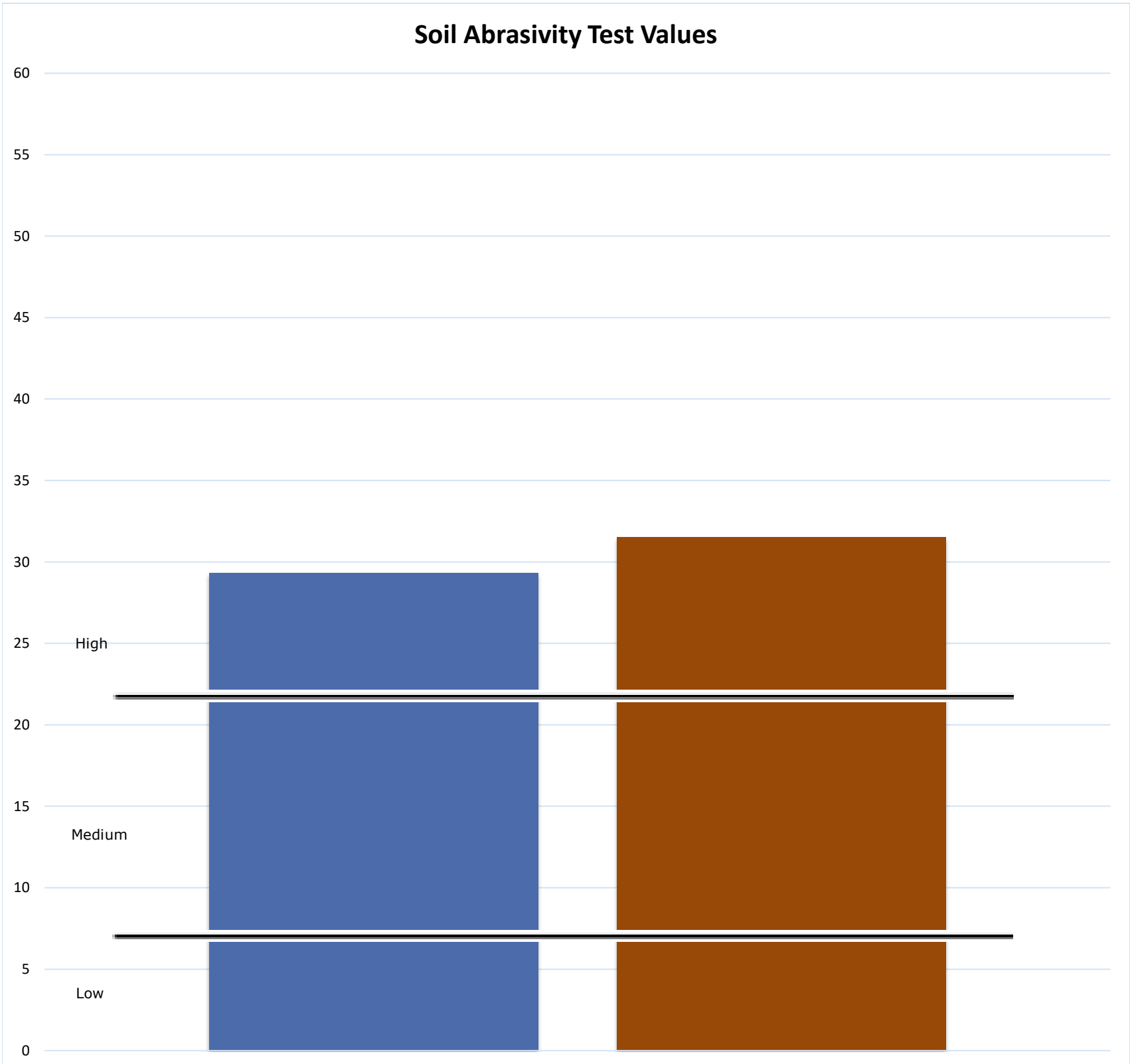
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-23
Sample ID:	LSB-003
Depth, ft:	94.26-94.78

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-002
Depth, ft:	68.24-68.73

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	29.7
2	27.3
Average	28.5

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-002
Depth, ft:	68.24-68.73

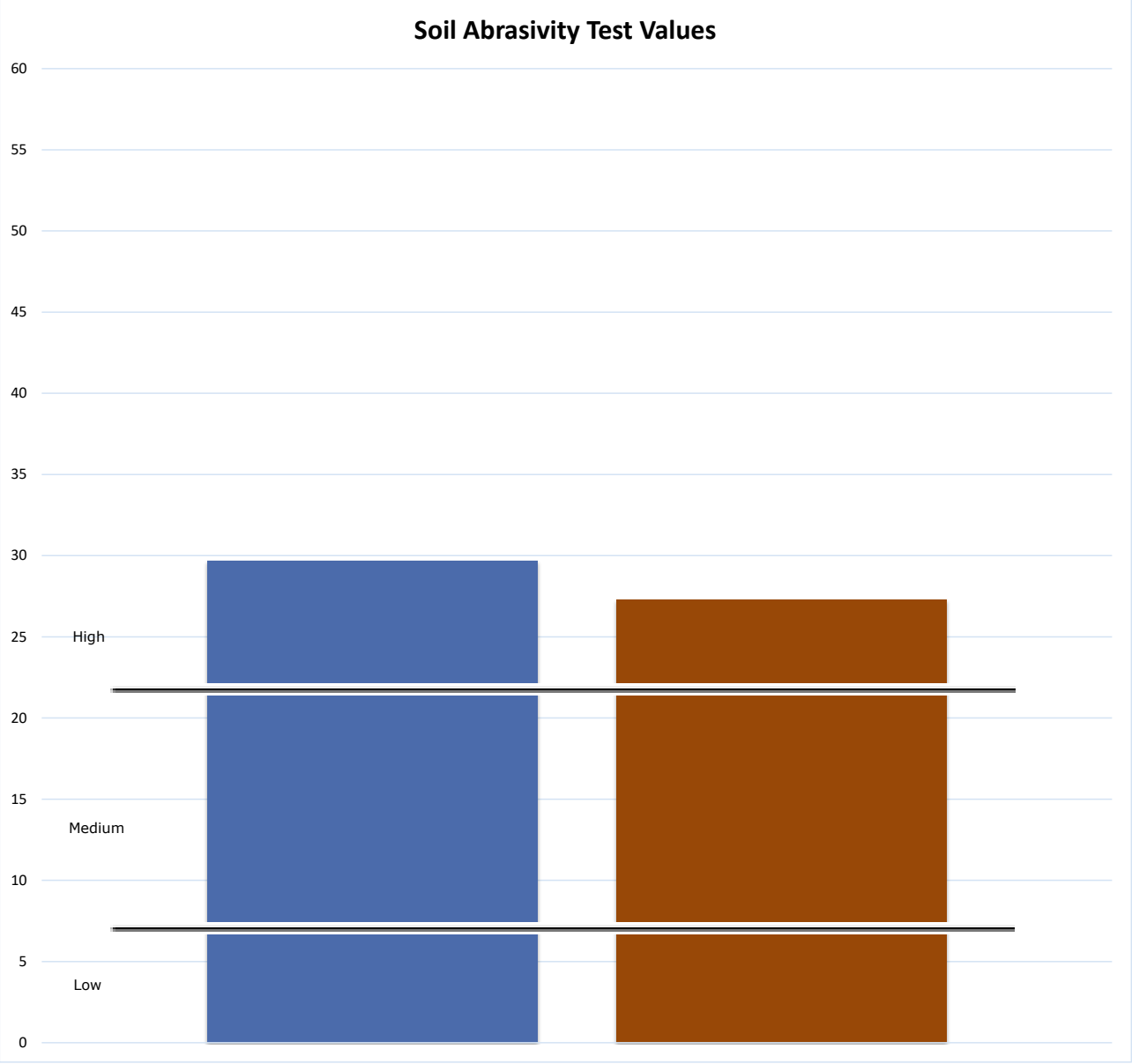
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-002
Depth, ft:	68.24-68.73

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-004
Depth, ft:	120.08-120.57

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	35.1
2	34.5
Average	34.8

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

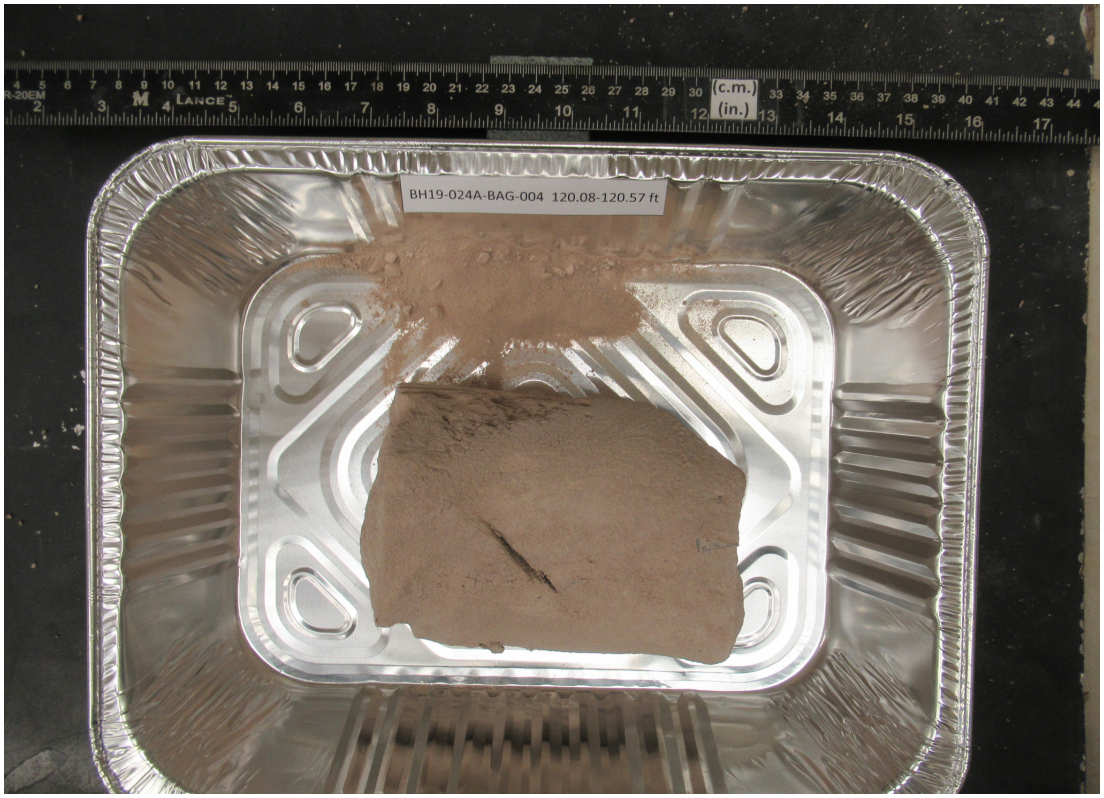
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-004
Depth, ft:	120.08-120.57

Soil Abrasivity Test - Sample As-Received

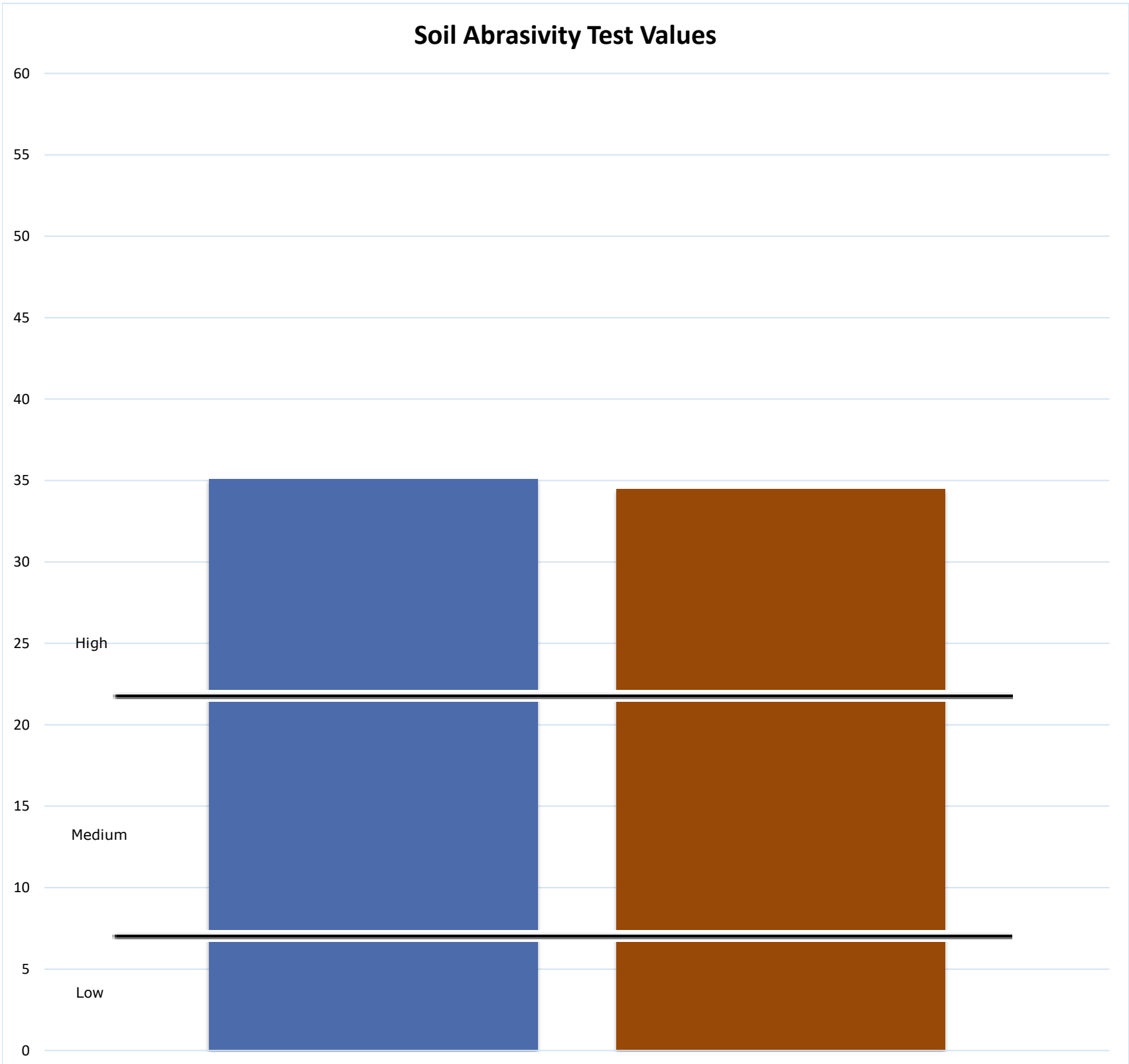


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-004
Depth, ft:	120.08-120.57

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-006
Depth, ft:	156.66-157.32

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	32.1
2	33.9
Average	33.0

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

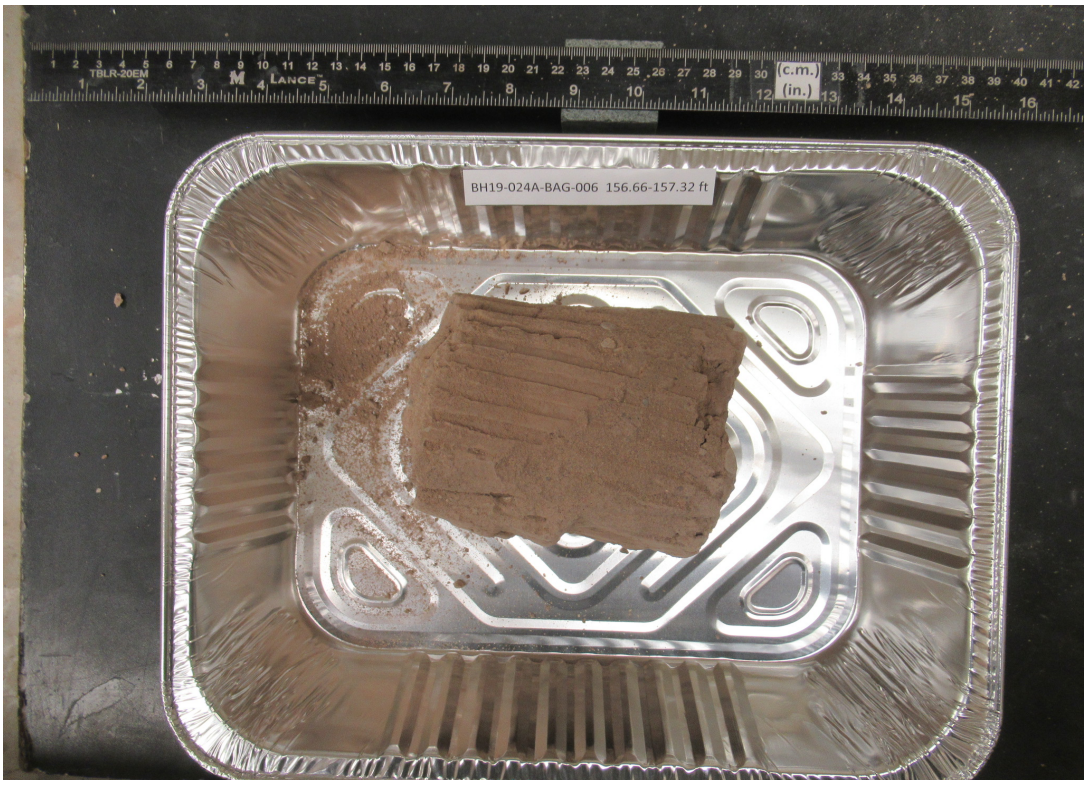
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-006
Depth, ft:	156.66-157.32

Soil Abrasivity Test - Sample As-Received

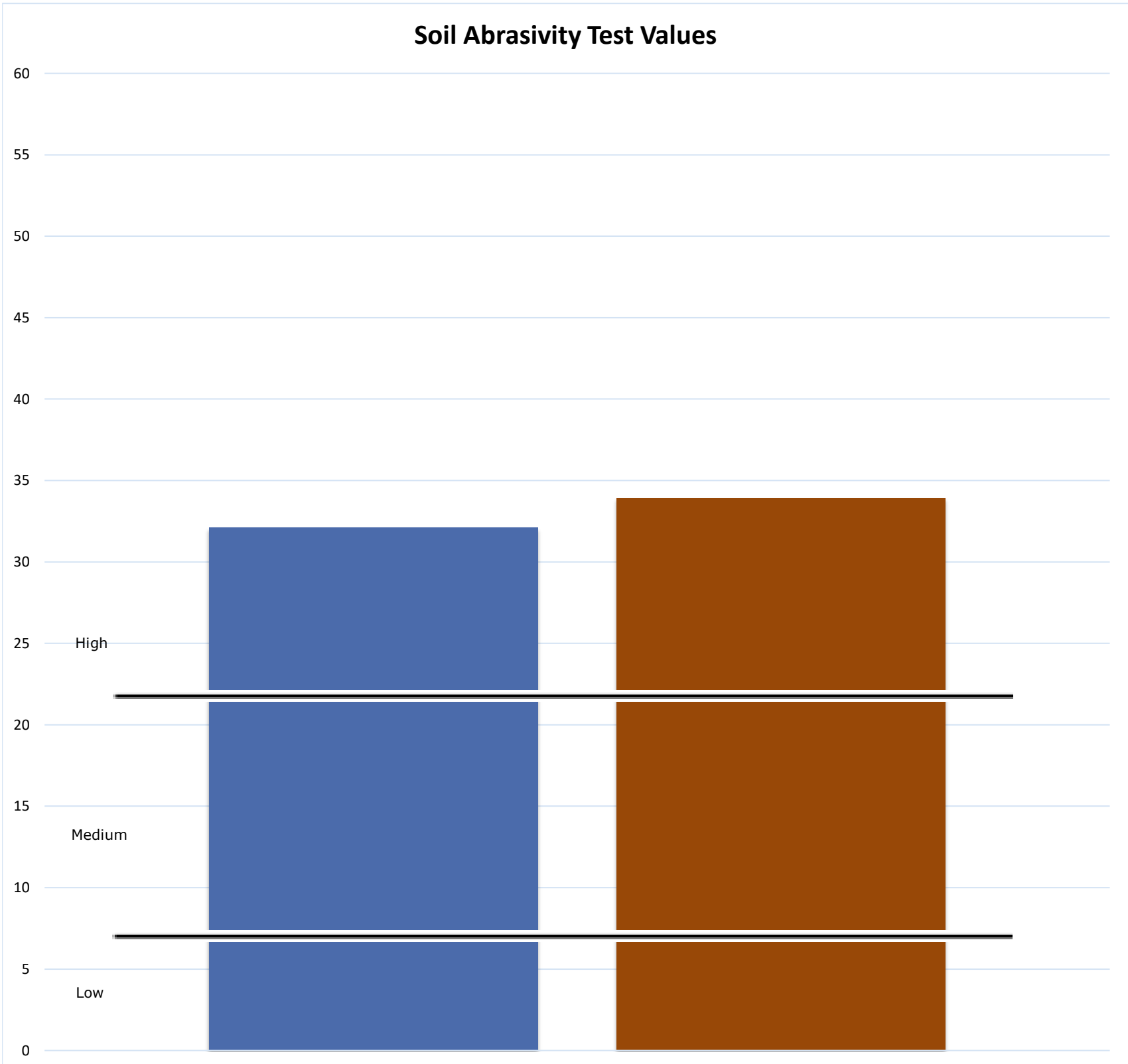


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-006
Depth, ft:	156.66-157.32

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-007
Depth, ft:	174.54-175.03

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	28.7
2	29.6
Average	29.2

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-007
Depth, ft:	174.54-175.03

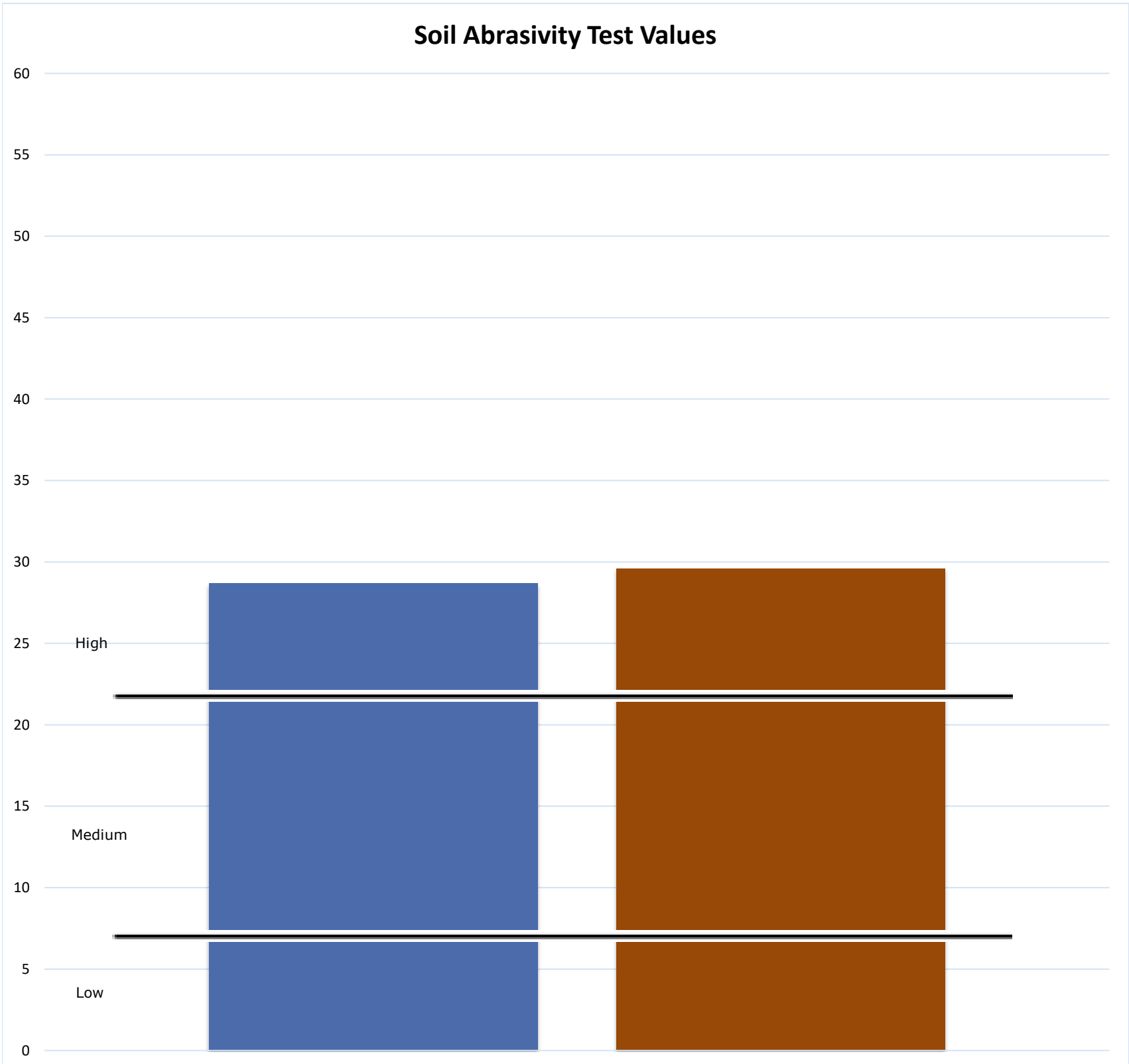
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-007
Depth, ft:	174.54-175.03

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-008
Depth, ft:	180.94-181.43

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	6.7
2	7.6
Average	7.1

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

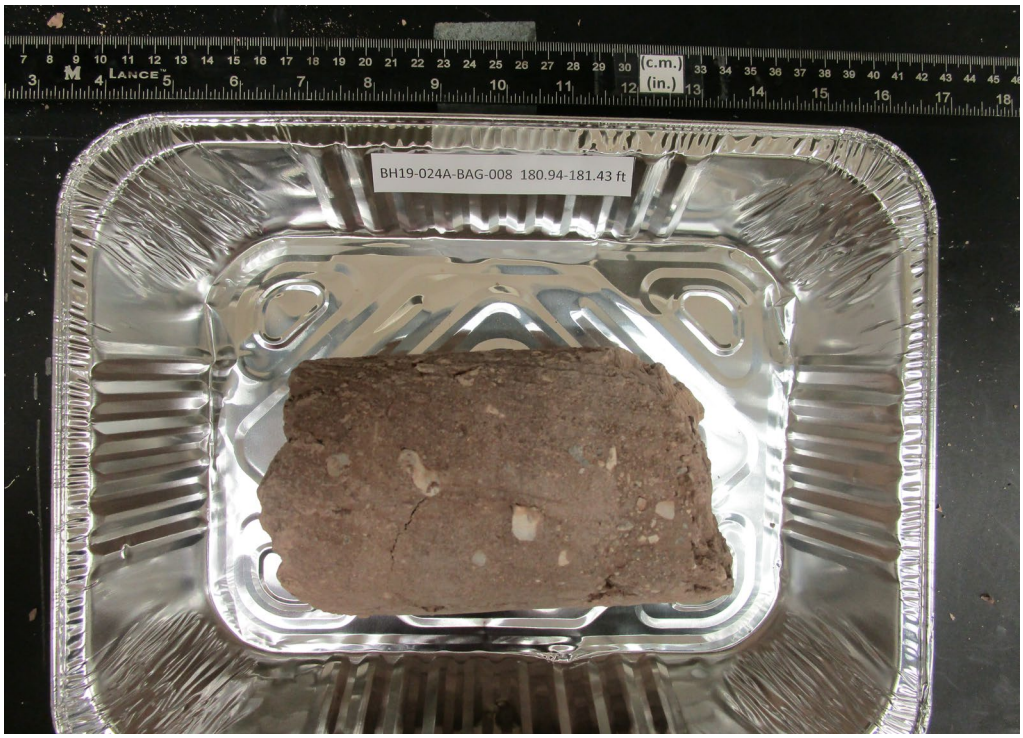
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-008
Depth, ft:	180.94-181.43

Soil Abrasivity Test - Sample As-Received

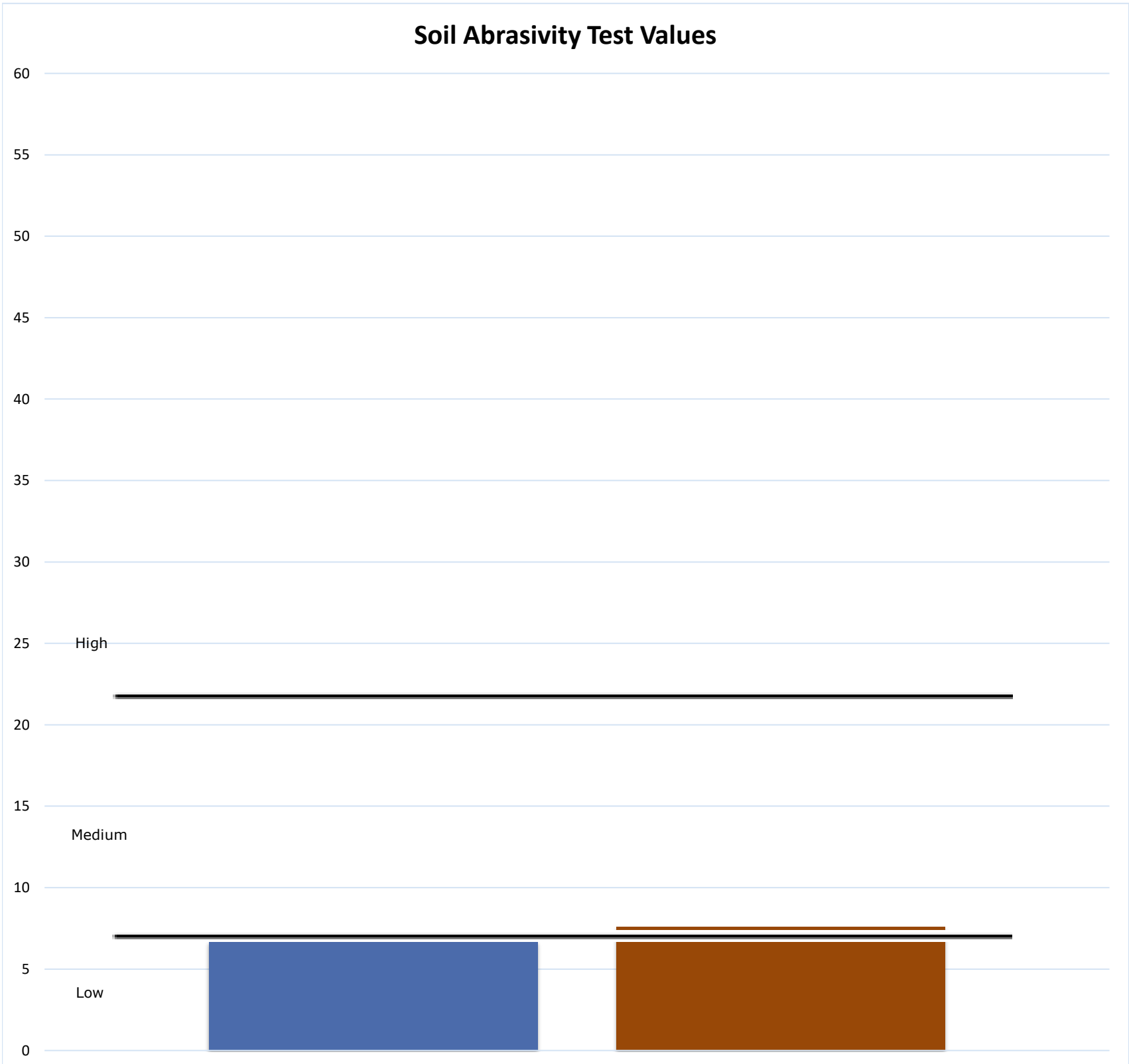


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-008
Depth, ft:	180.94-181.43

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-009
Depth, ft:	185.20-185.69

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	0.7
2	0.6
Average	0.7

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-009
Depth, ft:	185.20-185.69

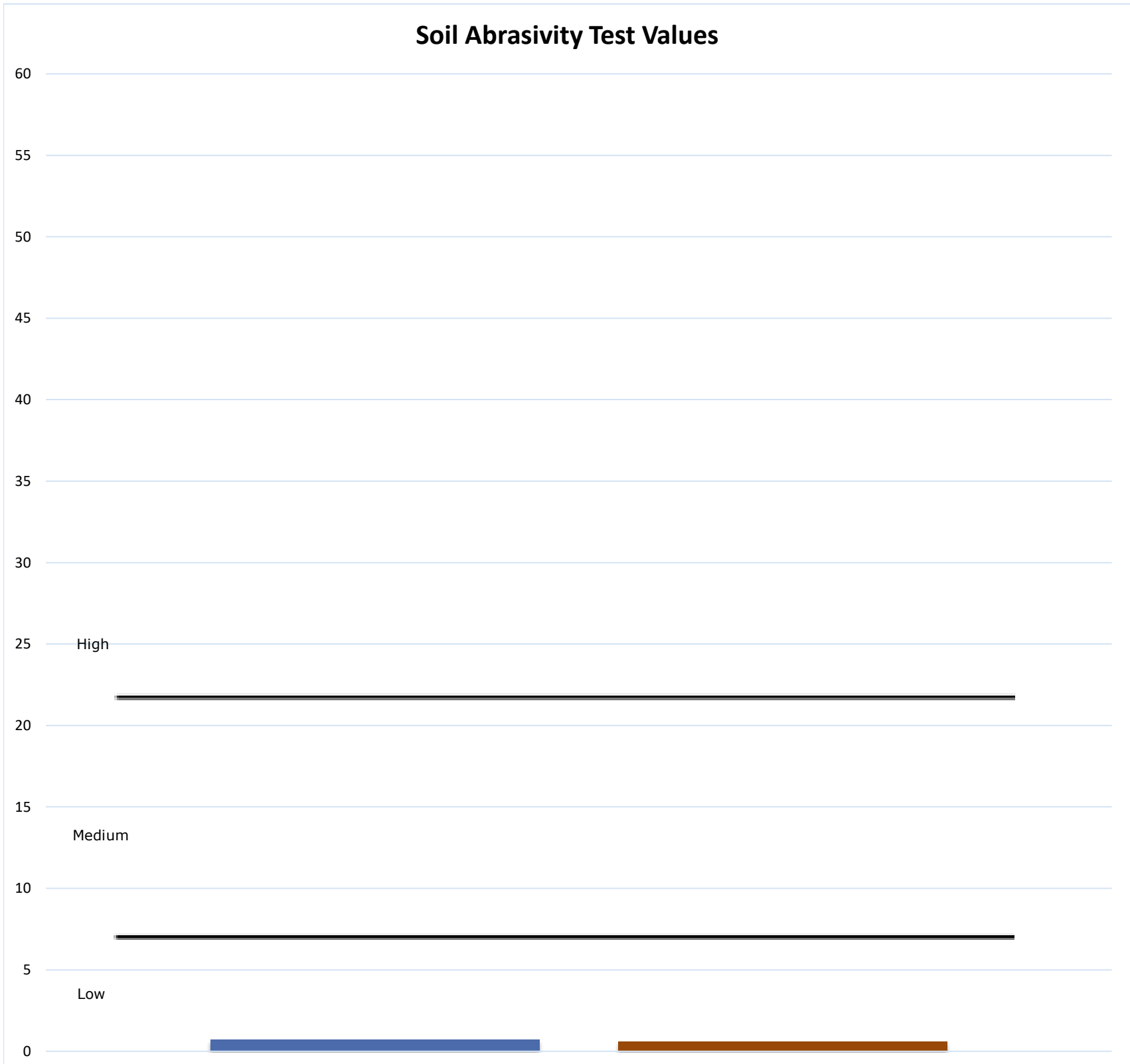
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-009
Depth, ft:	185.20-185.69

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-010
Depth, ft:	189.57-190.22

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	2.5
2	2.6
Average	2.5

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

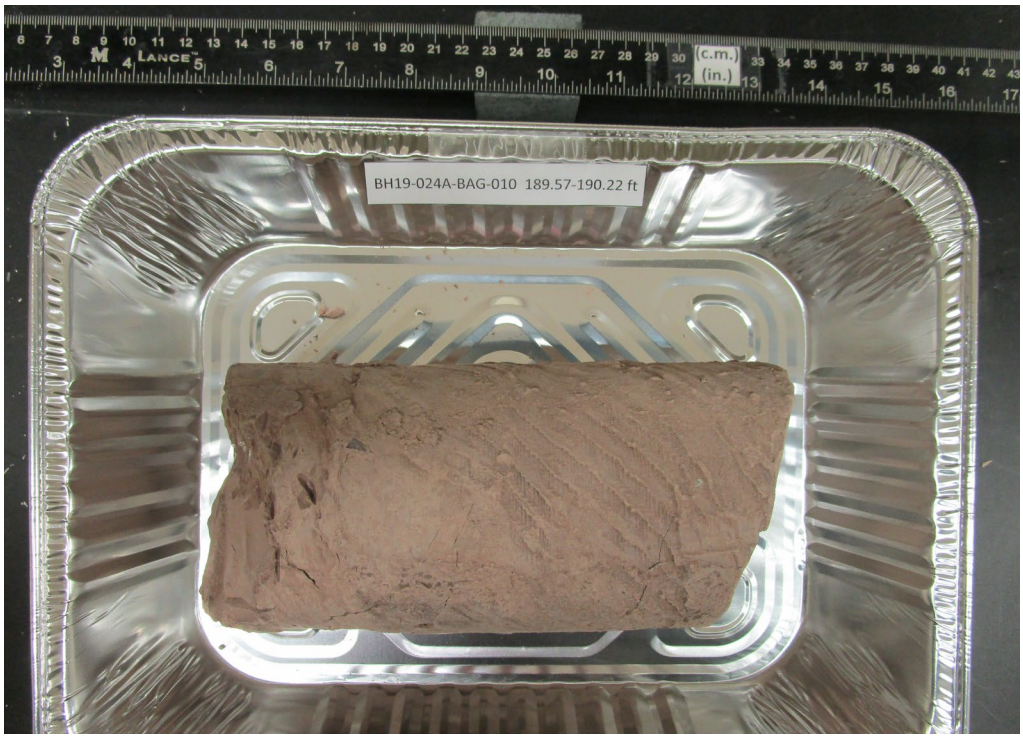
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-010
Depth, ft:	189.57-190.22

Soil Abrasivity Test - Sample As-Received

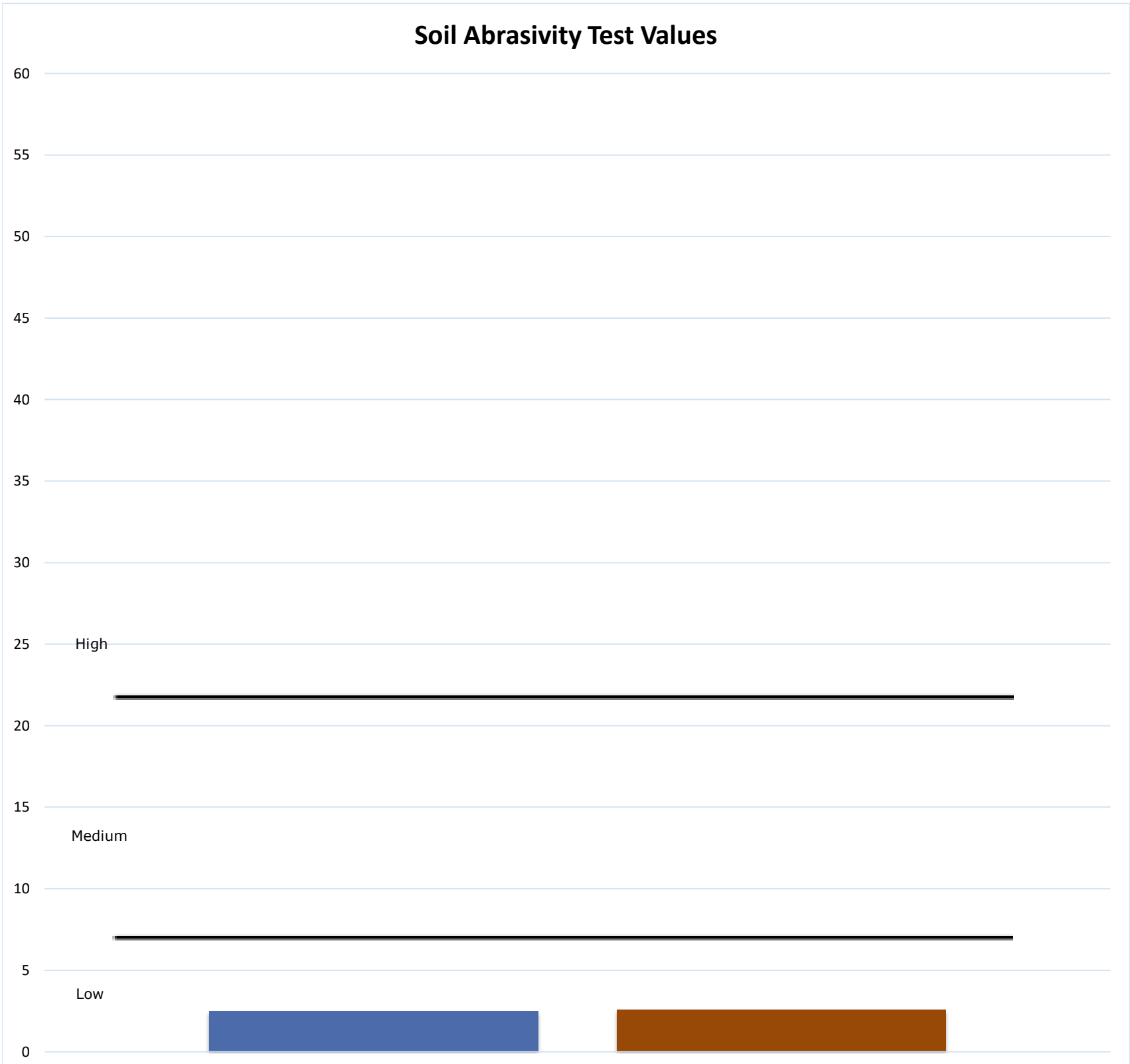


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-010
Depth, ft:	189.57-190.22

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-011
Depth, ft:	193.96-194.42

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.3
2	1.1
Average	1.2

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-011
Depth, ft:	193.96-194.42

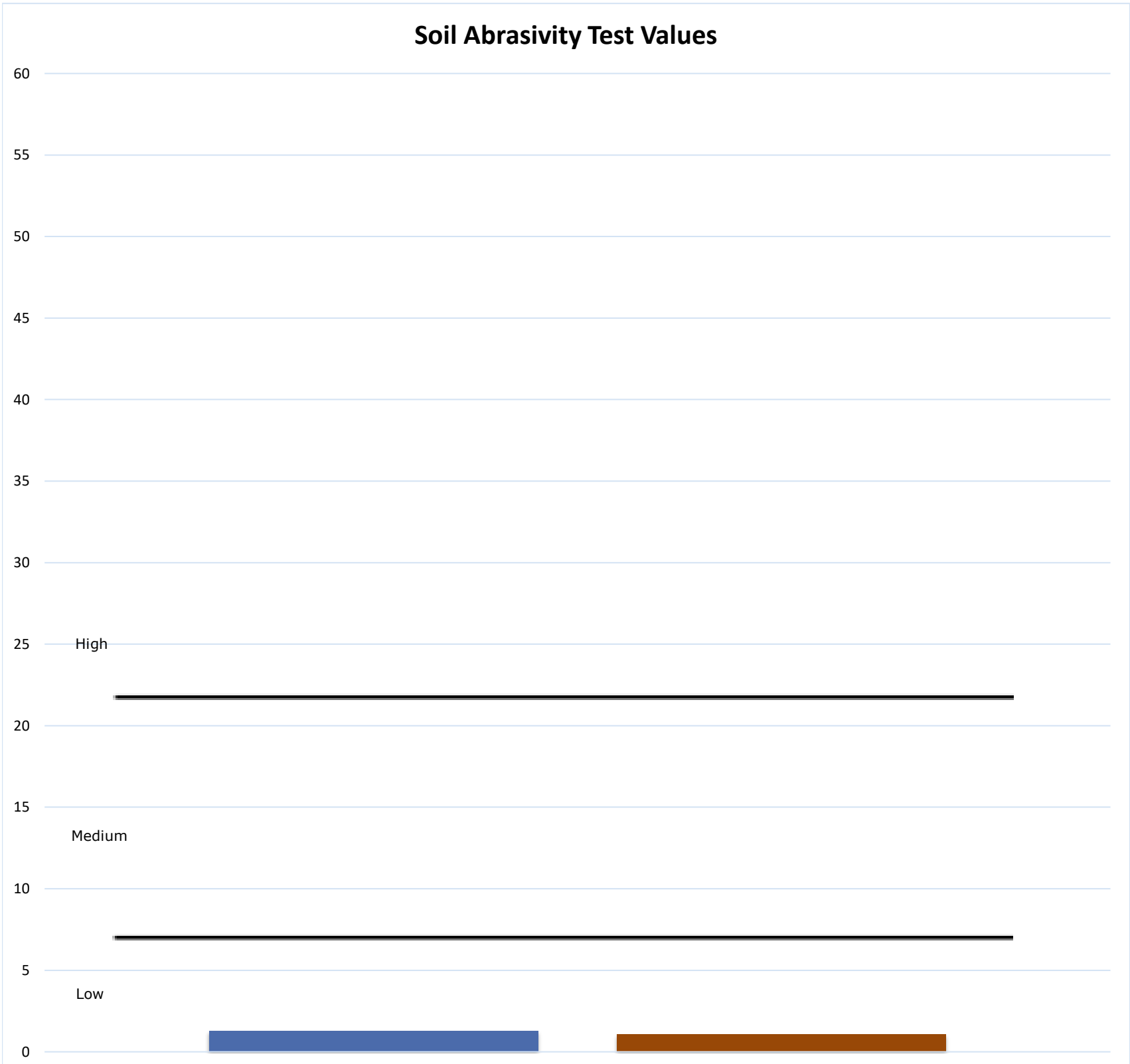
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-011
Depth, ft:	193.96-194.42

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-012
Depth, ft:	200.85-200.41

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	2.4
2	2.6
Average	2.5

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-012
Depth, ft:	200.85-200.41

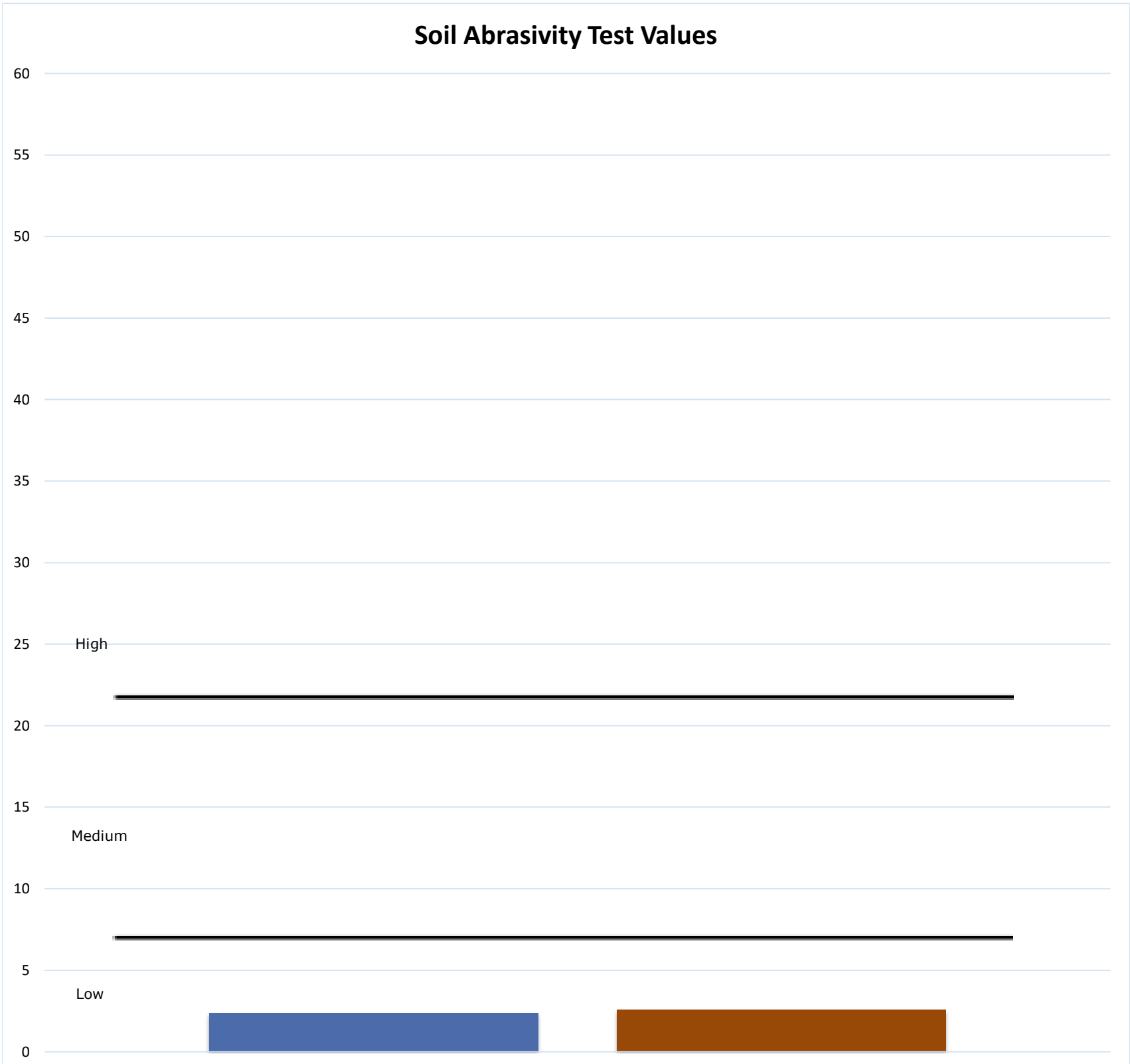
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-012
Depth, ft:	200.85-200.41

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-013
Depth, ft:	204.33-204.92

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	7.1
2	7.5
Average	7.3

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-013
Depth, ft:	204.33-204.92

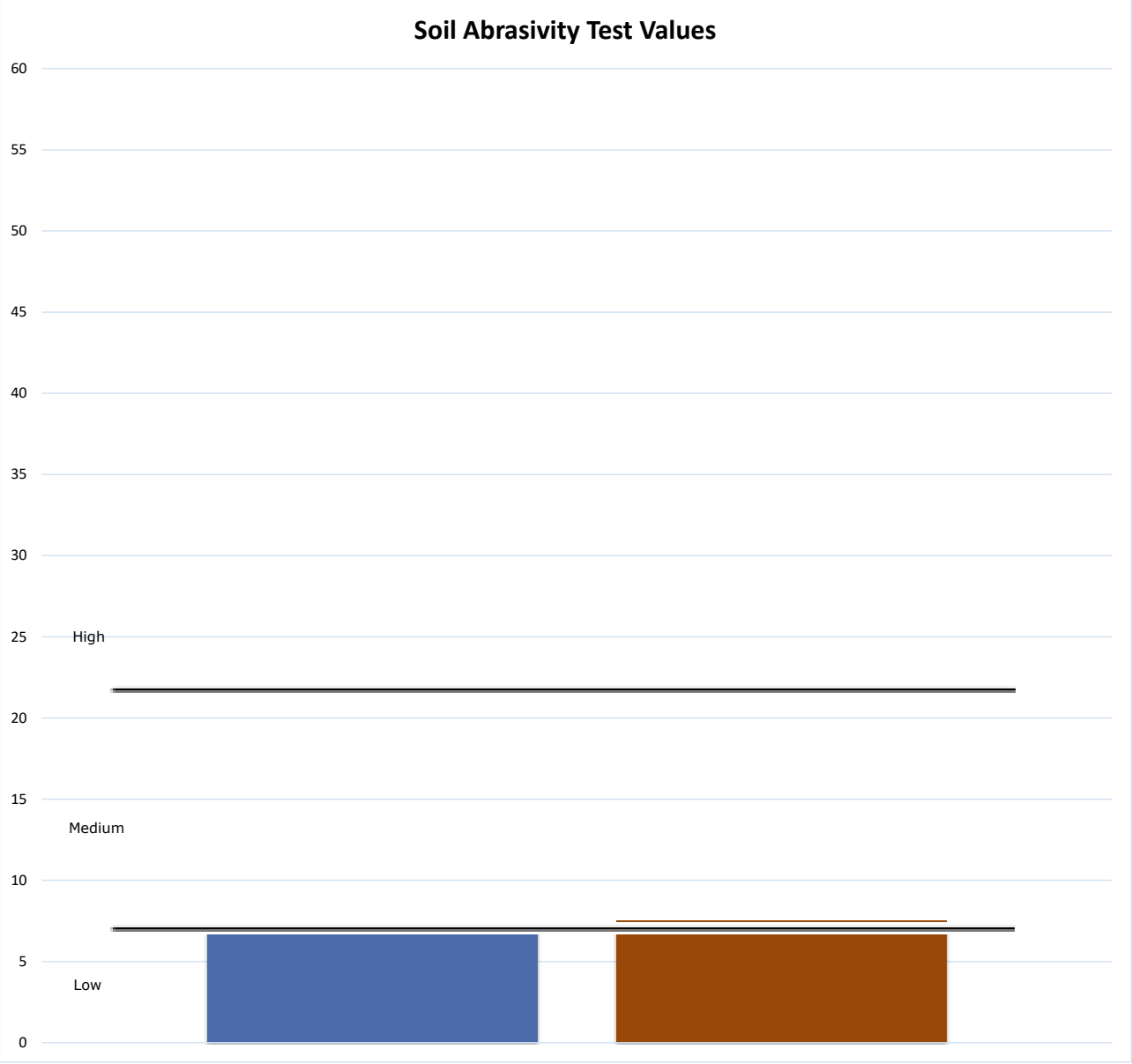
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-013
Depth, ft:	204.33-204.92

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-015
Depth, ft:	218.50-218.99

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	30.8
2	29.7
Average	30.3

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-024A
Sample ID:	LSB-015
Depth, ft:	218.50-218.99

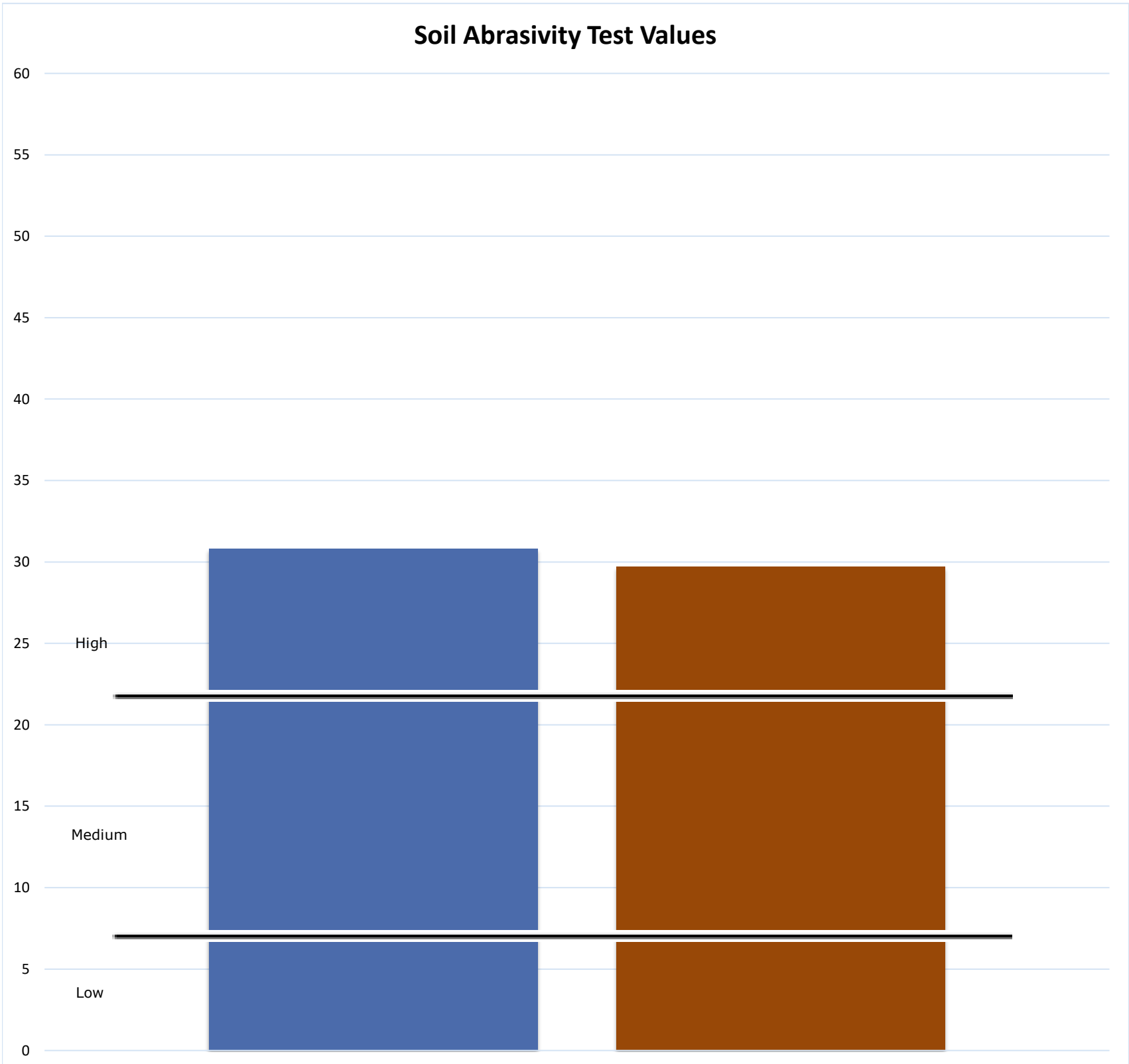
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-024A
Sample ID:	LSB-015
Depth, ft:	218.50-218.99

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24
Sample ID:	LSB-002
Depth, ft:	83.20-83.89

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	24.9
2	23.8
Average	24.4

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

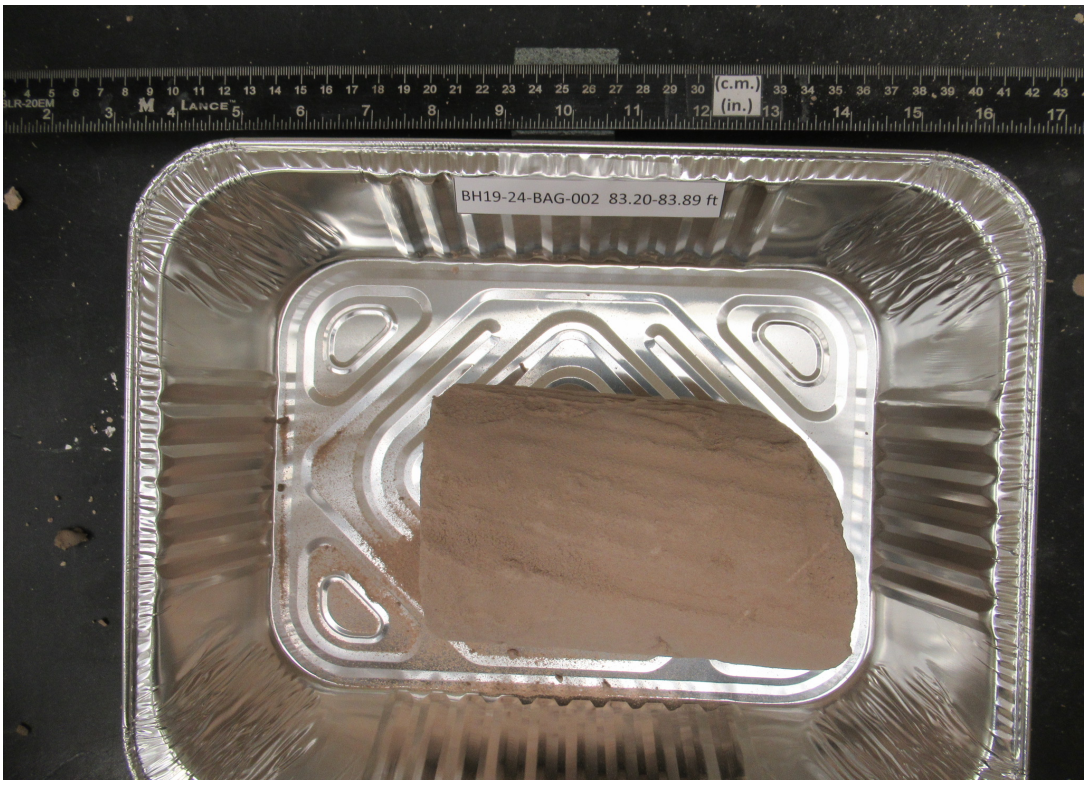
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-24
Sample ID:	LSB-002
Depth, ft:	83.20-83.89

Soil Abrasivity Test - Sample As-Received

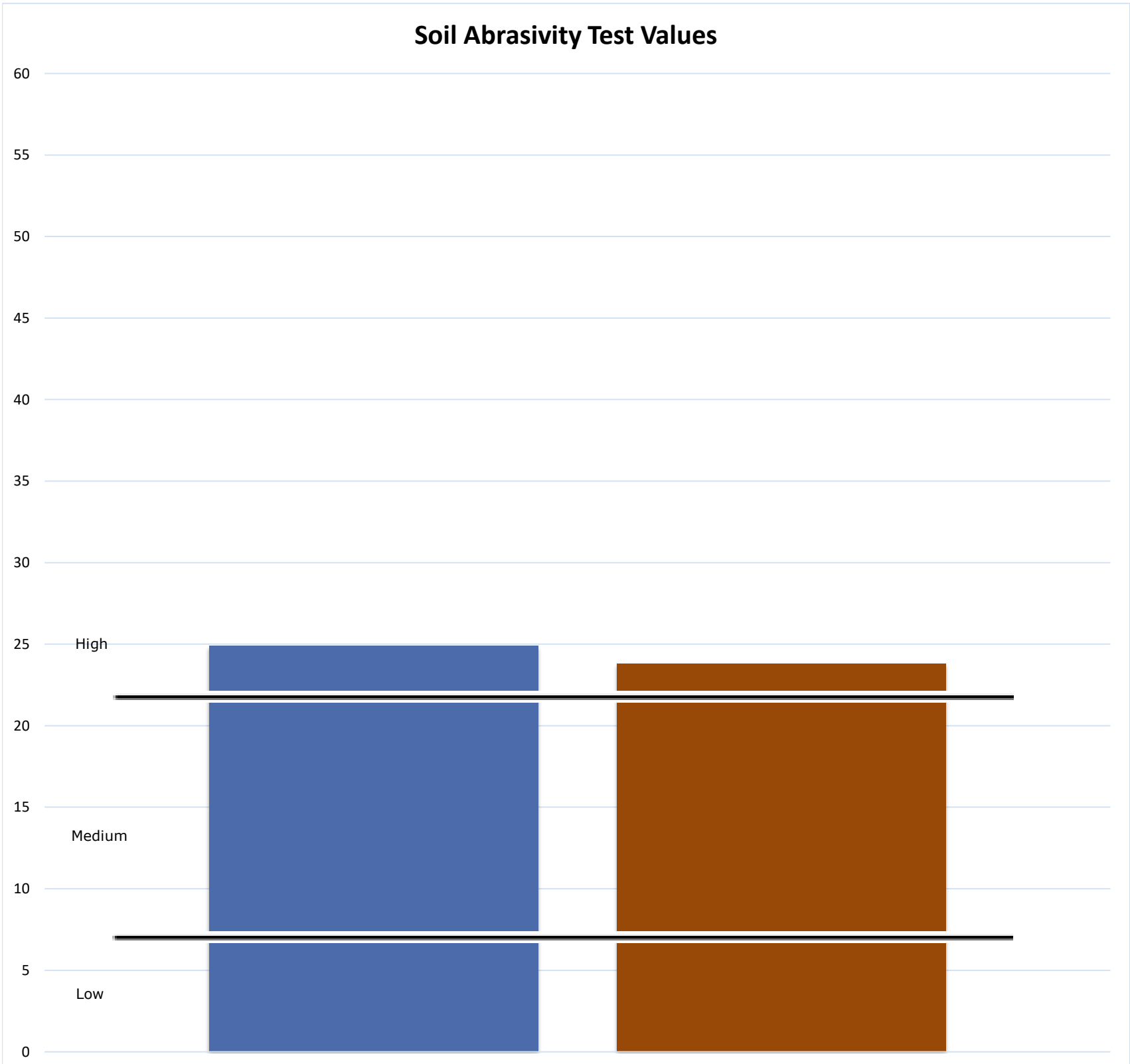


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24
Sample ID:	LSB-002
Depth, ft:	83.20-83.89

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24
Sample ID:	LSB-004
Depth, ft:	130.51-131.07

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	19.9
2	20.2
Average	20.0

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-24
Sample ID:	LSB-004
Depth, ft:	130.51-131.07

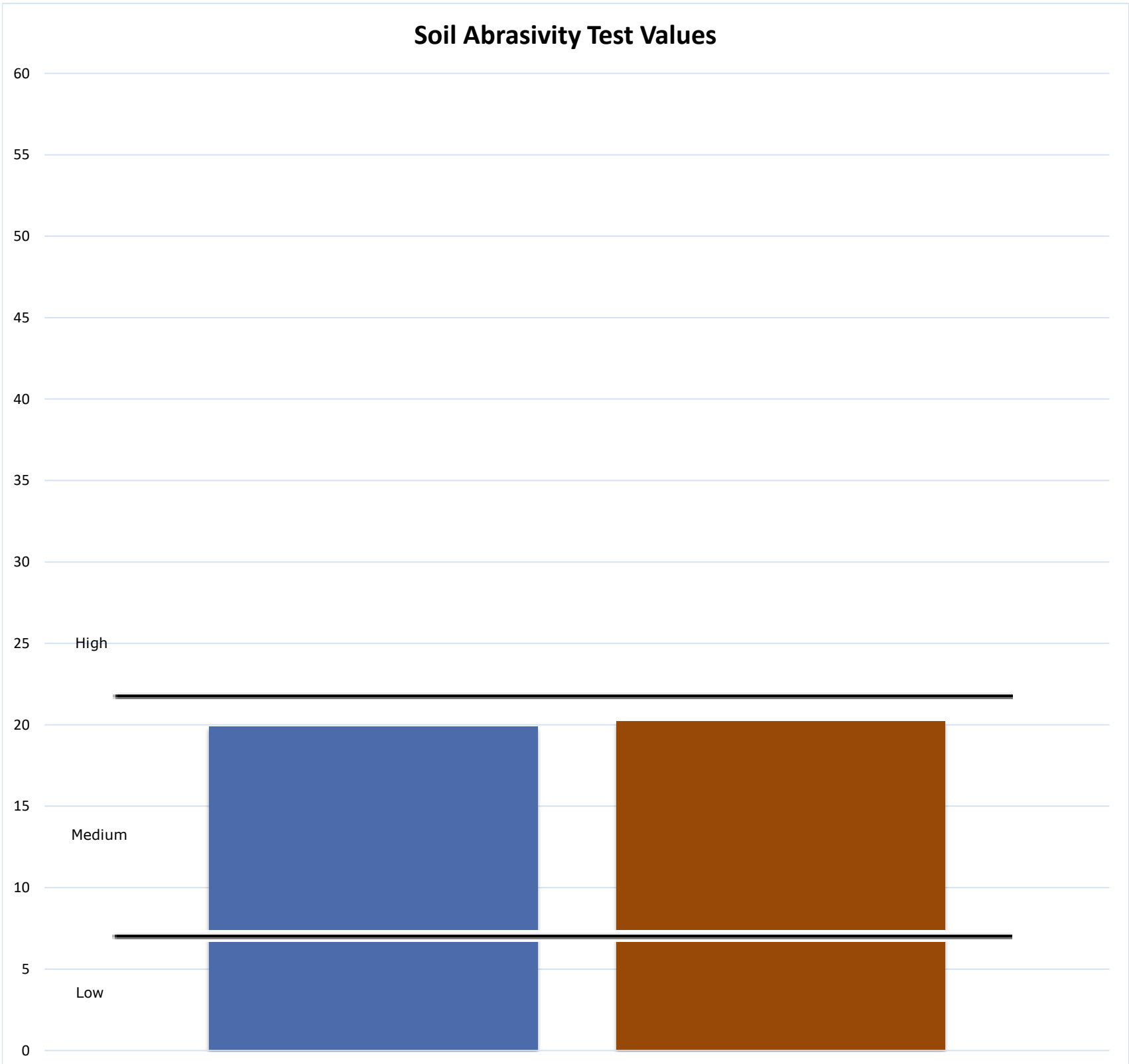
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24
Sample ID:	LSB-004
Depth, ft:	130.51-131.07

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24
Sample ID:	LSB-006
Depth, ft:	148.06-148.62

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.3
2	1.1
Average	1.2

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

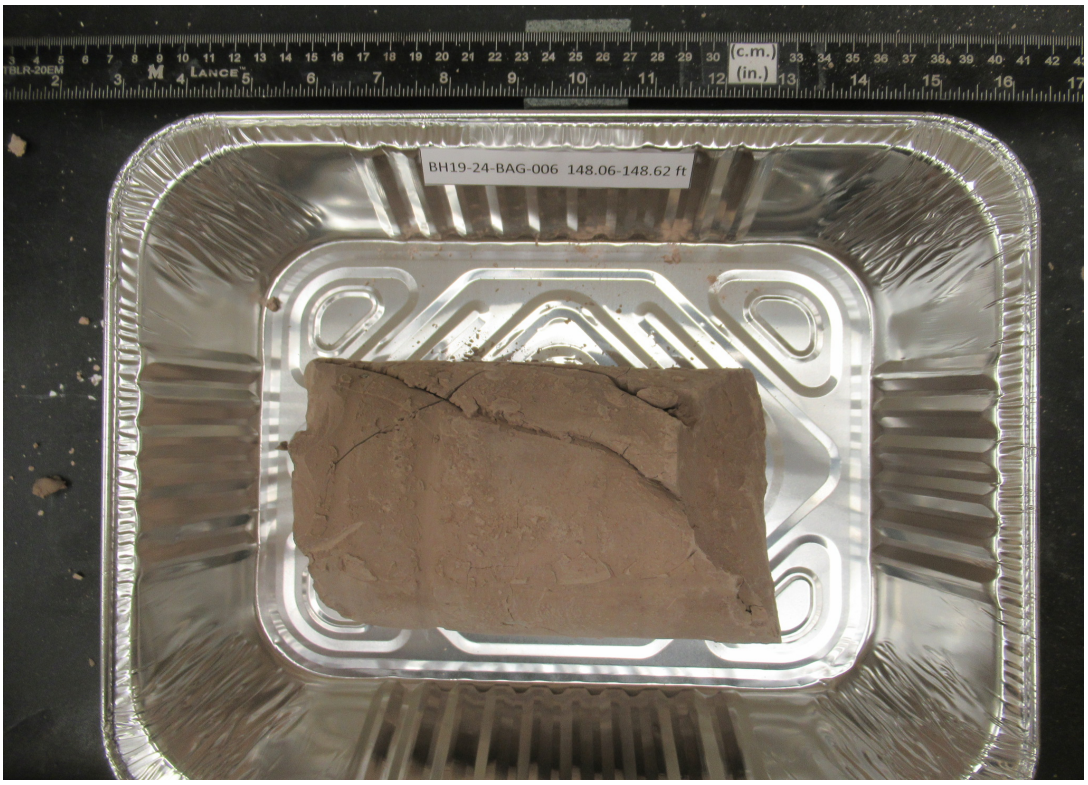
Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-24
Sample ID:	LSB-006
Depth, ft:	148.06-148.62

Soil Abrasivity Test - Sample As-Received

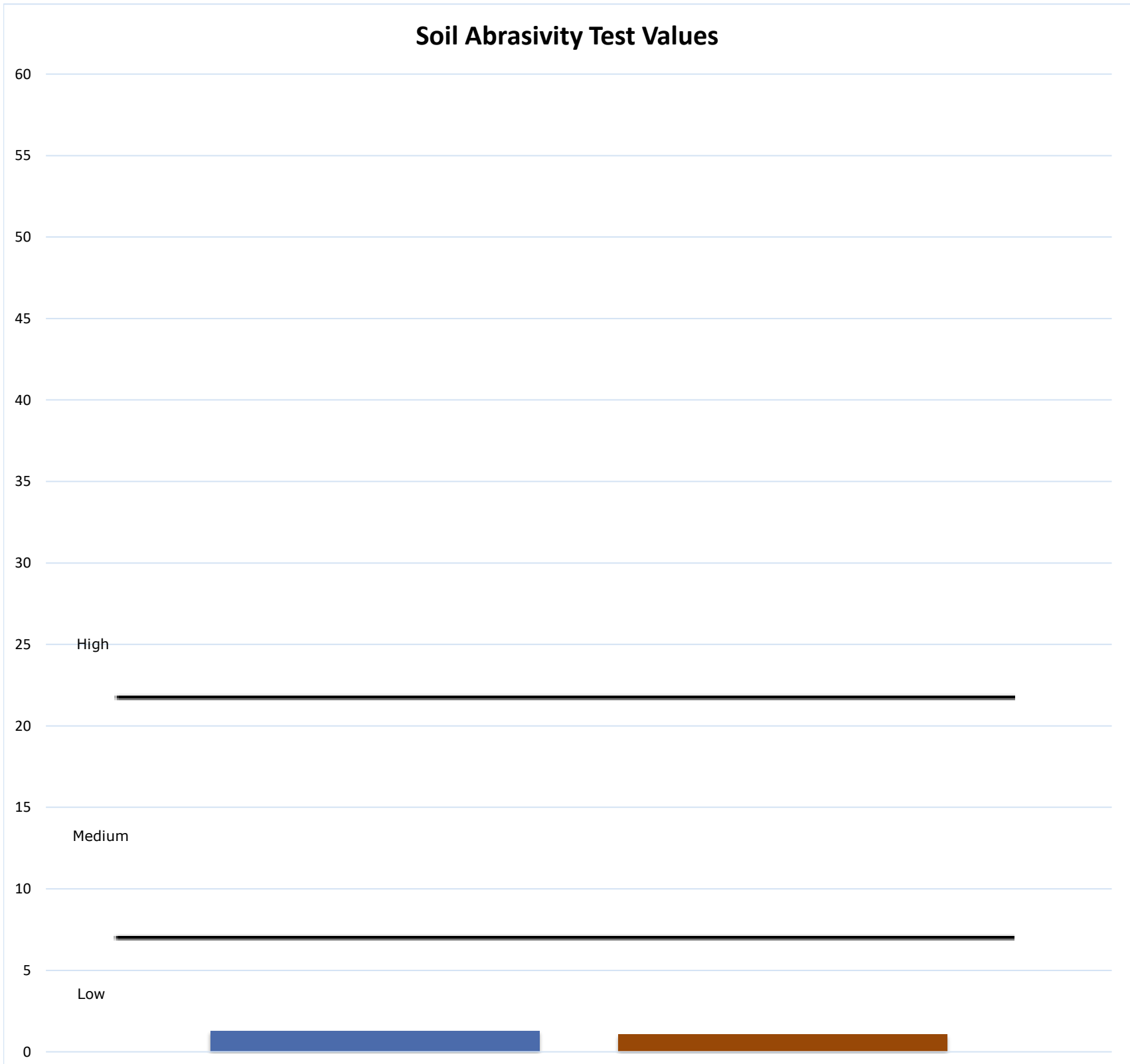


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-24
Sample ID:	LSB-006
Depth, ft:	148.06-148.62

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-002
Depth, ft:	102.69-103.28

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	34.7
2	33.6
Average	34.2

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-002
Depth, ft:	102.69-103.28

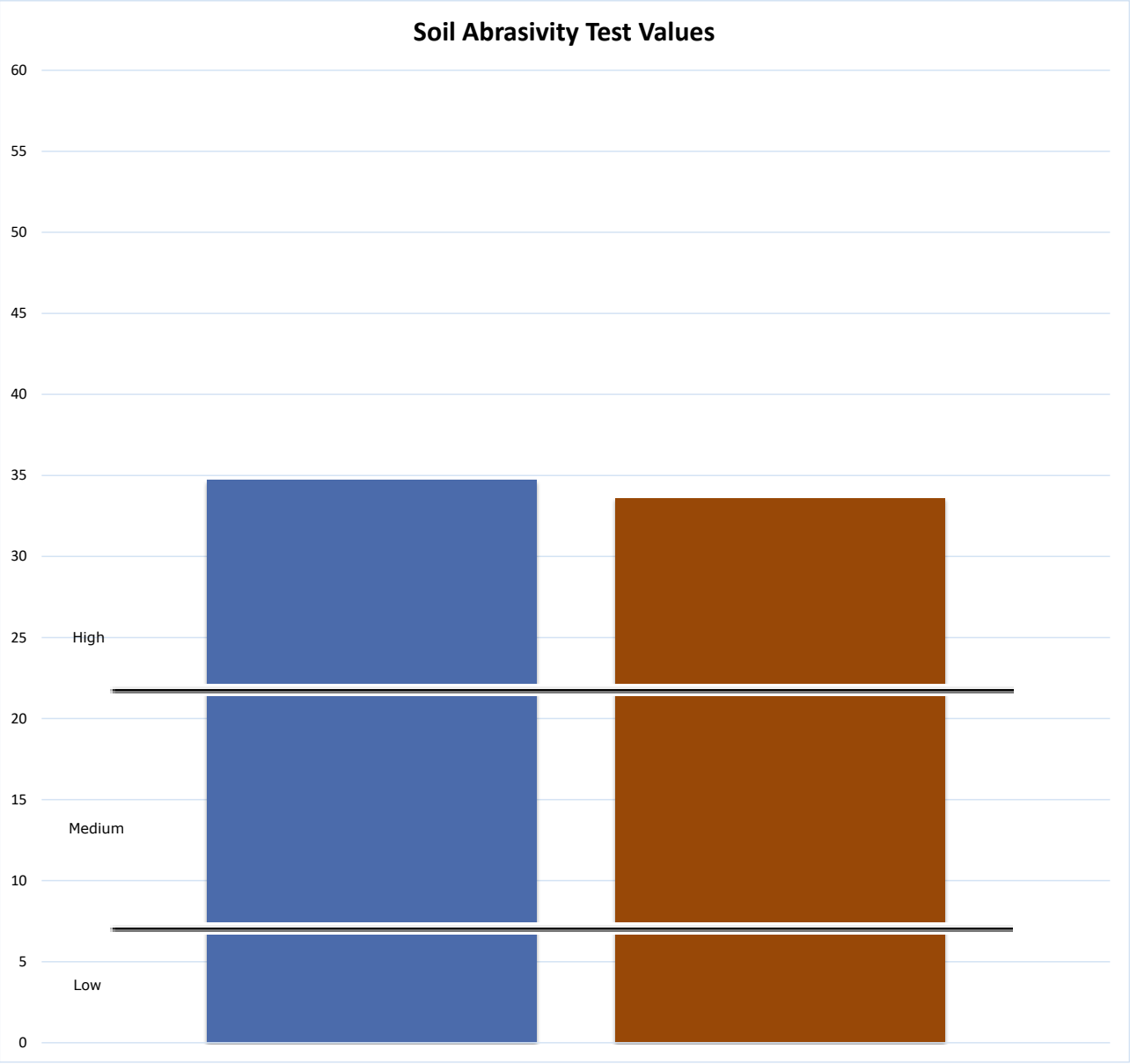
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-002
Depth, ft:	102.69-103.28

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-004
Depth, ft:	116.79-117.39

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	41.6
2	39.3
Average	40.4

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-004
Depth, ft:	116.79-117.39

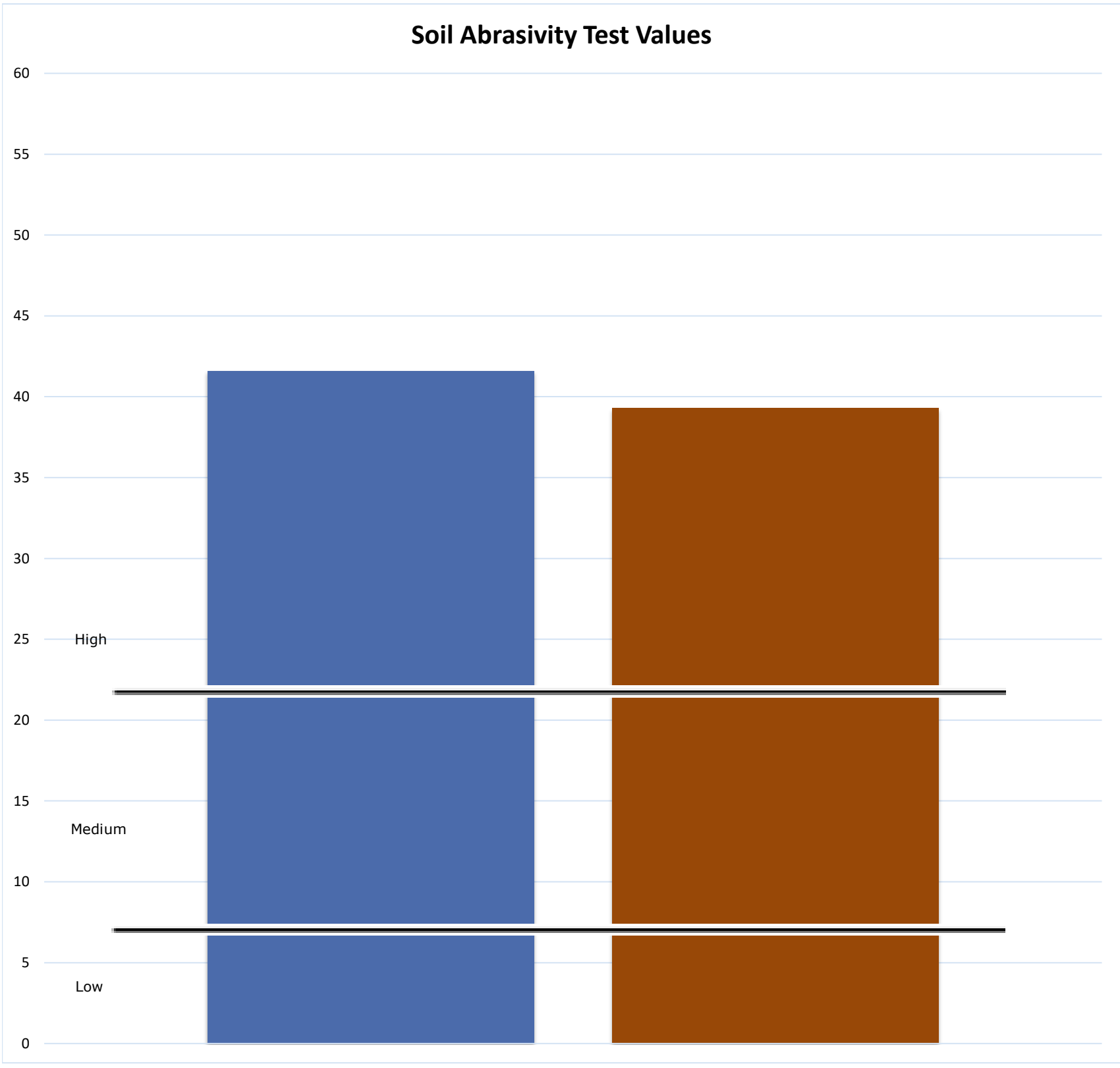
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-004
Depth, ft:	116.79-117.39

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.

The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-006
Depth, ft:	136.88-137.43

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	32.8
2	31.4
Average	32.1

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-006
Depth, ft:	136.88-137.43

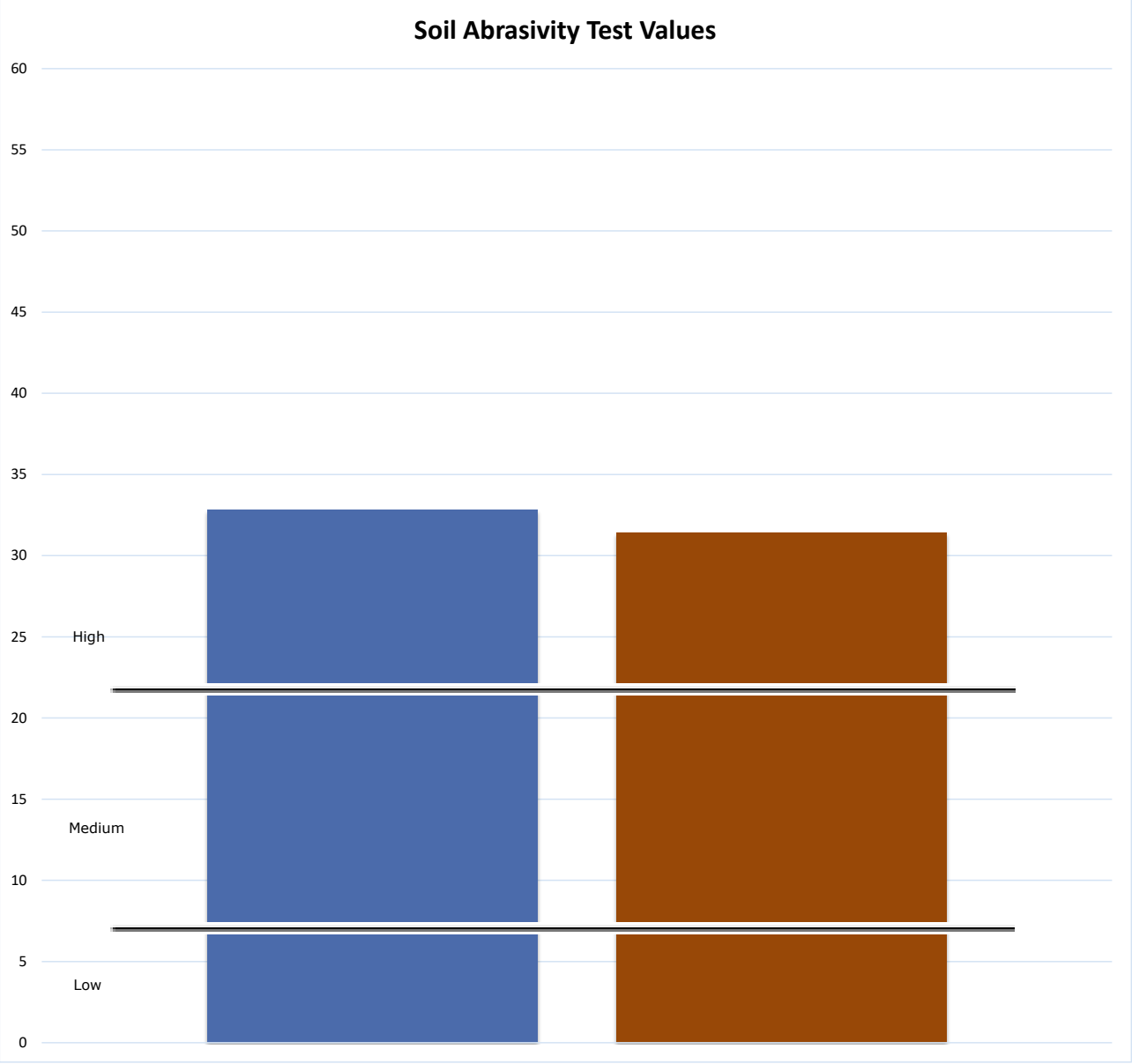
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-006
Depth, ft:	136.88-137.43

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-009
Depth, ft:	167.49-168.11

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	31.6
2	28.6
Average	30.1

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-009
Depth, ft:	167.49-168.11

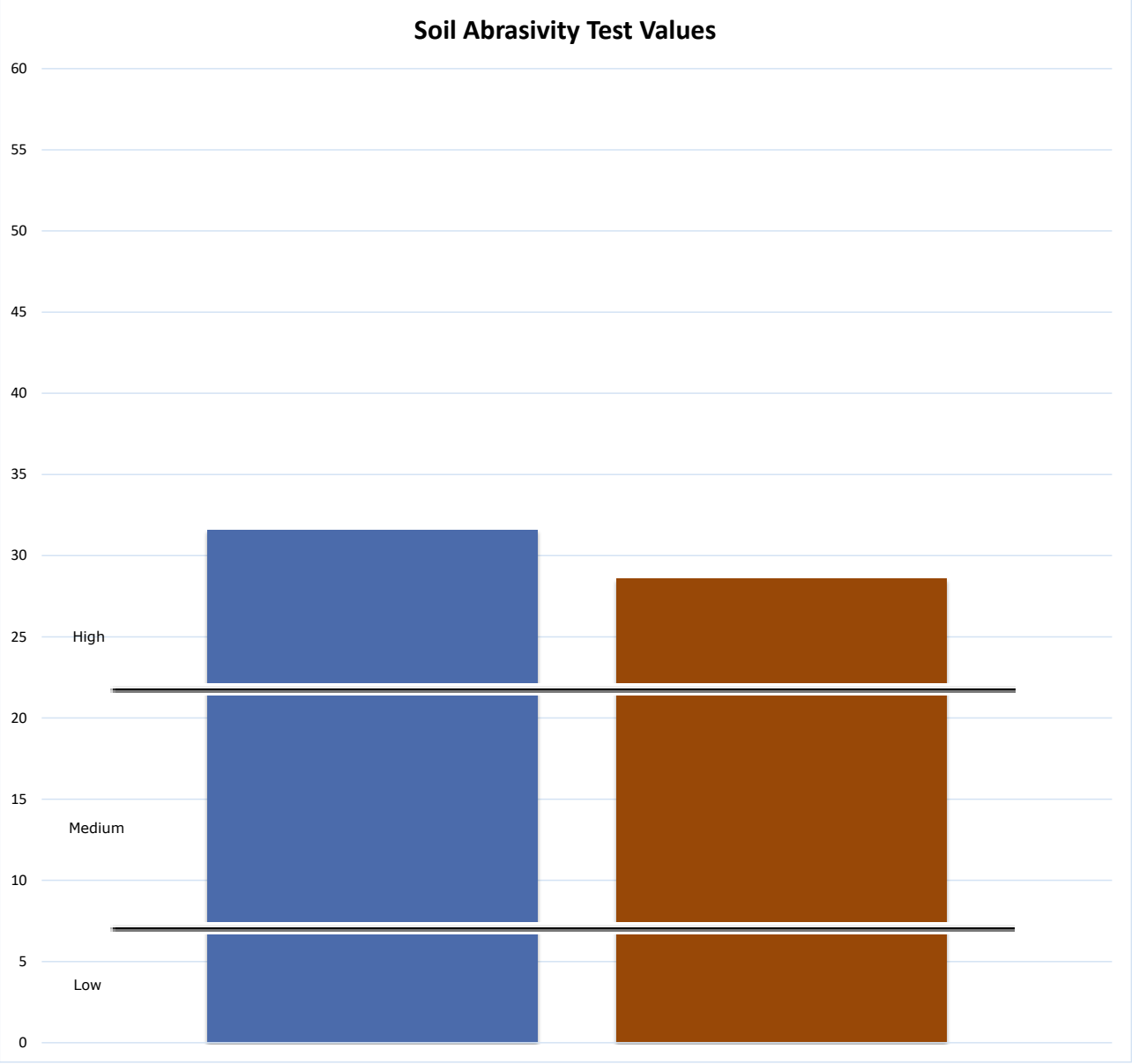
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-009
Depth, ft:	167.49-168.11

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-011
Depth, ft:	201.44-202.00

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	16.1
2	17.1
Average	16.6

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-011
Depth, ft:	201.44-202.00

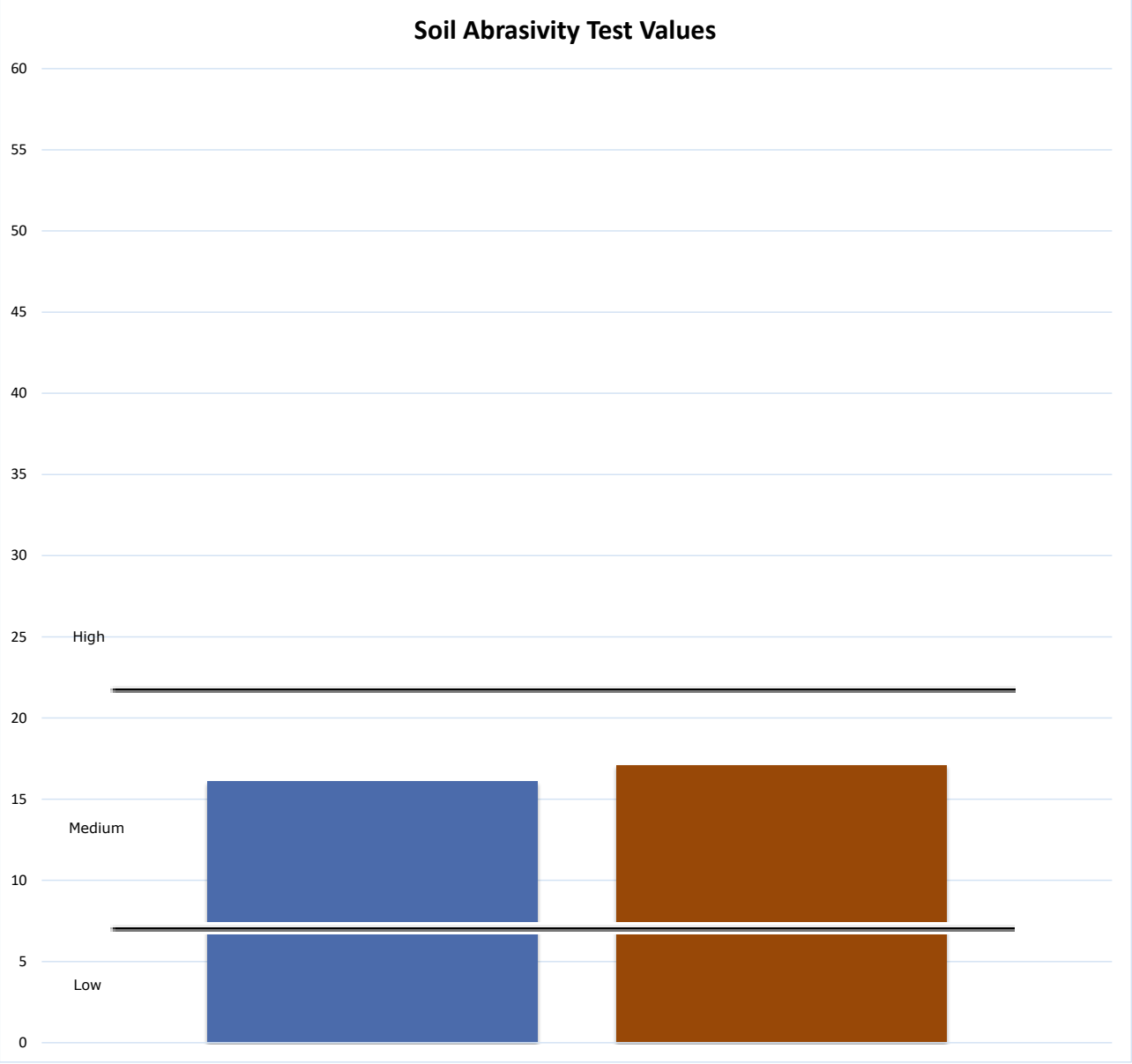
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-011
Depth, ft:	201.44-202.00

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-012
Depth, ft:	210.20-210.73

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	29.3
2	27.6
Average	28.4

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-012
Depth, ft:	210.20-210.73

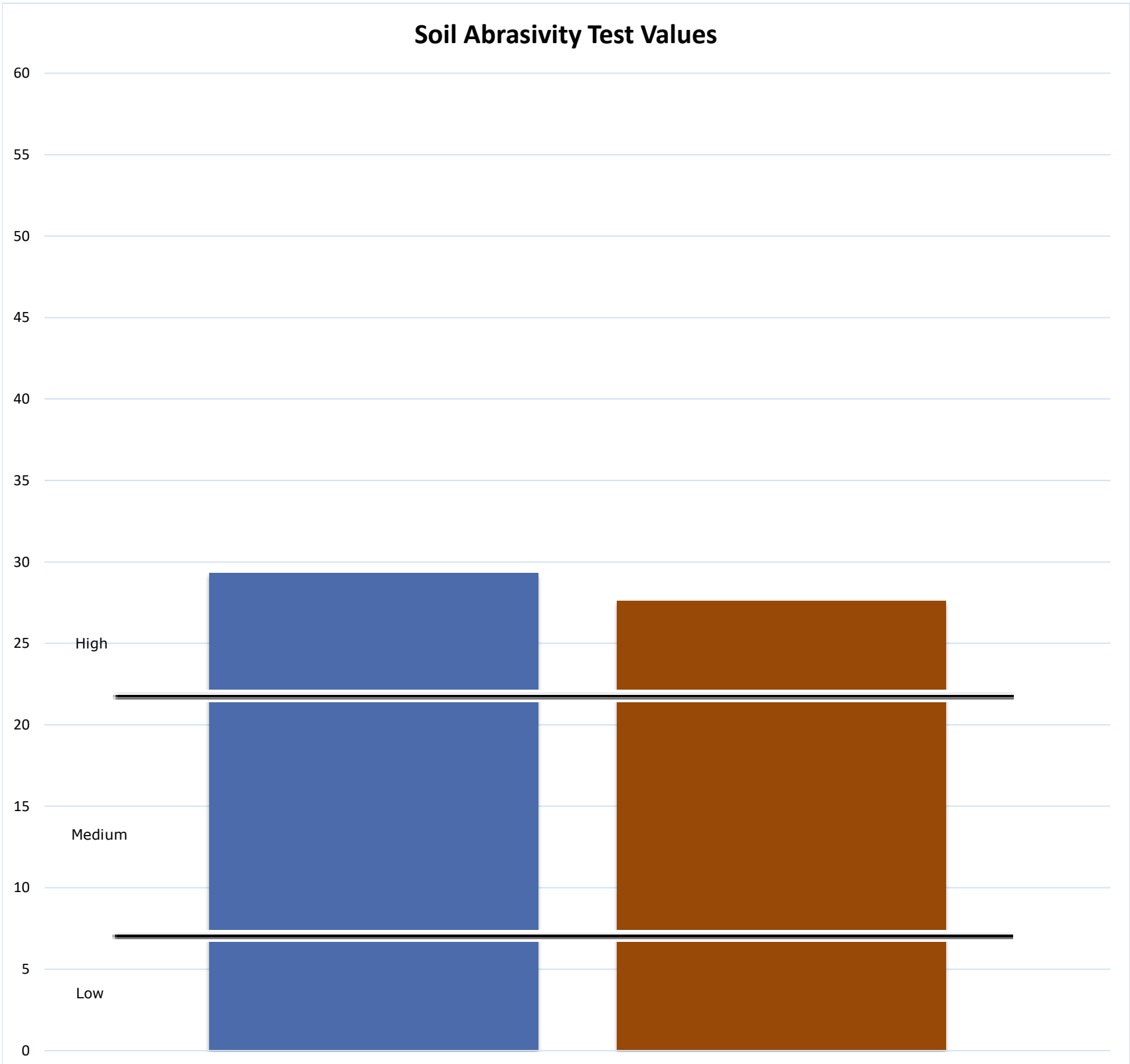
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-012
Depth, ft:	210.20-210.73

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-013
Depth, ft:	220.37-220.93

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	0.8
2	0.4
Average	0.6

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-013
Depth, ft:	220.37-220.93

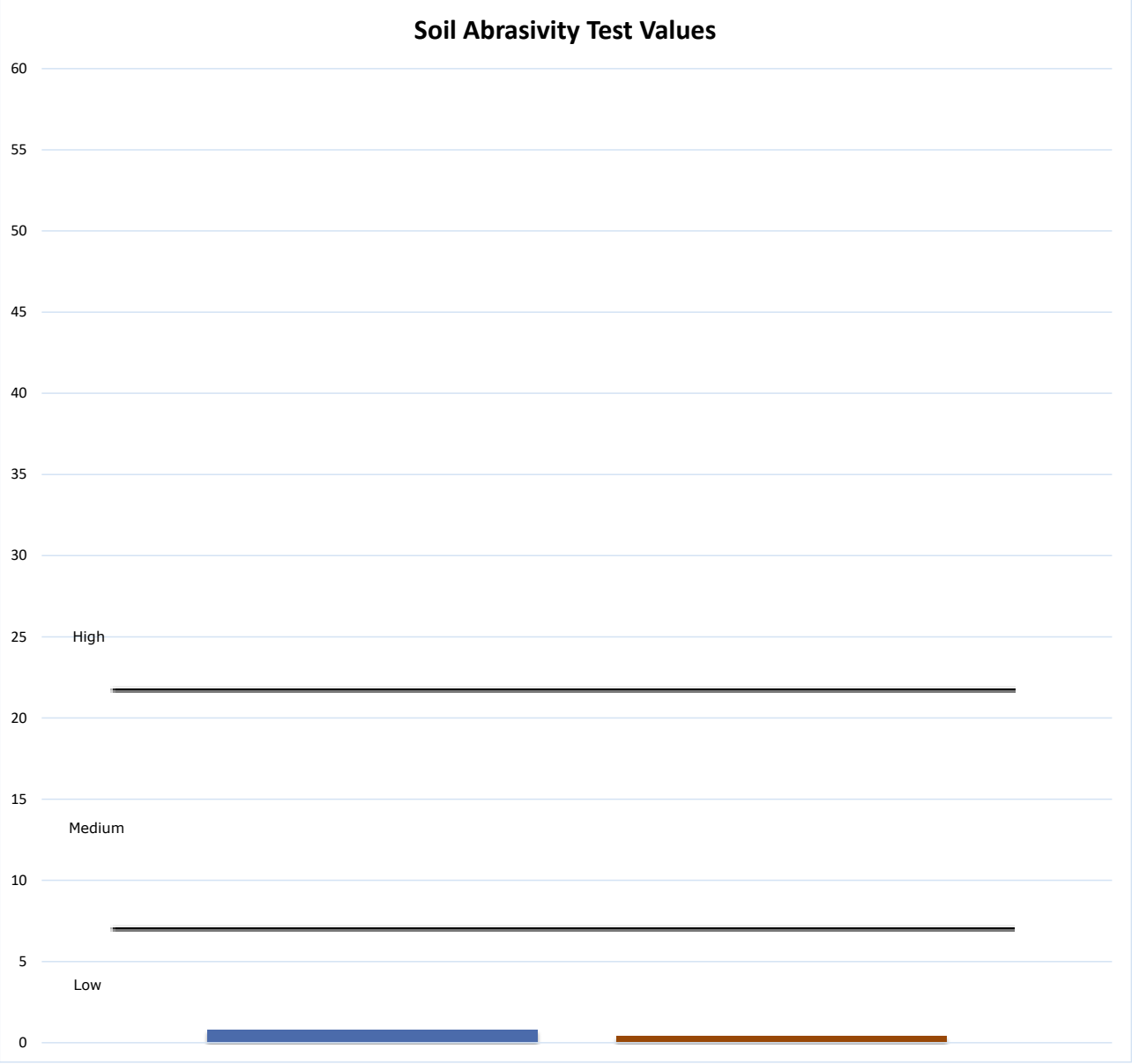
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-013
Depth, ft:	220.37-220.93

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-015
Depth, ft:	240.55-241.08

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	3.0
2	2.1
Average	2.6

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-25
Sample ID:	LSB-015
Depth, ft:	240.55-241.08

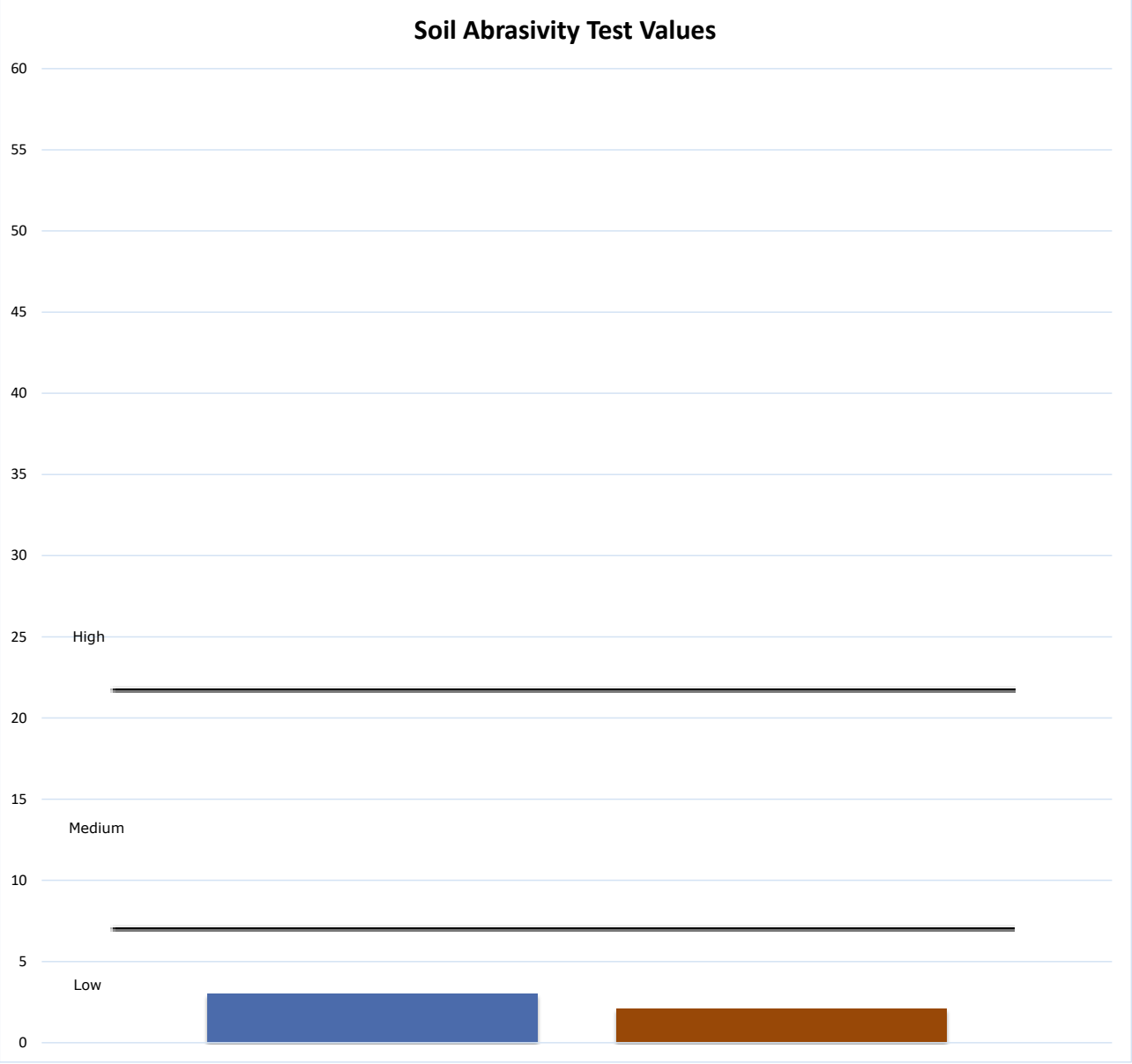
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-25
Sample ID:	LSB-015
Depth, ft:	240.55-241.08

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-007
Depth, ft:	172.28-172.83

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	19.7
2	17.5
Average	18.6

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

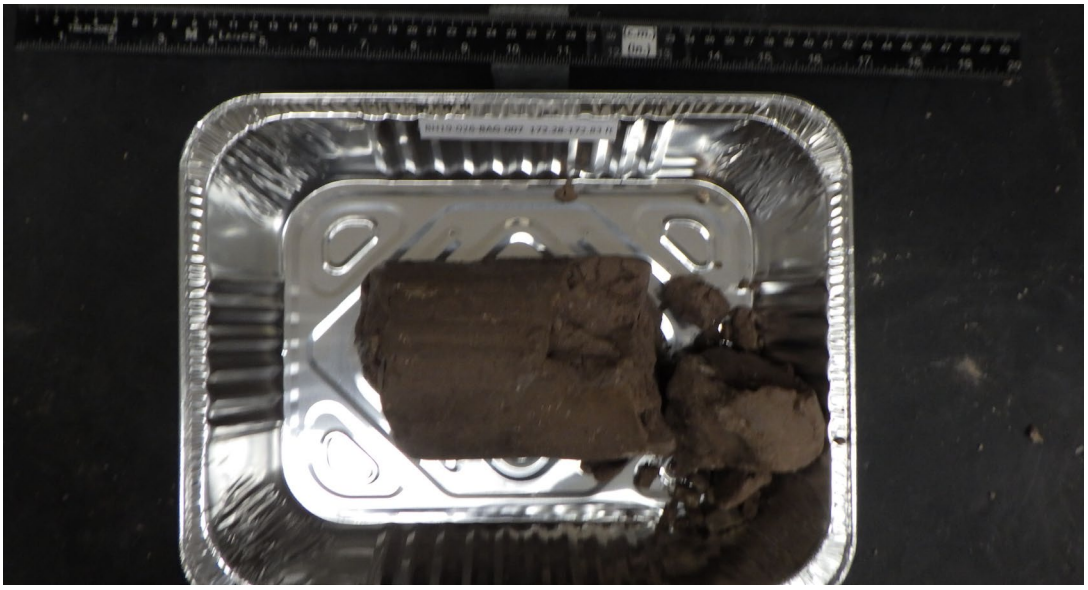
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-026
Sample ID:	LSB-007
Depth, ft:	172.28-172.83

Soil Abrasivity Test - Sample As-Received

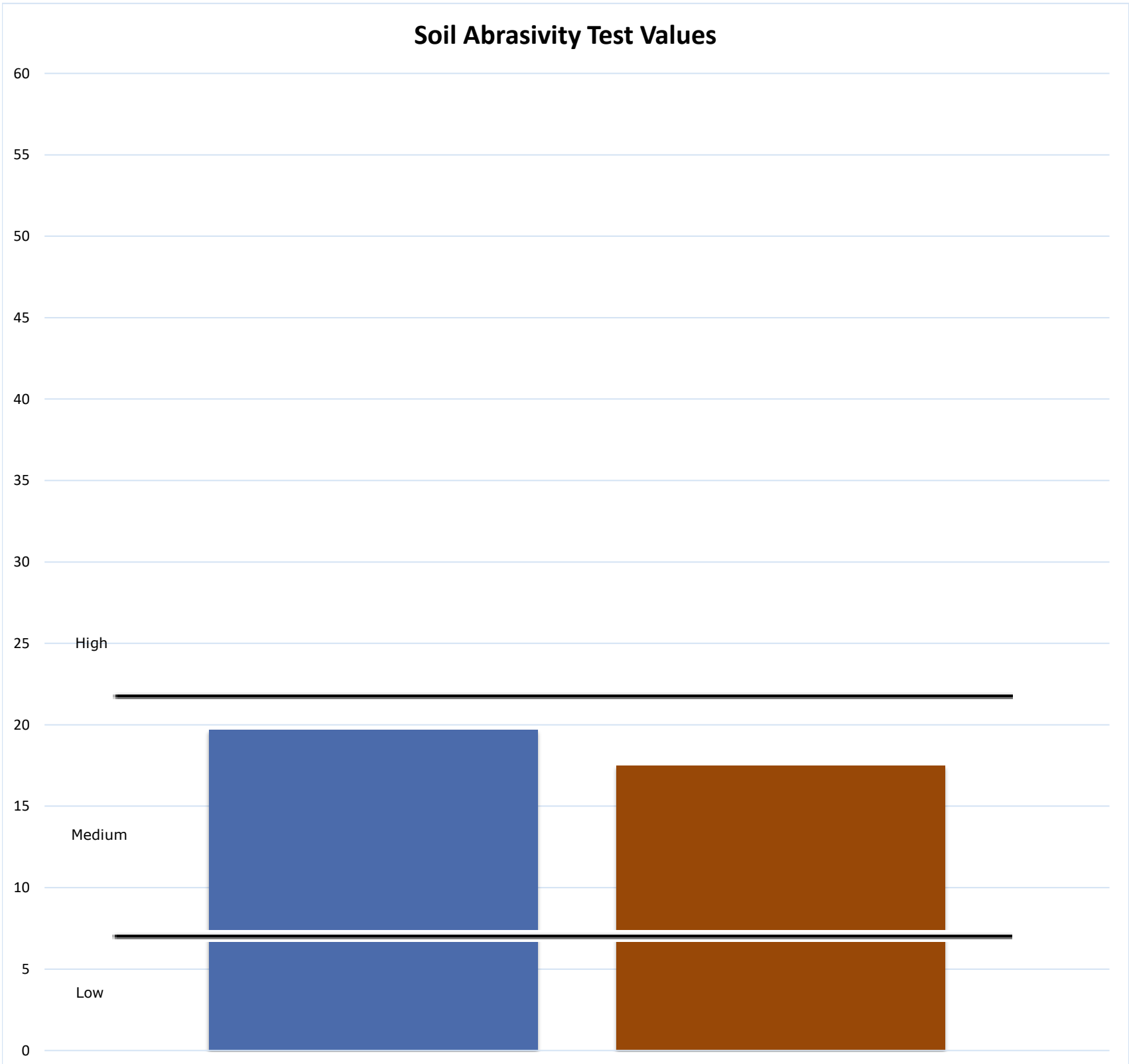


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-007
Depth, ft:	172.28-172.83

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-009
Depth, ft:	191.37-191.96

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.3
2	1.1
Average	1.2

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-026
Sample ID:	LSB-009
Depth, ft:	191.37-191.96

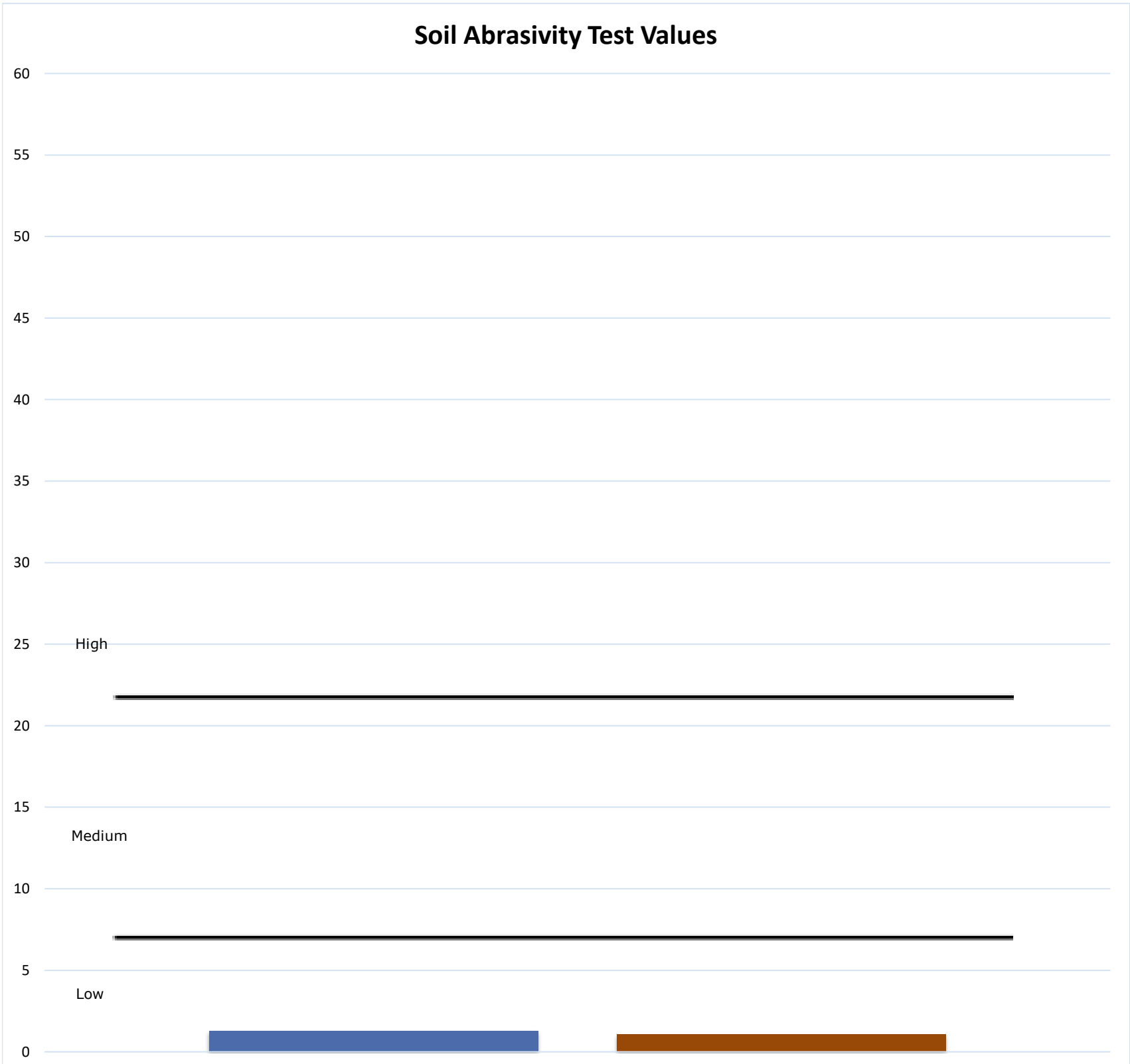
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-009
Depth, ft:	191.37-191.96

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-011
Depth, ft:	209.94-210.49

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	13.3
2	11.8
Average	12.5

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-026
Sample ID:	LSB-011
Depth, ft:	209.94-210.49

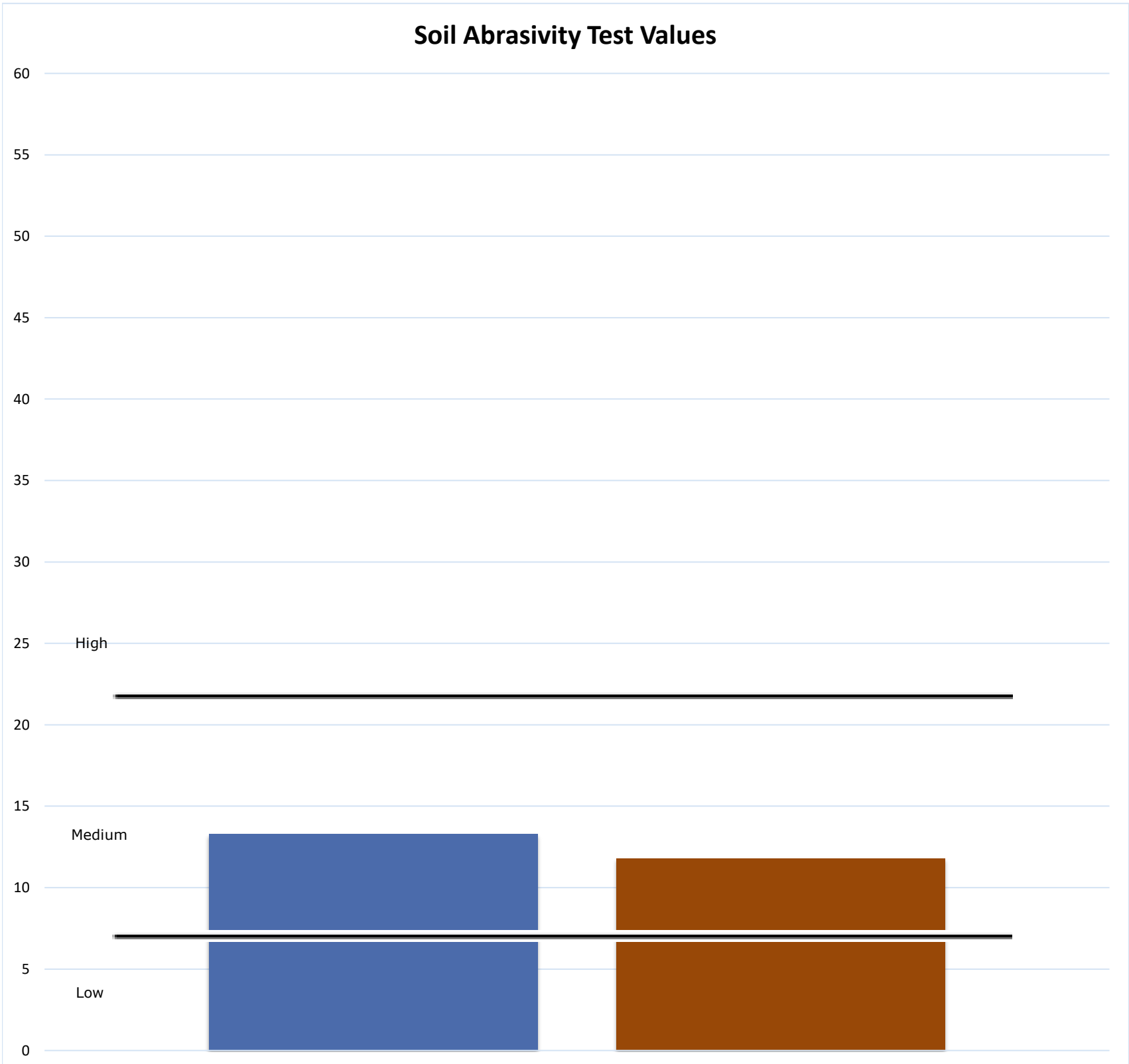
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	2/14/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-011
Depth, ft:	209.94-210.49

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.

The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-002
Depth, ft:	116.17-116.67

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	21.9
2	20.8
Average	21.3

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

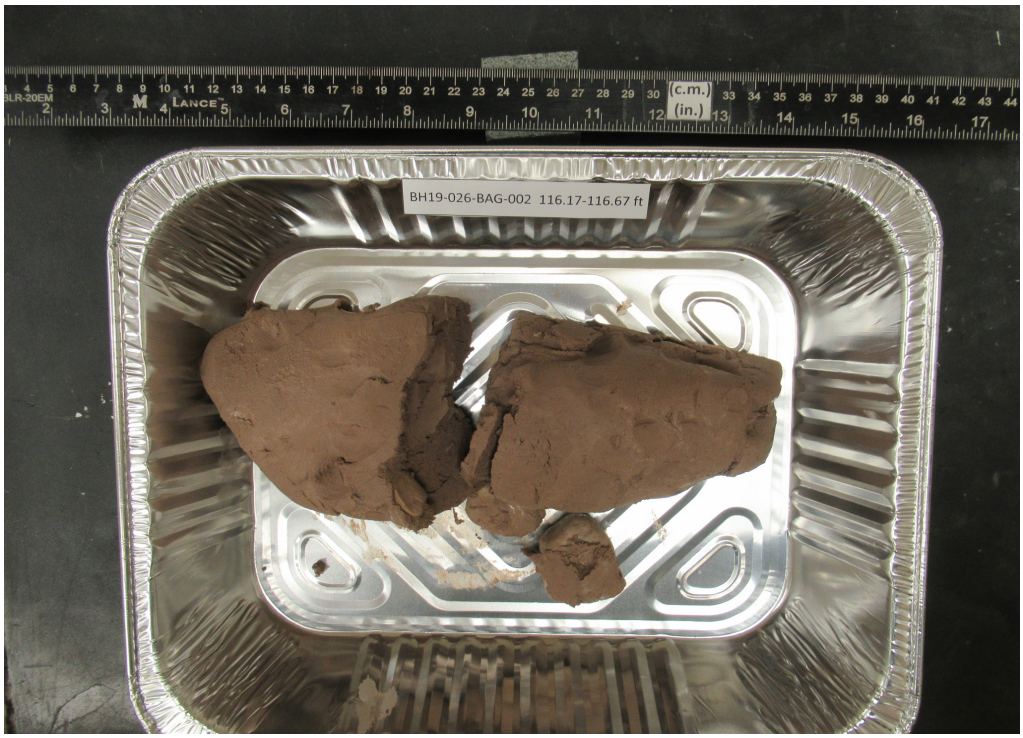
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-026
Sample ID:	LSB-002
Depth, ft:	116.17-116.67

Soil Abrasivity Test - Sample As-Received

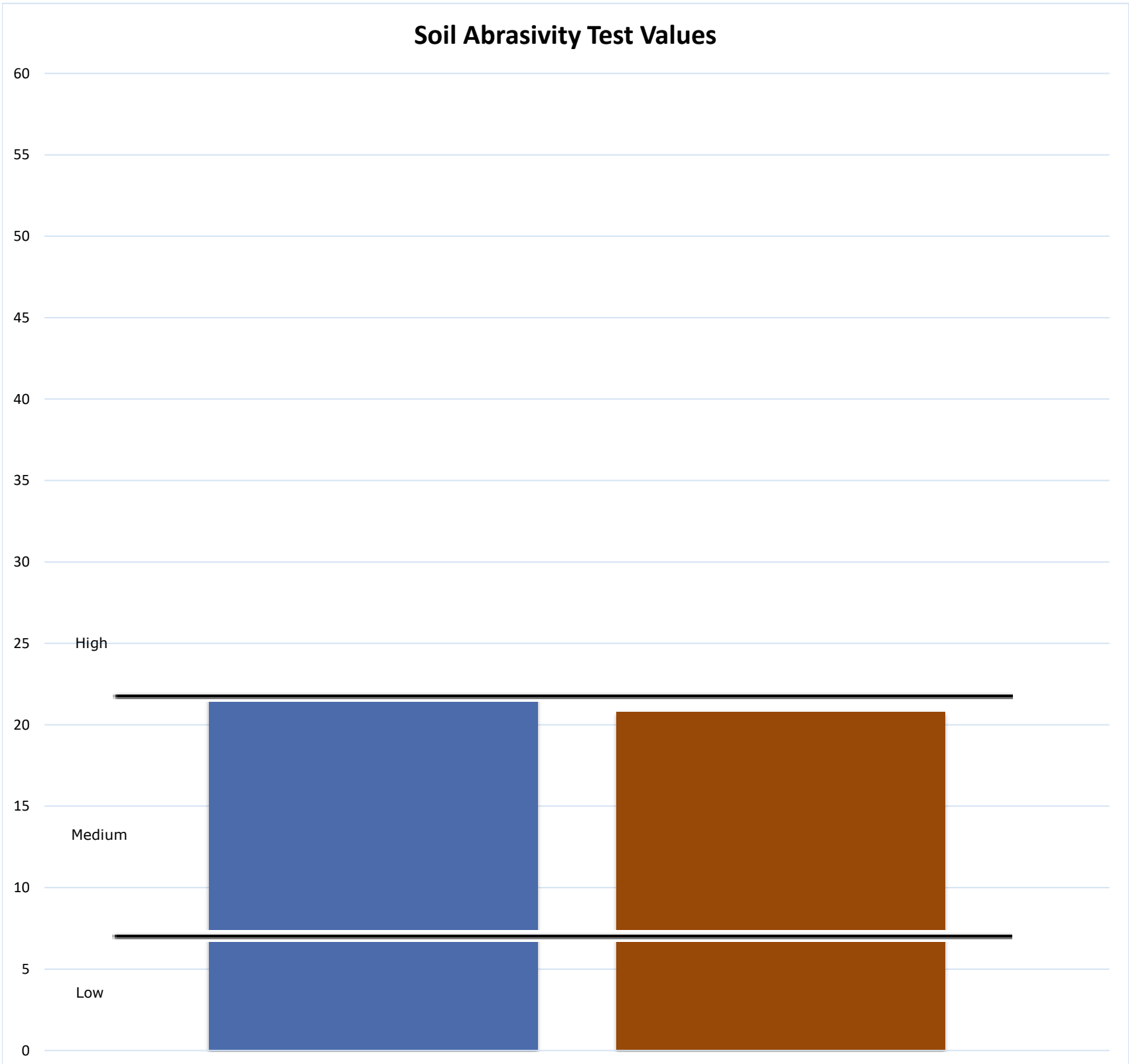


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-002
Depth, ft:	116.17-116.67

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH-19-26
Sample ID:	LSB-004
Depth, ft:	141.83-142.45

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	11.1
2	11.6
Average	11.4

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

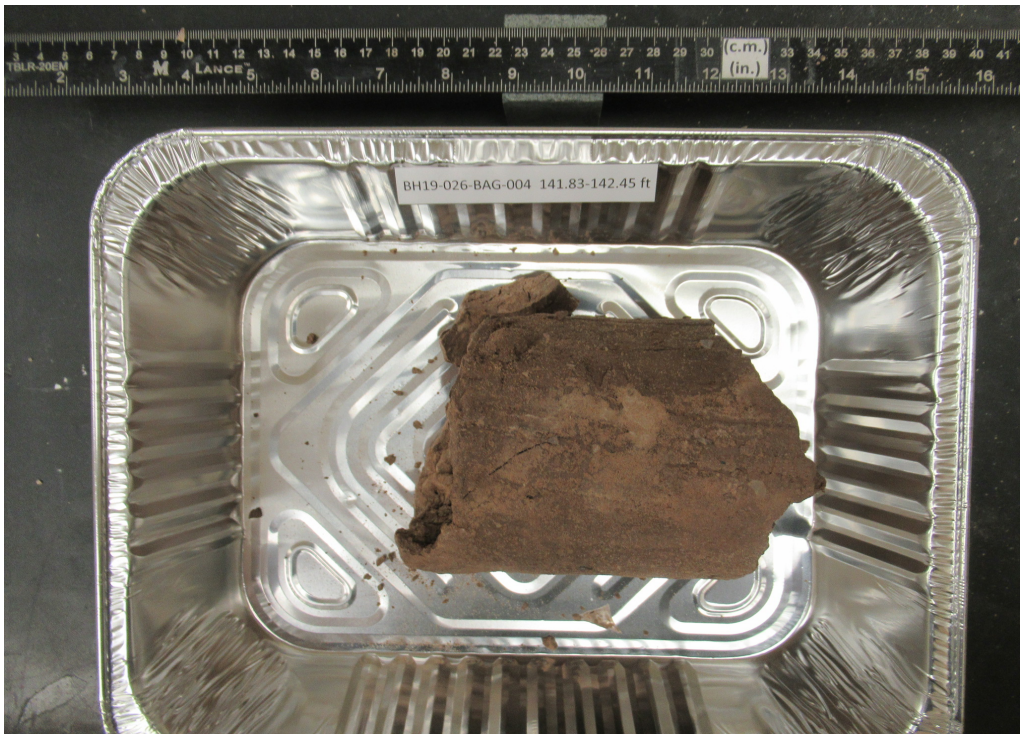
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH-19-26
Sample ID:	LSB-004
Depth, ft:	141.83-142.45

Soil Abrasivity Test - Sample As-Received

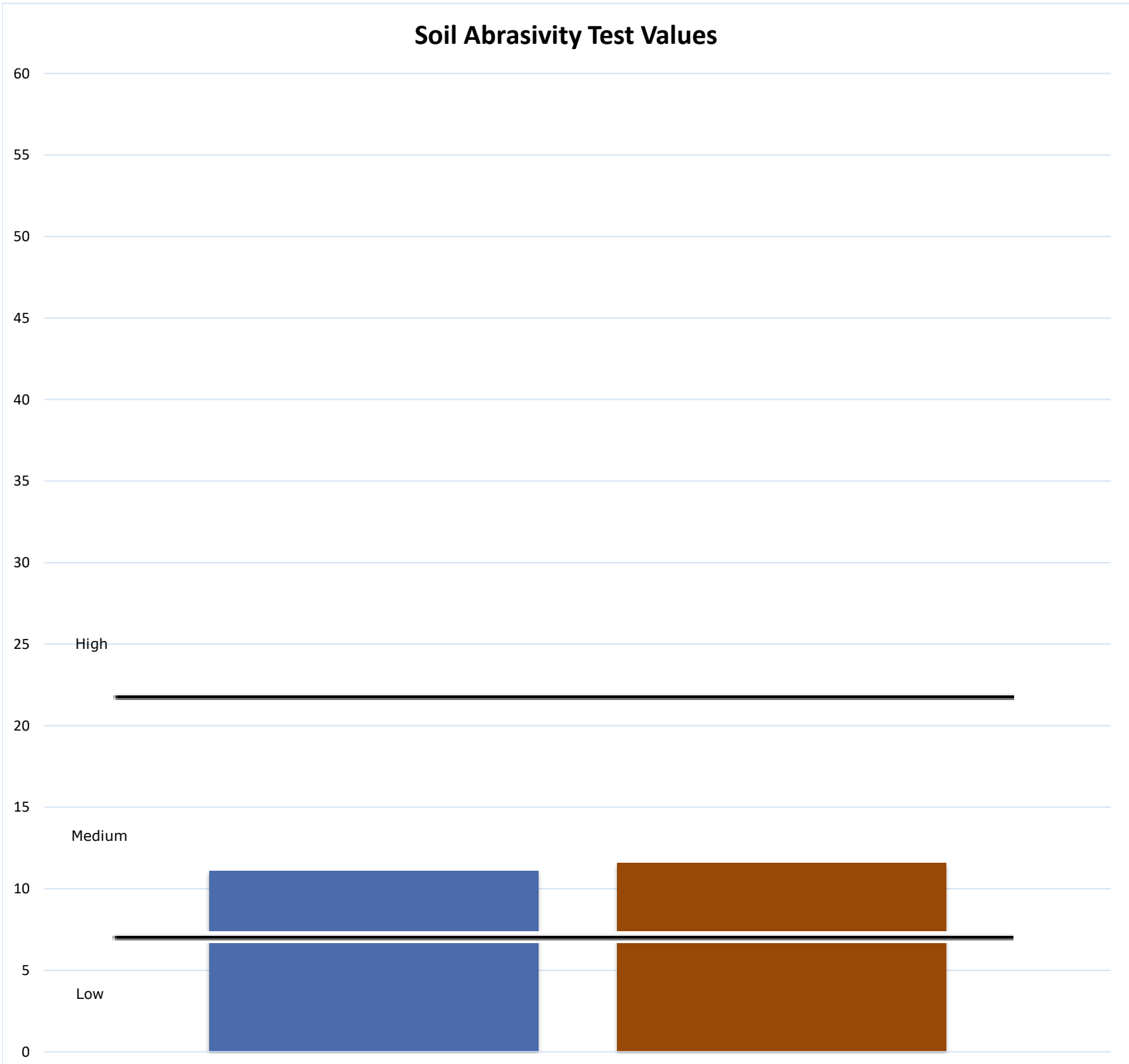


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH-19-26
Sample ID:	LSB-004
Depth, ft:	141.83-142.45

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-006
Depth, ft:	159.12-159.68

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	7.0
2	8.1
Average	7.6

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-026
Sample ID:	LSB-006
Depth, ft:	159.12-159.68

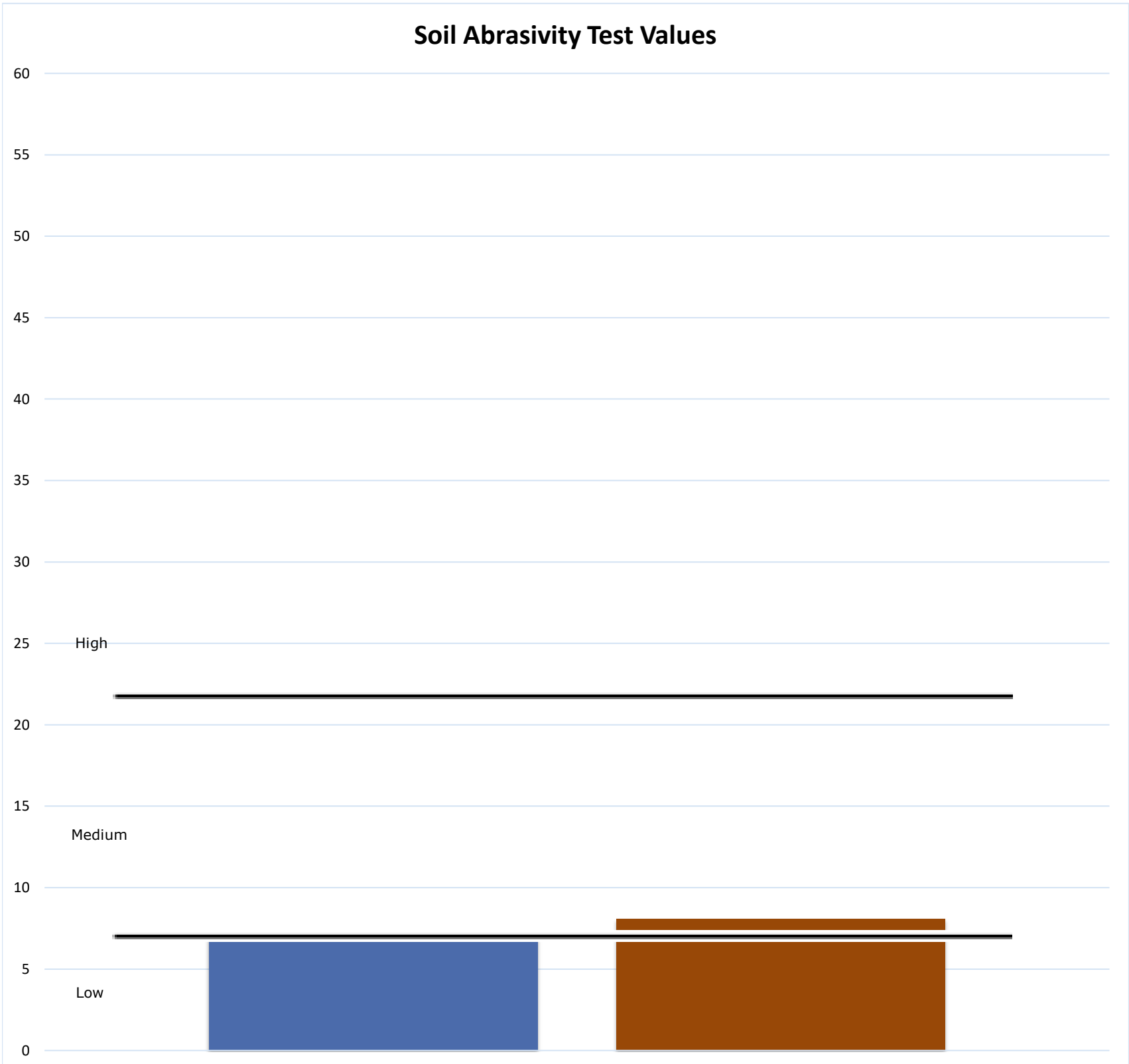
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/13/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-026
Sample ID:	LSB-006
Depth, ft:	159.12-159.68

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-26
Sample ID:	LSB-013
Depth, ft:	228.02-228.54

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.7
2	1.2
Average	1.4

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

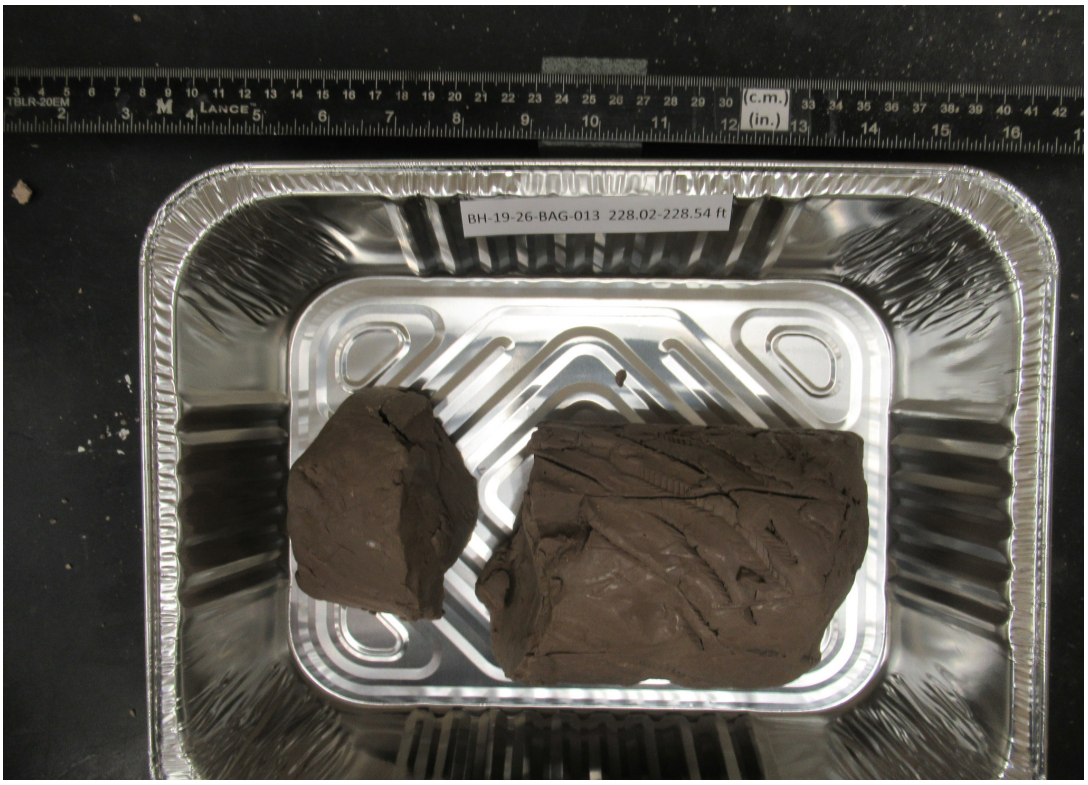
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-26
Sample ID:	LSB-013
Depth, ft:	228.02-228.54

Soil Abrasivity Test - Sample As-Received

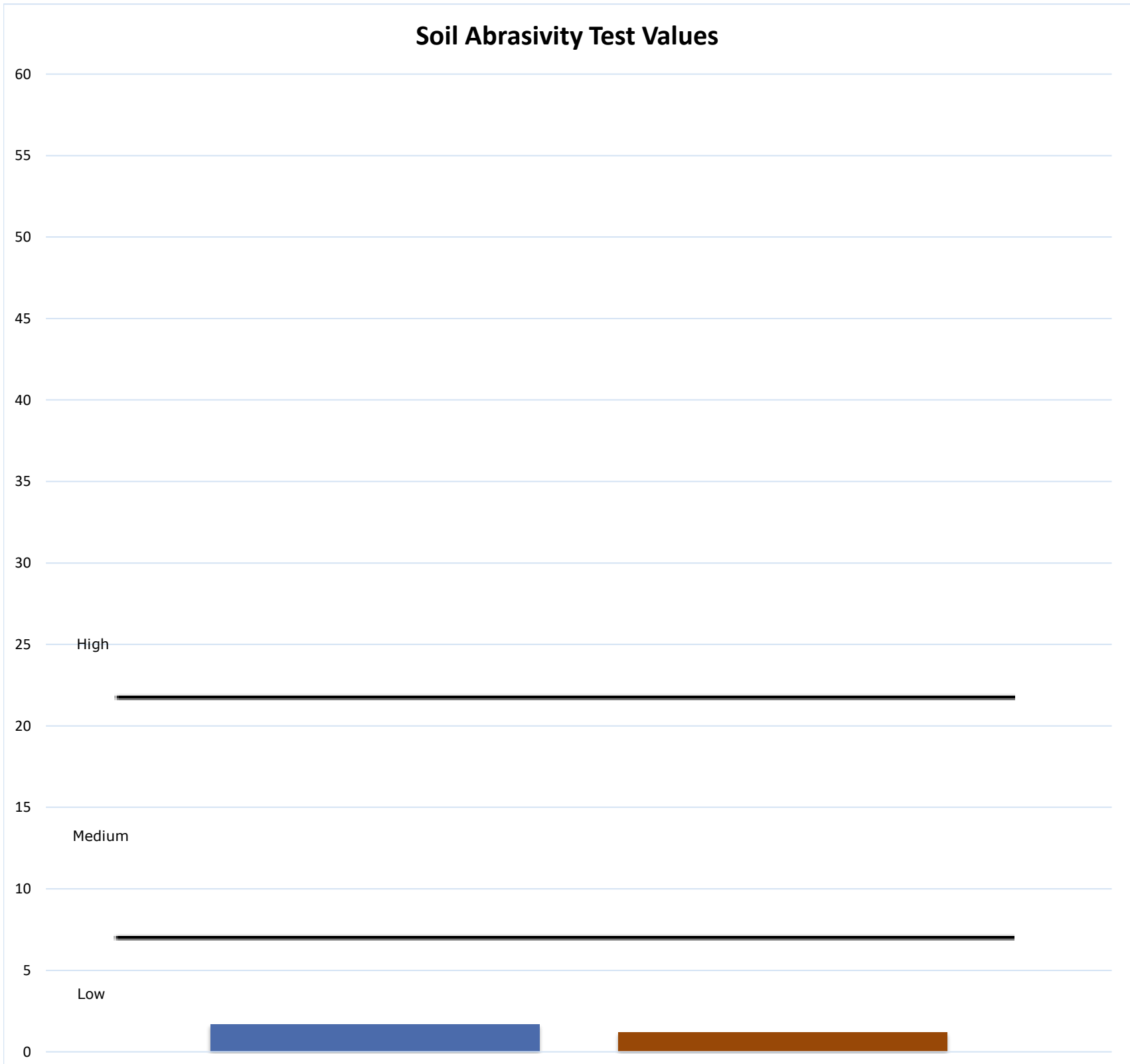


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-26
Sample ID:	LSB-013
Depth, ft:	228.02-228.54

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-26
Sample ID:	LSB-015
Depth, ft:	250.85-251.38

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	9.2
2	8.0
Average	8.6

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

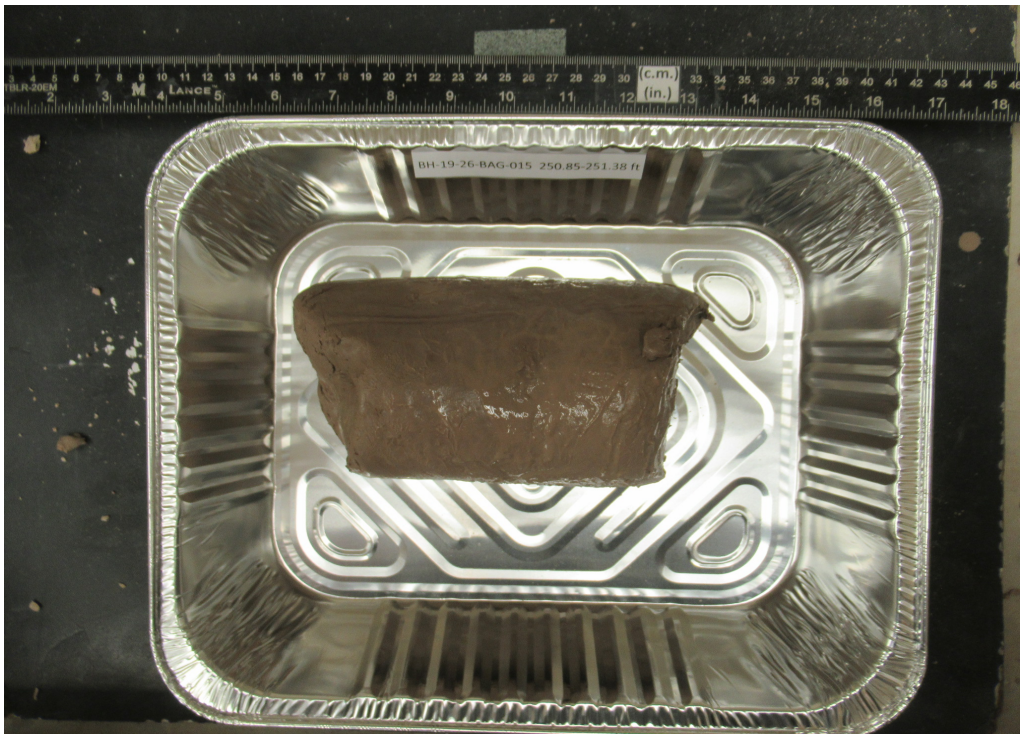
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-26
Sample ID:	LSB-015
Depth, ft:	250.85-251.38

Soil Abrasivity Test - Sample As-Received

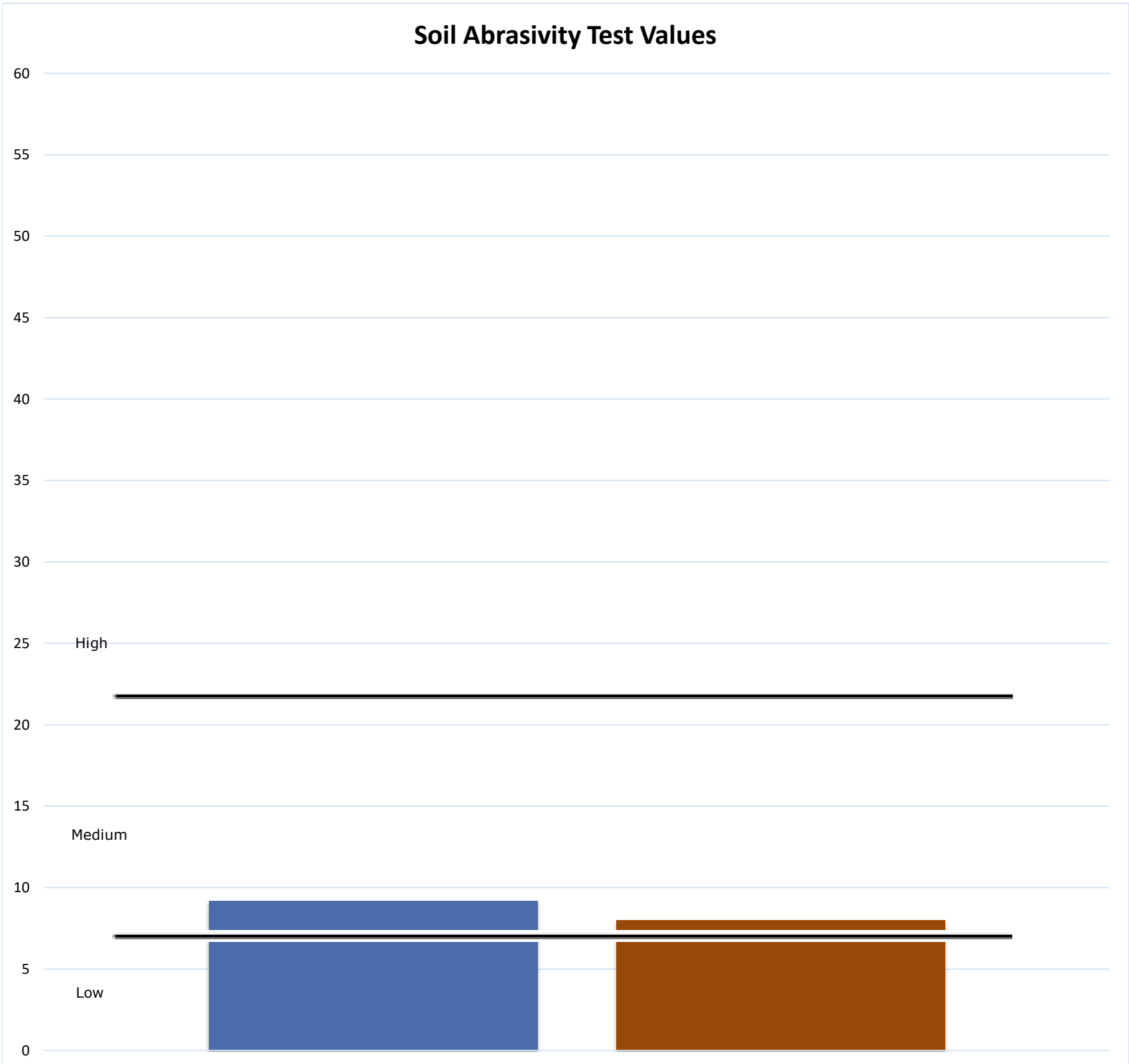


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-26
Sample ID:	LSB-015
Depth, ft:	250.85-251.38

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.

The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-26
Sample ID:	LSB-017
Depth, ft:	267.81-268.44

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	11.1
2	9.5
Average	10.3

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-26
Sample ID:	LSB-017
Depth, ft:	267.81-268.44

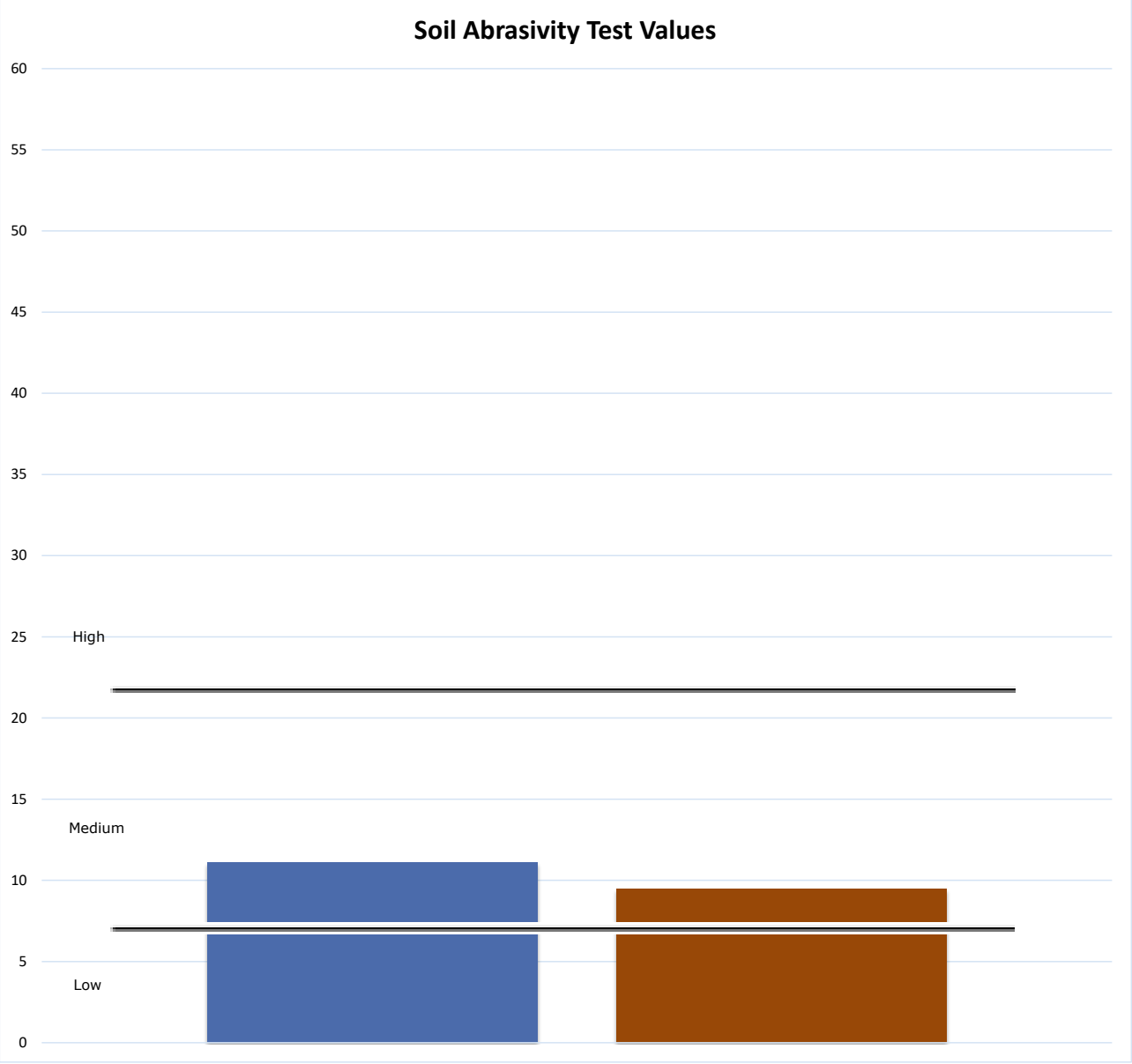
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-26
Sample ID:	LSB-017
Depth, ft:	267.81-268.44

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-001
Depth, ft:	120.31-120.89

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	15.9
2	16.3
Average	16.1

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

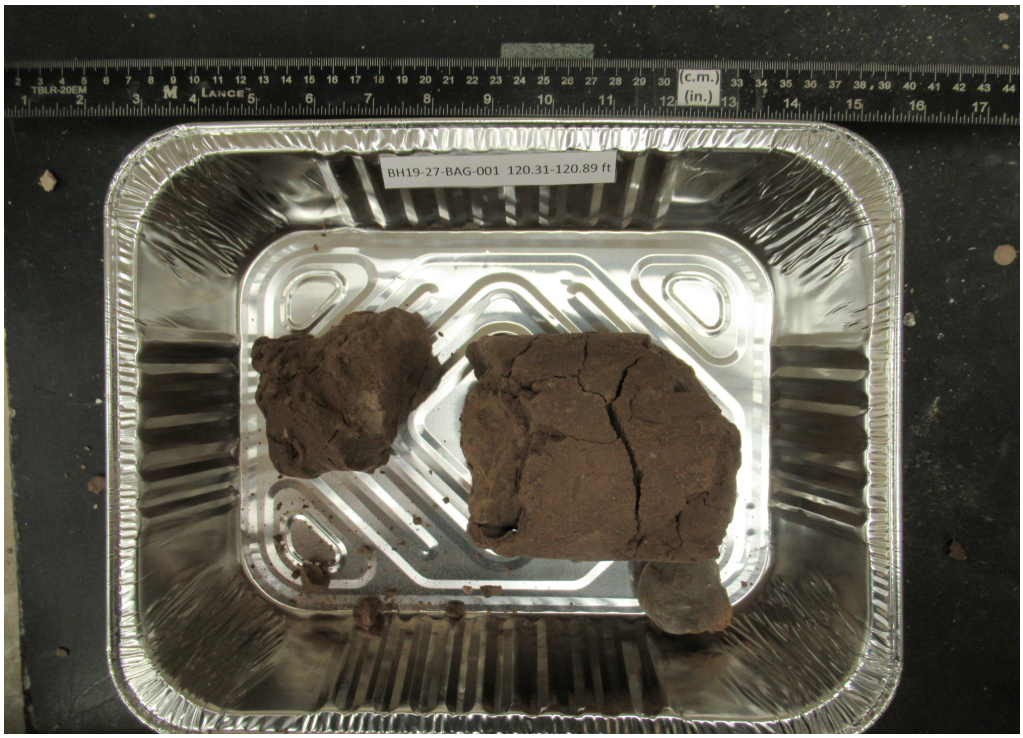
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-001
Depth, ft:	120.31-120.89

Soil Abrasivity Test - Sample As-Received

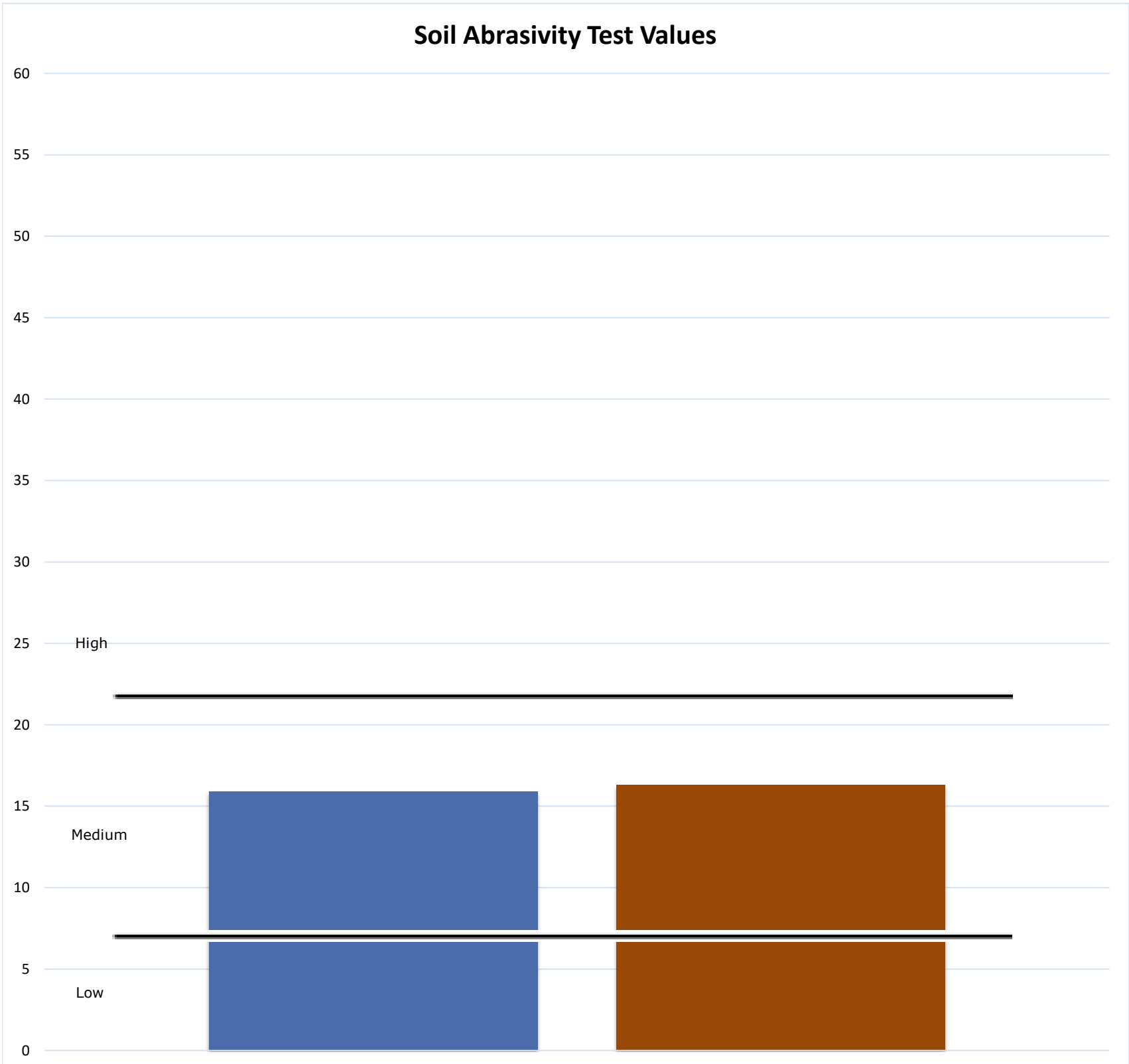


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-001
Depth, ft:	120.31-120.89

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-008
Depth, ft:	195.37-195.87

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	12.2
2	13.9
Average	13.0

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-008
Depth, ft:	195.37-195.87

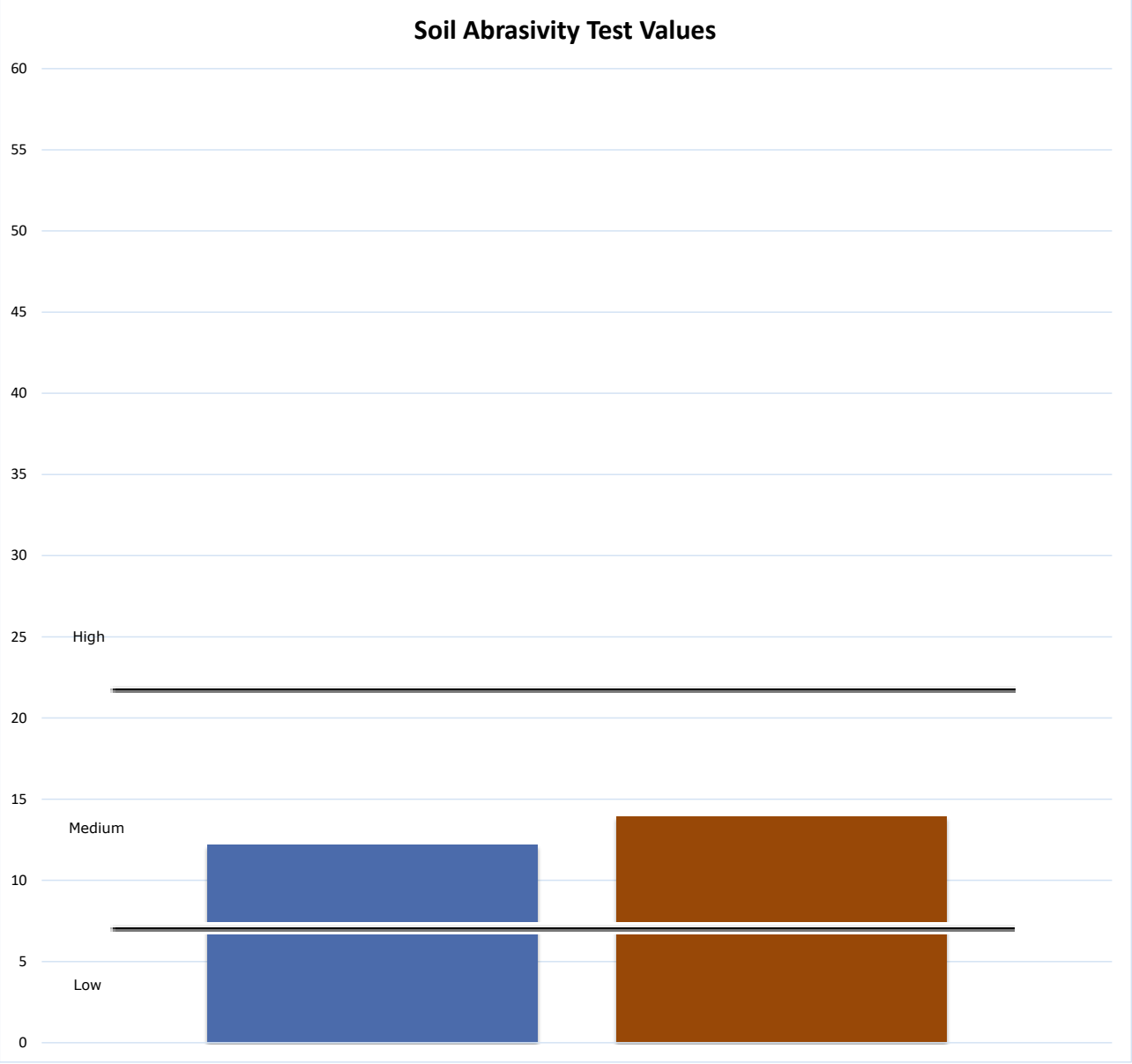
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-008
Depth, ft:	195.37-195.87

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-009
Depth, ft:	198.33-198.82

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	15.2
2	14.7
Average	14.9

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-009
Depth, ft:	198.33-198.82

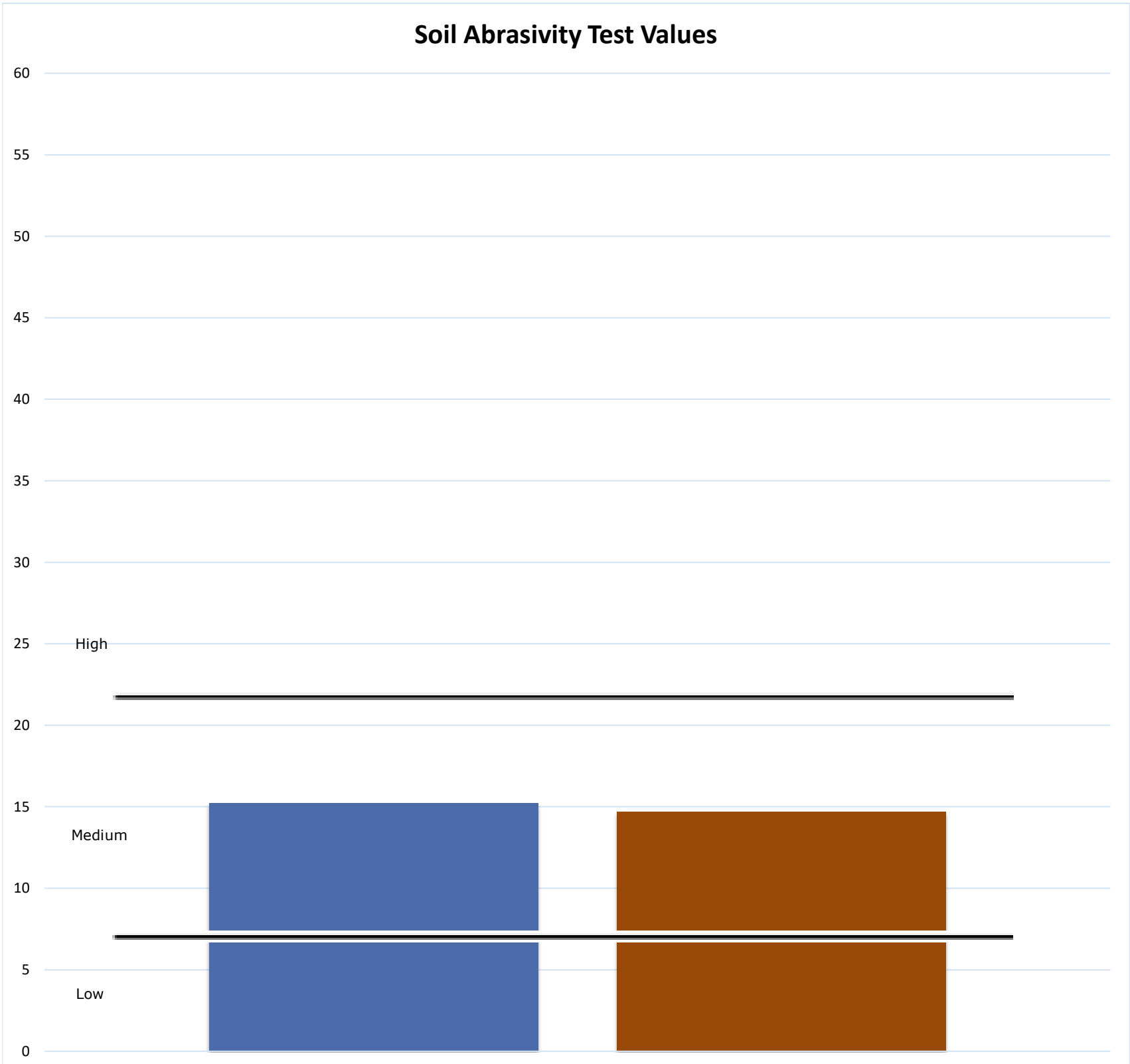
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-009
Depth, ft:	198.33-198.82

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/29/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-011
Depth, ft:	217.06-217.49

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	14.5
2	16.0
Average	15.3

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-011
Depth, ft:	217.06-217.49

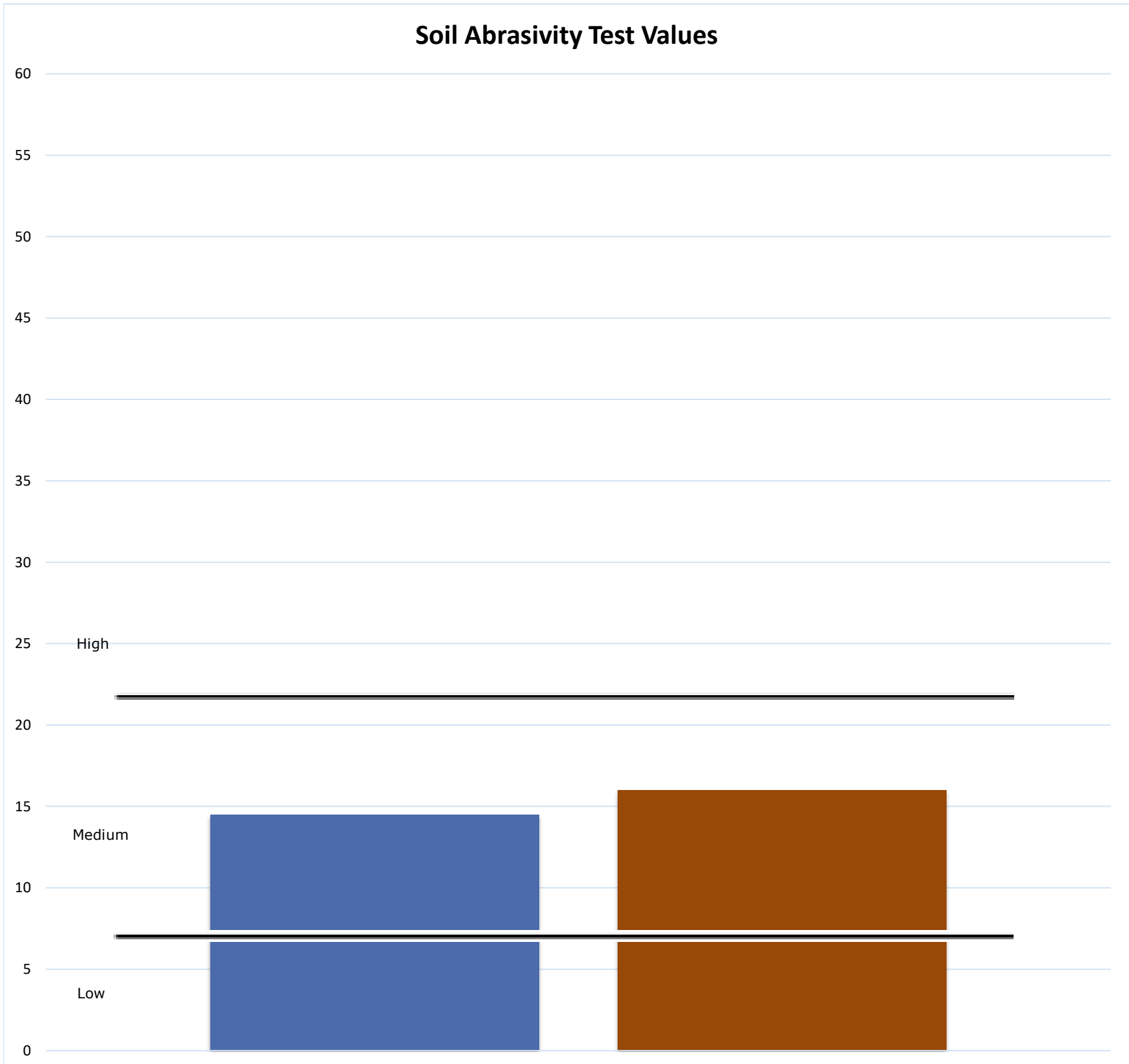
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43859
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-011
Depth, ft:	217.06-217.49

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-015
Depth, ft:	252.79-252.95

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.8
2	1.1
Average	1.4

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-015
Depth, ft:	252.79-252.95

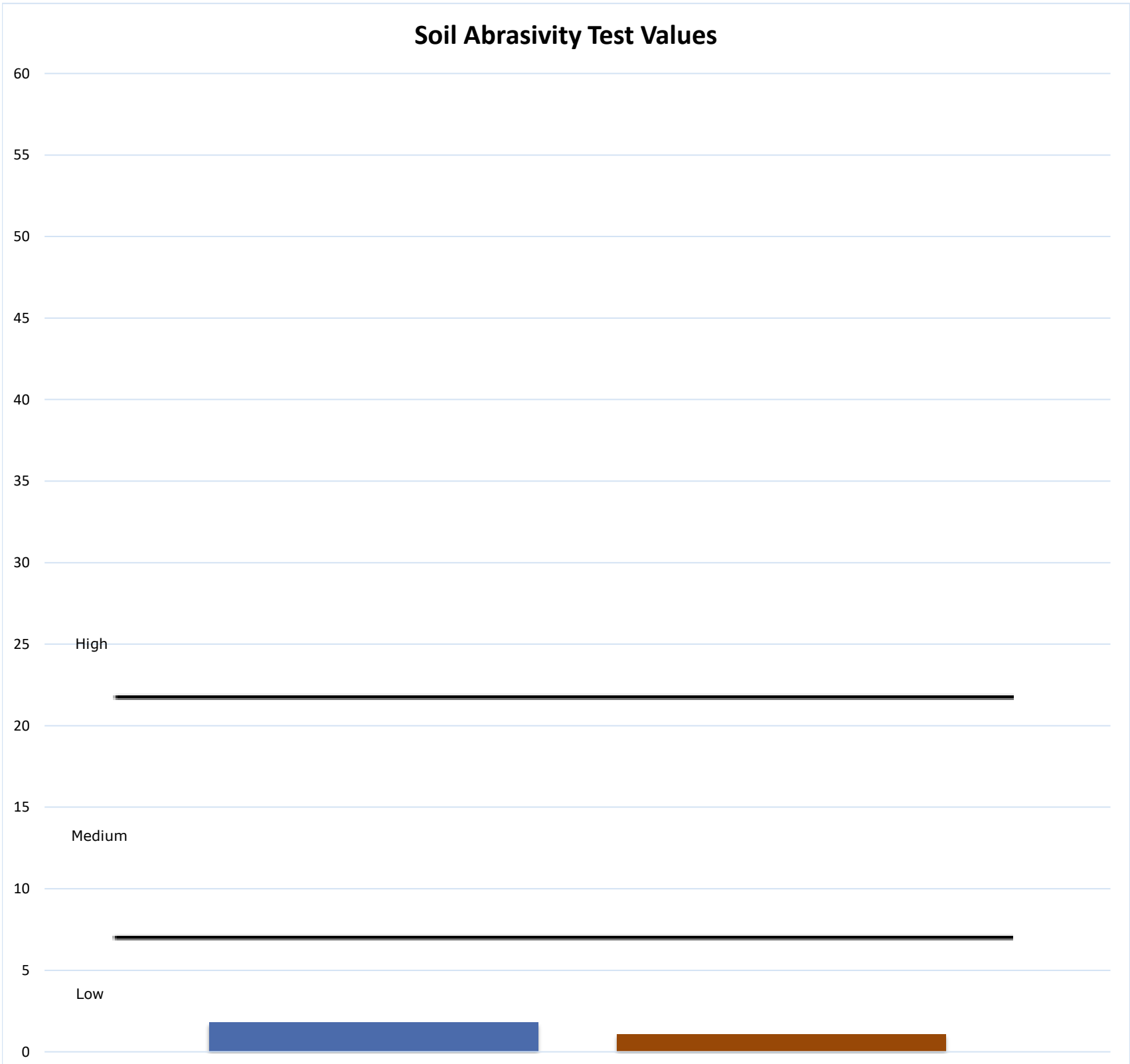
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-015
Depth, ft:	252.79-252.95

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-017
Depth, ft:	271.09-271.62

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	6.7
2	5.3
Average	6.0

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

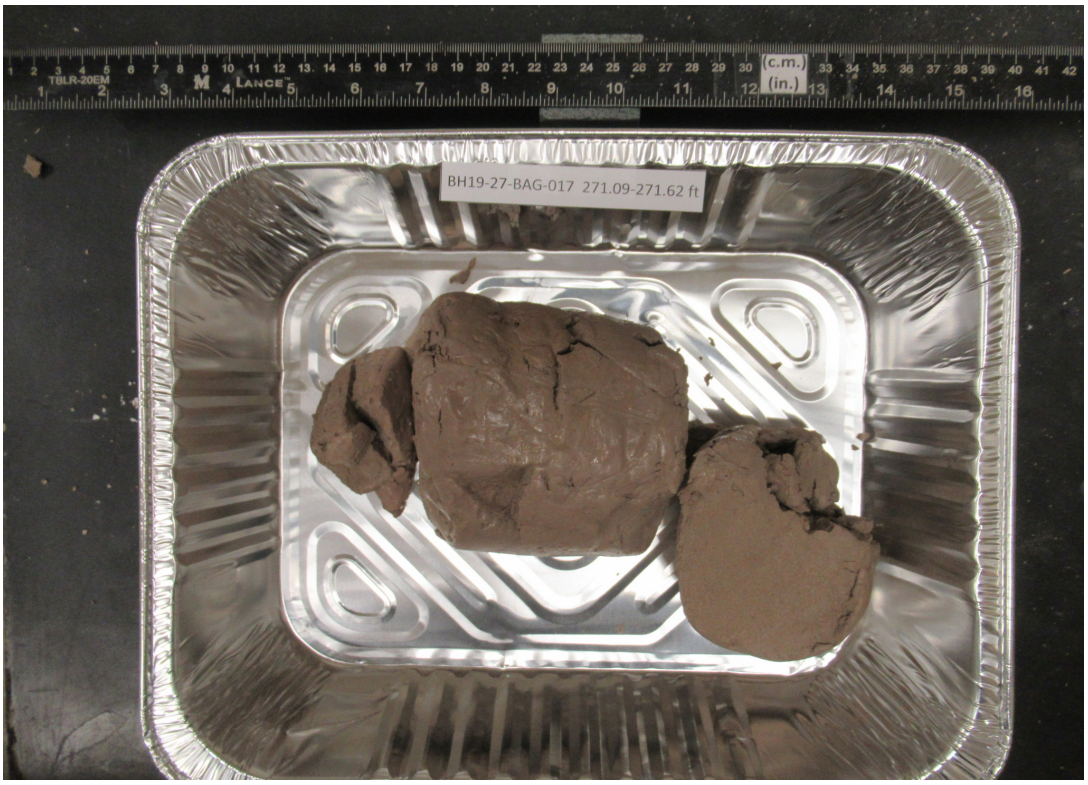
Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-017
Depth, ft:	271.09-271.62

Soil Abrasivity Test - Sample As-Received

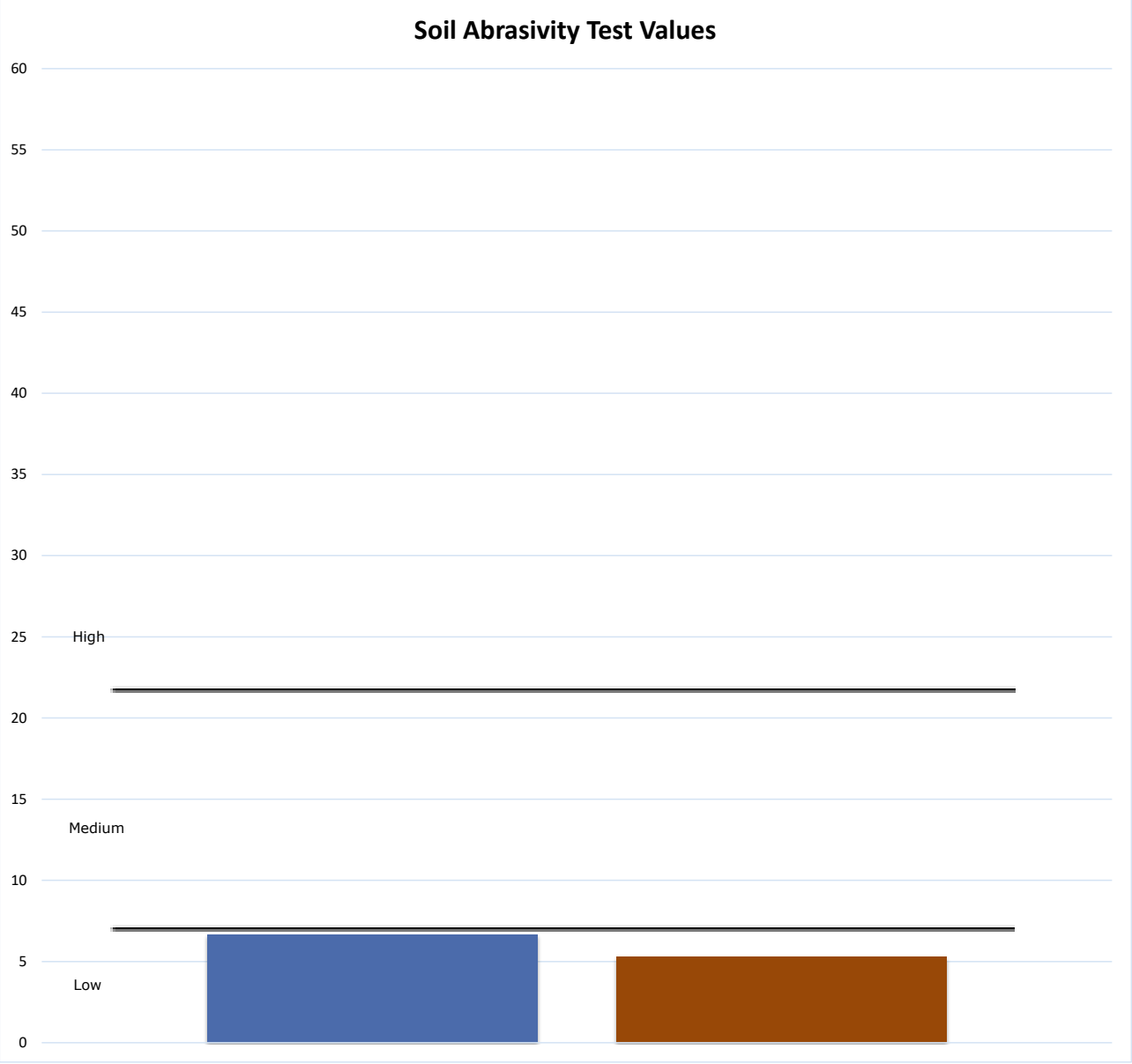


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-017
Depth, ft:	271.09-271.62

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-003
Depth, ft:	144.23-144.75

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	22.9
2	24.1
Average	23.5

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

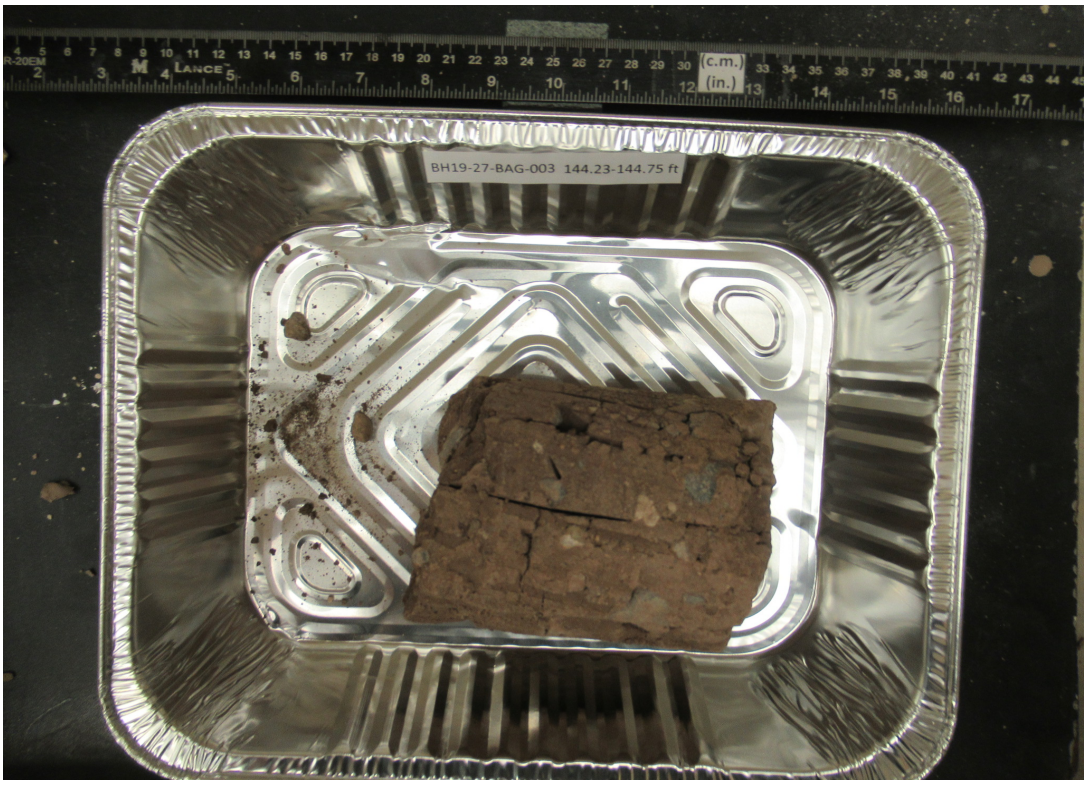
Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-003
Depth, ft:	144.23-144.75

Soil Abrasivity Test - Sample As-Received

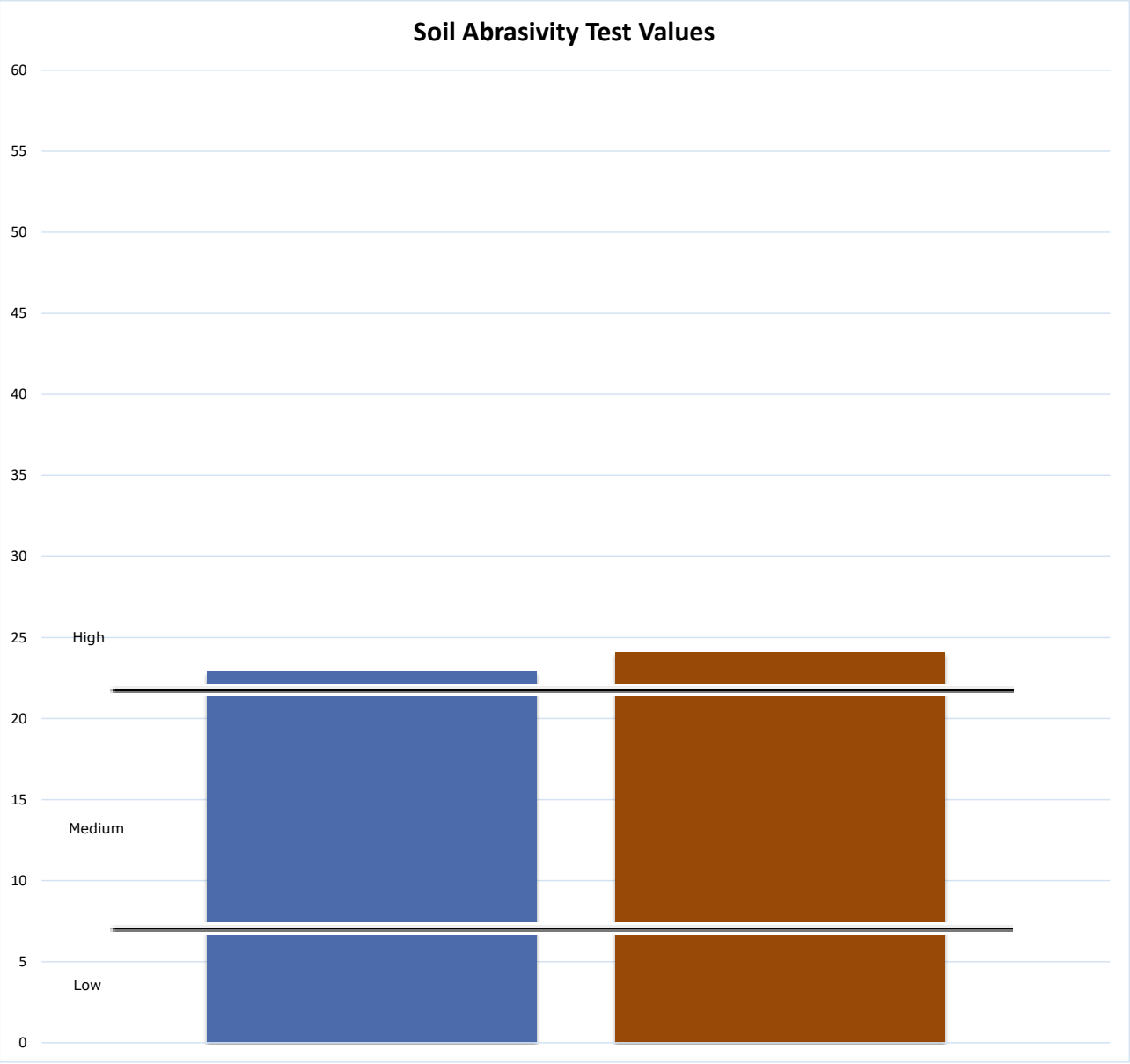


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-003
Depth, ft:	144.23-144.75

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-005
Depth, ft:	162.40-162.86

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	20.3
2	19.5
Average	19.9

Sample Classification: Medium

Soil Abrasivity Test Value Reference Classification Chart

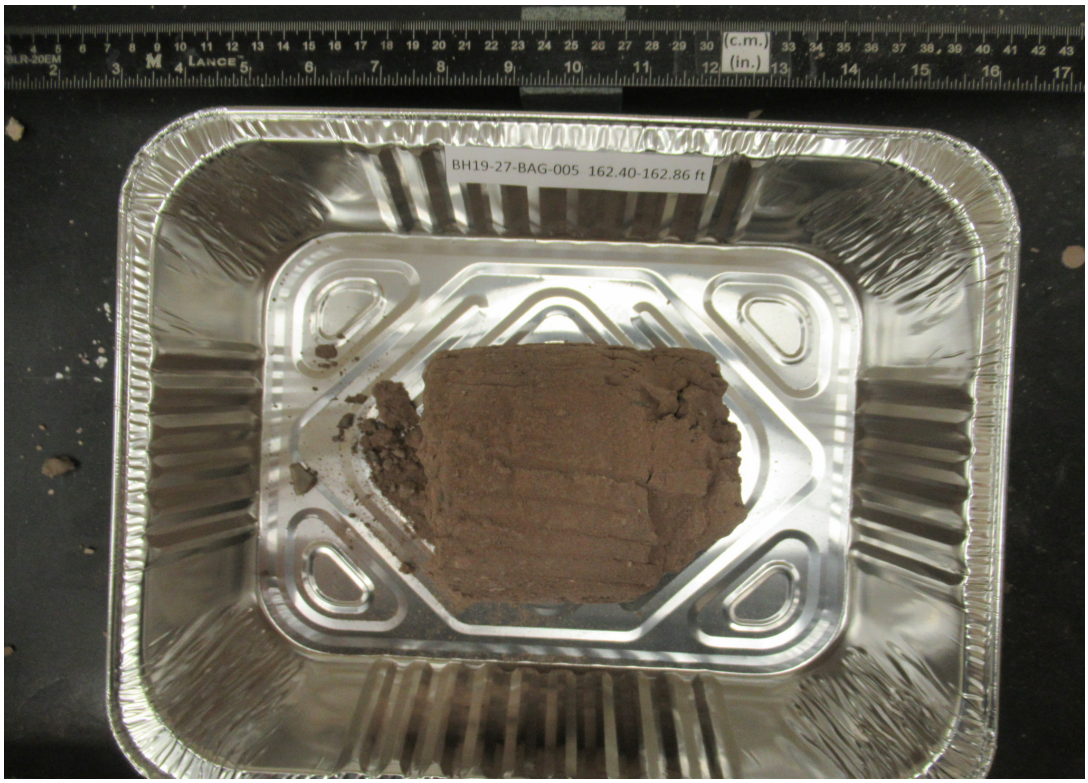
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-005
Depth, ft:	162.40-162.86

Soil Abrasivity Test - Sample As-Received

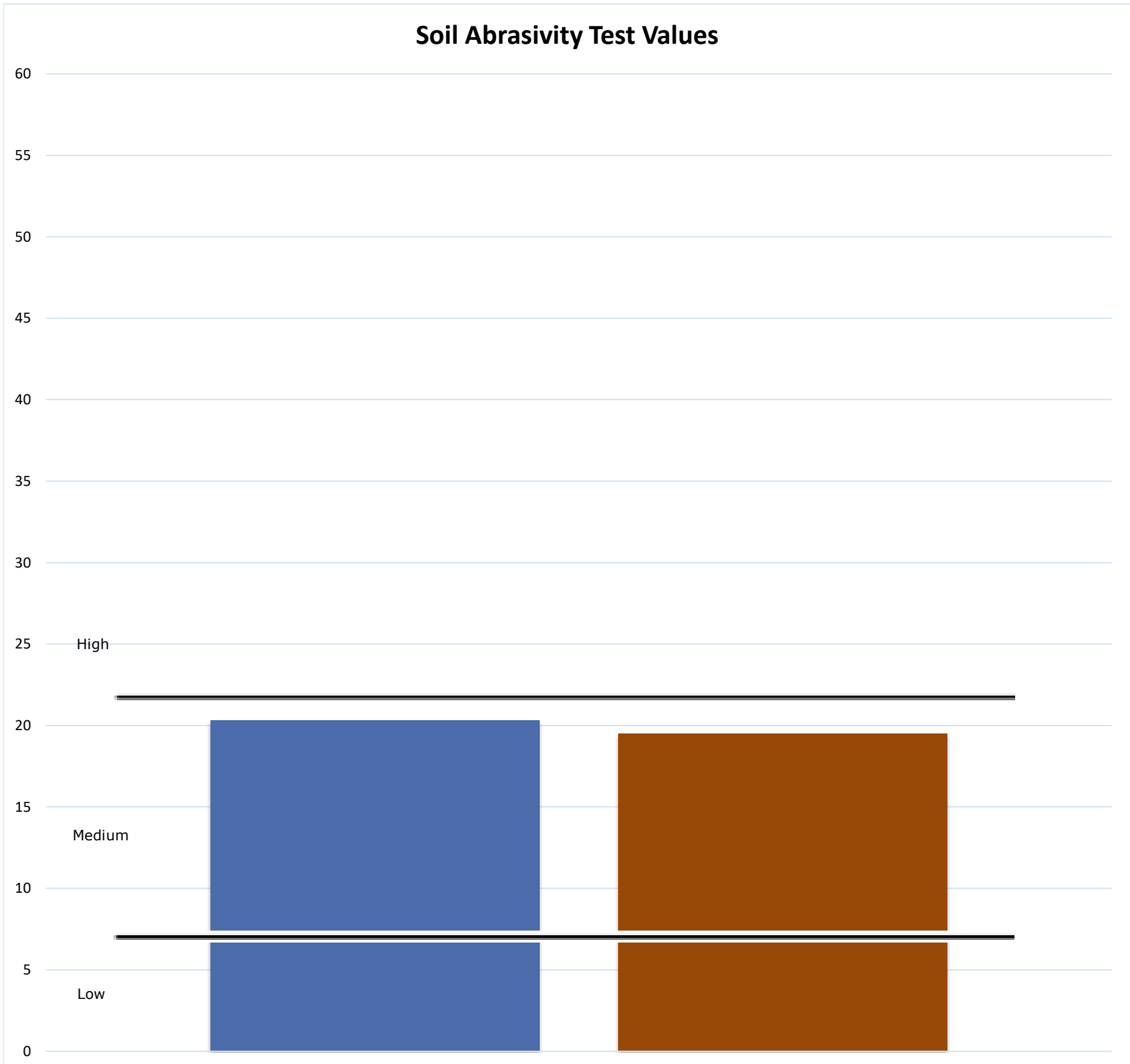


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-005
Depth, ft:	162.40-162.86

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-013
Depth, ft:	232.28-232.81

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	29.8
2	28.6
Average	29.2

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

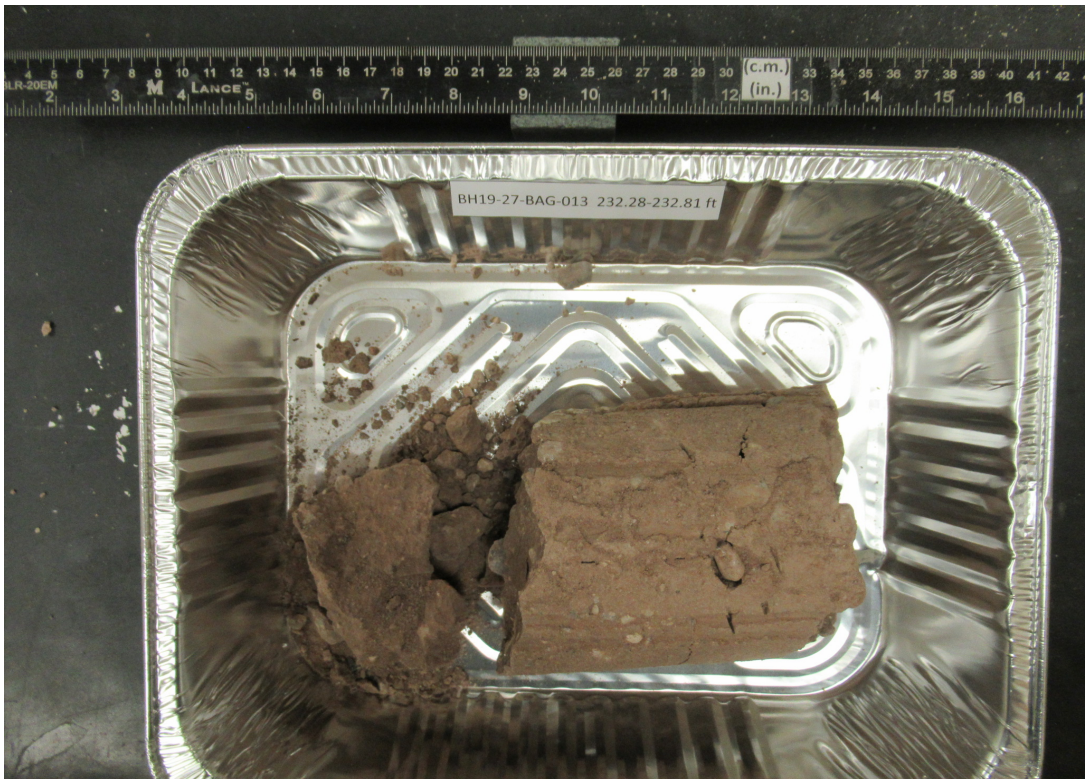
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-27
Sample ID:	LSB-013
Depth, ft:	232.28-232.81

Soil Abrasivity Test - Sample As-Received

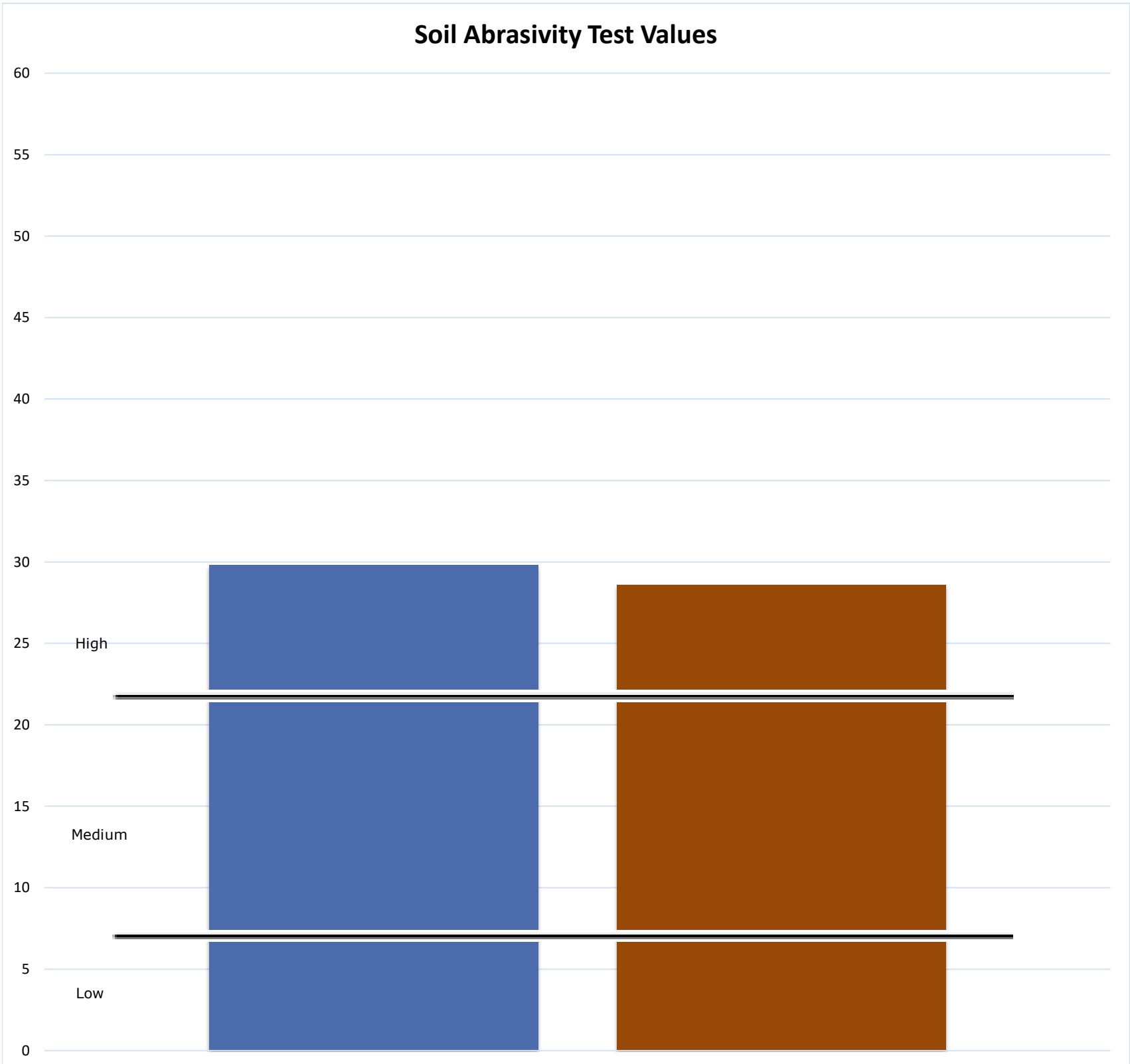


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	43839
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-27
Sample ID:	LSB-013
Depth, ft:	232.28-232.81

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LSB-001
Depth, ft:	87.5-88.12

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	4.3
2	4.4
Average	4.3

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

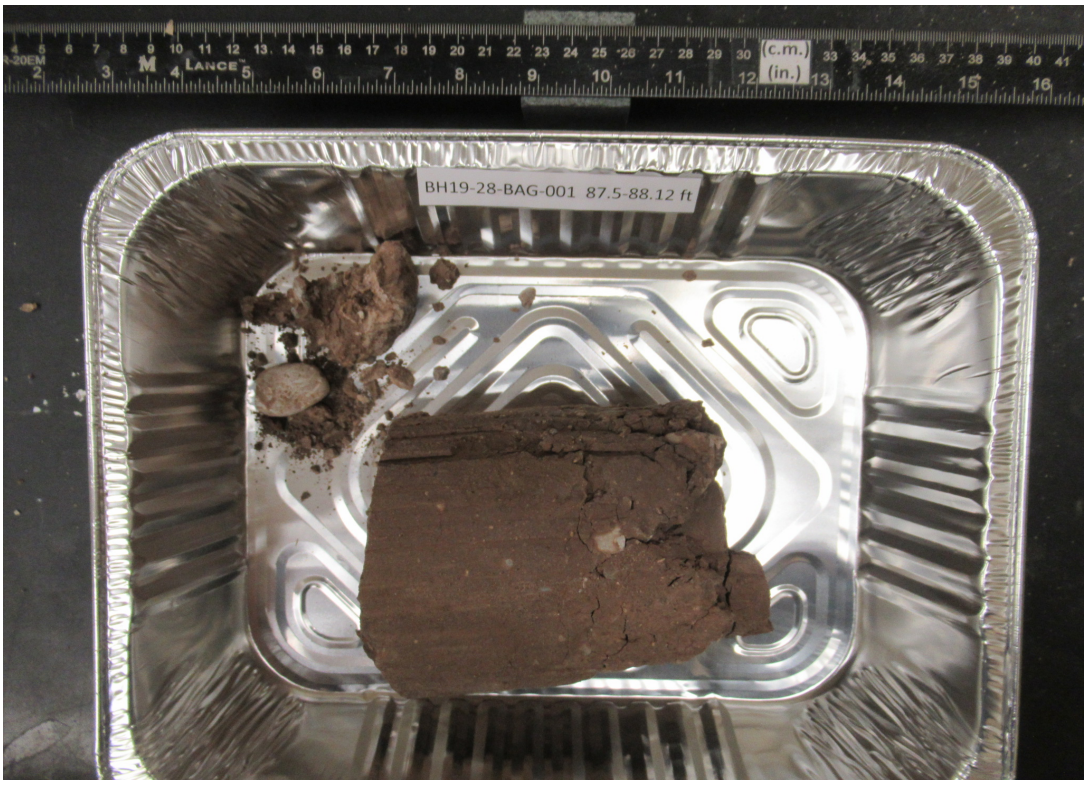
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-28
Sample ID:	LSB-001
Depth, ft:	87.5-88.12

Soil Abrasivity Test - Sample As-Received

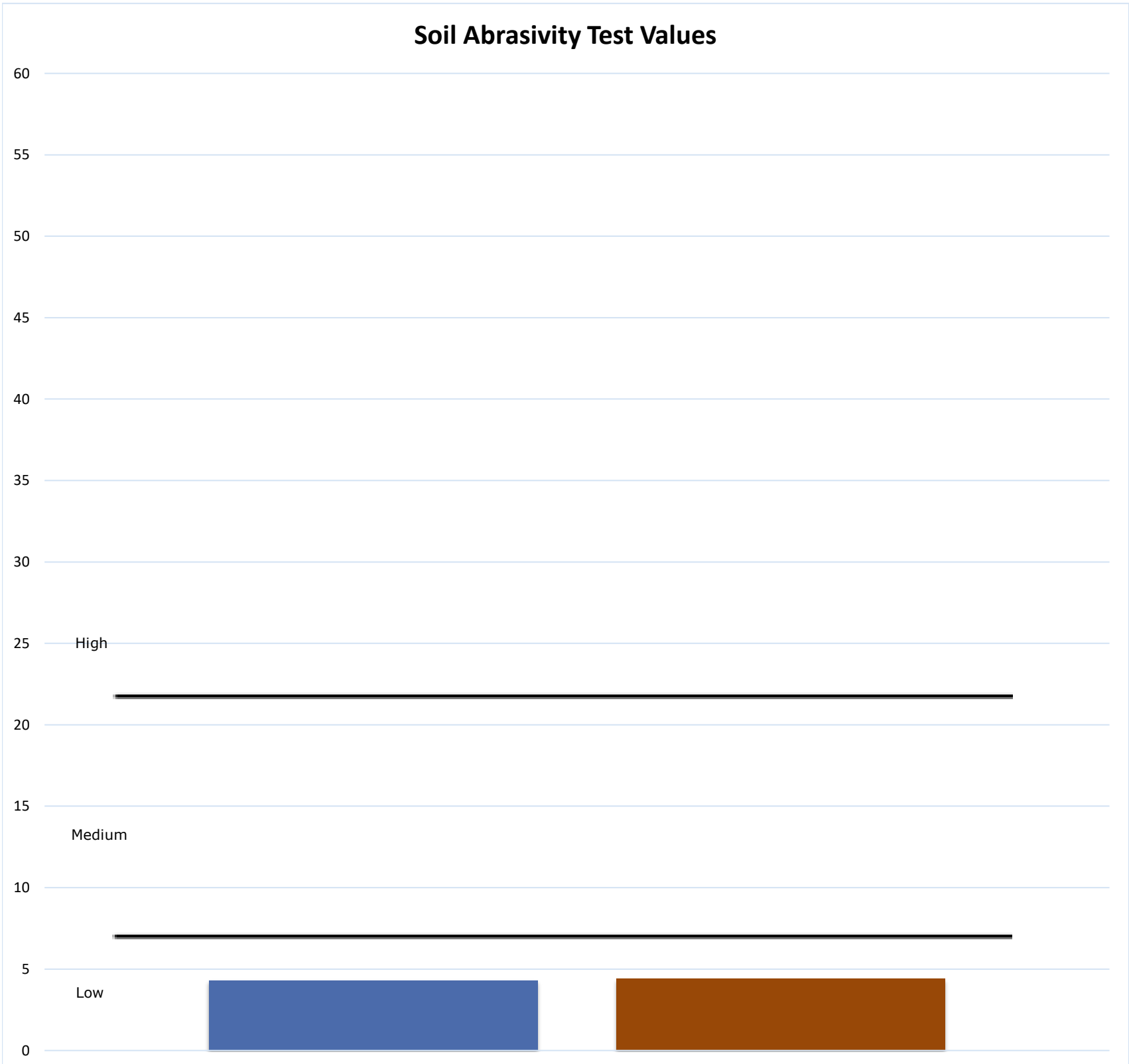


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LSB-001
Depth, ft:	87.5-88.12

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LSB-002
Depth, ft:	102.79-103.35

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	27.1
2	25.9
Average	26.5

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

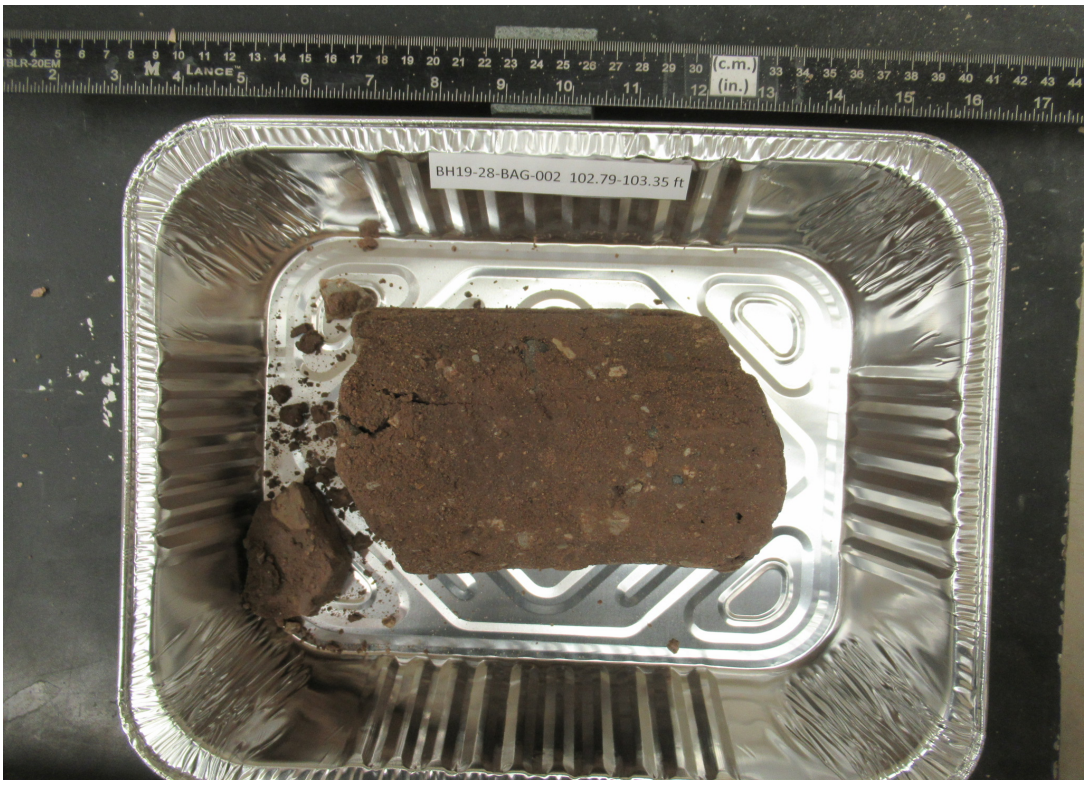
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-28
Sample ID:	LSB-002
Depth, ft:	102.79-103.35

Soil Abrasivity Test - Sample As-Received

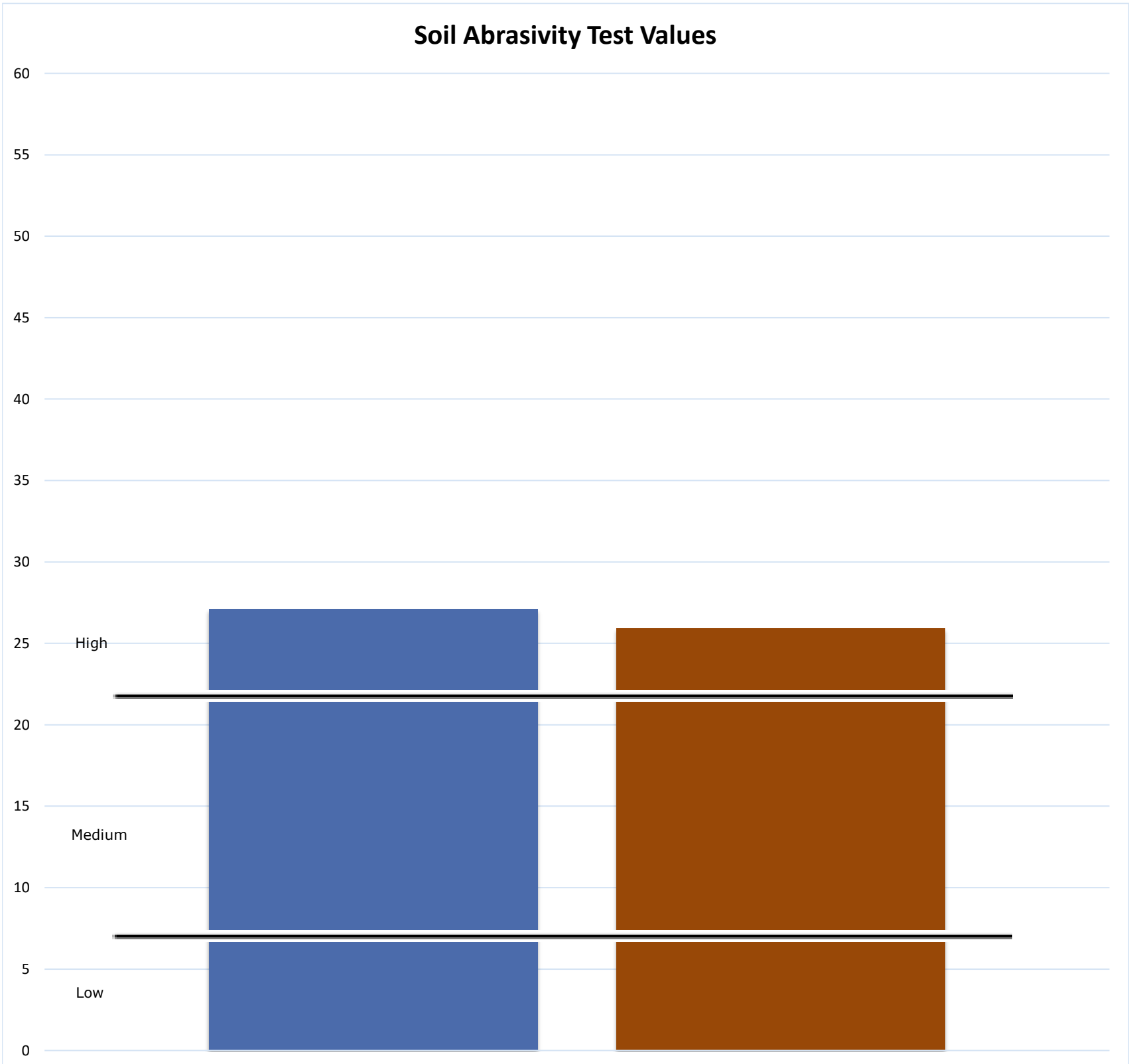


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LSB-002
Depth, ft:	102.79-103.35

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LSB-004
Depth, ft:	152.72-153.31

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	36.2
2	35.4
Average	35.8

Sample Classification: High

Soil Abrasivity Test Value Reference Classification Chart

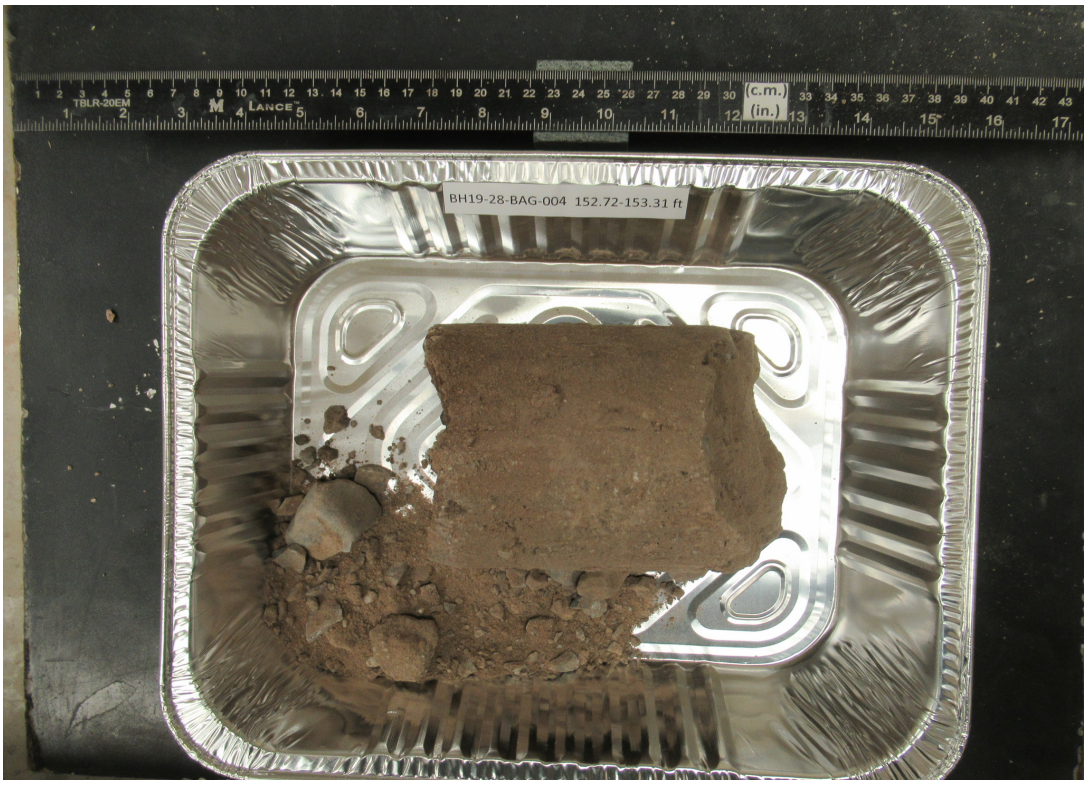
Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-28
Sample ID:	LSB-004
Depth, ft:	152.72-153.31

Soil Abrasivity Test - Sample As-Received

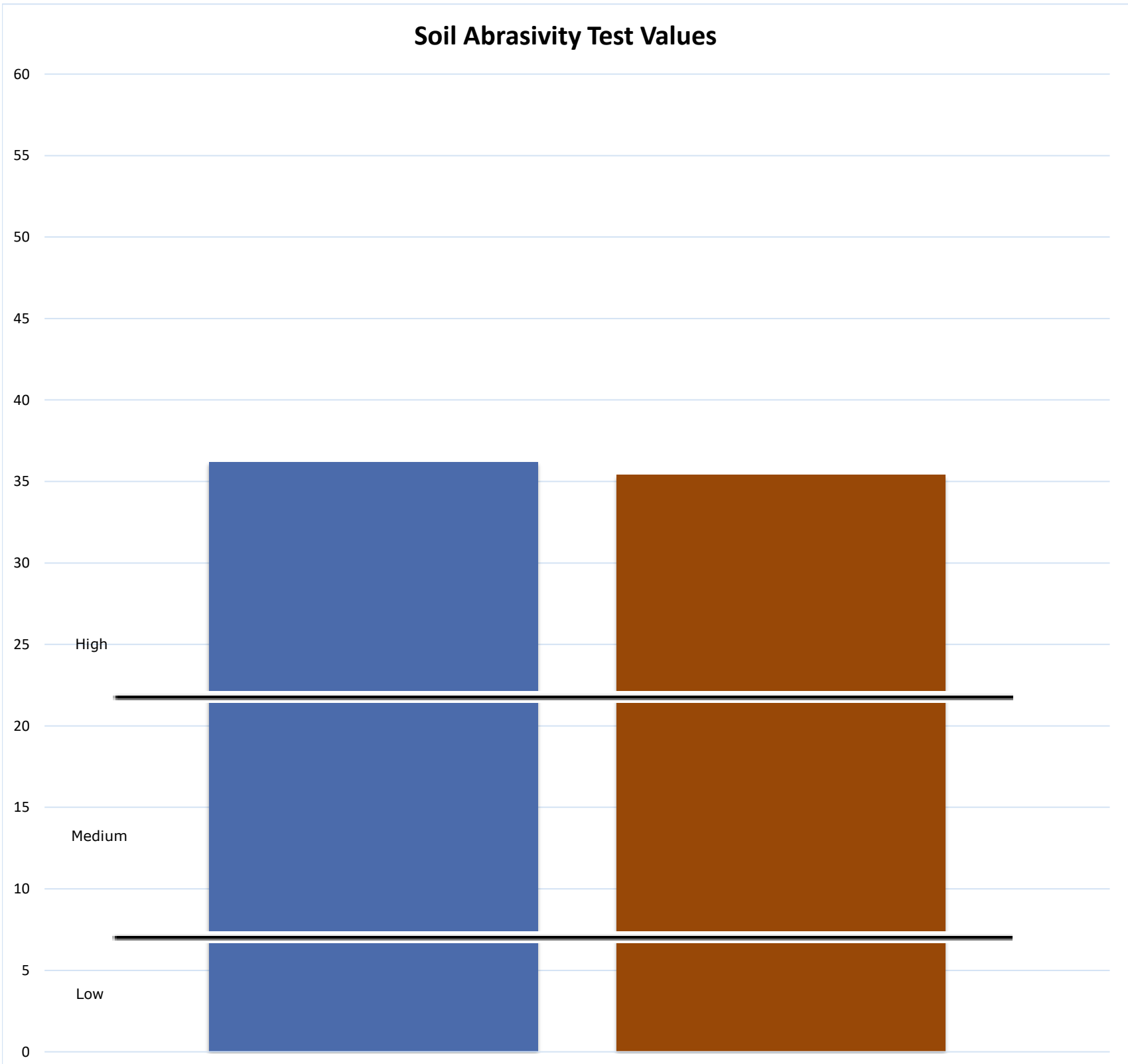


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT^{TM} and Soil Abrasion Test^{TM} are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/9/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-28
Sample ID:	LSB-004
Depth, ft:	152.72-153.31

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.

The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-31
Sample ID:	LSB-001
Depth, ft:	131.23-131.56

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	2.1
2	2.2
Average	2.2

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

Category	Soil Abrasivity Test value (mg)
Low	$\leq$ 7.0
Medium	7.1 - 21.9
High	$\geq$ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-31
Sample ID:	LSB-001
Depth, ft:	131.23-131.56

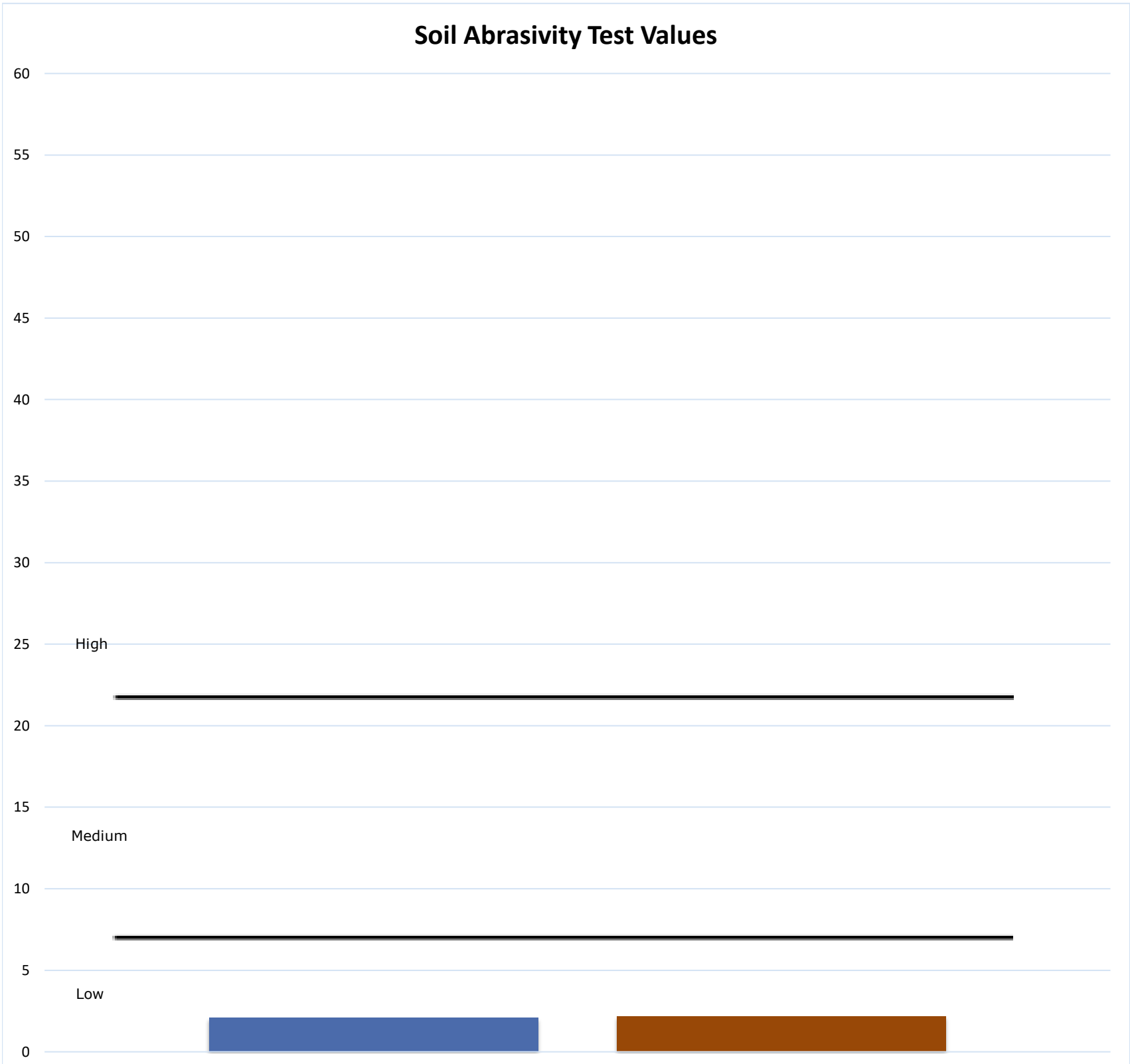
Soil Abrasivity Test - Sample As-Received

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	1/10/2020
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-31
Sample ID:	LSB-001
Depth, ft:	131.23-131.56

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-35
Sample ID:	LRB-002
Depth, ft:	215.72

Soil Abrasivity Test

Individual Test Results

Test Number	Soil Abrasivity Test value (mg)
1	1.6
2	1.6
Average	1.6

Sample Classification: Low

Soil Abrasivity Test Value Reference Classification Chart

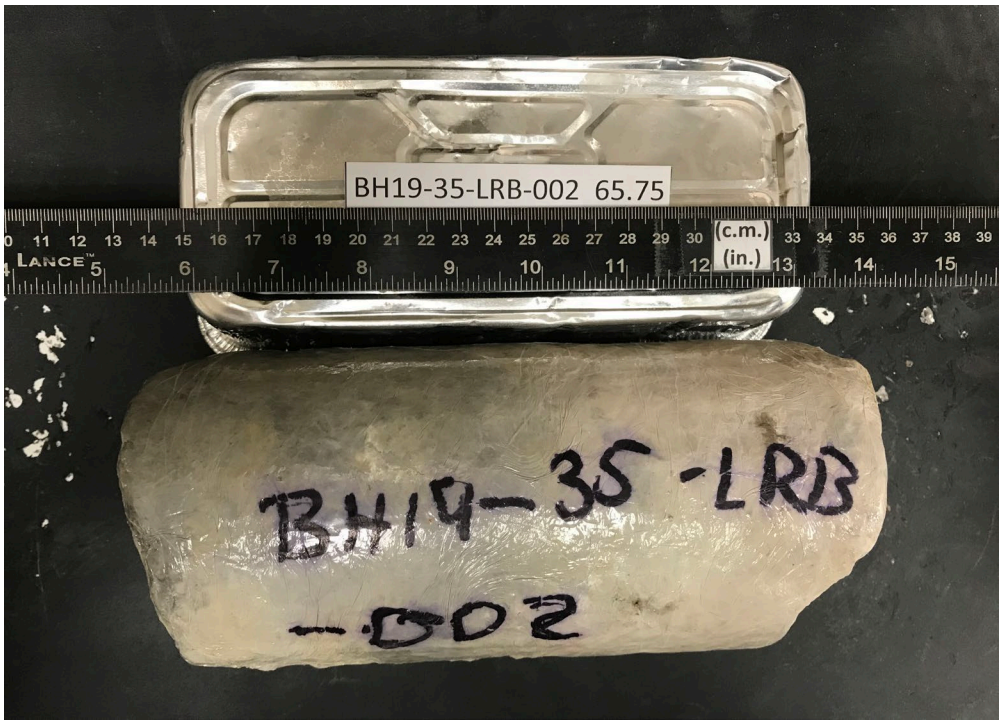
Category	Soil Abrasivity Test value (mg)
Low	≤ 7.0
Medium	7.1 - 21.9
High	≥ 22.0

Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
   The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.
2. Abrasion test material was provided to GTX by client. The test material was dried at 30°C for 3-4 days until dry. The Soil Abrasion Test pieces are comprised of cutter ring steel.
3. Test was performed at 20 RPM for 1 minute for a total of 20 revolutions.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Boring ID:	BH19-35
Sample ID:	LRB-002
Depth, ft:	215.72

Soil Abrasivity Test - Sample As-Received

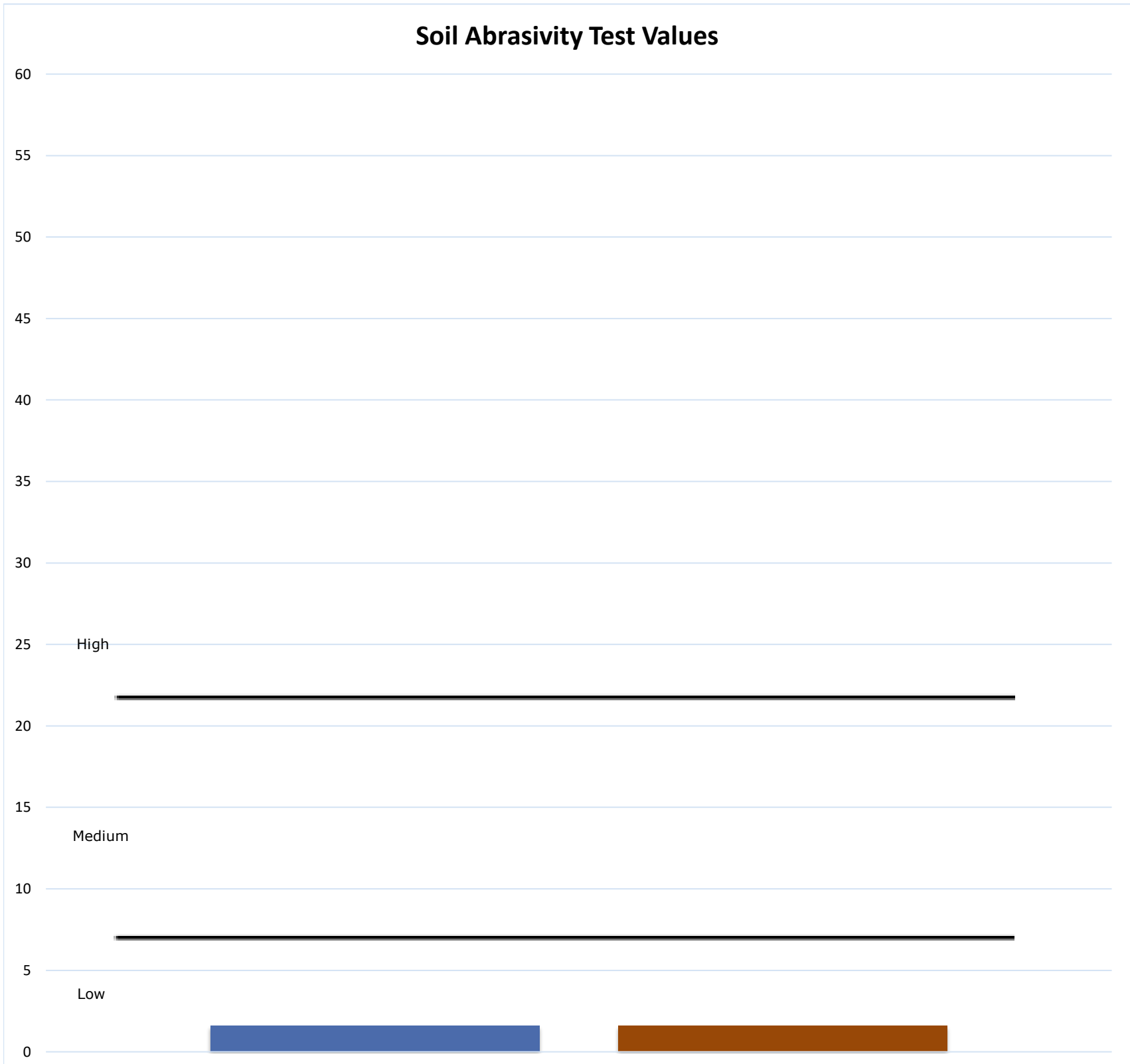


Notes:

1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116. The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

Client:	WSP
Project Name:	Line 5 Replacement and Tunnel Project
Project Location:	Straits of Mackinac
GTX #:	310187
Test Date:	9/4/2019
Tested By:	tlm
Checked By:	jsc
Boring ID:	BH19-35
Sample ID:	LRB-002
Depth, ft:	65.75

Soil Abrasivity Test



Notes: 1. GTX's Soil Abrasivity Test is based on Nilsen, B., Dahl, F., Holzhäuser J., Raleigh P., New test methodology for estimating the abrasiveness of soils for TBM tunneling. proceeding of RETC conference 2007: 104- 116.
The trademarked acronyms and terms SAT™ and Soil Abrasion Test™ are unique for test results and calculated indices originating from NTNU/SINTEF and can only be obtained by testing samples at their reference laboratory in Trondheim, Norway.

K/T GeoServices, Inc.

219 N. Iowa St., Unit J
Gunnison CO 81230 USA

www.ktgeo.com
970-641-1235

August 7, 2019

Jon Campbell
GeoTesting Express
125 Nagog Park
Acton MA 01720
(978) 635-0424
jcampbell@geotesting.com

GTX No.:	310187
Project	Line 5 Replacement Tunnel, Straits of Mackinac
Subject:	X-ray Diffraction Analysis
K/T File No.:	Z19217

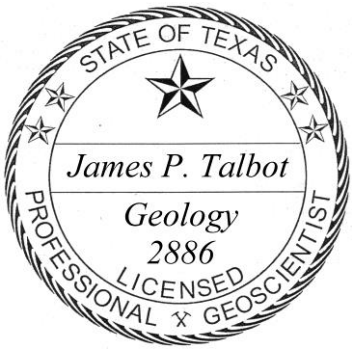
Dear Jon,

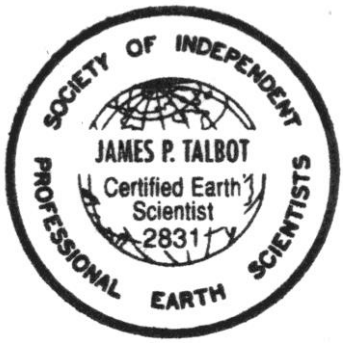
This report presents the results of Whole Rock X-ray diffraction (XRD) analysis performed on 4 samples. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

If you have any questions concerning these results or if you need anything else please contact me at (970) 641-1235. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,





James P. Talbot, P.G.

NOTICE: The results and interpretations presented in this report are based on materials and information supplied by the client and represent the judgment of K/T GeoServices, Inc. This report is intended for the client's exclusive and confidential use, and any user of this report agrees that K/T GeoServices, Inc. and its employees assume no responsibility and make no warranties or representation as to the utility of this report for any reason. K/T GeoServices, Inc. and its employees shall not be liable for any loss or damage, regardless of cause, resulting from the use of any information contained herein.

X-ray Diffraction Data (Weight Percent)

Sample ID	Quartz	K-Feldspar	Plagioclase	Calcite	Dolomite	Pyrite	Hematite	Total Clay*	TOTAL
BH19-16 LRB-006 233.50-233.61 ft	15.2	8.9	1.6	3	49.9	1	0	20.4	100
BH19-16 LRB-008 253.42-253.50 ft	14.2	8.3	1.5	0	53.9	0.5	0	21.6	100
BH19-16 LRB-012 317.78-317.89 ft	11.7	5	0.8	13.9	58.3	0	0.3	10	100
BH19-15-LRB-004 163.94-164.08 ft	0.9	0	0	5.1	92.8	0	0	1.2	100

*Total Clay - +/- Illite&Mica, Chlorite, Kaolinite and Mixed-Layer Clay Minerals.

See page 3 for mineral definitions.
See page 4 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 5.
X-ray diffraction traces are presented on pages 6 – 9.

Mineral Definitions

Rock Forming (nonclay) Minerals

Quartz
Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar
K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase
Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Calcite
Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Dolomite
Dolomite is a hexagonal carbonate mineral with the formula $CaMg(CO_3)_2$.

Pyrite
Pyrite (FeS_2) is an iron sulfide iron sulfide with a cubic crystal structure. Pyrite is also known as fool's gold.

Hematite
Hematite (Fe_2O_3) and its' alteration products are the most common cause of a red coloration in rocks and sediments.

Phyllosilicate (Clay) Minerals

Illite & Mica
Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Kaolinite
Kaolinite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate with the general formula $Al_2(Si_2O_5)(OH)_4$.

Chlorite
Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Clay Minerals
Clay mineral groups containing Illite or Chlorite layers interlayered or interstratified with Smectite layers.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative; there are many factors affecting the results.

XRD methods can quantify crystalline material only. Non-crystalline material in large concentrations can be detected but not quantified. Therefore, any non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of <1 to 5 weight percent. Detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Sample Preparation and Analytical Procedures
(Copyright 2019 K/T GeoServices, Inc.)

Sample Preparation

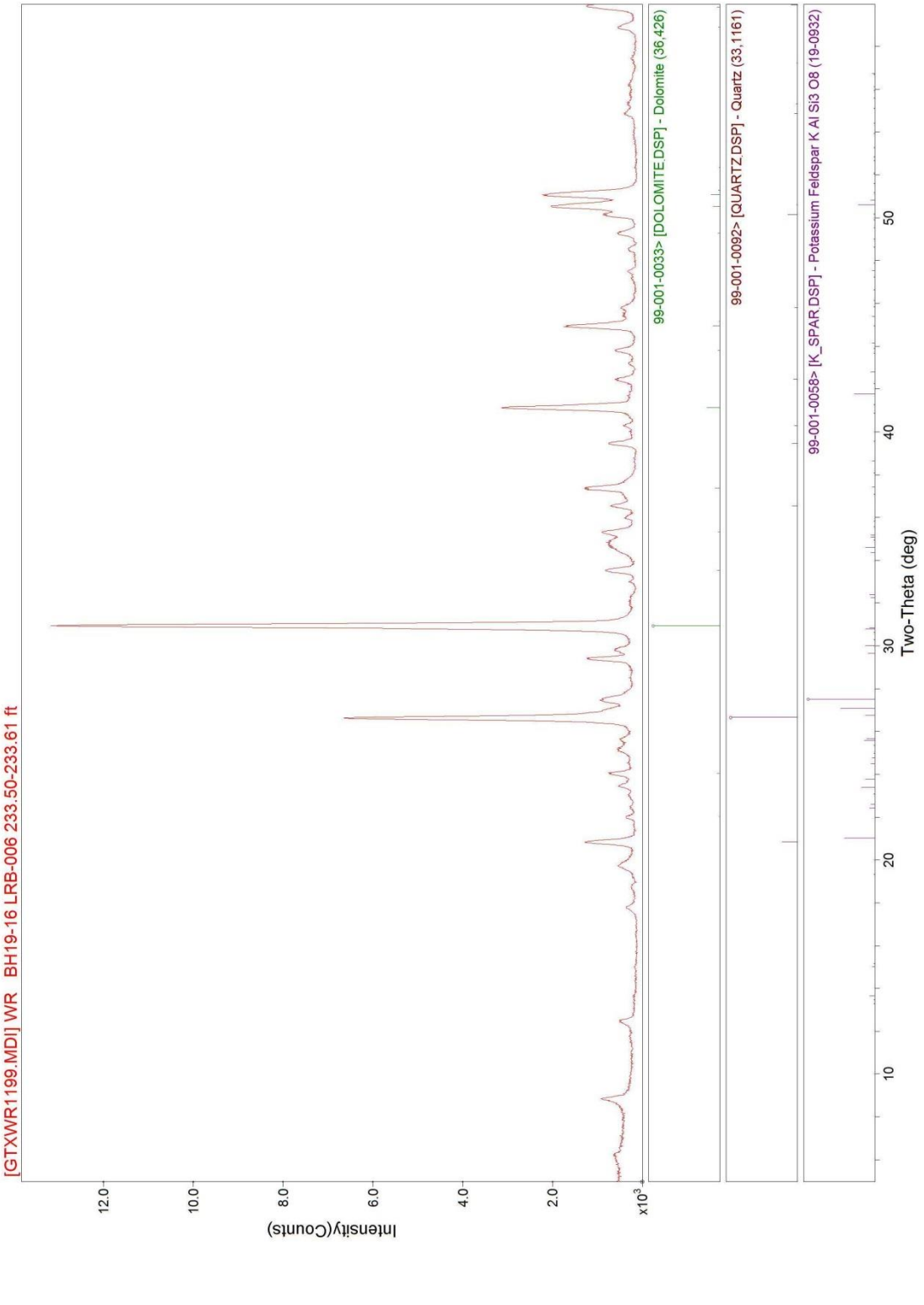
Samples submitted for bulk XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of the sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random bulk mounts.

Analytical Procedures

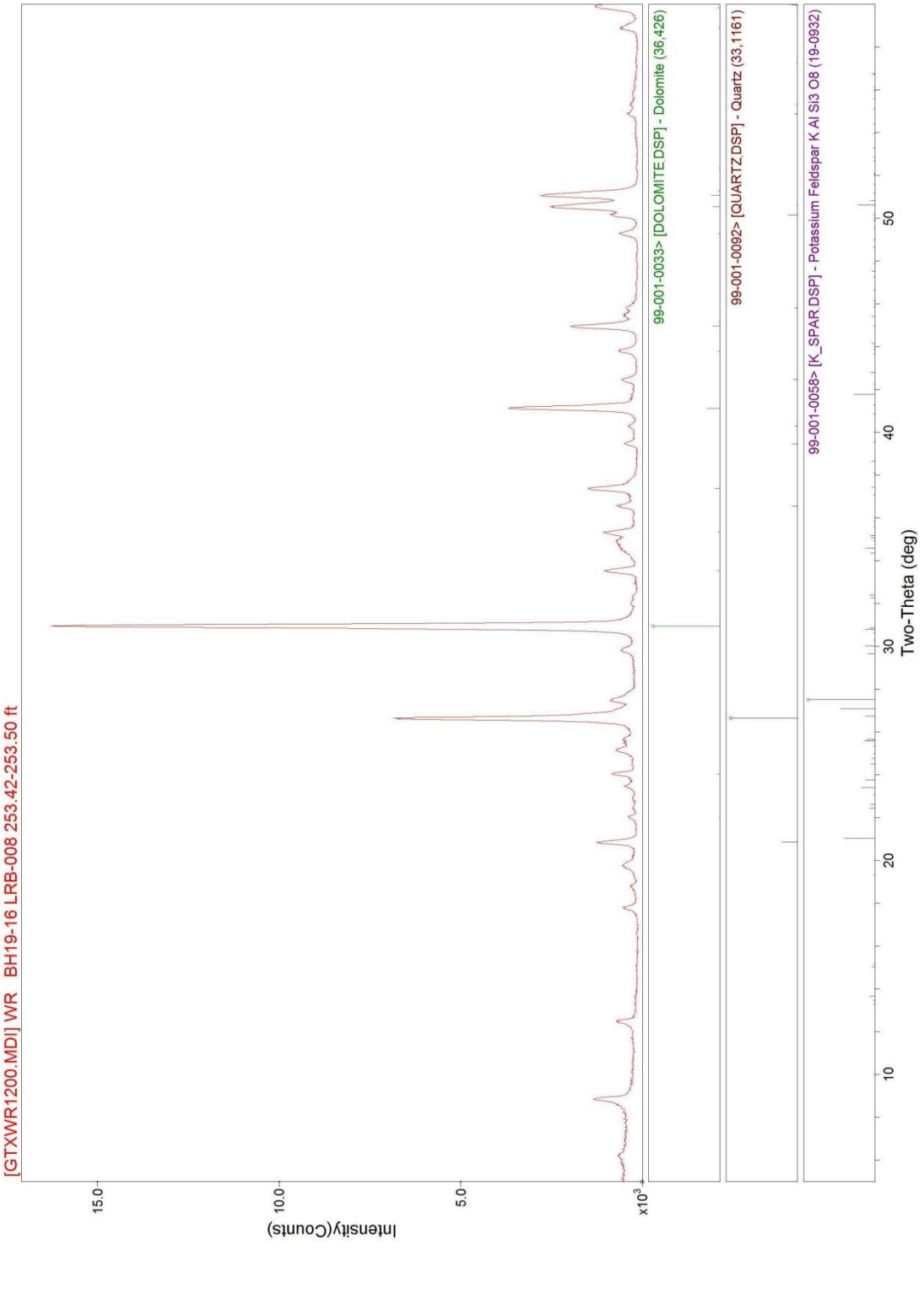
X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The bulk powder samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute.

Semiquantitative determinations of bulk powder mineral amounts are done using Jade Software (Materials Data, Inc.) with the Whole Pattern Fitting option. All quantitative data (including an estimate of clay mineral amounts) come from the bulk powder pattern. This is done by using Whole Pattern Fitting (WPF) and Rietveld refinement methods on the observed data. A diffraction model is fit to the measured pattern by non-linear least-square optimization in which certain parameters are varied to improve the fit of the model to the observed data. Modeling parameters include background, profile parameters, and lattice constants. For Rietveld refinement, a complete physics simulation is generally used in which crystal structures of the phases are required. Since the physics of scattering is well known, this method can be very exact and even allow adjustment of atomic coordinates, occupancies, and thermal parameters.

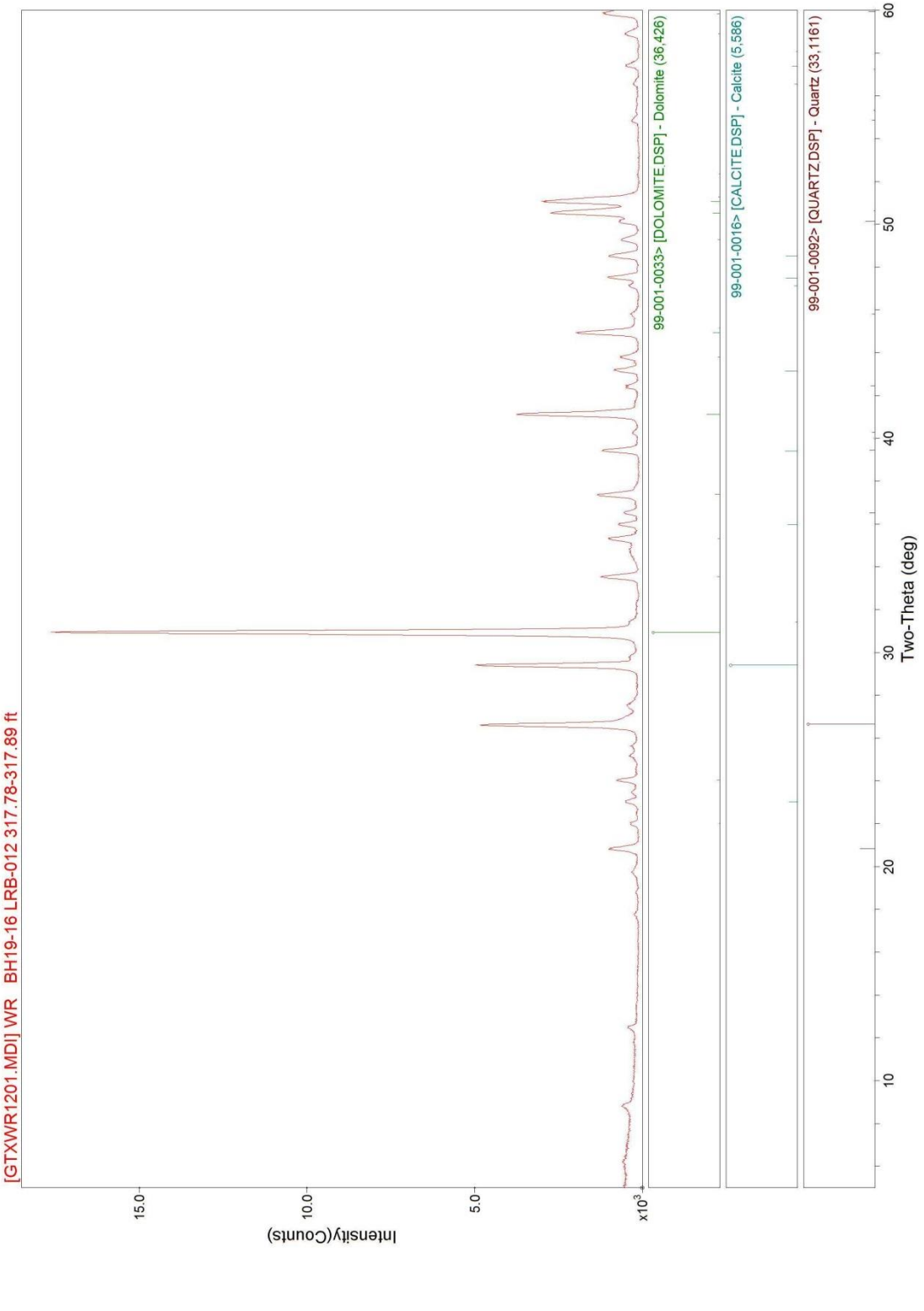
Whole Rock X-ray Diffraction Trace



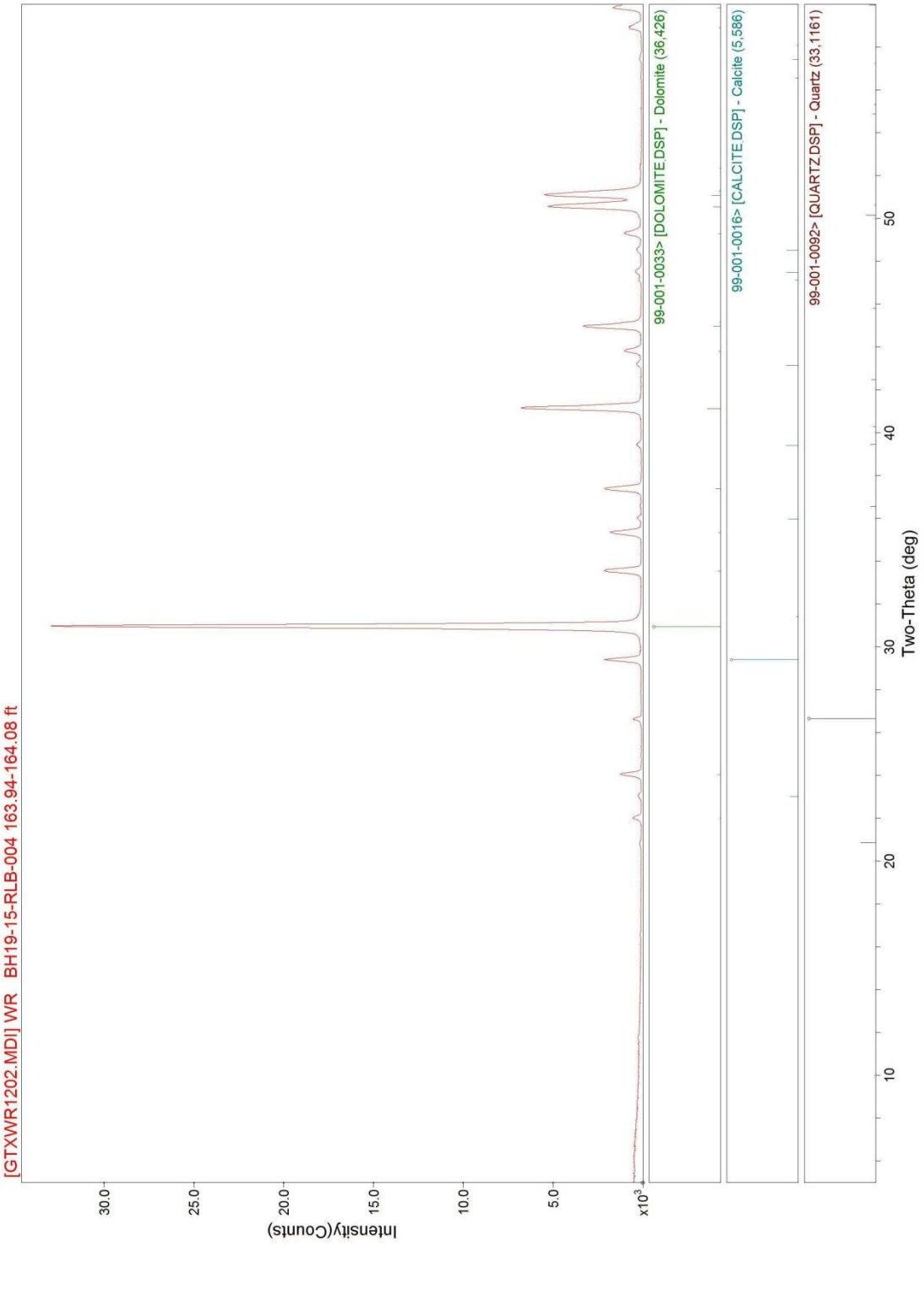
Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



K/T GeoServices, Inc.

219 N. Iowa St., Unit J *www.ktgeo.com*
Gunnison CO 81230 USA *970-641-1235*

September 3, 2019

Jon Campbell
GeoTesting Express
125 Nagog Park
Acton MA 01720
(978) 635-0424
jcampbell@geotesting.com

GTX No.:	310187
Project	Line 5 Replacement Tunnel, Straits of Mackinac
Subject:	X-ray Diffraction Analysis
K/T File No.:	Z19243

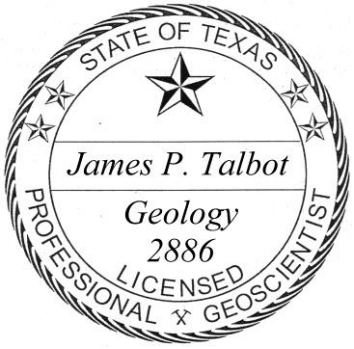
Dear Jon,

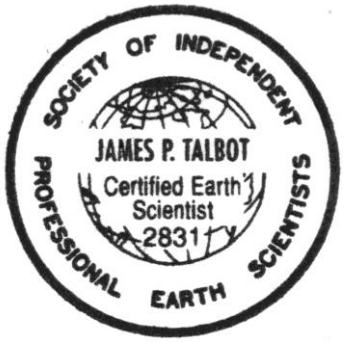
This report presents the results of Whole Rock X-ray diffraction (XRD) analysis performed on 4 samples. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

If you have any questions concerning these results or if you need anything else please contact me at (970) 641-1235. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,





James P. Talbot, P.G.

NOTICE: The results and interpretations presented in this report are based on materials and information supplied by the client and represent the judgment of K/T GeoServices, Inc. This report is intended for the client's exclusive and confidential use, and any user of this report agrees that K/T GeoServices, Inc. and its employees assume no responsibility and make no warranties or representation as to the utility of this report for any reason. K/T GeoServices, Inc. and its employees shall not be liable for any loss or damage, regardless of cause, resulting from the use of any information contained herein.

X-ray Diffraction Data (Weight Percent)

XRD#	Sample ID	Quartz	K-Feldspar	Plagioclase	Calcite	Dolomite	Pyrite	Hematite	Total Clay*	TOTAL
GTX1209	BH19-07 LRB-005 (A-K) 129.4-134.7	0.9	0	0	1.3	96.5	0	0	1.3	100
GTX1210	BH19-17 LRB-003 343.3-343.7	19.6	6	0	2.2	42.3	0	1.6	28.3	100
GTX1211	BH19-37 LRB-006 209.7-210.2	13	9.1	0	4.8	61.2	2.2	0	9.7	100
GTX1212	BH19-38 LRB-007 165.2-165.4	2.1	1.8	0	0.2	94.3	0	0	1.6	100

*Total Clay - +/- Illite&Mica, Chlorite, Kaolinite and Mixed-Layer Clay Minerals.

See page 3 for mineral definitions.
See page 4 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 5.
X-ray diffraction traces are presented on pages 6 – 9.

Mineral Definitions

Rock Forming (nonclay) Minerals

Quartz
Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar
K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase
Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Calcite
Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Dolomite
Dolomite is a hexagonal carbonate mineral with the formula $CaMg(CO_3)_2$.

Pyrite
Pyrite (FeS_2) is an iron sulfide iron sulfide with a cubic crystal structure. Pyrite is also known as fool's gold.

Hematite
Hematite (Fe_2O_3) and its' alteration products are the most common cause of a red coloration in rocks and sediments.

Phyllosilicate (Clay) Minerals

Illite & Mica
Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Kaolinite
Kaolinite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate with the general formula $Al_2(Si_2O_5)(OH)_4$.

Chlorite
Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Clay Minerals
Clay mineral groups containing Illite or Chlorite layers interlayered or interstratified with Smectite layers.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative; there are many factors affecting the results.

XRD methods can quantify crystalline material only. Non-crystalline material in large concentrations can be detected but not quantified. Therefore, any non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of <1 to 5 weight percent. Detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Sample Preparation and Analytical Procedures
(Copyright 2019 K/T GeoServices, Inc.)

Sample Preparation

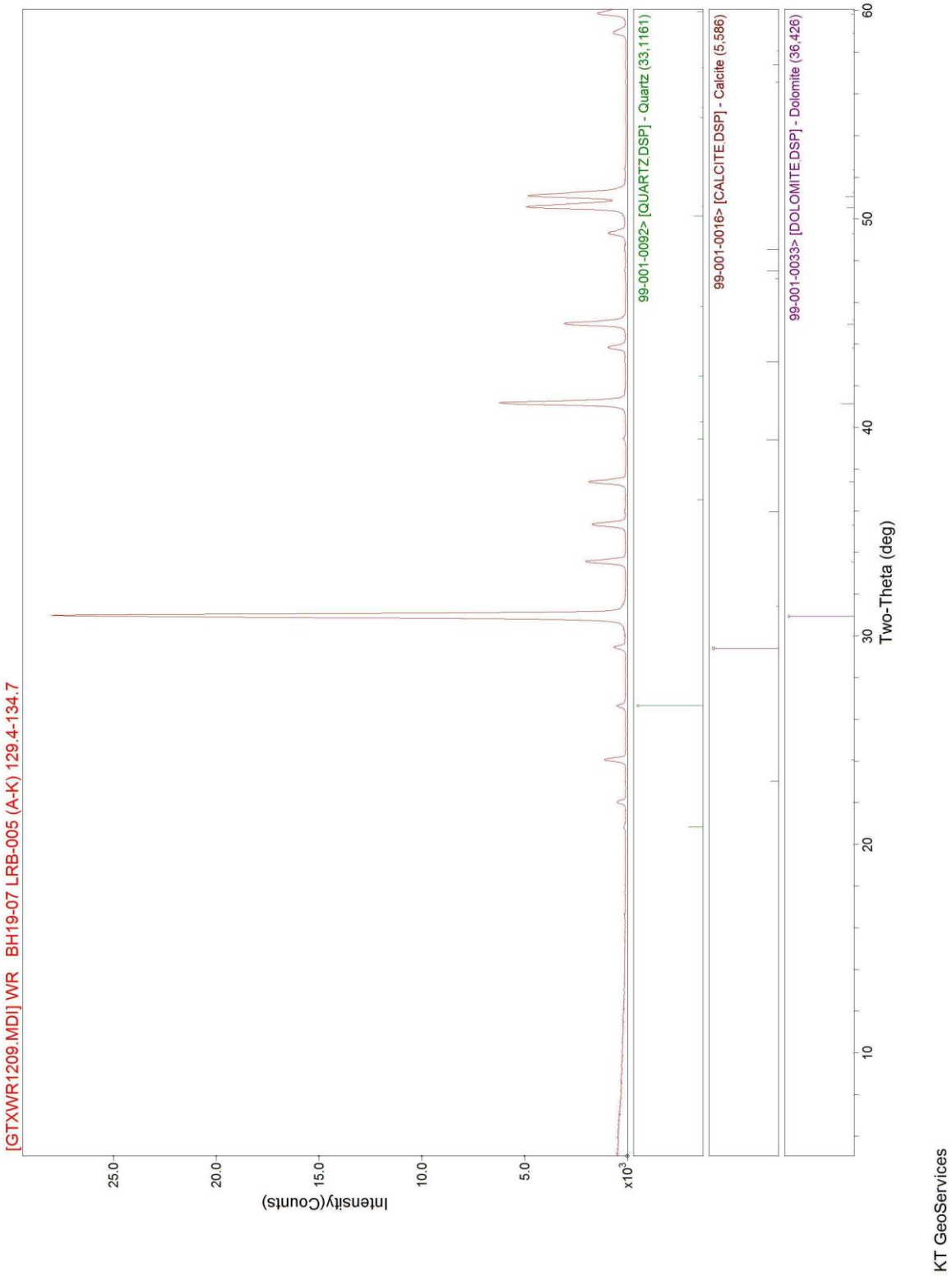
Samples submitted for bulk XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of the sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random bulk mounts.

Analytical Procedures

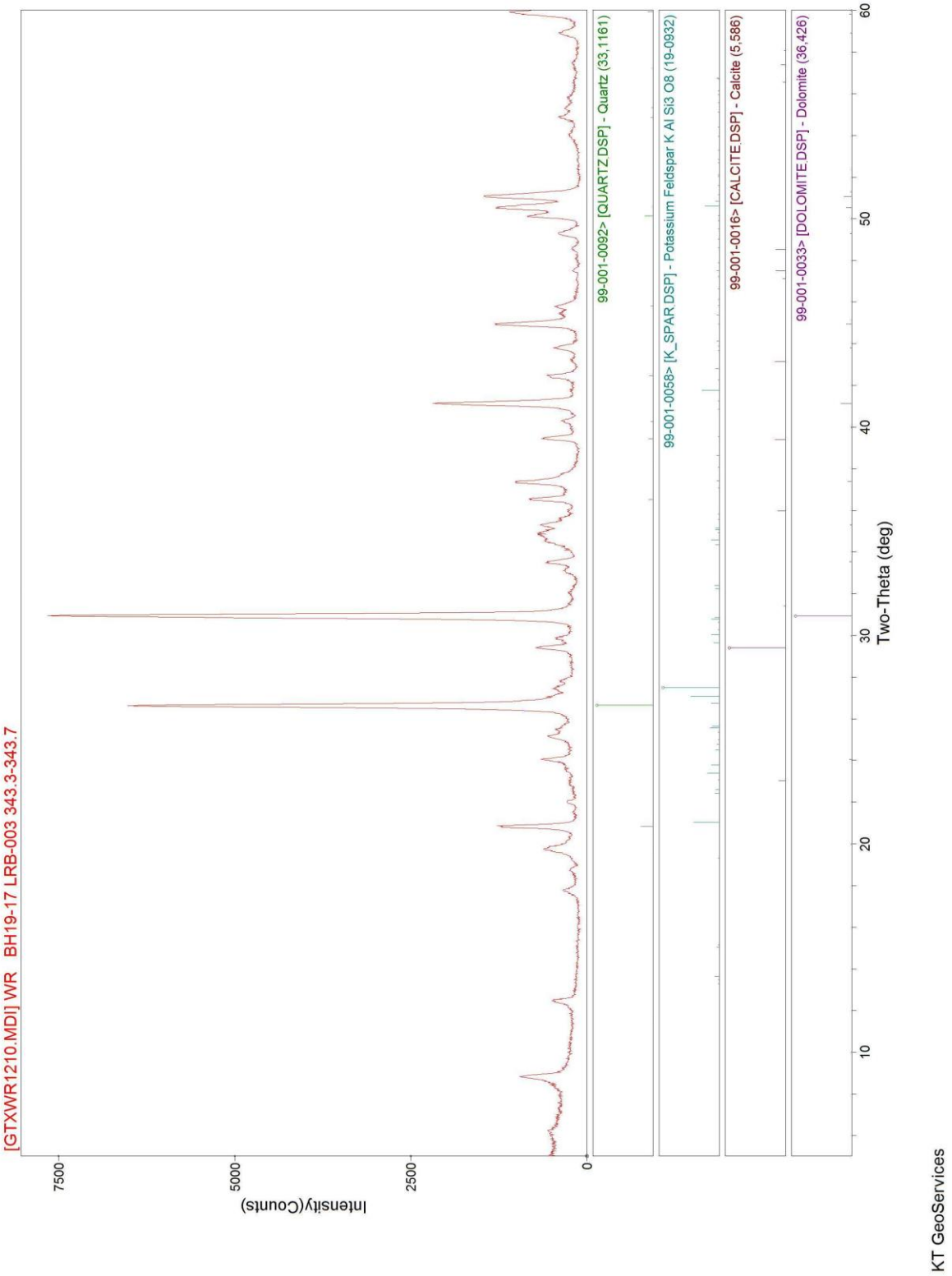
X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The bulk powder samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute.

Semiquantitative determinations of bulk powder mineral amounts are done using Jade Software (Materials Data, Inc.) with the Whole Pattern Fitting option. All quantitative data (including an estimate of clay mineral amounts) come from the bulk powder pattern. This is done by using Whole Pattern Fitting (WPF) and Rietveld refinement methods on the observed data. A diffraction model is fit to the measured pattern by non-linear least-square optimization in which certain parameters are varied to improve the fit of the model to the observed data. Modeling parameters include background, profile parameters, and lattice constants. For Rietveld refinement, a complete physics simulation is generally used in which crystal structures of the phases are required. Since the physics of scattering is well known, this method can be very exact and even allow adjustment of atomic coordinates, occupancies, and thermal parameters.

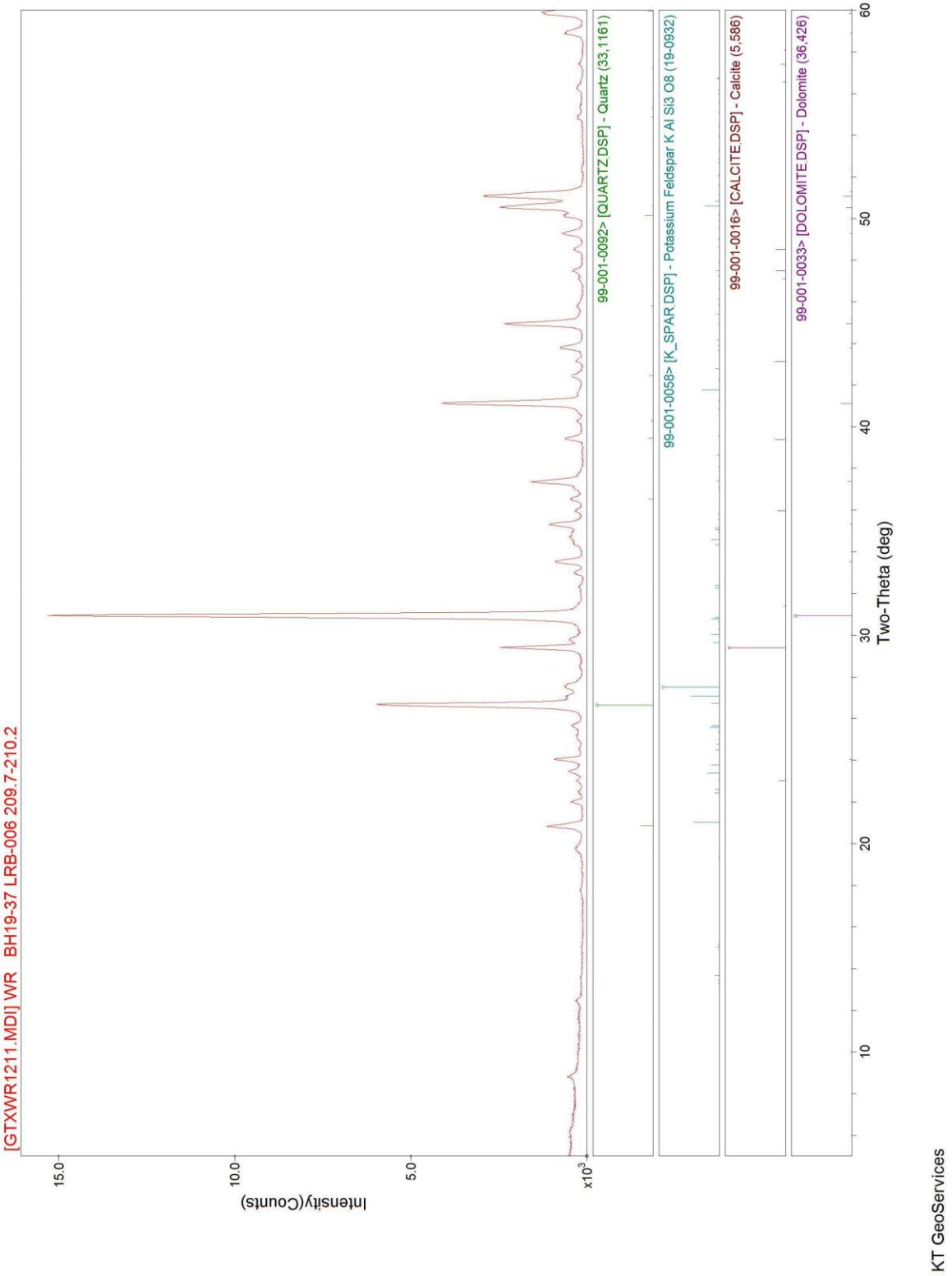
Whole Rock X-ray Diffraction Trace



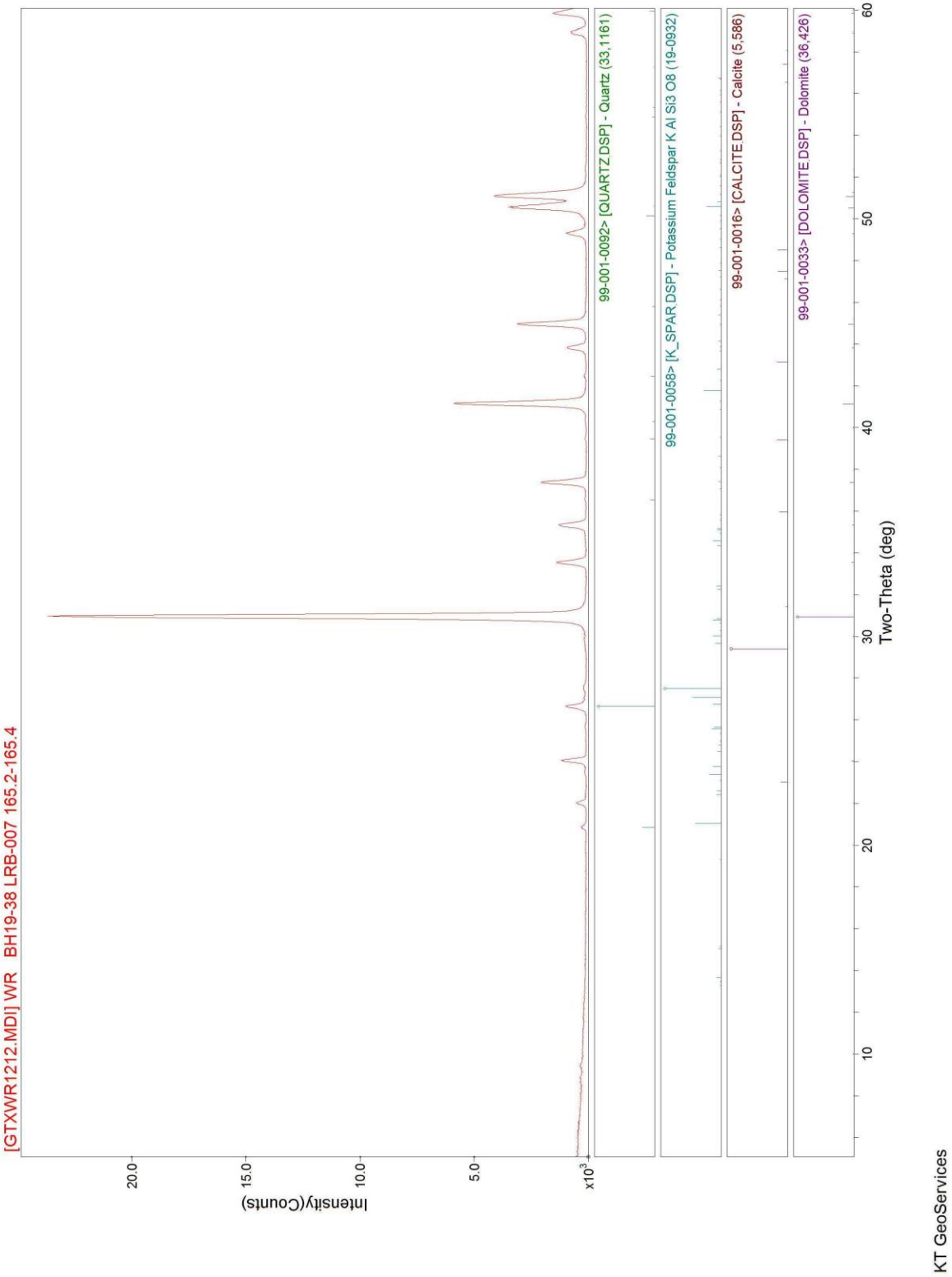
Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



K/T GeoServices, Inc.

219 N. Iowa St., Unit J
Gunnison CO 81230 USA

www.ktgeo.com
970-641-1235

September 16, 2019

Jon Campbell
GeoTesting Express
125 Nagog Park
Acton MA 01720
(978) 635-0424
jcampbell@geotesting.com

GTX No.:	310187
Project	Line 5 Replacement Tunnel, Straits of Mackinac
Subject:	X-ray Diffraction Analysis
K/T File No.:	Z19257

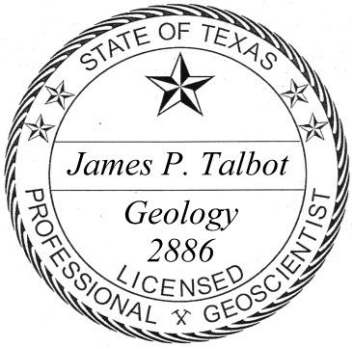
Dear Jon,

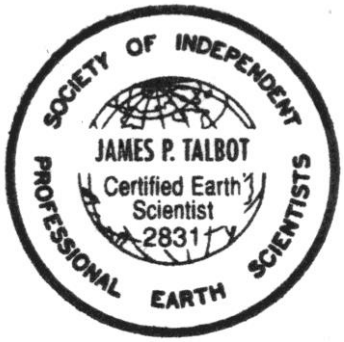
This report presents the results of Whole Rock X-ray diffraction (XRD) analysis performed on 5 samples. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

If you have any questions concerning these results or if you need anything else please contact me at (970) 641-1235. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,





James P. Talbot, P.G.

NOTICE: The results and interpretations presented in this report are based on materials and information supplied by the client and represent the judgment of K/T GeoServices, Inc. This report is intended for the client's exclusive and confidential use, and any user of this report agrees that K/T GeoServices, Inc. and its employees assume no responsibility and make no warranties or representation as to the utility of this report for any reason. K/T GeoServices, Inc. and its employees shall not be liable for any loss or damage, regardless of cause, resulting from the use of any information contained herein.

X-ray Diffraction Data (Weight Percent)

Sample ID	Quartz	K-Feldspar	Plagioclase	Calcite	Dolomite	Pyrite	Hematite	Total Clay*	TOTAL
BH19-9-LRB-002 12.6 ft	6.8	0.9	0	49.1	41.3	0	0	1.9	100
BH19-33-LRB-005 153.05 ft	9.7	4.3	0	62	14.6	0.4	0	9	100
BH19-9-LRB-009 55.8 ft	69.1	0	0	0.4	29	0	0	1.5	100
BH19-08-LRB-012 54.75 ft	14.8	1.2	0	0.4	79.9	0	0	3.7	100
BH19-09-LRB-013 74.0 ft	12.3	1.5	0	1.6	81.3	0.8	0	2.5	100

*Total Clay - +/- Illite&Mica, Chlorite, Kaolinite and Mixed-Layer Clay Minerals.

See page 3 for mineral definitions.
See page 4 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 5.
X-ray diffraction traces are presented on pages 6 – 10.

Mineral Definitions

Rock Forming (nonclay) Minerals

Quartz
Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar
K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase
Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Calcite
Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Dolomite
Dolomite is a hexagonal carbonate mineral with the formula $CaMg(CO_3)_2$.

Pyrite
Pyrite (FeS_2) is an iron sulfide iron sulfide with a cubic crystal structure. Pyrite is also known as fool's gold.

Hematite
Hematite (Fe_2O_3) and its' alteration products are the most common cause of a red coloration in rocks and sediments.

Phyllosilicate (Clay) Minerals

Illite & Mica
Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Kaolinite
Kaolinite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate with the general formula $Al_2(Si_2O_5)(OH)_4$.

Chlorite
Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Clay Minerals
Clay mineral groups containing Illite or Chlorite layers interlayered or interstratified with Smectite layers.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative; there are many factors affecting the results.

XRD methods can quantify crystalline material only. Non-crystalline material in large concentrations can be detected but not quantified. Therefore, any non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of <1 to 5 weight percent. Detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Sample Preparation and Analytical Procedures
(Copyright 2019 K/T GeoServices, Inc.)

Sample Preparation

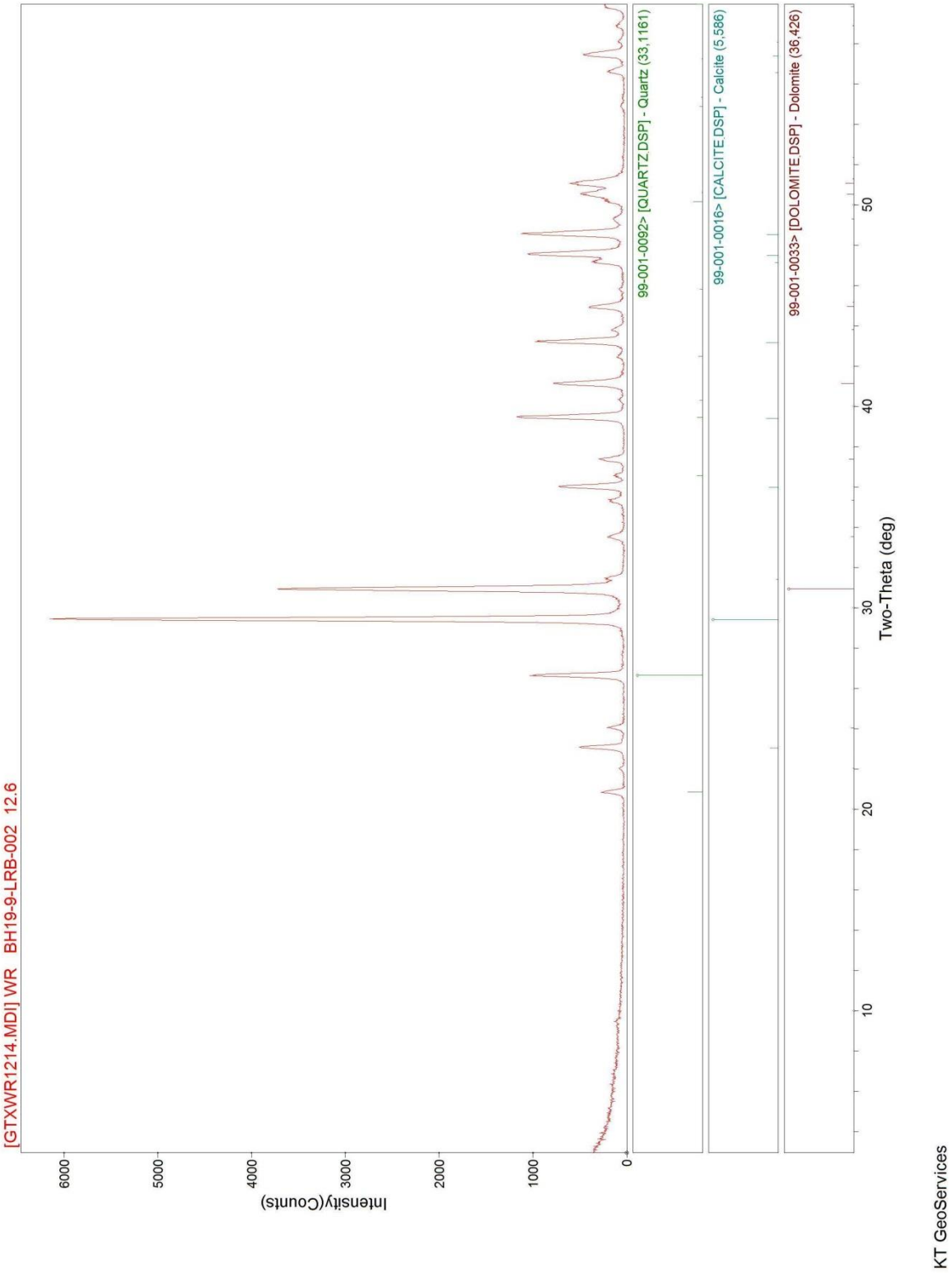
Samples submitted for bulk XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of the sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random bulk mounts.

Analytical Procedures

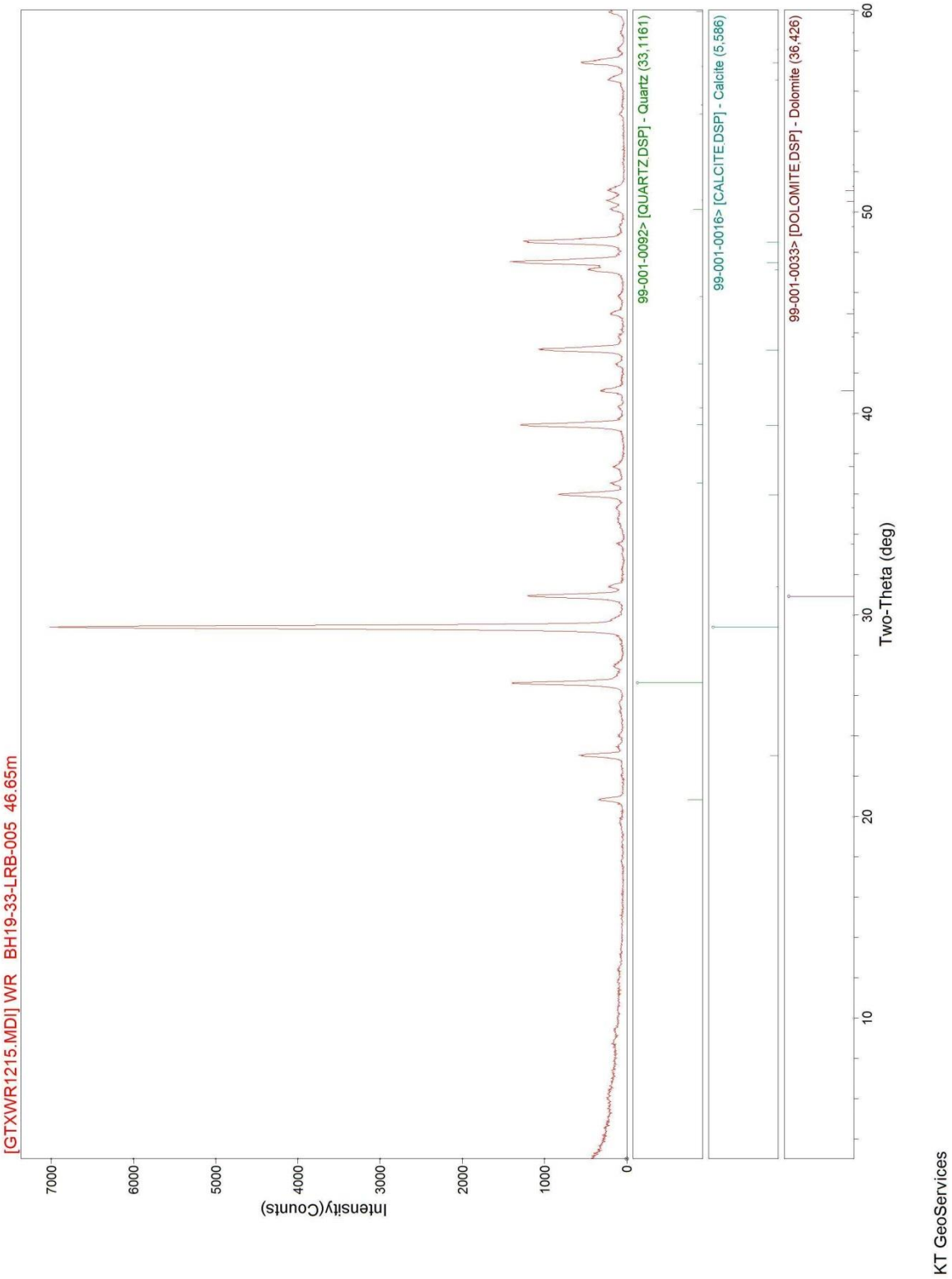
X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The bulk powder samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute.

Semiquantitative determinations of bulk powder mineral amounts are done using Jade Software (Materials Data, Inc.) with the Whole Pattern Fitting option. All quantitative data (including an estimate of clay mineral amounts) come from the bulk powder pattern. This is done by using Whole Pattern Fitting (WPF) and Rietveld refinement methods on the observed data. A diffraction model is fit to the measured pattern by non-linear least-square optimization in which certain parameters are varied to improve the fit of the model to the observed data. Modeling parameters include background, profile parameters, and lattice constants. For Rietveld refinement, a complete physics simulation is generally used in which crystal structures of the phases are required. Since the physics of scattering is well known, this method can be very exact and even allow adjustment of atomic coordinates, occupancies, and thermal parameters.

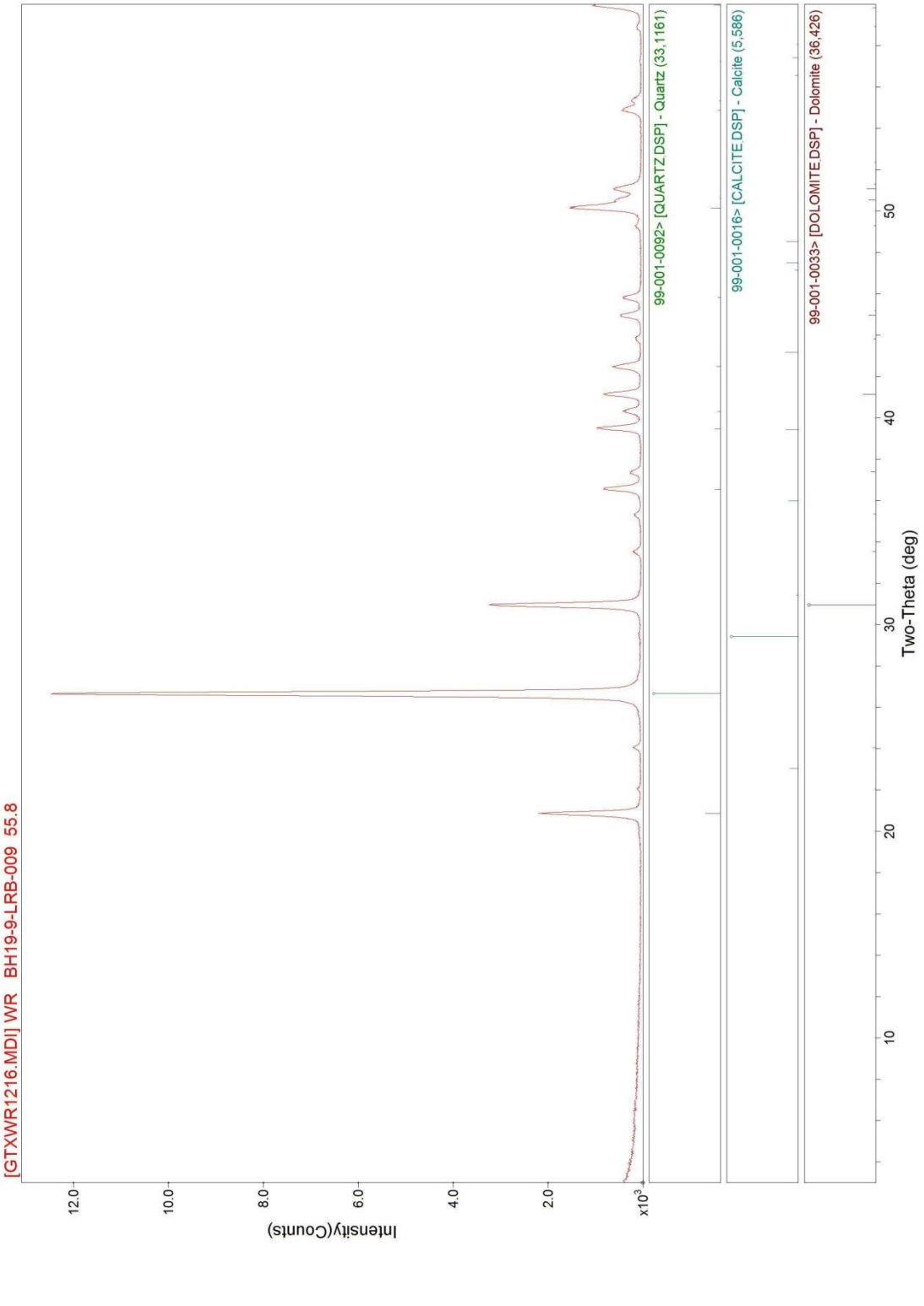
Whole Rock X-ray Diffraction Trace



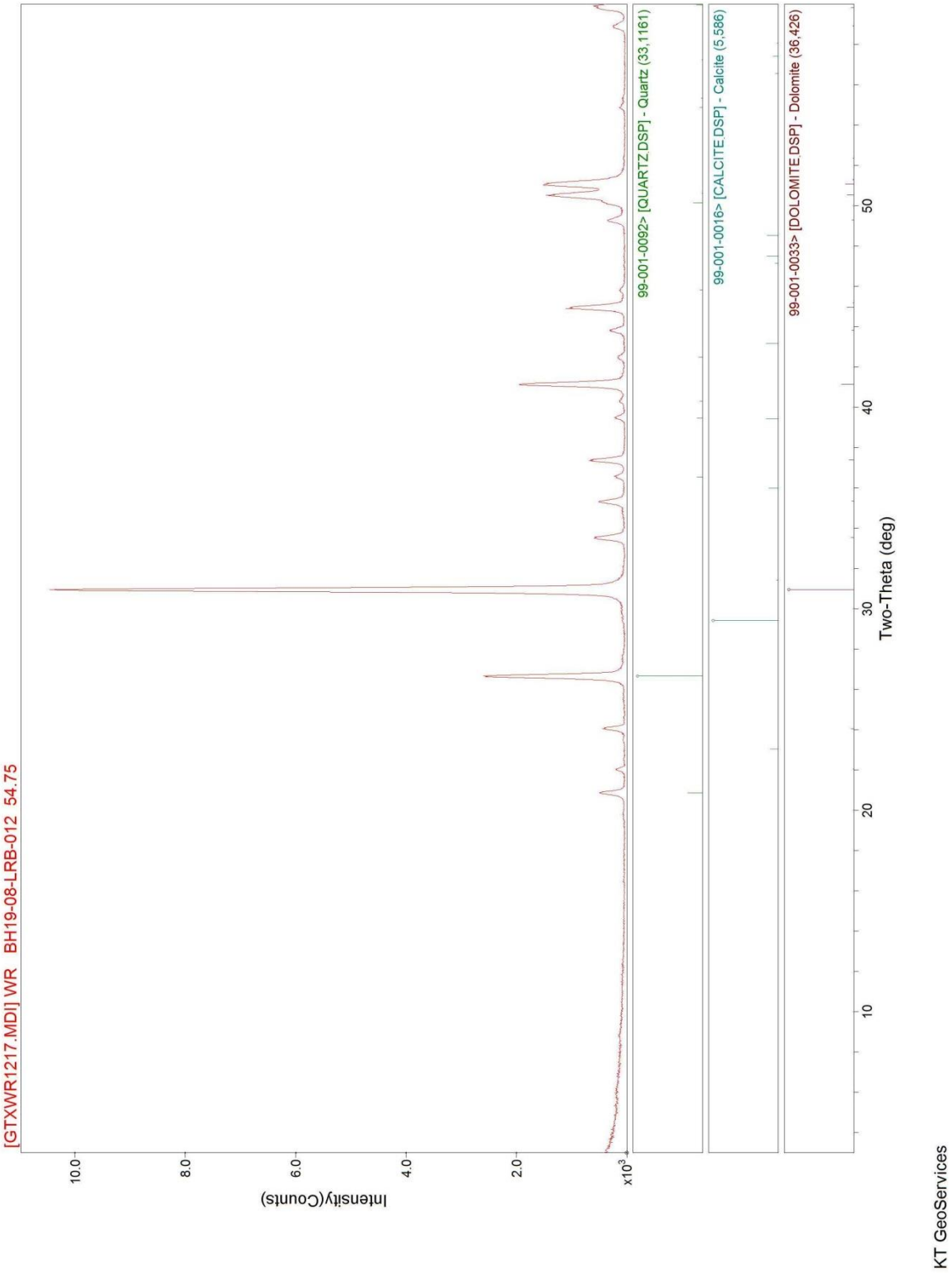
Whole Rock X-ray Diffraction Trace



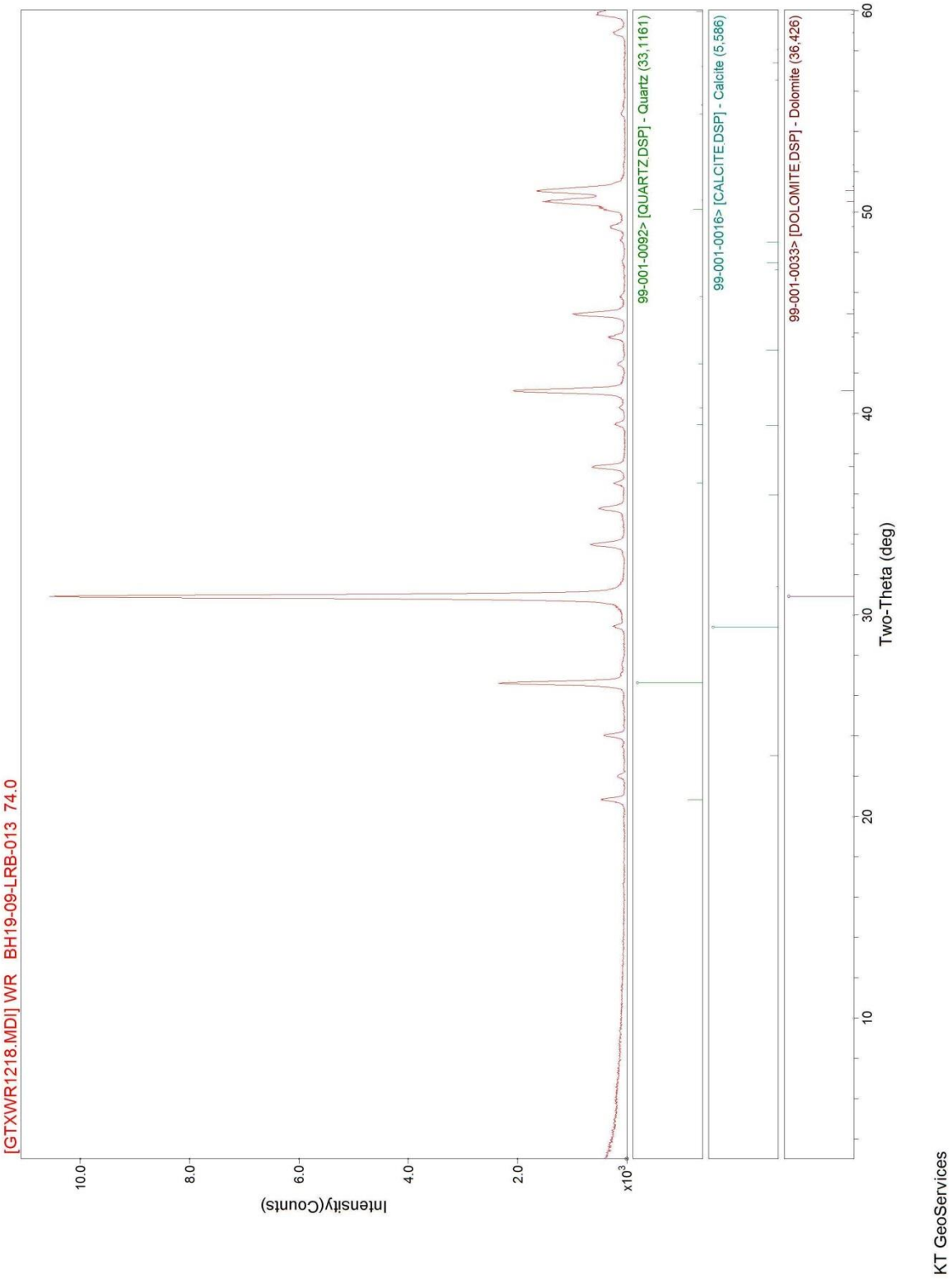
Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



K/T GeoServices, Inc.

219 N. Iowa St., Unit J *www.ktgeo.com*
Gunnison CO 81230 USA *970-641-1235*

January 8, 2020

Jon Campbell
GeoTesting Express
125 Nagog Park
Acton MA 01720
(978) 635-0424
jcampbell@geotesting.com

GTX No.:	310187
Project	Line 5 Replacement Tunnel, Straits of Mackinac
Subject:	X-ray Diffraction Analysis
K/T File No.:	Z20009

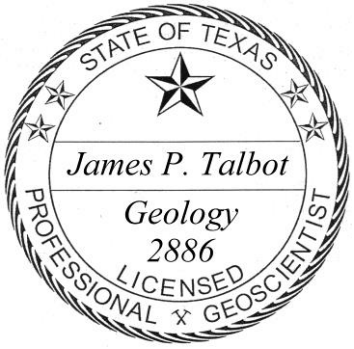
Dear Jon,

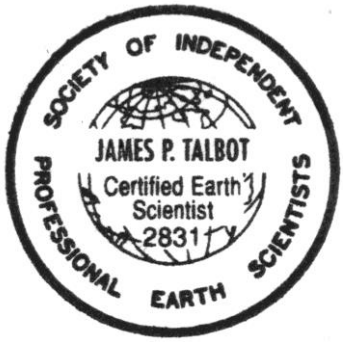
This report presents the results of Whole Rock X-ray diffraction (XRD) analysis performed on 5 samples. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

If you have any questions concerning these results or if you need anything else please contact me at (970) 641-1235. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,





James P. Talbot, P.G.

NOTICE: The results and interpretations presented in this report are based on materials and information supplied by the client and represent the judgment of K/T GeoServices, Inc. This report is intended for the client's exclusive and confidential use, and any user of this report agrees that K/T GeoServices, Inc. and its employees assume no responsibility and make no warranties or representation as to the utility of this report for any reason. K/T GeoServices, Inc. and its employees shall not be liable for any loss or damage, regardless of cause, resulting from the use of any information contained herein.

X-ray Diffraction Data (Weight Percent)

Sample ID	Quartz	K-Feldspar	Plagioclase	Calcite	Dolomite	Pyrite	Hematite	Total Clay*	TOTAL
BH19-19-LRB-004 116.67-117.13 ft	0.9	0.4	0.5	3.1	94.5	0	0	0.6	100
BH19-19-LRB-006 137.55-137.60 ft	17.8	7	0.5	0.5	53.7	0	0.3	20.2	100
BH19-19-LRB-005 124.51-125.0 ft	13.8	6.8	0.4	7	54.9	1.4	0	15.7	100
BH19-36-LRB-005 211.61-212.27 ft	13.6	6.7	0.4	0	61.8	0	0	17.5	100
BH19-36-LRB-003 173.38-173.56 ft	12.8	8.6	0.6	15.8	48	1.1	0	13.1	100

*Total Clay - +/- Illite&Mica, Chlorite, Kaolinite and Mixed-Layer Clay Minerals.

See page 3 for mineral definitions.
See page 4 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 5.
X-ray diffraction traces are presented on pages 6 – 10.

Mineral Definitions

Rock Forming (nonclay) Minerals

Quartz
Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar
K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase
Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Calcite
Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Dolomite
Dolomite is a hexagonal carbonate mineral with the formula $CaMg(CO_3)_2$.

Pyrite
Pyrite (FeS_2) is an iron sulfide iron sulfide with a cubic crystal structure. Pyrite is also known as fool's gold.

Hematite
Hematite (Fe_2O_3) and its' alteration products are the most common cause of a red coloration in rocks and sediments.

Phyllosilicate (Clay) Minerals

Illite & Mica
Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Kaolinite
Kaolinite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate with the general formula $Al_2(Si_2O_5)(OH)_4$.

Chlorite
Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Clay Minerals
Clay mineral groups containing Illite or Chlorite layers interlayered or interstratified with Smectite layers.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative; there are many factors affecting the results.

XRD methods can quantify crystalline material only. Non-crystalline material in large concentrations can be detected but not quantified. Therefore, any non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of <1 to 5 weight percent. Detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Sample Preparation and Analytical Procedures
(Copyright 2019 K/T GeoServices, Inc.)

Sample Preparation

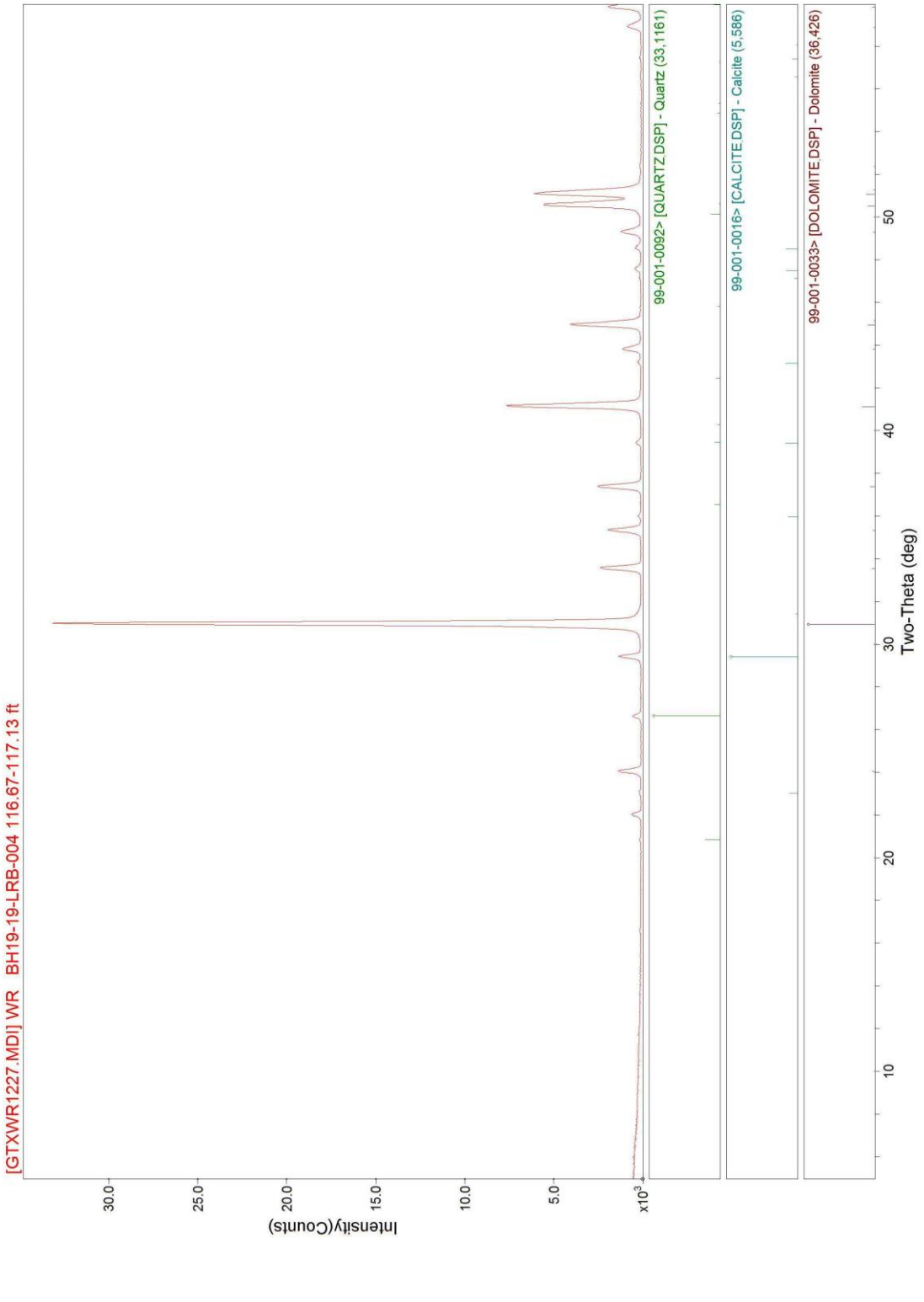
Samples submitted for bulk XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of the sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random bulk mounts.

Analytical Procedures

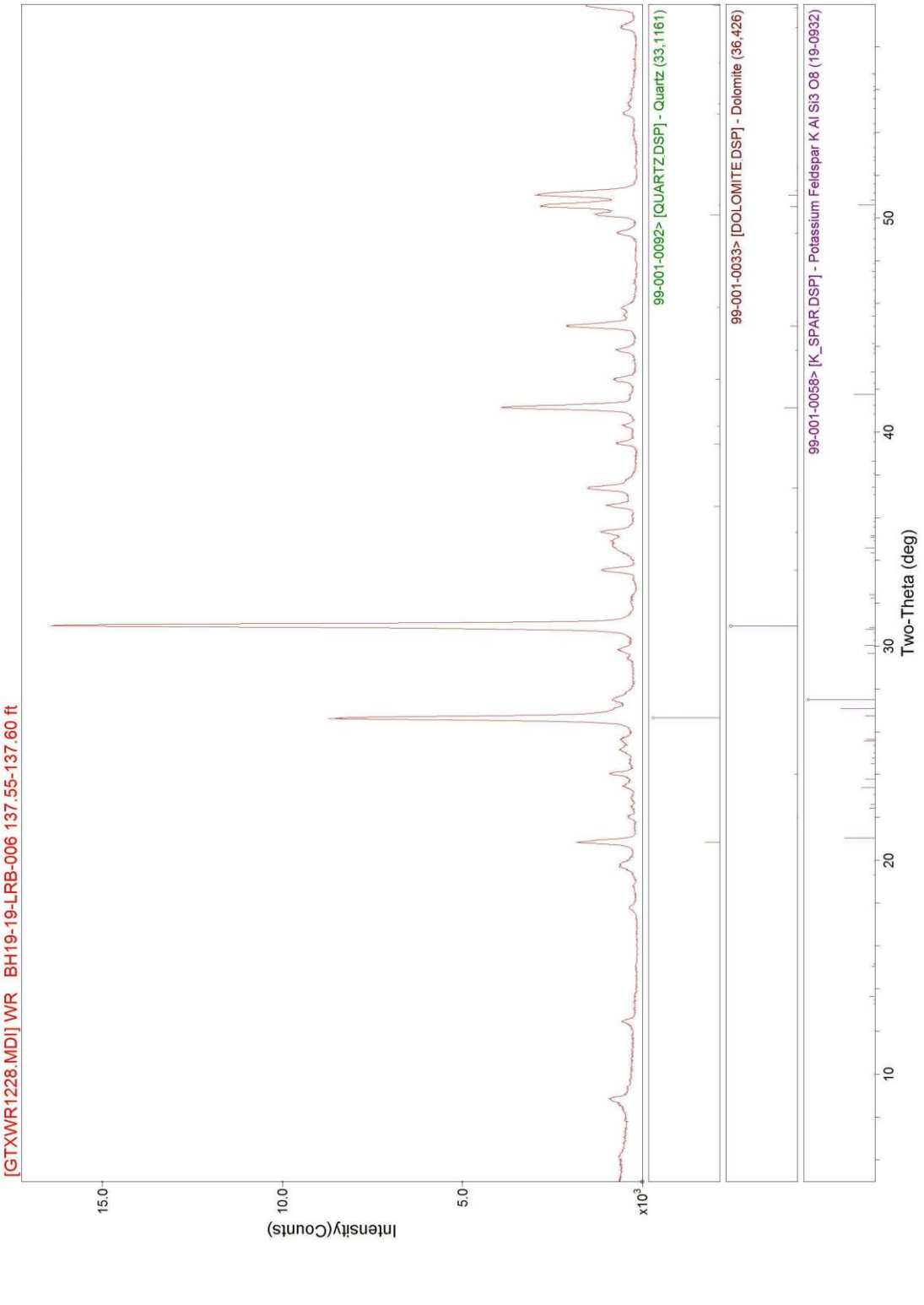
X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The bulk powder samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute.

Semiquantitative determinations of bulk powder mineral amounts are done using Jade Software (Materials Data, Inc.) with the Whole Pattern Fitting option. All quantitative data (including an estimate of clay mineral amounts) come from the bulk powder pattern. This is done by using Whole Pattern Fitting (WPF) and Rietveld refinement methods on the observed data. A diffraction model is fit to the measured pattern by non-linear least-square optimization in which certain parameters are varied to improve the fit of the model to the observed data. Modeling parameters include background, profile parameters, and lattice constants. For Rietveld refinement, a complete physics simulation is generally used in which crystal structures of the phases are required. Since the physics of scattering is well known, this method can be very exact and even allow adjustment of atomic coordinates, occupancies, and thermal parameters.

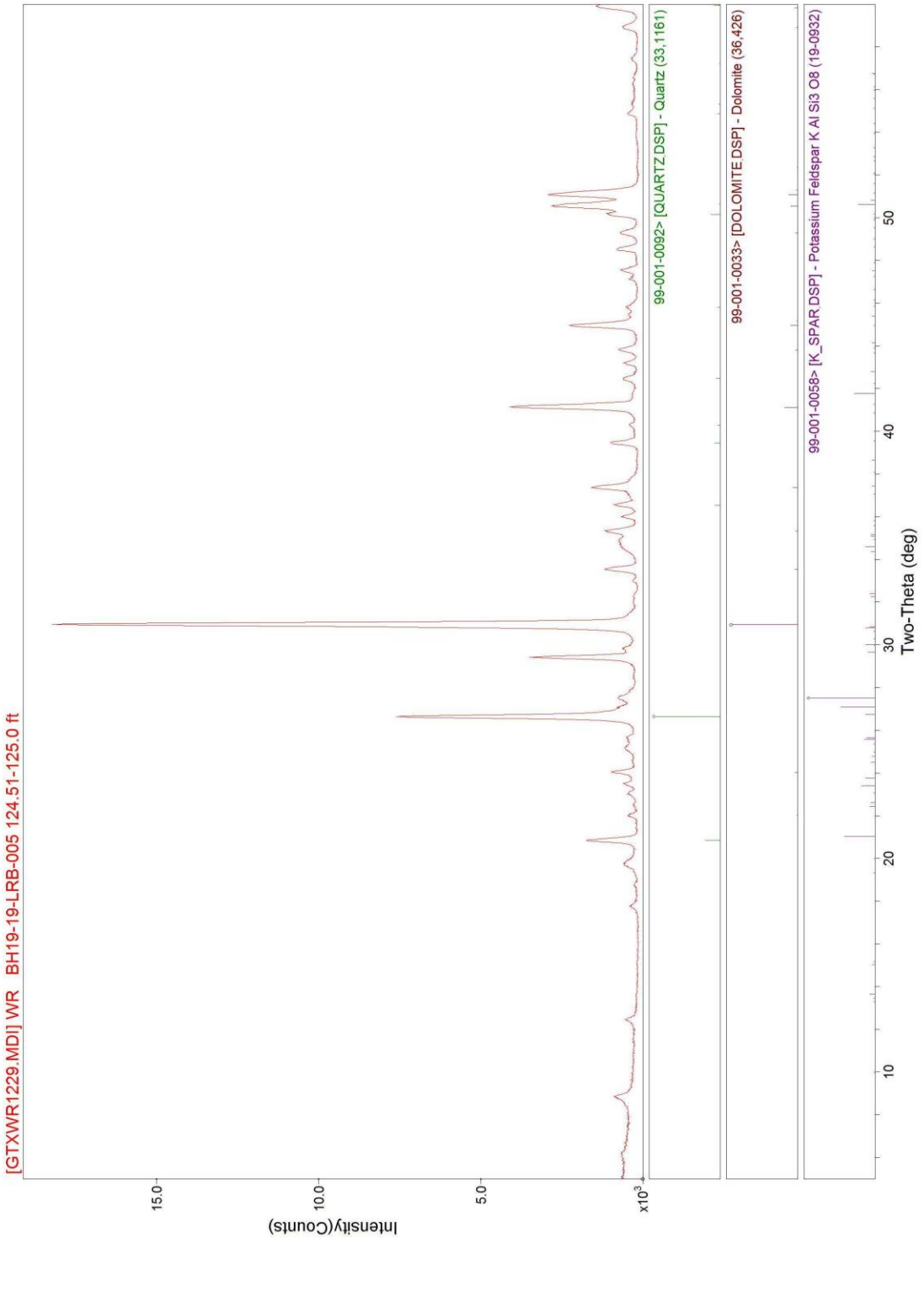
Whole Rock X-ray Diffraction Trace



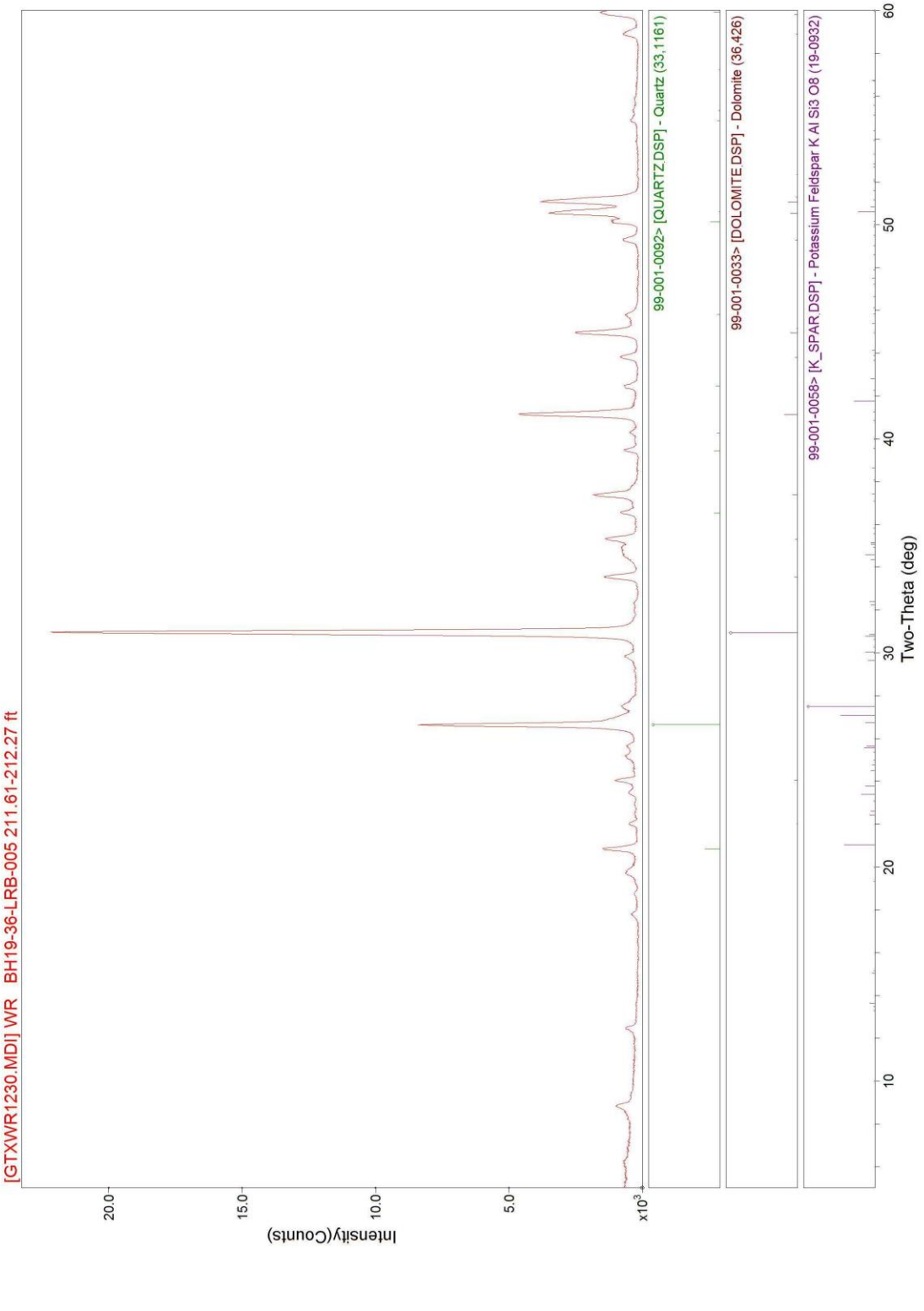
Whole Rock X-ray Diffraction Trace



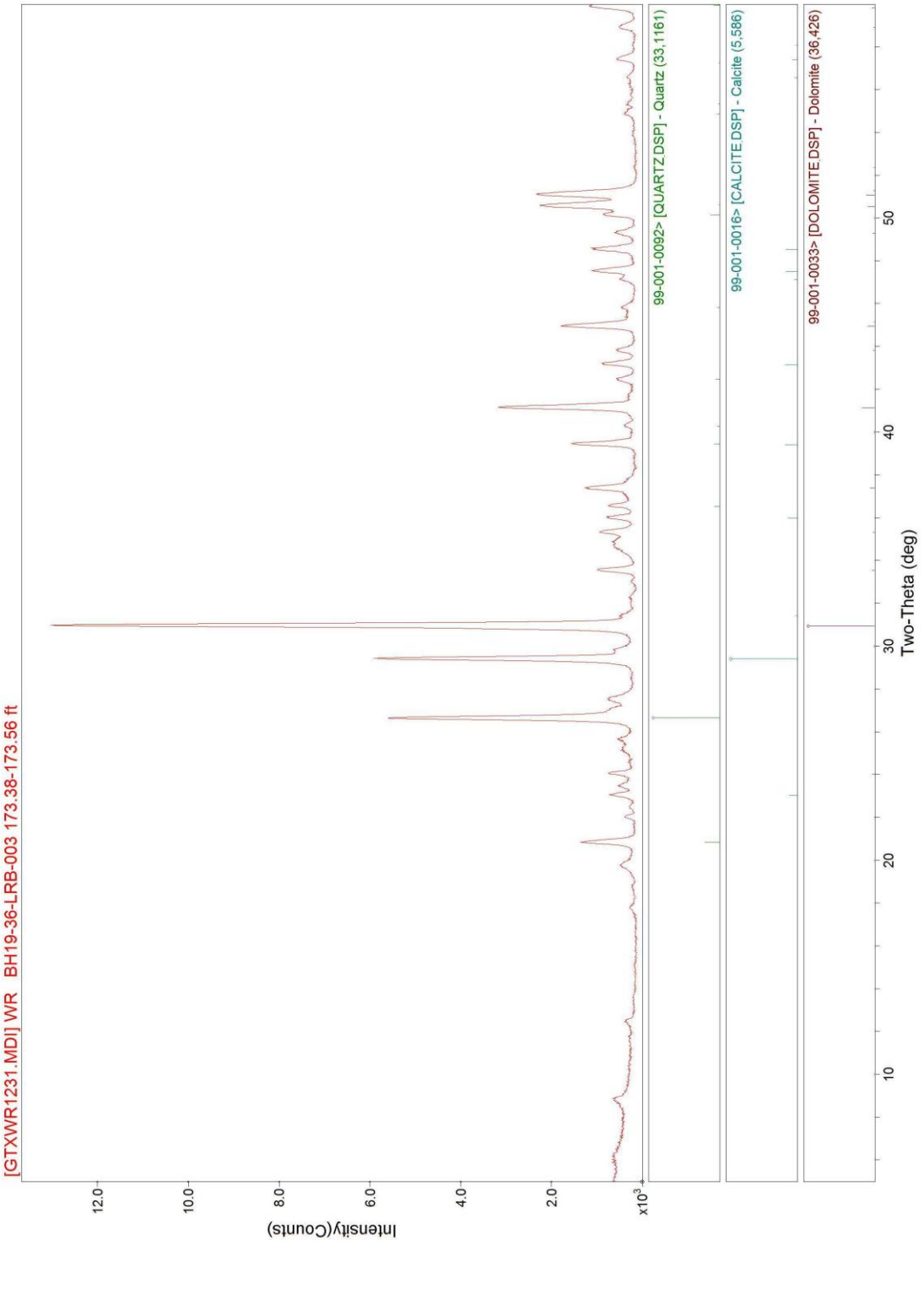
Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



K/T GeoServices, Inc.

219 N. Iowa St., Unit J *www.ktgeo.com*
Gunnison CO 81230 USA *970-641-1235*

January 30, 2020

Jon Campbell
GeoTesting Express
125 Nagog Park
Acton MA 01720
(978) 635-0424
jcampbell@geotesting.com

GTX No.:	310187
Project	Line 5 Replacement Tunnel, Straits of Mackinac
Subject:	X-ray Diffraction Analysis
K/T File No.:	Z20030

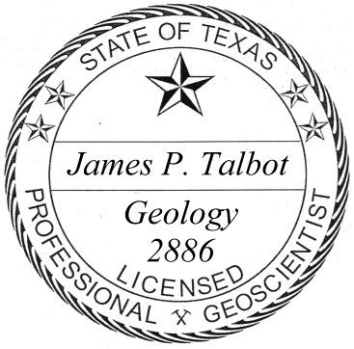
Dear Jon,

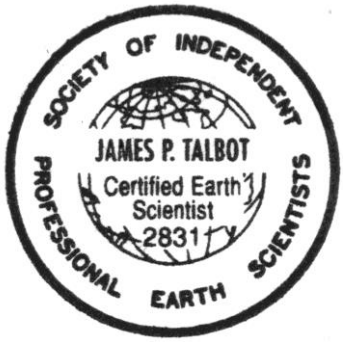
This report presents the results of Whole Rock X-ray diffraction (XRD) analysis performed on 10 samples. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

If you have any questions concerning these results or if you need anything else please contact me at (970) 641-1235. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,





James P. Talbot, P.G.

NOTICE: The results and interpretations presented in this report are based on materials and information supplied by the client and represent the judgment of K/T GeoServices, Inc. This report is intended for the client's exclusive and confidential use, and any user of this report agrees that K/T GeoServices, Inc. and its employees assume no responsibility and make no warranties or representation as to the utility of this report for any reason. K/T GeoServices, Inc. and its employees shall not be liable for any loss or damage, regardless of cause, resulting from the use of any information contained herein.

X-ray Diffraction Data (Weight Percent)

Sample ID	Quartz	K-Feldspar	Plagioclase	Biotite	Calcite	Dolomite	Pyrite	Hematite	Gypsum	Total Clay*	TOTAL
BH19-21 LRB-001 55.77-56.76 ft	22.6	6.3	1	0	0	44	0	0.5	5.9	19.7	100
BH19-23 LRB-004 173.56-175.20 ft	13.6	6.7	0.9	0	0	47.8	0	0.4	12.3	18.3	100
BH19-24A LRB-004 249.34-251.31 ft	13	7	0.9	0	0	52.8	0	0.3	10.7	15.3	100
BH19-24A LRB-010 296.59-300.20 ft	9.1	5.1	0.6	0	0	54.7	0	0.5	14	16	100
BH19-26 LRB-002 319.88-320.54 ft	38.4	14.4	37.4	5.6	0	0	0	0	0	4.2	100
BH19-27 LRB-002 300.20-300.52 ft	14.8	5.6	0.6	0	2	35.3	0	0.4	27.2	14.1	100
BH19-28 LRB-002 180.77-182.41 ft	16.9	5.4	0.5	0	1	46.8	0	0.7	8.2	20.5	100
BH19-28 LRB-005 200.46-201.77 ft	19.8	4.6	0.4	0	5.3	39.6	0	0.4	10.6	19.3	100
BH19-31 LRB-005 195.87-197.83 ft	18	11.9	0.3	0	6.6	43.8	2	0	2	15.4	100
BH19-31 LRB-008 210.30-211.61 ft	17.8	7.7	0.3	0	0	49.3	0.5	0	0	24.4	100

*Total Clay - +/- Illite&Mica, Chlorite, Kaolinite and Mixed-Layer Clay Minerals.

See page 3 for mineral definitions.
See page 4 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 5.
X-ray diffraction traces are presented on pages 6 – 15.

Mineral Definitions

Quartz

Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar

K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase

Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Biotite

Biotite is a common rock forming mineral that is a member of the mica group. It is black in hand specimen and brown to green in thin section. Biotite has the general formula $K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$.

Calcite

Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Dolomite

Dolomite is a hexagonal carbonate mineral with the formula $CaMg(CO_3)_2$.

Pyrite

Pyrite (FeS_2) is an iron sulfide iron sulfide with a cubic crystal structure. Pyrite is also known as fool's gold.

Hematite

Hematite (Fe_2O_3) and its' alteration products are the most common cause of a red coloration in rocks and sediments.

Gypsum

Gypsum is a hydrated calcium sulfate mineral that has the formula $CaSO_4 \bullet 2(H_2O)$.

Illite & Mica

Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Kaolinite

Kaolinite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate with the general formula $Al_2(Si_2O_5)(OH)_4$.

Chlorite

Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Clay Minerals

Clay mineral groups containing Illite or Chlorite layers interlayered or interstratified with Smectite layers.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative; there are many factors affecting the results.

XRD methods can quantify crystalline material only. Non-crystalline material in large concentrations can be detected but not quantified. Therefore, any non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of <1 to 5 weight percent. Detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

K/T GeoServices, Inc.
XRD1 - Bulk Only XRD Analysis
Sample Preparation and Analytical Procedures
(Copyright 2019 K/T GeoServices, Inc.)

Sample Preparation

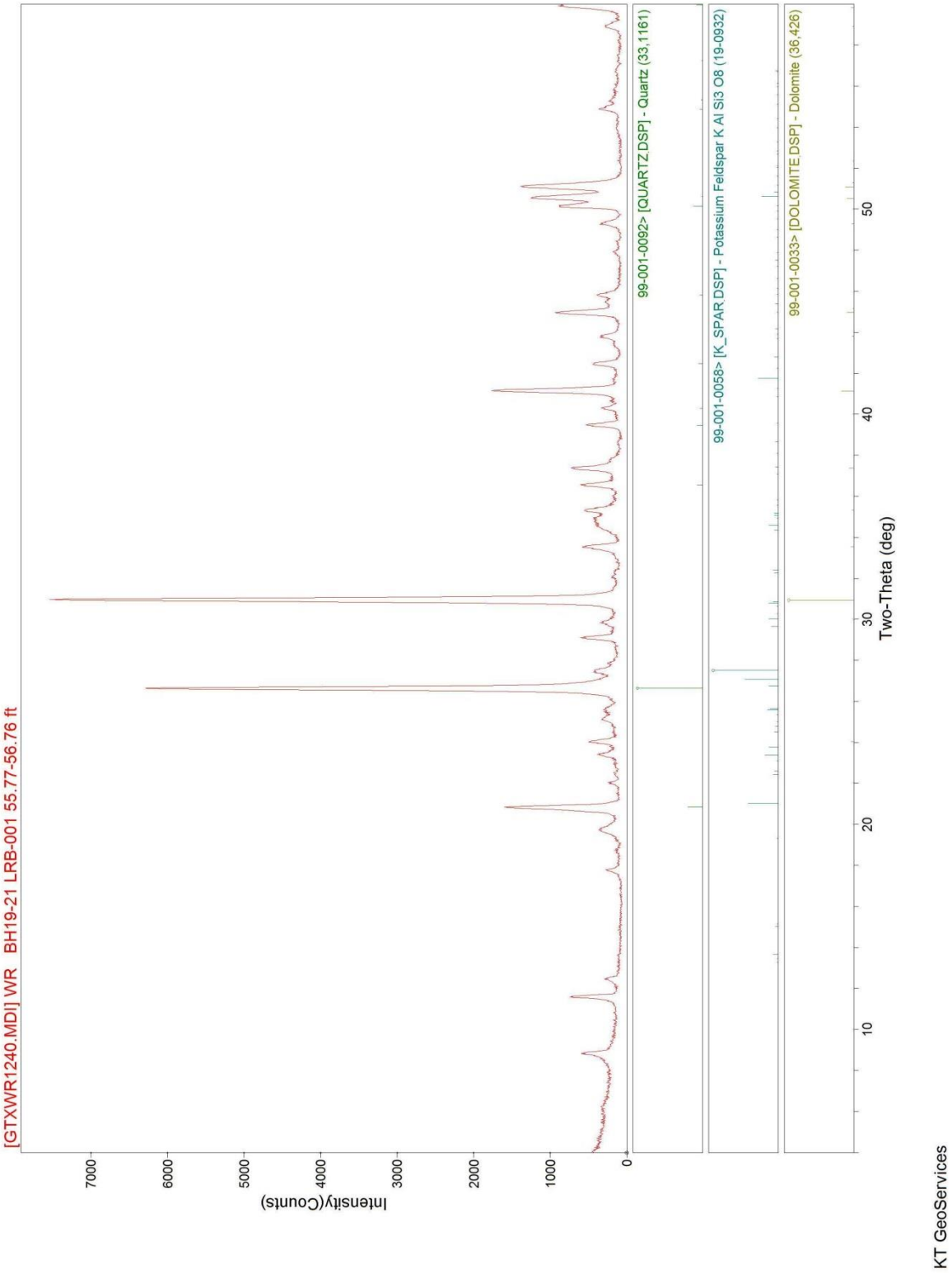
Samples submitted for bulk XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of the sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random bulk mounts.

Analytical Procedures

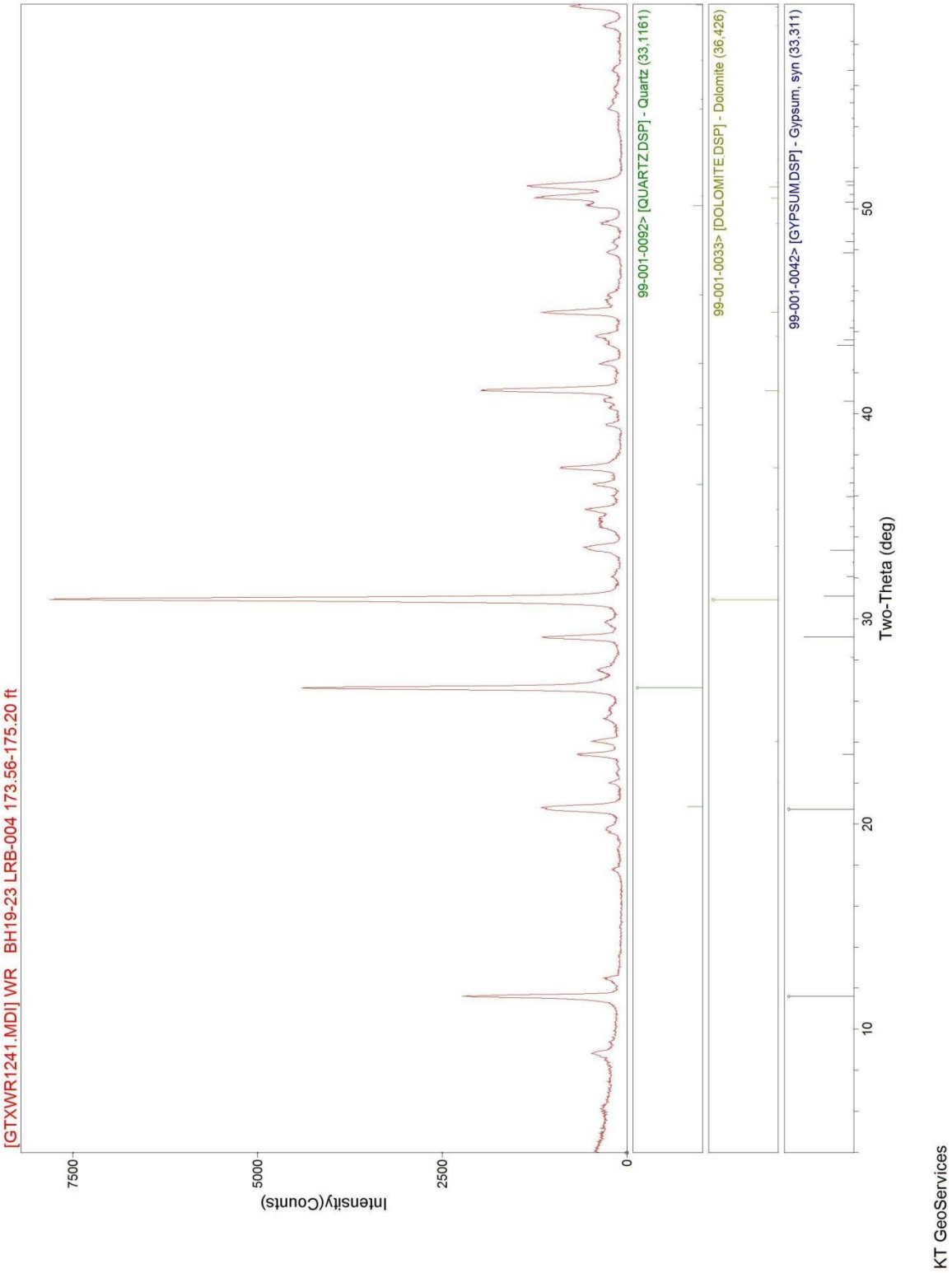
X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The bulk powder samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute.

Semiquantitative determinations of bulk powder mineral amounts are done using Jade Software (Materials Data, Inc.) with the Whole Pattern Fitting option. All quantitative data (including an estimate of clay mineral amounts) come from the bulk powder pattern. This is done by using Whole Pattern Fitting (WPF) and Rietveld refinement methods on the observed data. A diffraction model is fit to the measured pattern by non-linear least-square optimization in which certain parameters are varied to improve the fit of the model to the observed data. Modeling parameters include background, profile parameters, and lattice constants. For Rietveld refinement, a complete physics simulation is generally used in which crystal structures of the phases are required. Since the physics of scattering is well known, this method can be very exact and even allow adjustment of atomic coordinates, occupancies, and thermal parameters.

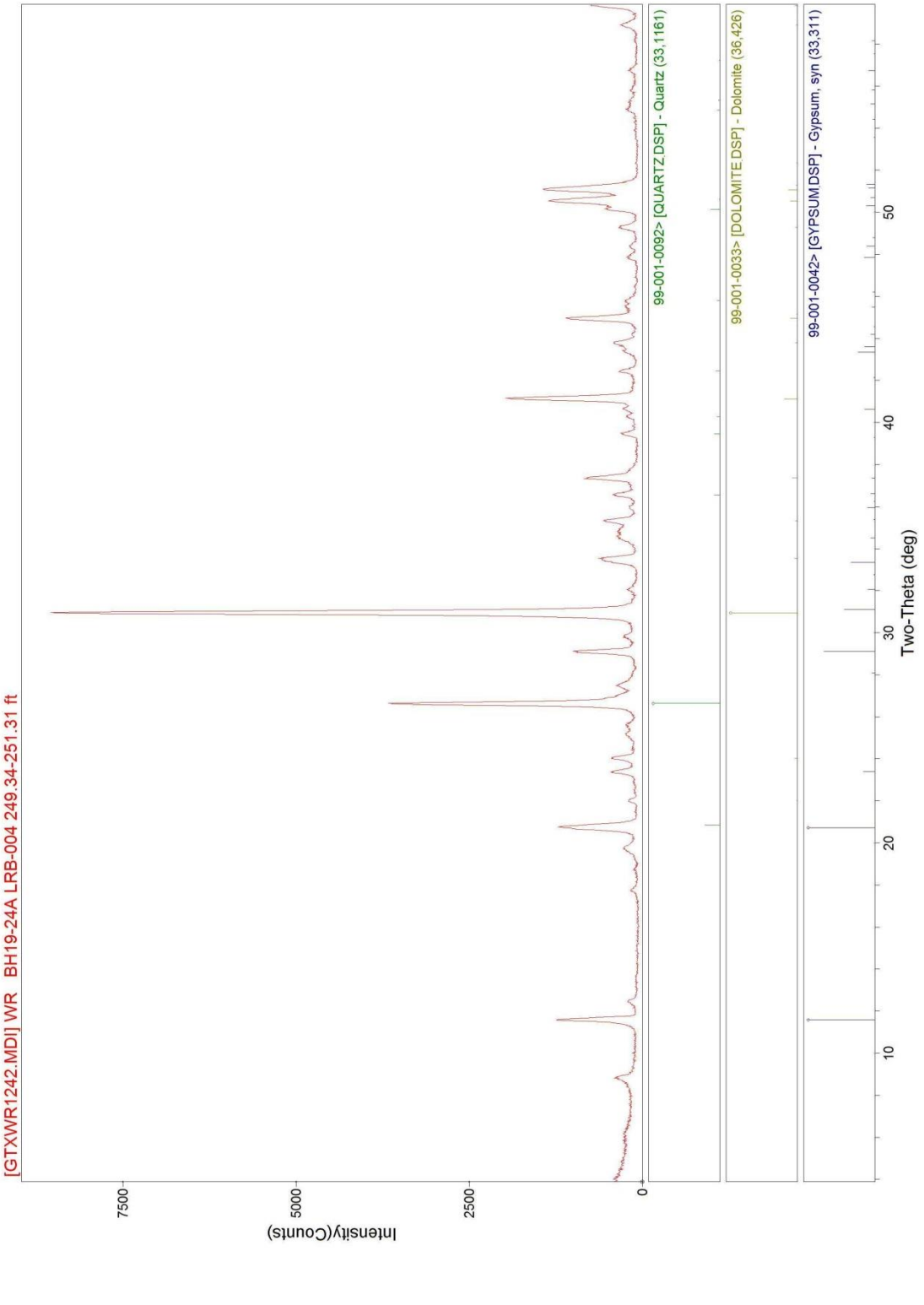
Whole Rock X-ray Diffraction Trace



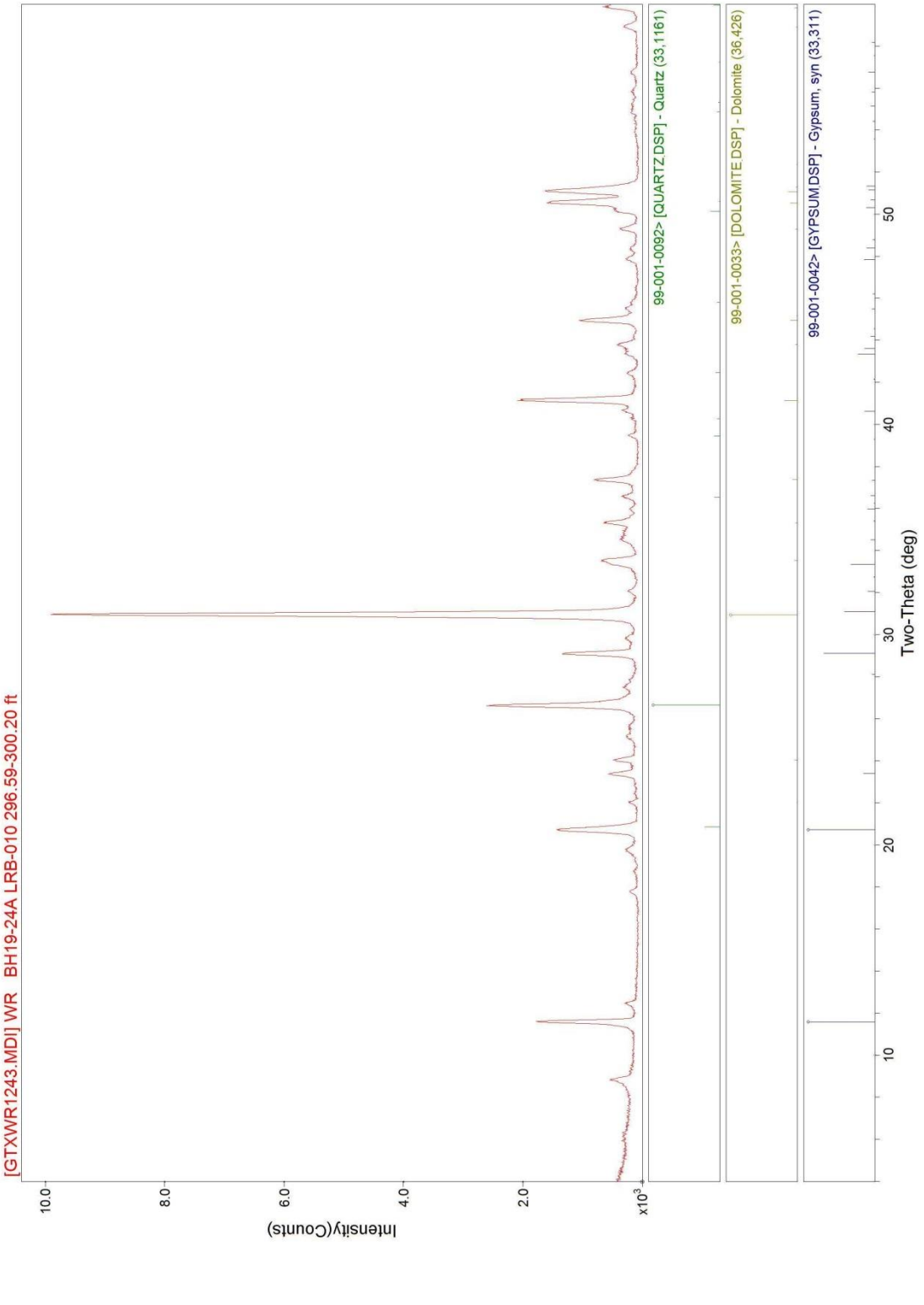
Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace

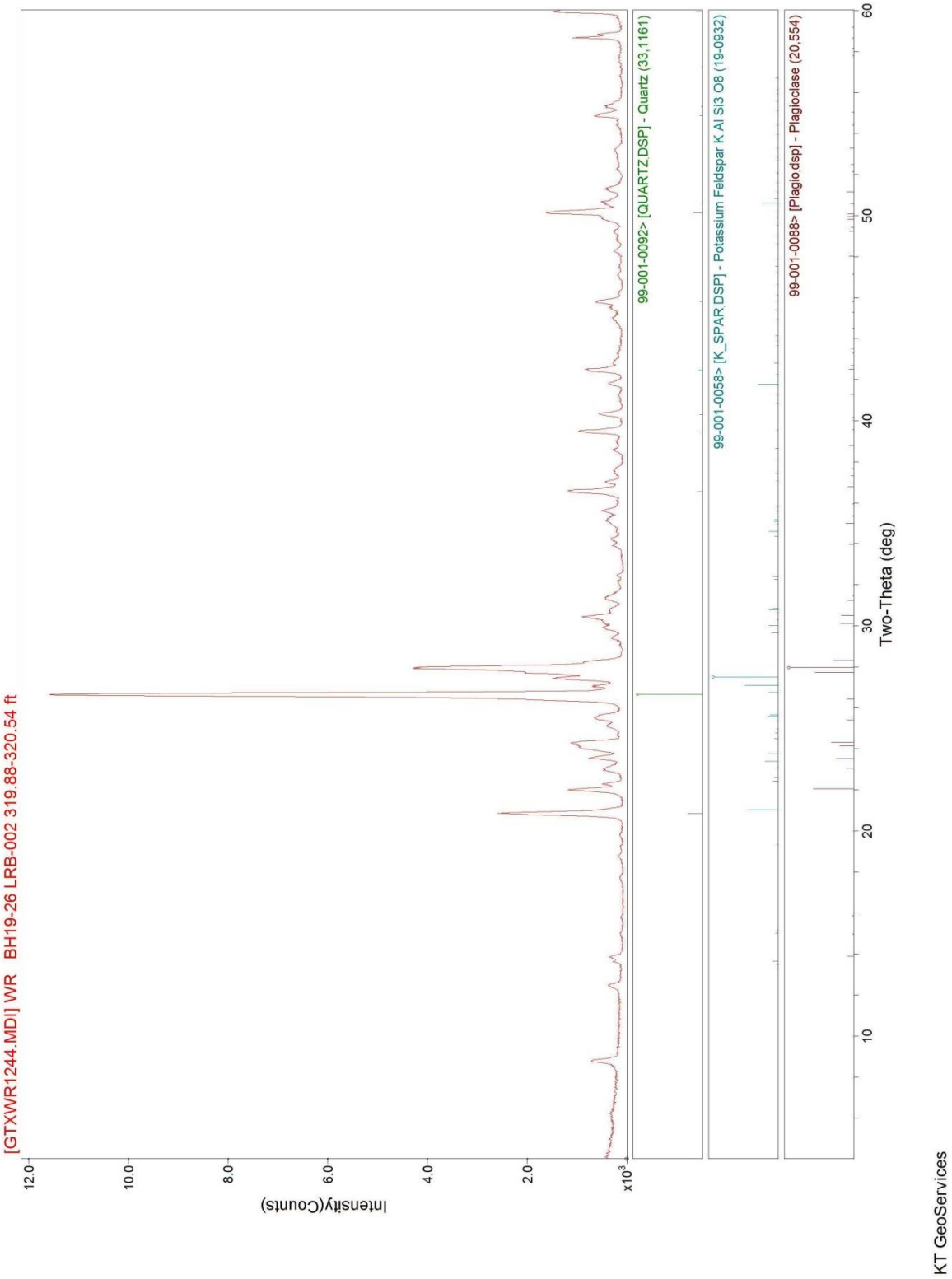


Whole Rock X-ray Diffraction Trace

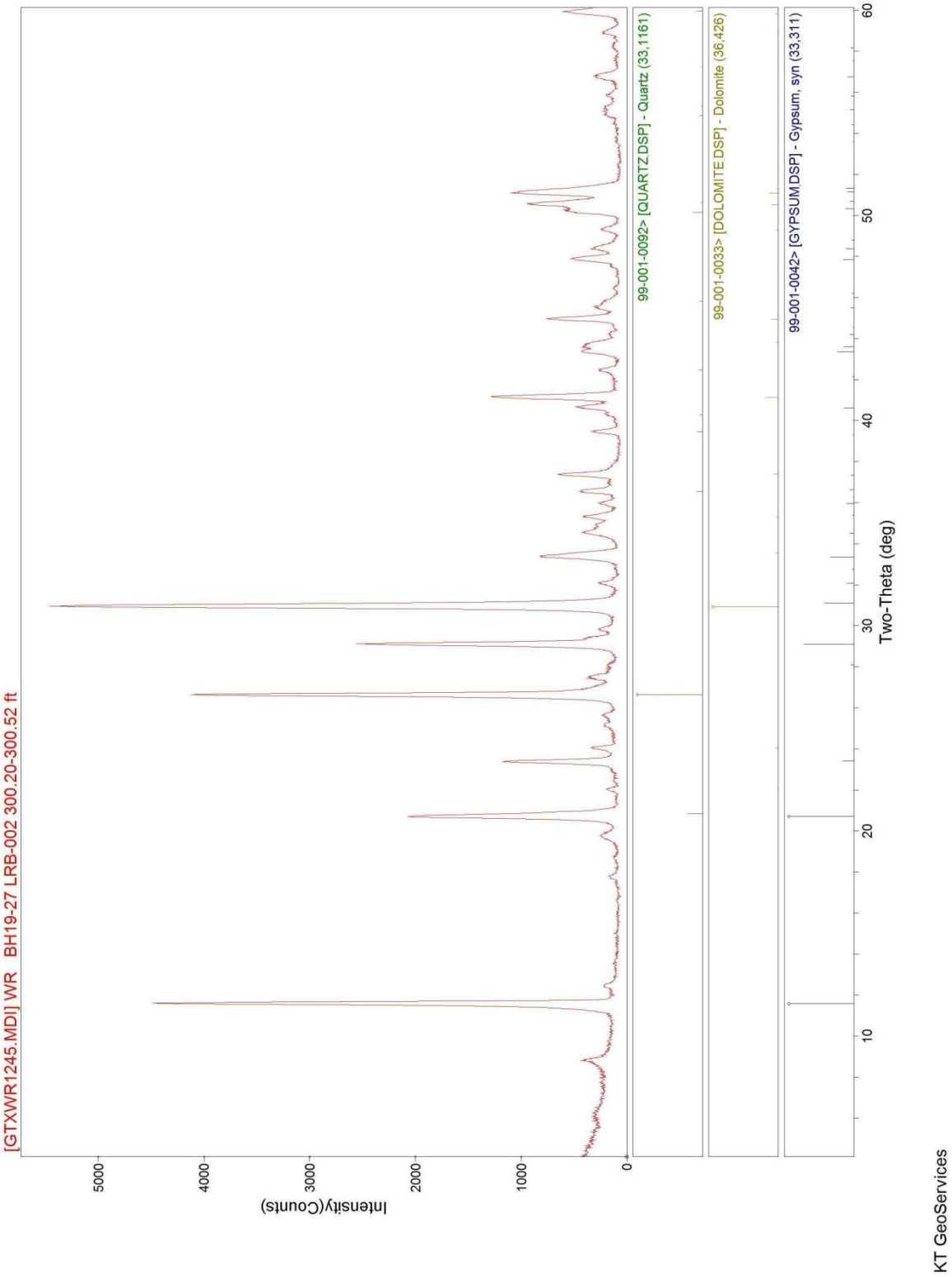


KT GeoServices

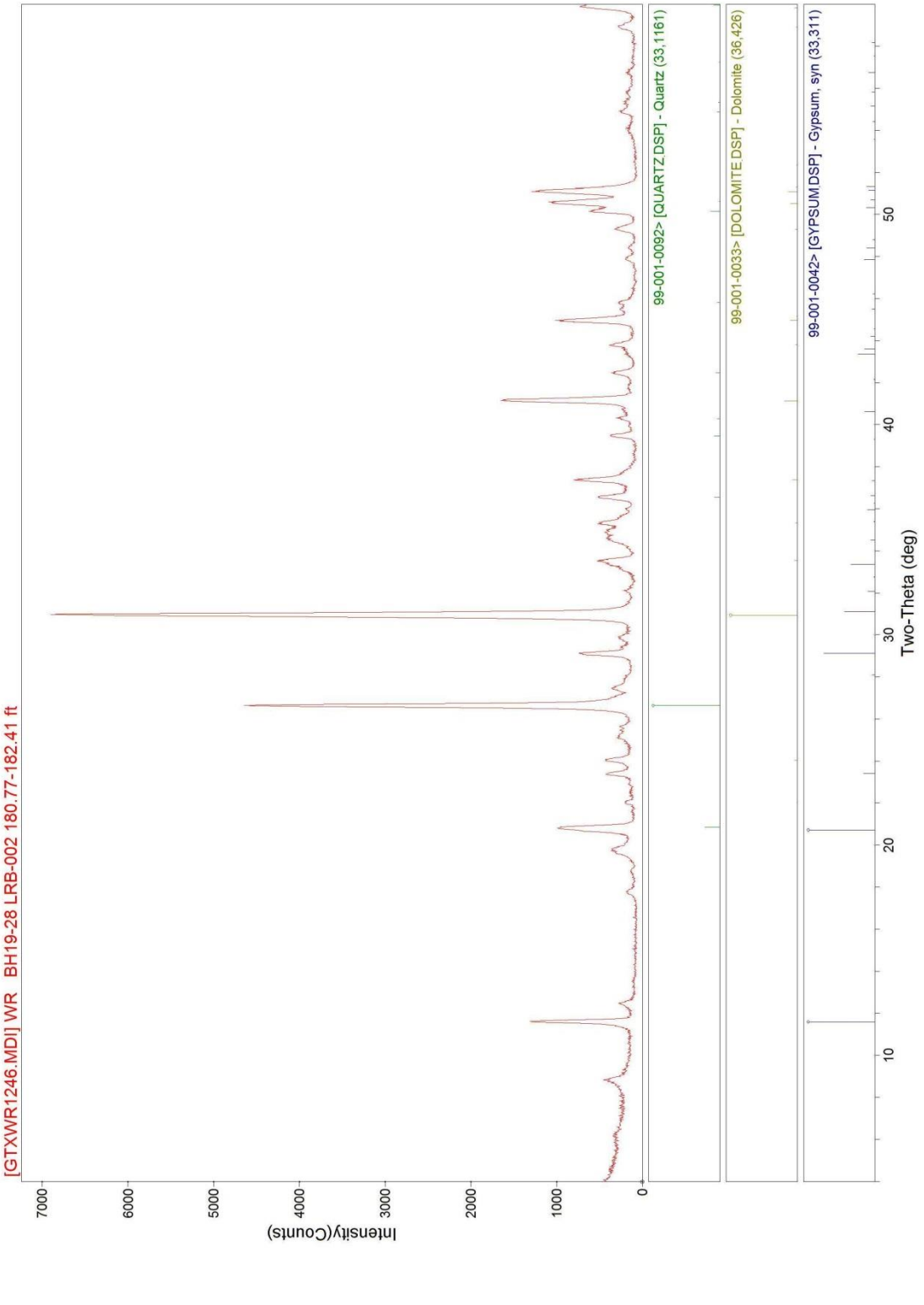
Whole Rock X-ray Diffraction Trace



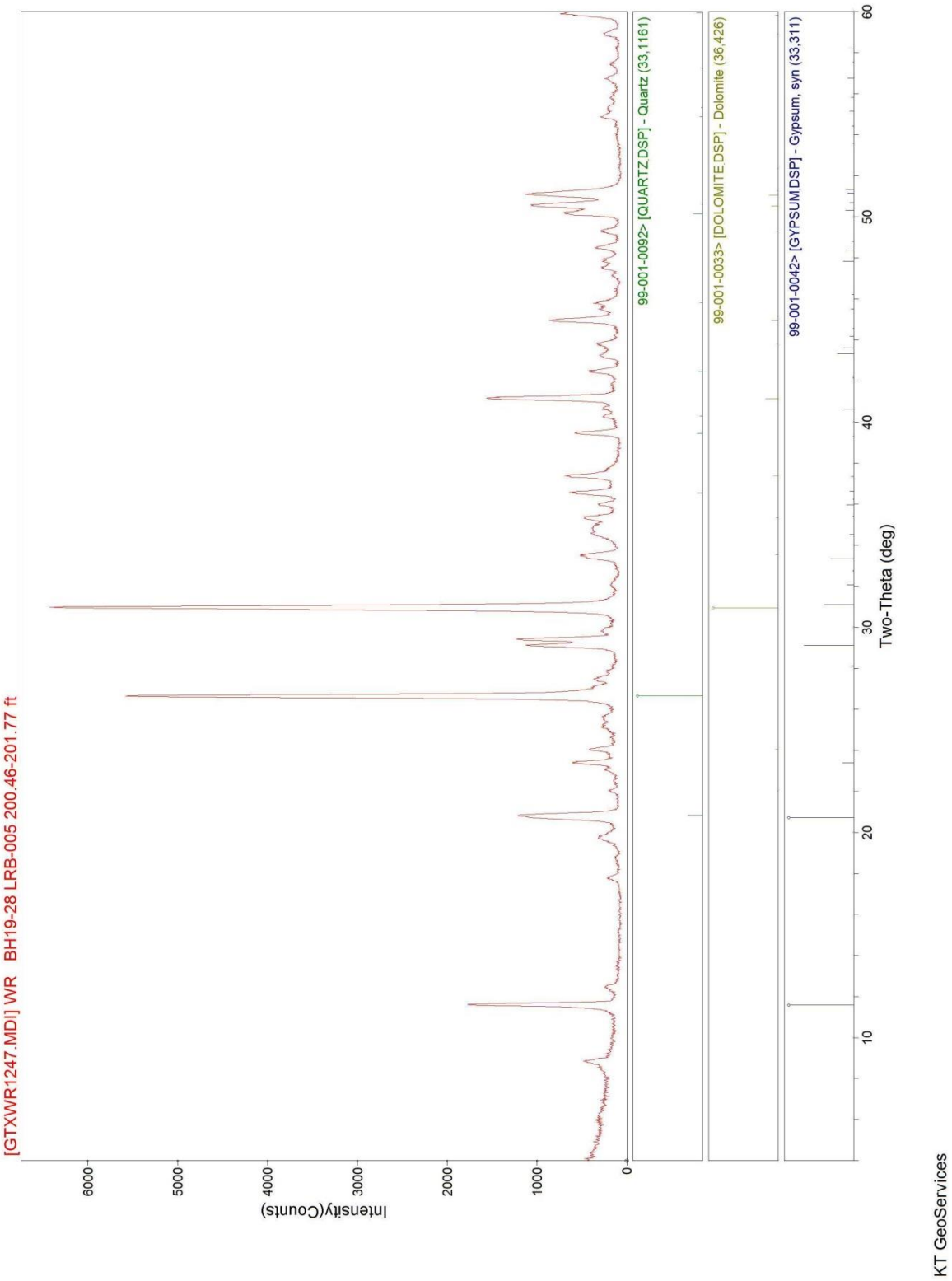
Whole Rock X-ray Diffraction Trace



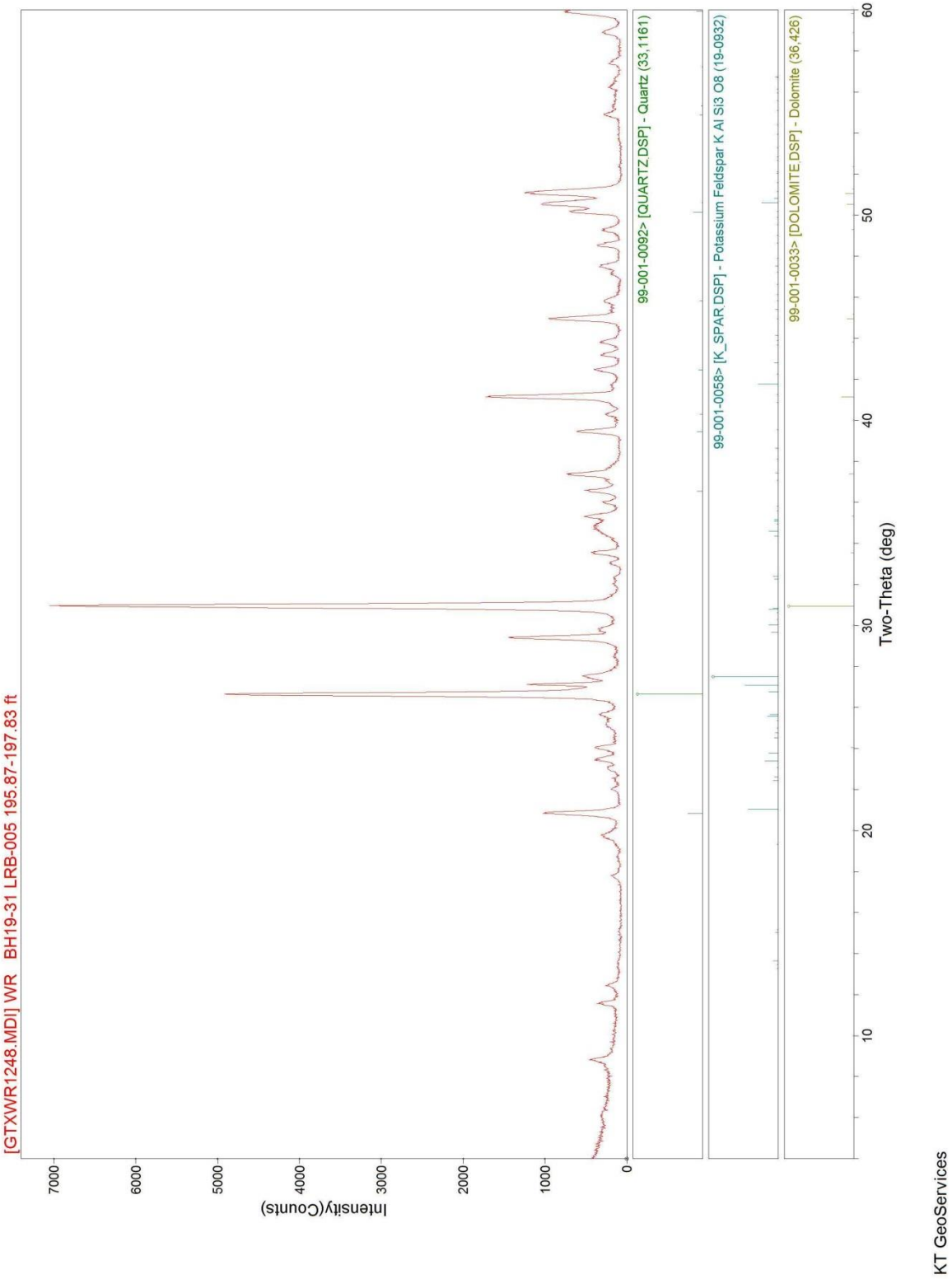
Whole Rock X-ray Diffraction Trace



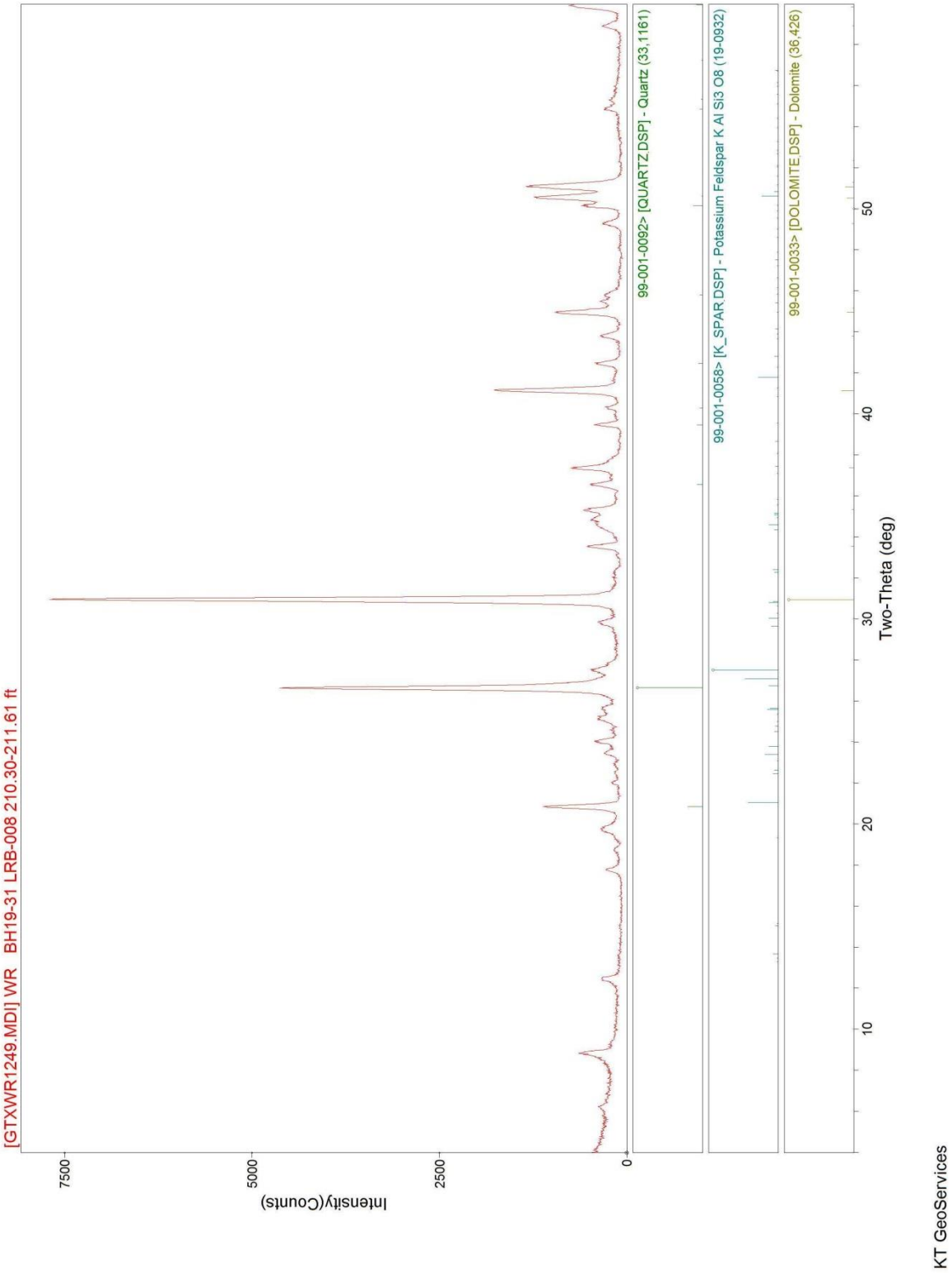
Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



Whole Rock X-ray Diffraction Trace



APPENDIX

F HYDROGEOLOGY DATA

APPENDIX

F-1 *PACKER TEST DATA*

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/25/19
WSP Personnel	K. Zeiger, X. You
Subcontractor	Cascade Drilling
Driller	M. Bond, C. Barden

Boring ID	BH19-07
Number of Tests	11
Lattitude	45.83808° N
Longitude	84.75731° W

Top of Rock, ft	68.00
Bottom of Boring, ft	203.00
Groundwater Depth (D_{VWL}), ft	18.49

Datum Elevation	600.4
Top of Rock Elevation, ft	536.5
Bottom of Hole Elevation, ft	409.6
Groundwater Elevation, ft	581.9

Total Length of Testing, ft	108.90
Boring Angle from Vertical, °	20.0
Borehole Diameter, ft	0.32/0.40

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	72.6	87.6	saturated	86.5	86.4	15	0.00	0.00	13.9	32.1	0.00E+00	0.0		
1-2	72.6	102.6	saturated	102.4	102.3	15	0.00	0.00	29.7	68.6	0.00E+00	0.0		
1-3	72.6	117.6	saturated	116.7	116.6	15	0.00	0.00	44.1	101.6	0.00E+00	0.0		
1-4	72.6	102.6	saturated	103.2	103.1	15	0.00	0.00	30.3	70.0	0.00E+00	0.0		
1-5	72.6	87.6	saturated	87.3	87.2	15	0.00	0.00	14.6	33.6	0.00E+00	0.0		
2-1	67.1	82.1	saturated	82.5	82.4	15	0.00	0.00	15.3	35.4	0.00E+00	0.0		
2-2	67.1	97.1	saturated	98.0	97.9	15	31.38	2.18	31.0	71.5	1.10E-04	10.3		
2-3	67.1	112.1	saturated	110.9	110.8	15	50.16	3.43	43.6	100.6	1.23E-04	11.5		
2-4	67.1	97.1	saturated	98.3	98.2	15	24.10	1.70	31.1	71.7	8.55E-05	8.0		
2-5	67.1	82.1	saturated	82.5	82.4	15	35.05	2.48	15.4	35.5	2.53E-04	23.6		
3-1	57.2	72.2	saturated	64.3	64.3	15	502.14	33.29	7.4	17.0	8.49E-03	773.2		
4-1	55.2	70.2	saturated	71.4	71.4	15	38.21	2.54	16.4	37.7	2.91E-04	26.6		
4-2	55.2	85.2	saturated	85.8	85.7	15	47.02	3.16	30.7	70.9	1.93E-04	17.6		
4-3	55.2	100.2	saturated	100.1	100.1	15	44.30	3.16	44.7	103.2	1.32E-04	12.1		
4-4	55.2	85.2	saturated	86.2	86.2	15	34.10	2.30	31.1	71.8	1.38E-04	12.7		
4-5	55.2	70.2	saturated	71.7	71.7	15	43.22	2.87	16.6	38.2	3.25E-04	29.8		
5-1	50.9	65.9	saturated	66.2	66.2	15	128.18	8.60	15.6	35.9	1.04E-03	94.8		
5-2	50.9	80.9	saturated	81.2	81.2	15	181.16	12.11	30.6	70.5	7.42E-04	68.0		
5-3	50.9	95.9	saturated	94.8	94.8	15	239.00	15.95	43.8	101.1	6.82E-04	62.4		
5-4	50.9	80.9	saturated	81.6	81.6	15	195.37	13.23	30.8	71.1	8.03E-04	73.6		
5-5	50.9	65.9	saturated	65.5	65.5	15	126.59	8.33	14.6	33.6	1.07E-03	98.1		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/25/19
WSP Personnel	K. Zeiger, X. You
Subcontractor	Cascade Drilling
Driller	M. Bond, C. Barden

Boring ID	BH19-07
Number of Tests	11
Lattitude	45.83808° N
Longitude	84.75731° W

Top of Rock, ft	68.00
Bottom of Boring, ft	203.00
Groundwater Depth (D_{VWL}), ft	18.49

Datum Elevation	600.4
Top of Rock Elevation, ft	536.5
Bottom of Hole Elevation, ft	409.6
Groundwater Elevation, ft	581.9

Total Length of Testing, ft	108.90
Boring Angle from Vertical, °	20.0
Borehole Diameter, ft	0.32/0.40

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
6-1	46.6	61.6	saturated	62.4	62.4	15	189.46	12.62	16.0	36.9	1.48E-03	135.3		
6-2	46.6	76.6	saturated	77.0	77.0	15	333.77	22.21	30.4	70.1	1.37E-03	125.3		
6-3	46.6	91.6	saturated	82.7	82.7	15	410.65	27.30	36.1	83.4	1.41E-03	129.6		
6-4	46.6	76.6	saturated	75.9	75.9	15	348.71	23.01	29.2	67.4	1.47E-03	135.1		
6-5	46.6	61.6	saturated	61.0	61.0	15	185.20	11.91	14.2	32.9	1.57E-03	143.4		
7-1	41.2	56.2	saturated	55.2	55.2	15	167.64	11.36	13.8	31.9	1.54E-03	140.7		
7-2	41.2	71.2	saturated	72.6	72.6	1	25.26	25.26	32.5	74.9	1.46E-03	133.4		
7-3	41.2	71.2	saturated	70.9	70.9	3	77.28	24.93	29.6	68.3	1.58E-03	144.3		
7-4	41.2	56.2	saturated	53.9	53.9	15	217.61	14.64	12.6	29.1	2.18E-03	199.3		
8-1	35.1	50.1	saturated	51.7	51.7	15	395.85	27.15	16.6	38.3	3.06E-03	280.4		
8-2	35.1	45.1	saturated	45.3	45.3	15	293.16	19.74	10.1	23.3	3.66E-03	335.4		
8-3	35.1	40.1	saturated	40.7	40.7	15	197.90	13.54	5.5	12.6	4.63E-03	423.8		
9-1	31.5	36.5	saturated	36.7	36.7	15	11.11	0.79	5.2	12.1	2.84E-04	26.0		
9-2	31.5	41.5	saturated	41.3	41.3	15	30.93	2.12	9.8	22.7	4.04E-04	37.0		
9-3	31.5	46.5	saturated	46.7	46.7	15	43.88	3.07	15.2	35.0	3.80E-04	34.7		
9-4	31.5	41.5	saturated	40.9	40.9	15	28.30	1.98	9.4	21.8	3.93E-04	36.0		
9-5	31.5	36.5	saturated	36.6	36.6	15	3.42	0.24	5.1	11.8	8.79E-05	8.0		
10-1	27.0	32.0	saturated	30.6	30.5	15	0.00	0.00	3.3	7.7	0.00E+00	0.0		
10-2	27.0	37.0	saturated	35.9	35.9	15	0.02	0.00	8.7	20.0	3.94E-07	0.0		
10-3	27.0	42.0	saturated	42.2	42.2	15	0.00	0.00	15.2	35.0	0.00E+00	0.0		
10-4	27.0	37.0	saturated	35.8	35.8	15	0.15	0.02	8.6	19.9	3.12E-06	0.3		
10-5	27.0	32.0	saturated	30.2	30.1	15	0.00	0.00	2.7	6.2	0.00E+00	0.0		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/25/19
WSP Personnel	K. Zeiger, X. You
Subcontractor	Cascade Drilling
Driller	M. Bond, C. Barden

Boring ID	BH19-07
Number of Tests	11
Lattitude	45.83808° N
Longitude	84.75731° W

Top of Rock, ft	68.00
Bottom of Boring, ft	203.00
Groundwater Depth (D_{VWL}), ft	18.49

Datum Elevation	600.4
Top of Rock Elevation, ft	536.5
Bottom of Hole Elevation, ft	409.6
Groundwater Elevation, ft	581.9

Total Length of Testing, ft	108.90
Boring Angle from Vertical, °	20.0
Borehole Diameter, ft	0.32/0.40

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_l)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
11-1	24.2	29.2	saturated	29.3	29.3	15	0.23	0.02	5.0	11.6	8.04E-06	0.8	||	
11-2	24.2	34.2	saturated	35.1	35.1	15	0.00	0.00	10.9	25.1	0.00E+00	0.0		
11-3	24.2	39.2	saturated	39.4	39.4	15	7.38	0.48	15.1	34.9	5.94E-05	5.4	||||||||||||||	
11-4	24.2	34.2	saturated	34.9	34.9	15	0.00	0.00	10.7	24.7	0.00E+00	0.0		
11-5	24.2	29.2	saturated	28.4	28.4	15	0.00	0.00	4.2	9.6	0.00E+00	0.0		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/25/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	1
Borehole Diameter, ft	0.40
Boring Angle from Vertical, °	20
**Top of Test Interval Depth, ft	190.50
**Bottom of Test Interval Depth, ft	202.80

Hydrostatic Pressure (P_0), psi	72.60
Transducer Zero Reading (R_0)	0.086
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	196.50
Vertical Center of Test Interval (D), ft	184.79
Test Interval Length (L), ft	12.30

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	421.3
Bottom of Test Interval Elevation, ft	409.8

Note: ** Test interval adjusted from 188.6-200.9 based on recorded hydrostatic pressure

Start Time: 04:15 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				86.2		0	0.7						
1-1A	72.6	87.6	saturated	86.1	86.1	1	0.7	0.00	13.45	31.0	0.00E+00	0.0	
1-1B	72.6	87.6	saturated	85.8	85.8	3	0.7	0.00	13.16	30.4	0.00E+00	0.0	
1-1C	72.6	87.6	saturated	85.7	85.6	5	0.7	0.00	12.98	29.9	0.00E+00	0.0	
1-1D	72.6	87.6	saturated	87.5	87.4	10	0.7	0.00	14.83	34.2	0.00E+00	0.0	
1-1E	72.6	87.6	saturated	87.8	87.7	15	0.7	0.00	15.10	34.8	0.00E+00	0.0	
Test Averages/Summary													
1-1	**72.6**	**87.6**	**saturated**	**86.5**	**86.4**	**15**	**0.0**	**0.00**	**13.90**	**32.08**	**0.00E+00**	**0.0**	

Notes: Very hard to keep P stable (no flow).

Start Time: — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				102.2		0	1.2						
1-2A	72.6	102.6	saturated	102.2	102.1	1	1.2	0.00	29.50	68.1	0.00E+00	0.0	
1-2B	72.6	102.6	saturated	102.5	102.4	3	1.2	0.00	29.79	68.7	0.00E+00	0.0	
1-2C	72.6	102.6	saturated	102.1	102.0	5	1.2	0.00	29.42	67.9	0.00E+00	0.0	
1-2D	72.6	102.6	saturated	102.2	102.2	10	1.2	0.00	29.56	68.2	0.00E+00	0.0	
1-2E	72.6	102.6	saturated	103.1	103.1	15	1.2	0.00	30.46	70.3	0.00E+00	0.0	
Test Averages/Summary													
1-2	**72.6**	**102.6**	**saturated**	**102.4**	**102.3**	**15**	**0.0**	**0.00**	**29.75**	**68.62**	**0.00E+00**	**0.0**	

Notes:

Start Time: — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				116.4		0	1.4						
1-3A	72.6	117.6	saturated	116.6	116.6	1	1.4	0.00	43.96	101.4	0.00E+00	0.0	
1-3B	72.6	117.6	saturated	116.2	116.1	3	1.4	0.00	43.51	100.4	0.00E+00	0.0	
1-3C	72.6	117.6	saturated	115.6	115.5	5	1.4	0.00	42.87	98.9	0.00E+00	0.0	
1-3D	72.6	117.6	saturated	116.2	116.2	10	1.4	0.00	43.56	100.5	0.00E+00	0.0	
1-3E	72.6	117.6	saturated	119.1	119.0	15	1.4	0.00	46.41	107.1	0.00E+00	0.0	
Test Averages/Summary													
1-3	**72.6**	**117.6**	**saturated**	**116.7**	**116.6**	**15**	**0.0**	**0.00**	**44.06**	**101.65**	**0.00E+00**	**0.0**	

Notes: Hard to keep P stable with no take.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/25/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	1
Borehole Diameter, ft	0.40
Boring Angle from Vertical, °	20
**Top of Test Interval Depth, ft	190.50
**Bottom of Test Interval Depth, ft	202.80

Hydrostatic Pressure (P_0), psi	72.60
Transducer Zero Reading (R_0)	0.086
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	196.50
Vertical Center of Test Interval (D), ft	184.79
Test Interval Length (L), ft	12.30

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	421.3
Bottom of Test Interval Elevation, ft	409.8

Note: ** Test interval adjusted from 188.6-200.9 based on recorded hydrostatic pressure

Start Time | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				103.9		0	1.4						
1-4A	72.6	102.6	saturated	103.7	103.6	1	1.4	0.00	30.99	71.5	0.00E+00	0.0	
1-4B	72.6	102.6	saturated	103.6	103.5	3	1.4	0.00	30.89	71.3	0.00E+00	0.0	
1-4C	72.6	102.6	saturated	103.5	103.4	5	1.4	0.00	30.81	71.1	0.00E+00	0.0	
1-4D	72.6	102.6	saturated	102.2	102.1	10	1.4	0.00	29.48	68.0	0.00E+00	0.0	
1-4E	72.6	102.6	saturated	102.1	102.1	15	1.4	0.00	29.45	67.9	0.00E+00	0.0	
Test Averages/Summary													
1-4	**72.6**	**102.6**	**saturated**	**103.2**	**103.1**	**15**	**0.0**	**0.00**	**30.32**	**69.95**	**0.00E+00**	**0.0**	

Notes

Start Time | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				87.6		0	1.4						
1-5A	72.6	87.6	saturated	87.6	87.5	1	1.4	0.00	14.94	34.5	0.00E+00	0.0	
1-5B	72.6	87.6	saturated	87.5	87.4	3	1.4	0.00	14.84	34.2	0.00E+00	0.0	
1-5C	72.6	87.6	saturated	87.4	87.3	5	1.4	0.00	14.71	33.9	0.00E+00	0.0	
1-5D	72.6	87.6	saturated	87.0	87.0	10	1.4	0.00	14.36	33.1	0.00E+00	0.0	
1-5E	72.6	87.6	saturated	86.6	86.5	15	1.4	0.00	13.94	32.2	0.00E+00	0.0	
Test Averages/Summary													
1-5	**72.6**	**87.6**	**saturated**	**87.3**	**87.2**	**15**	**0.0**	**0.00**	**14.56**	**33.58**	**0.00E+00**	**0.0**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/25/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	2
Borehole Diameter, ft	0.40
Boring Angle from Vertical, °	20
**Top of Test Interval Depth, ft	177.20
**Bottom of Test Interval Depth, ft	189.50

Hydrostatic Pressure (P_0), psi	67.15
Transducer Zero Reading (R_0)	0.086
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	183.20
Vertical Center of Test Interval (D), ft	172.29
Test Interval Length (L), ft	12.30

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	433.8
Bottom of Test Interval Elevation, ft	422.3

Note: ** Test interval adjusted from 176.3-188.6 based on recorded hydrostatic pressure

Start Time: 08:18 — Packer Pressure, psi: 130

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				82.1		0	8.8						
2-1A	67.1	82.1	saturated	82.2	82.1	1	8.8	0.00	14.98	34.6	0.00E+00	0.0	
2-1B	67.1	82.1	saturated	82.3	82.2	3	8.8	0.00	15.09	34.8	0.00E+00	0.0	
2-1C	67.1	82.1	saturated	82.6	82.5	5	8.8	0.00	15.36	35.4	0.00E+00	0.0	
2-1D	67.1	82.1	saturated	82.8	82.7	10	8.8	0.00	15.57	35.9	0.00E+00	0.0	
2-1E	67.1	82.1	saturated	82.9	82.8	15	8.8	0.00	15.68	36.2	0.00E+00	0.0	
Test Averages/Summary													
2-1	**67.1**	**82.1**	**saturated**	**82.5**	**82.4**	**15**	**0.0**	**0.00**	**15.33**	**35.38**	**0.00E+00**	**0.0**	

Notes:

Start Time: 08:38 — Packer Pressure, psi: 130

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				96.9		0	15.7						
2-2A	67.1	97.1	saturated	97.3	97.2	1	18.0	2.36	30.02	69.3	1.23E-04	11.5	
2-2B	67.1	97.1	saturated	97.6	97.5	3	22.7	2.32	30.34	70.0	1.20E-04	11.2	
2-2C	67.1	97.1	saturated	98.3	98.2	5	27.1	2.22	31.06	71.7	1.12E-04	10.5	
2-2D	67.1	97.1	saturated	98.7	98.7	10	37.0	1.98	31.51	72.7	9.84E-05	9.2	
2-2E	67.1	97.1	saturated	99.2	99.1	15	47.1	2.01	31.94	73.7	9.86E-05	9.2	
Test Averages/Summary													
2-2	**67.1**	**97.1**	**saturated**	**98.0**	**97.9**	**15**	**31.4**	**2.18**	**30.98**	**71.46**	**1.10E-04**	**10.3**	

Notes:

Start Time: 08:59 — Packer Pressure, psi: 130

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				111.3		0	57.4						
2-3A	67.1	112.1	saturated	111.6	111.5	1	61.0	3.60	44.32	102.2	1.27E-04	11.9	
2-3B	67.1	112.1	saturated	110.2	110.1	3	67.9	3.43	42.99	99.2	1.25E-04	11.7	
2-3C	67.1	112.1	saturated	110.5	110.4	5	75.1	3.61	43.23	99.7	1.31E-04	12.2	
2-3D	67.1	112.1	saturated	110.4	110.3	10	91.7	3.31	43.18	99.6	1.20E-04	11.2	
2-3E	67.1	112.1	saturated	111.5	111.4	15	107.6	3.19	44.30	102.2	1.13E-04	10.5	
Test Averages/Summary													
2-3	**67.1**	**112.1**	**saturated**	**110.9**	**110.8**	**15**	**50.2**	**3.43**	**43.60**	**100.60**	**1.23E-04**	**11.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/25/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	2
Borehole Diameter, ft	0.40
Boring Angle from Vertical, °	20
**Top of Test Interval Depth, ft	177.20
**Bottom of Test Interval Depth, ft	189.50

Hydrostatic Pressure (P_0), psi	67.15
Transducer Zero Reading (R_0)	0.086
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	183.20
Vertical Center of Test Interval (D), ft	172.29
Test Interval Length (L), ft	12.30

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	433.8
Bottom of Test Interval Elevation, ft	422.3

Note: ** Test interval adjusted from 176.3-188.6 based on recorded hydrostatic pressure

Start Time: 09:19 — Packer Pressure, psi: 130

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				98.3		0	115.5						
2-4A	67.1	97.1	saturated	98.4	98.3	1	117.4	1.92	31.19	72.0	9.64E-05	9.0	
2-4B	67.1	97.1	saturated	98.7	98.6	3	120.9	1.75	31.46	72.6	8.72E-05	8.1	
2-4C	67.1	97.1	saturated	99.4	99.4	5	124.5	1.79	32.21	74.3	8.71E-05	8.1	
2-4D	67.1	97.1	saturated	97.0	97.0	10	132.2	1.54	29.81	68.8	8.11E-05	7.6	
2-4E	67.1	97.1	saturated	97.9	97.8	15	139.6	1.48	30.64	70.7	7.55E-05	7.1	
Test Averages/Summary													
2-4	**67.1**	**97.1**	**saturated**	**98.3**	**98.2**	**15**	**24.1**	**1.70**	**31.06**	**71.66**	**8.55E-05**	**8.0**	

Notes: Pressure adjusted to ~97 psi at time step 2-4D.

Start Time: 09:38 — Packer Pressure, psi: 130

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				81.9		0	145.7						
2-5A	67.1	82.1	saturated	82.1	82.0	1	148.9	3.15	14.83	34.2	3.33E-04	31.1	
2-5B	67.1	82.1	saturated	82.2	82.1	3	153.6	2.34	14.93	34.5	2.46E-04	22.9	
2-5C	67.1	82.1	saturated	82.2	82.1	5	158.4	2.41	14.93	34.5	2.53E-04	23.6	
2-5D	67.1	82.1	saturated	83.3	83.2	10	169.6	2.25	16.05	37.0	2.19E-04	20.5	
2-5E	67.1	82.1	saturated	83.4	83.3	15	180.8	2.23	16.18	37.3	2.16E-04	20.2	
Test Averages/Summary													
2-5	**67.1**	**82.1**	**saturated**	**82.5**	**82.4**	**15**	**35.1**	**2.48**	**15.38**	**35.49**	**2.53E-04**	**23.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	154.40
Bottom of Test Interval Depth, ft	164.90

Hydrostatic Pressure (P_0), psi	57.20
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	159.10
Vertical Center of Test Interval (D), ft	150.02
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	455.3
Bottom of Test Interval Elevation, ft	445.4

Start Time: 00:45 — Packer Pressure, psi: 225

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				62.9		0	49.7						
3-1A	57.2	72.2	saturated	63.6	63.6	1	82.7	33.02	6.44	14.9	9.60E-03	879.8	
3-1B	57.2	72.2	saturated	64.2	64.2	3	147.3	32.29	7.03	16.2	8.61E-03	788.4	
3-1C	57.2	72.2	saturated	64.6	64.6	5	214.7	33.71	7.40	17.1	8.54E-03	781.9	
3-1D	57.2	72.2	saturated	65.1	65.1	10	382.6	33.59	7.90	18.2	7.96E-03	729.2	
3-1E	57.2	72.2	saturated	65.4	65.4	15	551.8	33.84	8.17	18.8	7.76E-03	710.9	
Test Averages/Summary													
3-1	**57.2**	**72.2**	**saturated**	**64.3**	**64.3**	**15**	**502.1**	**33.29**	**7.39**	**17.04**	**8.49E-03**	**773.2**	

Notes: Pump at full capacity (~33.5 gpm).

Start Time: — Packer Pressure, psi: —

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0							
						1							
						3							
						5							
						10							
						15							
Test Averages/Summary													

Notes:

Start Time: — Packer Pressure, psi: —

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0							
						1							
						3							
						5							
						10							
						15							
Test Averages/Summary													

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	149.60
Bottom of Test Interval Depth, ft	160.10

Hydrostatic Pressure (P_0), psi	55.20
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	154.30
Vertical Center of Test Interval (D), ft	145.51
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	459.8
Bottom of Test Interval Elevation, ft	449.9

Start Time: 01:20 — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				70.5		0	580.6						
4-1A	55.2	70.2	saturated	70.5	70.5	1	582.9	2.39	15.31	35.3	2.92E-04	26.8	
4-1B	55.2	70.2	saturated	70.9	70.9	3	588.2	2.63	15.71	36.2	3.13E-04	28.7	
4-1C	55.2	70.2	saturated	71.3	71.3	5	593.4	2.58	16.13	37.2	3.00E-04	27.5	
4-1D	55.2	70.2	saturated	72.2	72.2	10	606.3	2.59	17.04	39.3	2.85E-04	26.1	
4-1E	55.2	70.2	saturated	72.8	72.8	15	618.8	2.49	17.57	40.5	2.65E-04	24.3	
Test Averages/Summary													
4-1	**55.2**	**70.2**	**saturated**	**71.4**	**71.4**	**15**	**38.2**	**2.54**	**16.35**	**37.72**	**2.91E-04**	**26.6**	

Notes: Pressure climbed even with adjustments.

Start Time: 01:37 — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				84.8		0	624.4						
4-2A	55.2	85.2	saturated	85.2	85.2	1	627.6	3.26	29.97	69.1	2.04E-04	18.7	
4-2B	55.2	85.2	saturated	86.4	86.4	3	633.9	3.12	31.22	72.0	1.87E-04	17.1	
4-2C	55.2	85.2	saturated	84.2	84.2	5	640.3	3.20	28.96	66.8	2.07E-04	19.0	
4-2D	55.2	85.2	saturated	86.7	86.7	10	655.9	3.12	31.51	72.7	1.86E-04	17.0	
4-2E	55.2	85.2	saturated	87.2	87.2	15	671.4	3.10	32.02	73.9	1.81E-04	16.6	
Test Averages/Summary													
4-2	**55.2**	**85.2**	**saturated**	**85.8**	**85.7**	**15**	**47.0**	**3.16**	**30.74**	**70.91**	**1.93E-04**	**17.6**	

Notes: Pressure climbed even with adjustments.

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				100.7		0	680.5						
4-3A	55.2	100.2	saturated	100.1	100.1	1	683.6	3.16	44.90	103.6	1.32E-04	12.1	
4-3B	55.2	100.2	saturated	101.1	101.1	3	689.5	2.91	45.88	105.8	1.19E-04	10.9	
4-3C	55.2	100.2	saturated	101.5	101.4	5	698.3	4.41	46.25	106.7	1.79E-04	16.4	
4-3D	55.2	100.2	saturated	98.6	98.6	10	710.1	2.37	43.38	100.1	1.02E-04	9.4	
4-3E	55.2	100.2	saturated	98.4	98.4	15	724.8	2.93	43.20	99.7	1.27E-04	11.6	
Test Averages/Summary													
4-3	**55.2**	**100.2**	**saturated**	**100.1**	**100.1**	**15**	**44.3**	**3.16**	**44.72**	**103.17**	**1.32E-04**	**12.1**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	149.60
Bottom of Test Interval Depth, ft	160.10

Hydrostatic Pressure (P_0), psi	55.20
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	154.30
Vertical Center of Test Interval (D), ft	145.51
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	459.8
Bottom of Test Interval Elevation, ft	449.9

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				85.6		0	730.6						
4-4A	55.2	85.2	saturated	86.2	86.2	1	732.9	2.32	31.00	71.5	1.40E-04	12.8	
4-4B	55.2	85.2	saturated	86.9	86.9	3	737.7	2.39	31.72	73.2	1.41E-04	12.9	
4-4C	55.2	85.2	saturated	84.6	84.6	5	742.2	2.28	29.41	67.8	1.45E-04	13.3	
4-4D	55.2	85.2	saturated	86.2	86.2	10	753.6	2.28	31.00	71.5	1.37E-04	12.6	
4-4E	55.2	85.2	saturated	87.6	87.6	15	764.7	2.21	32.41	74.8	1.28E-04	11.7	
Test Averages/Summary													
4-4	**55.2**	**85.2**	**saturated**	**86.2**	**86.2**	**15**	**34.1**	**2.30**	**31.11**	**71.76**	**1.38E-04**	**12.7**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				71.2		0	769.2						
4-5A	55.2	70.2	saturated	71.3	71.3	1	772.1	2.88	16.08	37.1	3.35E-04	30.7	
4-5B	55.2	70.2	saturated	71.3	71.3	3	777.8	2.86	16.10	37.1	3.33E-04	30.5	
4-5C	55.2	70.2	saturated	71.6	71.5	5	783.5	2.84	16.34	37.7	3.25E-04	29.8	
4-5D	55.2	70.2	saturated	72.1	72.1	10	798.2	2.93	16.90	39.0	3.24E-04	29.7	
4-5E	55.2	70.2	saturated	72.6	72.6	15	812.5	2.86	17.35	40.0	3.09E-04	28.3	
Test Averages/Summary													
4-5	**55.2**	**70.2**	**saturated**	**71.7**	**71.7**	**15**	**43.2**	**2.87**	**16.56**	**38.19**	**3.25E-04**	**29.8**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	139.10
Bottom of Test Interval Depth, ft	149.60

Hydrostatic Pressure (P_0), psi	50.89
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	143.80
Vertical Center of Test Interval (D), ft	135.64
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	469.6
Bottom of Test Interval Elevation, ft	459.8

Start Time: 03:02 — Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				64.7		0	837.6						
5-1A	50.9	65.9	saturated	65.4	65.4	1	846.2	8.53	14.49	33.4	1.10E-03	101.0	
5-1B	50.9	65.9	saturated	66.7	66.7	3	863.2	8.53	15.82	36.5	1.01E-03	92.5	
5-1C	50.9	65.9	saturated	66.3	66.3	5	881.2	9.02	15.44	35.6	1.09E-03	100.2	
5-1D	50.9	65.9	saturated	66.8	66.8	10	922.9	8.34	15.87	36.6	9.84E-04	90.2	
5-1E	50.9	65.9	saturated	67.1	67.1	15	965.8	8.57	16.16	37.3	9.93E-04	91.0	
Test Averages/Summary													
5-1	**50.9**	**65.9**	**saturated**	**66.2**	**66.2**	**15**	**128.2**	**8.60**	**15.56**	**35.89**	**1.04E-03**	**94.8**	

Notes:

Start Time: — Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.1		0	984.5						
5-2A	50.9	80.9	saturated	80.7	80.7	1	996.7	12.17	29.84	68.8	7.64E-04	70.0	
5-2B	50.9	80.9	saturated	80.9	80.9	3	1,020.0	11.69	30.05	69.3	7.28E-04	66.7	
5-2C	50.9	80.9	saturated	81.3	81.3	5	1,045.3	12.64	30.39	70.1	7.79E-04	71.3	
5-2D	50.9	80.9	saturated	82.1	82.1	10	1,105.4	12.01	31.24	72.1	7.20E-04	66.0	
5-2E	50.9	80.9	saturated	82.2	82.2	15	1,165.7	12.06	31.32	72.3	7.21E-04	66.0	
Test Averages/Summary													
5-2	**50.9**	**80.9**	**saturated**	**81.2**	**81.2**	**15**	**181.2**	**12.11**	**30.57**	**70.52**	**7.42E-04**	**68.0**	

Notes:

Start Time: — Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				95.4		0	1,197.8						
5-3A	50.9	95.9	saturated	96.5	96.5	1	1,213.7	15.96	45.61	105.2	6.55E-04	60.0	
5-3B	50.9	95.9	saturated	95.4	95.4	3	1,245.4	15.83	44.46	102.6	6.67E-04	61.1	
5-3C	50.9	95.9	saturated	94.5	94.5	5	1,277.6	16.10	43.61	100.6	6.91E-04	63.3	
5-3D	50.9	95.9	saturated	93.6	93.6	10	1,357.5	15.99	42.74	98.6	7.01E-04	64.2	
5-3E	50.9	95.9	saturated	93.5	93.5	15	1,436.8	15.84	42.60	98.3	6.96E-04	63.8	
Test Averages/Summary													
5-3	**50.9**	**95.9**	**saturated**	**94.8**	**94.8**	**15**	**239.0**	**15.95**	**43.80**	**101.06**	**6.82E-04**	**62.4**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	139.10
Bottom of Test Interval Depth, ft	149.60

Hydrostatic Pressure (P_0), psi	50.89
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	143.80
Vertical Center of Test Interval (D), ft	135.64
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	469.6
Bottom of Test Interval Elevation, ft	459.8

Start Time | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.9		0	1,454.4						
5-4A	50.9	80.9	saturated	81.2	81.2	1	1,466.9	12.52	30.31	69.9	7.74E-04	70.9	
5-4B	50.9	80.9	saturated	81.3	81.3	3.5	1,494.0	10.85	30.42	70.2	6.68E-04	61.2	
5-4C	50.9	80.9	saturated	81.7	81.7	5	1,518.9	16.60	30.76	71.0	1.01E-03	92.6	
5-4D	50.9	80.9	saturated	82.1	82.1	10	1,583.1	12.84	31.21	72.0	7.70E-04	70.6	
5-4E	50.9	80.9	saturated	82.4	82.3	15	1,649.8	13.33	31.45	72.6	7.93E-04	72.7	
Test Averages/Summary													
5-4	**50.9**	**80.9**	**saturated**	**81.6**	**81.6**	**15**	**195.4**	**13.23**	**30.83**	**71.12**	**8.03E-04**	**73.6**	

Notes

Start Time | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				65.6		0	1,670.0						
5-5A	50.9	65.9	saturated	65.5	65.5	1	1,678.1	8.07	14.62	33.7	1.03E-03	94.7	
5-5B	50.9	65.9	saturated	65.3	65.3	3	1,695.0	8.44	14.40	33.2	1.10E-03	100.5	
5-5C	50.9	65.9	saturated	65.3	65.3	5	1,711.0	8.03	14.40	33.2	1.04E-03	95.6	
5-5D	50.9	65.9	saturated	65.6	65.6	10	1,754.3	8.66	14.67	33.8	1.11E-03	101.3	
5-5E	50.9	65.9	saturated	65.6	65.6	15	1,796.6	8.45	14.75	34.0	1.07E-03	98.3	
Test Averages/Summary													
5-5	**50.9**	**65.9**	**saturated**	**65.5**	**65.5**	**15**	**126.6**	**8.33**	**14.57**	**33.61**	**1.07E-03**	**98.1**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	128.60
Bottom of Test Interval Depth, ft	139.10

Hydrostatic Pressure (P_0), psi	46.60
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	133.30
Vertical Center of Test Interval (D), ft	125.78
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	479.5
Bottom of Test Interval Elevation, ft	469.6

Start Time: 04:30 — Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				61.3		0	35.5						
6-1A	46.6	61.6	saturated	61.6	61.6	1	48.0	12.50	15.03	34.7	1.56E-03	142.7	
6-1B	46.6	61.6	saturated	62.1	62.1	3	73.3	12.63	15.53	35.8	1.52E-03	139.4	
6-1C	46.6	61.6	saturated	62.5	62.5	5	98.6	12.70	15.90	36.7	1.49E-03	136.9	
6-1D	46.6	61.6	saturated	63.3	63.2	10	161.2	12.52	16.65	38.4	1.41E-03	129.0	
6-1E	46.6	61.6	saturated	63.5	63.5	15	225.0	12.74	16.86	38.9	1.42E-03	129.7	
Test Averages/Summary													
6-1	**46.6**	**61.6**	**saturated**	**62.4**	**62.4**	**15**	**189.5**	**12.62**	**15.99**	**36.90**	**1.48E-03**	**135.3**	

Notes:

Start Time: — Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				77.1		0	269.2						
6-2A	46.6	76.6	saturated	77.2	77.2	1	291.7	22.47	30.56	70.5	1.38E-03	126.1	
6-2B	46.6	76.6	saturated	77.0	77.0	3	335.1	21.73	30.40	70.1	1.34E-03	122.6	
6-2C	46.6	76.6	saturated	77.0	77.0	5	379.4	22.13	30.40	70.1	1.36E-03	124.8	
6-2D	46.6	76.6	saturated	77.0	77.0	10	490.5	22.22	30.37	70.1	1.37E-03	125.5	
6-2E	46.6	76.6	saturated	76.9	76.9	15	603.0	22.50	30.29	69.9	1.39E-03	127.4	
Test Averages/Summary													
6-2	**46.6**	**76.6**	**saturated**	**77.0**	**77.0**	**15**	**333.8**	**22.21**	**30.40**	**70.14**	**1.37E-03**	**125.3**	

Notes:

Start Time: — Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				82.7		0	653.9						
6-3A	46.6	91.6	saturated	83.1	83.1	1	680.8	26.91	36.48	84.2	1.38E-03	126.5	
6-3B	46.6	91.6	saturated	83.2	83.2	4	762.8	27.36	36.56	84.3	1.40E-03	128.4	
6-3C	46.6	91.6	saturated	83.0	83.0	5	790.2	27.35	36.40	84.0	1.41E-03	128.9	
6-3D	46.6	91.6	saturated	82.5	82.4	10	926.0	27.17	35.85	82.7	1.42E-03	130.0	
6-3E	46.6	91.6	saturated	82.0	82.0	15	1,064.5	27.70	35.39	81.6	1.47E-03	134.3	
Test Averages/Summary													
6-3	**46.6**	**91.6**	**saturated**	**82.7**	**82.7**	**15**	**410.7**	**27.30**	**36.13**	**83.36**	**1.41E-03**	**129.6**	

Notes: Time Step 6-3C taken at 4 minutes from start instead of 3 minutes.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-07
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	128.60
Bottom of Test Interval Depth, ft	139.10

Hydrostatic Pressure (P_0), psi	46.60
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	133.30
Vertical Center of Test Interval (D), ft	125.78
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	479.5
Bottom of Test Interval Elevation, ft	469.6

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				76.1		0	1,110.9						
6-4A	46.6	76.6	saturated	75.7	75.7	1	1,133.1	22.23	29.07	67.1	1.43E-03	131.2	
6-4B	46.6	76.6	saturated	75.4	75.4	3	1,178.8	22.86	28.83	66.5	1.48E-03	136.0	
6-4C	46.6	76.6	saturated	76.0	76.0	5	1,224.8	22.98	29.39	67.8	1.46E-03	134.1	
6-4D	46.6	76.6	saturated	76.0	76.0	10	1,342.3	23.49	29.39	67.8	1.50E-03	137.1	
6-4E	46.6	76.6	saturated	76.0	76.0	15	1,459.6	23.47	29.39	67.8	1.50E-03	137.0	
Test Averages/Summary													
6-4	**46.6**	**76.6**	**saturated**	**75.9**	**75.9**	**15**	**348.7**	**23.01**	**29.21**	**67.39**	**1.47E-03**	**135.1**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				62.0		0	1,486.7						
6-5A	46.6	61.6	saturated	61.6	61.6	1	1,496.9	10.28	14.97	34.5	1.29E-03	117.8	
6-5B	46.6	61.6	saturated	61.1	61.1	3	1,519.8	11.44	14.47	33.4	1.48E-03	135.6	
6-5C	46.6	61.6	saturated	61.1	61.1	5	1,544.6	12.37	14.47	33.4	1.60E-03	146.7	
6-5D	46.6	61.6	saturated	60.5	60.5	10	1,608.6	12.82	13.86	32.0	1.73E-03	158.7	
6-5E	46.6	61.6	saturated	60.1	60.1	15	1,671.9	12.64	13.46	31.0	1.76E-03	161.2	
Test Averages/Summary													
6-5	**46.6**	**61.6**	**saturated**	**61.0**	**61.0**	**15**	**185.2**	**11.91**	**14.25**	**32.86**	**1.57E-03**	**143.4**	

Notes: Pressure kept dropping despite adjustments.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	7
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	115.00
Bottom of Test Interval Depth, ft	125.50

Hydrostatic Pressure (P_0), psi	41.15
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	119.70
Vertical Center of Test Interval (D), ft	113.00
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	492.3
Bottom of Test Interval Elevation, ft	482.4

Start Time: 08:15 — Packer Pressure, psi: 100

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				56.3		0	34.0						
7-1A	41.2	56.2	saturated	56.7	56.7	1	45.8	11.74	15.54	35.9	1.41E-03	129.6	
7-1B	41.2	56.2	saturated	55.5	55.5	3	69.3	11.77	14.37	33.2	1.53E-03	140.5	
7-1C	41.2	56.2	saturated	55.1	55.0	5	92.0	11.33	13.90	32.1	1.53E-03	139.9	
7-1D	41.2	56.2	saturated	54.2	54.2	10	147.6	11.13	13.07	30.2	1.59E-03	146.0	
7-1E	41.2	56.2	saturated	53.5	53.5	15	201.7	10.81	12.36	28.5	1.64E-03	150.1	
Test Averages/Summary													
7-1	**41.2**	**56.2**	**saturated**	**55.2**	**55.2**	**15**	**167.6**	**11.36**	**13.85**	**31.95**	**1.54E-03**	**140.7**	

Notes:

Start Time: 08:30 — Packer Pressure, psi: 100

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				71.5		0	227.4						
7-2A	41.2	71.2	saturated	73.6	73.6	1	252.7	25.26	32.48	74.9	1.46E-03	133.4	
						3							
						5							
						10							
						15							
Test Averages/Summary													
7-2	**41.2**	**71.2**	**saturated**	**72.6**	**72.6**	**1**	**25.3**	**25.26**	**32.48**	**74.93**	**1.46E-03**	**133.4**	

Notes: At 1 min from start of test, pressure lowered back to 71.25 psi. Unknown amout of time passed between 1min and next reading. Subsequent readings seperated into different stage.

Start Time: — Packer Pressure, psi: 100.00

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				71.3		0	272.7						
7-3A	41.2	71.2	saturated	70.7	70.7	1	295.1	22.44	29.56	68.2	1.42E-03	130.2	
7-3B	41.2	71.2	saturated	70.9	70.8	3	349.9	27.42	29.69	68.5	1.73E-03	158.4	
						5							
						10							
						15							
Test Averages/Summary													
7-3	**41.2**	**71.2**	**saturated**	**70.9**	**70.9**	**3**	**77.3**	**24.93**	**29.63**	**68.35**	**1.58E-03**	**144.3**	

Notes: After 4 minutes, test stage stopped due to water coming out of top.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	7
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	115.00
Bottom of Test Interval Depth, ft	125.50

Hydrostatic Pressure (P_0), psi	41.15
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	119.70
Vertical Center of Test Interval (D), ft	113.00
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	492.3
Bottom of Test Interval Elevation, ft	482.4

Start Time: 08:38 — Packer Pressure, psi: 100.00

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				54.7		0	428.3						
7-4A	41.2	56.2	saturated	53.4	53.4	1	444.4	16.09	12.25	28.3	2.46E-03	225.3	
7-4B	41.2	56.2	saturated	52.4	52.4	3	470.1	12.86	11.24	25.9	2.14E-03	196.2	
7-4C	41.2	56.2	saturated	54.3	54.3	5	500.5	15.19	13.12	30.3	2.17E-03	198.5	
7-4D	41.2	56.2	saturated	54.3	54.3	10	573.9	14.68	13.18	30.4	2.09E-03	191.1	
7-4E	41.2	56.2	saturated	54.4	54.4	15	645.9	14.41	13.23	30.5	2.04E-03	186.9	
Test Averages/Summary													
7-4	**41.2**	**56.2**	**saturated**	**53.9**	**53.9**	**15**	**217.6**	**14.64**	**12.60**	**29.08**	**2.18E-03**	**199.3**	

Notes: Stage skipped.

Start Time: — Packer Pressure, psi: 100

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0							
						1							
						3							
						5							
						10							
						15							
Test Averages/Summary													

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	8
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	100.00
Bottom of Test Interval Depth, ft	110.50

Hydrostatic Pressure (P_0), psi	35.15
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	104.70
Vertical Center of Test Interval (D), ft	98.90
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	506.4
Bottom of Test Interval Elevation, ft	496.5

Start Time: 09:16 — Packer Pressure, psi: 85

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				51.3		0	744.7						
8-1A	35.1	50.1	saturated	51.7	51.7	1	774.7	30.04	16.52	38.1	3.40E-03	311.9	
8-1B	35.1	50.1	saturated	52.2	52.2	3	828.1	26.67	17.08	39.4	2.92E-03	267.8	
8-1C	35.1	50.1	saturated	51.4	51.4	5	883.2	27.55	16.20	37.4	3.18E-03	291.6	
8-1D	35.1	50.1	saturated	51.7	51.7	10	1,010.5	25.47	16.52	38.1	2.89E-03	264.4	
8-1E	35.1	50.1	saturated	51.9	51.9	15	1,140.6	26.01	16.71	38.5	2.92E-03	267.0	
Test Averages/Summary													
8-1	**35.1**	**50.1**	**saturated**	**51.7**	**51.7**	**15**	**395.9**	**27.15**	**16.61**	**38.32**	**3.06E-03**	**280.4**	

Notes:

Start Time: 09:38 — Packer Pressure, psi: 85

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				45.5		0	1,267.8						
8-2A	35.1	45.1	saturated	45.1	45.1	1	1,283.7	15.94	9.99	23.0	2.99E-03	273.7	
8-2B	35.1	45.1	saturated	45.2	45.2	3	1,331.5	23.86	10.04	23.2	4.45E-03	407.5	
8-2C	35.1	45.1	saturated	45.2	45.2	5	1,374.9	21.69	10.07	23.2	4.03E-03	369.5	
8-2D	35.1	45.1	saturated	45.3	45.3	10	1,468.8	18.78	10.15	23.4	3.47E-03	317.4	
8-2E	35.1	45.1	saturated	45.4	45.4	15	1,561.0	18.44	10.23	23.6	3.38E-03	309.2	
Test Averages/Summary													
8-2	**35.1**	**45.1**	**saturated**	**45.3**	**45.3**	**15**	**293.2**	**19.74**	**10.10**	**23.29**	**3.66E-03**	**335.4**	

Notes: Pump maxed out. Pressure can not reach past 55 psi. Adjusted pressure down to 10 psi above hydrostatic.

Start Time: 09:56 — Packer Pressure, psi: 85

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				40.9		0	1,588.9						
8-3A	35.1	40.1	saturated	40.8	40.8	1	1,602.8	13.94	5.66	13.1	4.61E-03	422.3	
8-3B	35.1	40.1	saturated	40.7	40.7	3	1,629.7	13.42	5.50	12.7	4.57E-03	418.3	
8-3C	35.1	40.1	saturated	40.7	40.7	5	1,659.5	14.90	5.50	12.7	5.07E-03	464.4	
8-3D	35.1	40.1	saturated	40.6	40.6	10	1,722.0	12.50	5.45	12.6	4.29E-03	393.3	
8-3E	35.1	40.1	saturated	40.4	40.4	15	1,786.8	12.97	5.29	12.2	4.59E-03	420.4	
Test Averages/Summary													
8-3	**35.1**	**40.1**	**saturated**	**40.7**	**40.7**	**15**	**197.9**	**13.54**	**5.48**	**12.65**	**4.63E-03**	**423.8**	

Notes: Pump maxed out. Pressure can not reach past 55 psi. Adjusted pressure down to 5 psi above hydrostatic.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	9
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	90.50
Bottom of Test Interval Depth, ft	101.00

Hydrostatic Pressure (P_0), psi	31.47
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	95.20
Vertical Center of Test Interval (D), ft	89.98
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	515.3
Bottom of Test Interval Elevation, ft	505.4

Start Time: 10:31 — Packer Pressure, psi: 65

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				36.8		0	1,823.7						
9-1A	31.5	36.5	saturated	36.7	36.6	1	1,824.6	0.89	5.17	11.9	3.22E-04	29.5	
9-1B	31.5	36.5	saturated	36.7	36.7	3	1,826.3	0.84	5.25	12.1	3.00E-04	27.4	
9-1C	31.5	36.5	saturated	36.7	36.7	5	1,828.0	0.89	5.20	12.0	3.21E-04	29.4	
9-1D	31.5	36.5	saturated	36.7	36.7	10	1,831.7	0.74	5.25	12.1	2.63E-04	24.0	
9-1E	31.5	36.5	saturated	36.8	36.8	15	1,834.8	0.62	5.33	12.3	2.16E-04	19.8	
Test Averages/Summary													
9-1	**31.5**	**36.5**	**saturated**	**36.7**	**36.7**	**15**	**11.1**	**0.79**	**5.24**	**12.09**	**2.84E-04**	**26.0**	

Notes:

Start Time: 10:49 — Packer Pressure, psi: 65

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				41.3		0	1,836.7						
9-2A	31.5	41.5	saturated	41.1	41.1	1	1,839.1	2.41	9.66	22.3	4.67E-04	42.8	
9-2B	31.5	41.5	saturated	41.2	41.2	3	1,843.2	2.08	9.71	22.4	4.01E-04	36.7	
9-2C	31.5	41.5	saturated	41.3	41.3	5	1,847.3	2.05	9.79	22.6	3.92E-04	35.9	
9-2D	31.5	41.5	saturated	41.4	41.4	10	1,857.5	2.03	9.95	23.0	3.82E-04	35.0	
9-2E	31.5	41.5	saturated	41.5	41.5	15	1,867.6	2.02	10.00	23.1	3.79E-04	34.7	
Test Averages/Summary													
9-2	**31.5**	**41.5**	**saturated**	**41.3**	**41.3**	**15**	**30.9**	**2.12**	**9.82**	**22.66**	**4.04E-04**	**37.0**	

Notes:

Start Time: 11:08 — Packer Pressure, psi: 65

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				46.7		0	1,875.4						
9-3A	31.5	46.5	saturated	46.4	46.4	1	1,879.2	3.75	14.97	34.5	4.69E-04	43.0	
9-3B	31.5	46.5	saturated	46.5	46.5	3	1,885.4	3.09	15.02	34.7	3.85E-04	35.3	
9-3C	31.5	46.5	saturated	46.6	46.5	5	1,891.2	2.91	15.07	34.8	3.61E-04	33.1	
9-3D	31.5	46.5	saturated	46.8	46.8	10	1,905.1	2.79	15.37	35.5	3.40E-04	31.1	
9-3E	31.5	46.5	saturated	47.0	46.9	15	1,919.3	2.84	15.47	35.7	3.43E-04	31.5	
Test Averages/Summary													
9-3	**31.5**	**46.5**	**saturated**	**46.7**	**46.7**	**15**	**43.9**	**3.07**	**15.18**	**35.02**	**3.80E-04**	**34.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	9
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	90.50
Bottom of Test Interval Depth, ft	101.00

Hydrostatic Pressure (P_0), psi	31.47
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	95.20
Vertical Center of Test Interval (D), ft	89.98
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	515.3
Bottom of Test Interval Elevation, ft	505.4

Start Time: 11:26 — Packer Pressure, psi: 65

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				40.8		0	1,921.6						
9-4A	31.5	41.5	saturated	40.8	40.8	1	1,923.9	2.28	9.31	21.5	4.59E-04	42.0	
9-4B	31.5	41.5	saturated	40.8	40.8	3	1,927.7	1.90	9.36	21.6	3.80E-04	34.8	
9-4C	31.5	41.5	saturated	40.9	40.9	5	1,931.9	2.11	9.42	21.7	4.20E-04	38.4	
9-4D	31.5	41.5	saturated	41.0	41.0	10	1,940.7	1.76	9.50	21.9	3.48E-04	31.9	
9-4E	31.5	41.5	saturated	41.1	41.1	15	1,949.9	1.84	9.58	22.1	3.59E-04	32.9	
Test Averages/Summary													
9-4	**31.5**	**41.5**	**saturated**	**40.9**	**40.9**	**15**	**28.3**	**1.98**	**9.43**	**21.77**	**3.93E-04**	**36.0**	

Notes:

Start Time: 11:43 — Packer Pressure, psi: 65

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				36.5		0	1,951.1						
9-5A	31.5	36.5	saturated	36.5	36.5	1	1,951.4	0.26	5.06	11.7	9.62E-05	8.8	
9-5B	31.5	36.5	saturated	36.6	36.6	3	1,951.9	0.27	5.09	11.7	9.93E-05	9.1	
9-5C	31.5	36.5	saturated	36.6	36.6	5	1,952.4	0.24	5.12	11.8	8.78E-05	8.0	
9-5D	31.5	36.5	saturated	36.6	36.6	10	1,953.6	0.24	5.12	11.8	8.93E-05	8.2	
9-5E	31.5	36.5	saturated	36.6	36.6	15	1,954.6	0.18	5.14	11.9	6.70E-05	6.1	
Test Averages/Summary													
9-5	**31.5**	**36.5**	**saturated**	**36.6**	**36.6**	**15**	**3.4**	**0.24**	**5.11**	**11.78**	**8.79E-05**	**8.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	10
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	80.00
Bottom of Test Interval Depth, ft	90.50

Hydrostatic Pressure (P_0), psi	26.99
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	84.70
Vertical Center of Test Interval (D), ft	80.11
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	525.2
Bottom of Test Interval Elevation, ft	515.3

Start Time: 12:59 — Packer Pressure, psi: 55

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				31.8		0	1,955.7						
10-1A	27.0	32.0	saturated	30.3	30.3	1	1,955.7	0.00	3.34	7.7	0.00E+00	0.0	
10-1B	27.0	32.0	saturated	30.3	30.3	3	1,955.7	0.00	3.31	7.6	0.00E+00	0.0	
10-1C	27.0	32.0	saturated	30.3	30.3	5	1,955.7	0.00	3.34	7.7	0.00E+00	0.0	
10-1D	27.0	32.0	saturated	30.3	30.3	10	1,955.7	0.00	3.31	7.6	0.00E+00	0.0	
10-1E	27.0	32.0	saturated	30.3	30.3	15	1,955.7	0.00	3.29	7.6	0.00E+00	0.0	
Test Averages/Summary													
10-1	**27.0**	**32.0**	**saturated**	**30.6**	**30.5**	**15**	**0.0**	**0.00**	**3.32**	**7.66**	**0.00E+00**	**0.0**	

Notes:

Start Time: 13:17 — Packer Pressure, psi: 55

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				37.1		0	1,957.3						
10-2A	27.0	37.0	saturated	34.1	34.1	1	1,957.3	0.00	7.14	16.5	0.00E+00	0.0	
10-2B	27.0	37.0	saturated	36.5	36.5	3	1,957.3	0.01	9.50	21.9	1.97E-06	0.2	||
10-2C	27.0	37.0	saturated	36.3	36.3	5	1,957.3	0.00	9.29	21.4	0.00E+00	0.0	
10-2D	27.0	37.0	saturated	36.2	36.2	10	1,957.3	0.00	9.23	21.3	0.00E+00	0.0	
10-2E	27.0	37.0	saturated	35.3	35.2	15	1,957.3	0.00	8.25	19.0	0.00E+00	0.0	
Test Averages/Summary													
10-2	**27.0**	**37.0**	**saturated**	**35.9**	**35.9**	**15**	**0.0**	**0.00**	**8.68**	**20.03**	**3.94E-07**	**0.0**	

Notes: Pressure dropped and was adjusted back up to 36 between 1 and 3 min readings

Start Time: 13:35 — Packer Pressure, psi: 55

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				42.3		0	1,958.1						
10-3A	27.0	42.0	saturated	42.3	42.3	1	1,958.1	0.00	15.27	35.2	0.00E+00	0.0	
10-3B	27.0	42.0	saturated	42.3	42.3	3	1,958.1	0.00	15.29	35.3	0.00E+00	0.0	
10-3C	27.0	42.0	saturated	42.3	42.3	5	1,958.1	0.00	15.35	35.4	0.00E+00	0.0	
10-3D	27.0	42.0	saturated	41.9	41.9	10	1,958.1	0.00	14.92	34.4	0.00E+00	0.0	
10-3E	27.0	42.0	saturated	42.0	42.0	15	1,958.1	0.00	14.97	34.5	0.00E+00	0.0	
Test Averages/Summary													
10-3	**27.0**	**42.0**	**saturated**	**42.2**	**42.2**	**15**	**0.0**	**0.00**	**15.16**	**34.98**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	10
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	80.00
Bottom of Test Interval Depth, ft	90.50

Hydrostatic Pressure (P_0), psi	26.99
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	84.70
Vertical Center of Test Interval (D), ft	80.11
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	525.2
Bottom of Test Interval Elevation, ft	515.3

Start Time: 13:53 — Packer Pressure, psi: 55

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				36.6		0	1,958.1						
10-4A	27.0	37.0	saturated	34.1	34.1	1	1,958.1	0.00	7.11	16.4	0.00E+00	0.0	
10-4B	27.0	37.0	saturated	36.0	36.0	3	1,958.3	0.08	9.00	20.8	1.56E-05	1.4	
10-4C	27.0	37.0	saturated	36.0	36.0	5	1,958.3	0.00	9.02	20.8	0.00E+00	0.0	
10-4D	27.0	37.0	saturated	36.0	36.0	10	1,958.3	0.00	9.05	20.9	0.00E+00	0.0	
10-4E	27.0	37.0	saturated	36.0	36.0	15	1,958.3	0.00	9.05	20.9	0.00E+00	0.0	
Test Averages/Summary													
10-4	**27.0**	**37.0**	**saturated**	**35.8**	**35.8**	**15**	**0.2**	**0.02**	**8.65**	**19.95**	**3.12E-06**	**0.3**	

Notes: Pressure dropped at the start and was adjusted back up.

Start Time: 14:15 — Packer Pressure, psi: 55

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				32.4		0	1,958.3						
10-5A	27.0	32.0	saturated	30.8	30.8	1	1,958.3	0.00	3.84	8.9	0.00E+00	0.0	
10-5B	27.0	32.0	saturated	29.5	29.5	3	1,958.3	0.00	2.46	5.7	0.00E+00	0.0	
10-5C	27.0	32.0	saturated	29.4	29.4	5	1,958.3	0.00	2.41	5.6	0.00E+00	0.0	
10-5D	27.0	32.0	saturated	29.4	29.4	10	1,958.3	0.00	2.41	5.6	0.00E+00	0.0	
10-5E	27.0	32.0	saturated	29.4	29.4	15	1,958.3	0.00	2.38	5.5	0.00E+00	0.0	
Test Averages/Summary													
10-5	**27.0**	**32.0**	**saturated**	**30.2**	**30.1**	**15**	**0.0**	**0.00**	**2.70**	**6.23**	**0.00E+00**	**0.0**	

Notes: Target pressure adjusted to 5 psi above hydrostatic.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	11
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	73.00
Bottom of Test Interval Depth, ft	83.50

Hydrostatic Pressure (P_0), psi	24.23
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	77.70
Vertical Center of Test Interval (D), ft	73.53
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	531.8
Bottom of Test Interval Elevation, ft	521.9

Start Time: 15:00 — Packer Pressure, psi: 45

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				29.3		0	1,959.6						
11-1A	24.2	29.2	saturated	27.8	27.8	1	1,959.6	0.00	3.55	8.2	0.00E+00	0.0	
11-1B	24.2	29.2	saturated	29.6	29.6	3	1,959.9	0.12	5.36	12.4	4.02E-05	3.7	
11-1C	24.2	29.2	saturated	29.6	29.6	5	1,959.9	0.00	5.36	12.4	0.00E+00	0.0	
11-1D	24.2	29.2	saturated	29.6	29.6	10	1,959.9	0.00	5.41	12.5	0.00E+00	0.0	
11-1E	24.2	29.2	saturated	29.6	29.6	15	1,959.9	0.00	5.41	12.5	0.00E+00	0.0	
Test Averages/Summary													
11-1	**24.2**	**29.2**	**saturated**	**29.3**	**29.3**	**15**	**0.2**	**0.02**	**5.02**	**11.58**	**8.04E-06**	**0.8**	

Notes:

Start Time: 15:18 — Packer Pressure, psi: 45

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				35.0		0	1,961.1						
11-2A	24.2	34.2	saturated	35.0	35.0	1	1,961.1	0.00	10.81	24.9	0.00E+00	0.0	
11-2B	24.2	34.2	saturated	35.1	35.1	3	1,961.1	0.00	10.86	25.1	0.00E+00	0.0	
11-2C	24.2	34.2	saturated	35.1	35.1	5	1,961.1	0.00	10.89	25.1	0.00E+00	0.0	
11-2D	24.2	34.2	saturated	35.2	35.2	10	1,961.1	0.00	10.94	25.2	0.00E+00	0.0	
11-2E	24.2	34.2	saturated	35.3	35.2	15	1,961.1	0.00	11.02	25.4	0.00E+00	0.0	
Test Averages/Summary													
11-2	**24.2**	**34.2**	**saturated**	**35.1**	**35.1**	**15**	**0.0**	**0.00**	**10.90**	**25.15**	**0.00E+00**	**0.0**	

Notes:

Start Time: 15:37 — Packer Pressure, psi: 45

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				39.4		0	1,964.0						
11-3A	24.2	39.2	saturated	39.3	39.3	1	1,964.4	0.42	15.05	34.7	5.23E-05	4.8	
11-3B	24.2	39.2	saturated	39.3	39.3	3	1,965.3	0.45	15.08	34.8	5.59E-05	5.1	
11-3C	24.2	39.2	saturated	39.3	39.3	5	1,966.4	0.53	15.10	34.8	6.57E-05	6.0	
11-3D	24.2	39.2	saturated	39.5	39.5	10	1,968.9	0.51	15.31	35.3	6.24E-05	5.7	
11-3E	24.2	39.2	saturated	39.3	39.3	15	1,971.4	0.49	15.10	34.8	6.08E-05	5.6	
Test Averages/Summary													
11-3	**24.2**	**39.2**	**saturated**	**39.4**	**39.4**	**15**	**7.4**	**0.48**	**15.13**	**34.90**	**5.94E-05**	**5.4**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/24/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-07
Test Number	11
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	73.00
Bottom of Test Interval Depth, ft	83.50

Hydrostatic Pressure (P_0), psi	24.23
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.7
Transducer Depth, ft	77.70
Vertical Center of Test Interval (D), ft	73.53
Test Interval Length (L), ft	10.50

Vertical Groundwater Depth (D_{VWL}), ft	18.49
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	531.8
Bottom of Test Interval Elevation, ft	521.9

Start Time: 15:56 — Packer Pressure, psi: 45

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				34.7		0	1,971.9						
11-4A	24.2	34.2	saturated	34.8	34.8	1	1,971.9	0.00	10.61	24.5	0.00E+00	0.0	
11-4B	24.2	34.2	saturated	34.9	34.9	3	1,971.9	0.00	10.64	24.5	0.00E+00	0.0	
11-4C	24.2	34.2	saturated	34.9	34.9	5	1,971.9	0.00	10.69	24.7	0.00E+00	0.0	
11-4D	24.2	34.2	saturated	35.0	35.0	10	1,971.9	0.00	10.77	24.9	0.00E+00	0.0	
11-4E	24.2	34.2	saturated	35.0	35.0	15	1,971.9	0.00	10.80	24.9	0.00E+00	0.0	
Test Averages/Summary													
11-4	**24.2**	**34.2**	**saturated**	**34.9**	**34.9**	**15**	**0.0**	**0.00**	**10.70**	**24.69**	**0.00E+00**	**0.0**	

Notes:

Start Time: 16:15 — Packer Pressure, psi: 45

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				28.7		0	1,971.9						
11-5A	24.2	29.2	saturated	28.4	28.4	1	1,971.9	0.00	4.16	9.6	0.00E+00	0.0	
11-5B	24.2	29.2	saturated	28.4	28.4	3	1,971.9	0.00	4.13	9.5	0.00E+00	0.0	
11-5C	24.2	29.2	saturated	28.4	28.4	5	1,971.9	0.00	4.13	9.5	0.00E+00	0.0	
11-5D	24.2	29.2	saturated	28.4	28.4	10	1,971.9	0.00	4.16	9.6	0.00E+00	0.0	
11-5E	24.2	29.2	saturated	28.4	28.4	15	1,971.9	0.00	4.19	9.7	0.00E+00	0.0	
Test Averages/Summary													
11-5	**24.2**	**29.2**	**saturated**	**28.4**	**28.4**	**15**	**0.0**	**0.00**	**4.15**	**9.58**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	06/20/19
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Number of Tests	6
Lattitude	45.78830°N
Longitude	84.77656°W

Top of Rock, ft	12.00
Bottom of Boring, ft	113.00
Groundwater Depth (D_{VWL}), ft	1.41

Datum Elevation	584.3
Top of Rock Elevation, ft	573.0
Bottom of Hole Elevation, ft	478.1
Groundwater Elevation, ft	582.9

Total Length of Testing, ft	61.75
Boring Angle from Vertical, °	20.00
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	33.0	48.0	saturated	48.0	48.0	15	105.20	7.06	15.10	34.8	8.60E-04	78.3		
1-2	33.0	63.0	saturated	63.2	63.2	15	160.20	10.81	30.36	70.0	6.55E-04	59.7		
1-3	33.0	78.0	saturated	79.1	79.1	15	127.70	8.53	46.26	106.7	3.39E-04	30.9		
1-4	33.0	63.0	saturated	63.5	63.5	15	96.20	6.45	30.58	70.6	3.88E-04	35.3		
1-5	33.0	48.0	saturated	47.5	47.5	15	59.20	3.96	14.50	33.5	5.02E-04	45.7		
2-1	29.0	44.0	saturated	44.7	44.6	15	54.80	3.66	15.84	36.5	4.25E-04	38.7		
2-2	29.0	59.0	saturated	59.0	59.0	15	79.40	5.32	30.00	69.2	3.26E-04	29.7		
2-3	29.0	74.0	saturated	73.3	73.3	15	98.60	6.60	44.20	102.0	2.75E-04	25.0		
2-4	29.0	59.0	saturated	58.5	58.5	15	78.00	5.22	29.40	67.8	3.27E-04	29.8		
2-5	29.0	44.0	saturated	43.9	43.9	15	52.10	3.48	14.86	34.3	4.30E-04	39.2		
3-1	24.8	39.8	saturated	40.2	40.2	15	0.00	0.00	15.46	35.7	0.00E+00	0.0		
3-2	24.8	50.0	saturated	49.9	49.9	15	0.00	0.00	25.08	57.9	0.00E+00	0.0		
3-3	24.8	60.0	saturated	61.0	61.0	15	0.00	0.00	36.18	83.5	0.00E+00	0.0		No Flow
3-4	24.8	50.0	saturated	50.2	50.2	15	0.00	0.00	25.38	58.6	0.00E+00	0.0		
3-5	24.8	39.8	saturated	40.2	40.2	15	0.00	0.00	15.38	35.5	0.00E+00	0.0		
4-1	22.8	33.0	saturated	33.6	33.6	15	0.00	0.00	10.86	25.1	0.00E+00	0.0		
4-2	22.8	43.0	saturated	42.8	42.8	15	0.00	0.00	20.00	46.1	0.00E+00	0.0		
4-3	22.8	53.0	saturated	53.2	53.2	15	0.00	0.00	30.40	70.1	0.00E+00	0.0		No Flow
4-4	22.8	43.0	saturated	42.9	42.9	15	0.00	0.00	20.10	46.4	0.00E+00	0.0		
4-5	22.8	33.0	saturated	33.7	33.7	15	0.00	0.00	10.94	25.2	0.00E+00	0.0		
5-1	16.8	25.0	saturated	25.4	25.3	15	0.00	0.00	8.56	19.8	0.00E+00	0.0		
5-2	16.8	34.0	saturated	34.6	34.6	15	0.00	0.00	17.78	41.0	0.00E+00	0.0		
5-3	16.8	43.0	saturated	43.1	43.1	15	0.00	0.00	26.32	60.7	0.00E+00	0.0		No Flow
5-4	16.8	34.0	saturated	34.7	34.7	15	0.00	0.00	17.88	41.3	0.00E+00	0.0		
5-5	16.8	25.0	saturated	25.6	25.6	15	0.00	0.00	8.78	20.3	0.00E+00	0.0		

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	06/20/19
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Number of Tests	6
Lattitude	45.78830°N
Longitude	84.77656°W

Top of Rock, ft	12.00
Bottom of Boring, ft	113.00
Groundwater Depth (D_{VWL}), ft	1.41

Datum Elevation	584.3
Top of Rock Elevation, ft	573.0
Bottom of Hole Elevation, ft	478.1
Groundwater Elevation, ft	582.9

Total Length of Testing, ft	61.75
Boring Angle from Vertical, °	20.00
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
6-1	12.7	19.0	saturated	19.3	19.3	15	9.68	0.65	6.64	15.3	1.81E-04	16.5		
6-2	12.7	26.0	saturated	26.1	26.1	15	23.12	1.55	13.42	31.0	2.12E-04	19.3		
6-3	12.7	33.0	saturated	33.9	33.9	15	30.60	2.05	21.24	49.0	1.78E-04	16.2		
6-4	12.7	26.0	saturated	26.5	26.5	15	21.86	1.46	13.78	31.8	1.95E-04	17.7		
6-5	12.7	19.0	saturated	19.3	19.3	15	7.38	0.48	6.60	15.2	1.34E-04	12.2		

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	77.25
Bottom of Test Interval Depth, ft	88.00

Hydrostatic Pressure (P_0), psi	33.00
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	83.25
Vertical Center of Test Interval (D), ft	77.64
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	511.7
Bottom of Test Interval Elevation, ft	501.6

Start Time: 11:36 — Packer Pressure, psi: 162

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				47.6		0	13,865.0						
1-1A	33.0	48.0	saturated	47.8	47.8	1	13,872.2	7.20	14.78	34.1	8.96E-04	81.6	
1-1B	33.0	48.0	saturated	48.0	48.0	3	13,886.5	7.15	14.98	34.6	8.78E-04	80.0	
1-1C	33.0	48.0	saturated	48.1	48.1	5	13,900.5	7.00	15.08	34.8	8.54E-04	77.8	
1-1D	33.0	48.0	saturated	48.3	48.3	10	13,935.4	6.98	15.28	35.3	8.40E-04	76.5	
1-1E	33.0	48.0	saturated	48.4	48.4	15	13,970.2	6.96	15.38	35.5	8.32E-04	75.8	
Test Averages/Summary													
1-1	**33.0**	**48.0**	**saturated**	**48.0**	**48.0**	**15**	**105.2**	**7.06**	**15.10**	**34.84**	**8.60E-04**	**78.3**	

Notes: Flow Totalizer 1-10 gpm

Start Time: 11:52 — Packer Pressure, psi: 162

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				62.5		0	13,993.2						
1-2A	33.0	63.0	saturated	62.9	62.9	1	14,004.7	11.50	29.88	68.9	7.08E-04	64.5	
1-2B	33.0	63.0	saturated	63.3	63.3	3	14,026.3	10.80	30.28	69.9	6.56E-04	59.8	
1-2C	33.0	63.0	saturated	63.5	63.5	5	14,047.4	10.55	30.48	70.3	6.37E-04	58.0	
1-2D	33.0	63.0	saturated	63.6	63.6	10	14,100.1	10.54	30.58	70.6	6.34E-04	57.7	
1-2E	33.0	63.0	saturated	63.6	63.6	15	14,153.4	10.66	30.58	70.6	6.41E-04	58.4	
Test Averages/Summary													
1-2	**33.0**	**63.0**	**saturated**	**63.2**	**63.2**	**15**	**160.2**	**10.81**	**30.36**	**70.05**	**6.55E-04**	**59.7**	

Notes: Water return out of casing. Flow totalizer damaged.

Start Time: 12:39 — Packer Pressure, psi: 162

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				78.2		0	55.0						
1-3A	33.0	78.0	saturated	78.8	78.8	1	63.6	8.60	45.78	105.6	3.46E-04	31.5	
1-3B	33.0	78.0	saturated	79.3	79.3	3	80.7	8.55	46.28	106.8	3.40E-04	31.0	
1-3C	33.0	78.0	saturated	79.3	79.3	5	97.7	8.50	46.28	106.8	3.38E-04	30.8	
1-3D	33.0	78.0	saturated	79.6	79.6	10	140.2	8.50	46.58	107.5	3.36E-04	30.6	
1-3E	33.0	78.0	saturated	79.4	79.4	15	182.7	8.50	46.38	107.0	3.37E-04	30.7	
Test Averages/Summary													
1-3	**33.0**	**78.0**	**saturated**	**79.1**	**79.1**	**15**	**127.7**	**8.53**	**46.26**	**106.73**	**3.39E-04**	**30.9**	

Notes: New flow totalizer (flomec) 3-30 gpm. Water return out of casing

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	77.25
Bottom of Test Interval Depth, ft	88.00

Hydrostatic Pressure (P_0), psi	33.00
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	83.25
Vertical Center of Test Interval (D), ft	77.64
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	511.7
Bottom of Test Interval Elevation, ft	501.6

Start Time: 12:59 — Packer Pressure, psi: 162

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				62.7		0	208.0						
1-4A	33.0	63.0	saturated	62.8	62.8	1	214.6	6.60	29.78	68.7	4.08E-04	37.1	
1-4B	33.0	63.0	saturated	63.0	63.0	3	227.5	6.45	29.98	69.2	3.96E-04	36.0	
1-4C	33.0	63.0	saturated	63.4	63.4	5	240.3	6.40	30.38	70.1	3.87E-04	35.3	
1-4D	33.0	63.0	saturated	64.2	64.2	10	272.3	6.40	31.18	71.9	3.78E-04	34.4	
1-4E	33.0	63.0	saturated	64.6	64.6	15	304.2	6.38	31.58	72.9	3.72E-04	33.8	
Test Averages/Summary													
1-4	**33.0**	**63.0**	**saturated**	**63.5**	**63.5**	**15**	**96.2**	**6.45**	**30.58**	**70.55**	**3.88E-04**	**35.3**	

Notes:

Start Time: 13:17 — Packer Pressure, psi: 162

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				47.3		0	328.0						
1-5A	33.0	48.0	saturated	47.4	47.4	1	332.0	4.00	14.38	33.2	5.12E-04	46.6	
1-5B	33.0	48.0	saturated	47.5	47.5	3	339.9	3.95	14.48	33.4	5.02E-04	45.7	
1-5C	33.0	48.0	saturated	47.5	47.5	5	347.8	3.95	14.48	33.4	5.02E-04	45.7	
1-5D	33.0	48.0	saturated	47.5	47.5	10	367.6	3.96	14.48	33.4	5.03E-04	45.8	
1-5E	33.0	48.0	saturated	47.7	47.7	15	387.2	3.92	14.68	33.9	4.91E-04	44.7	
Test Averages/Summary													
1-5	**33.0**	**48.0**	**saturated**	**47.5**	**47.5**	**15**	**59.2**	**3.96**	**14.50**	**33.46**	**5.02E-04**	**45.7**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	66.75
Bottom of Test Interval Depth, ft	77.50

Hydrostatic Pressure (P_0), psi	29.00
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	72.75
Vertical Center of Test Interval (D), ft	67.78
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	521.6
Bottom of Test Interval Elevation, ft	511.5

Start Time: 14:26 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				43.6		0	433.0						
2-1A	29.0	44.0	saturated	44.3	44.3	1	436.7	3.70	15.28	35.3	4.45E-04	40.6	
2-1B	29.0	44.0	saturated	44.7	44.7	3	444.1	3.70	15.68	36.2	4.34E-04	39.5	
2-1C	29.0	44.0	saturated	44.9	44.9	5	451.3	3.60	15.88	36.6	4.17E-04	38.0	
2-1D	29.0	44.0	saturated	45.2	45.2	10	469.8	3.70	16.18	37.3	4.21E-04	38.3	
2-1E	29.0	44.0	saturated	45.2	45.2	15	487.8	3.60	16.18	37.3	4.09E-04	37.3	
Test Averages/Summary													
2-1	**29.0**	**44.0**	**saturated**	**44.7**	**44.6**	**15**	**54.8**	**3.66**	**15.84**	**36.55**	**4.25E-04**	**38.7**	

Notes:

Start Time: 14:43 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				58.7		0	559.0						
2-2A	29.0	59.0	saturated	58.8	58.8	1	564.5	5.50	29.78	68.7	3.40E-04	30.9	
2-2B	29.0	59.0	saturated	58.8	58.8	3	575.0	5.25	29.78	68.7	3.24E-04	29.5	
2-2C	29.0	59.0	saturated	59.1	59.1	5	585.5	5.25	30.08	69.4	3.21E-04	29.2	
2-2D	29.0	59.0	saturated	59.2	59.2	10	611.8	5.26	30.18	69.6	3.21E-04	29.2	
2-2E	29.0	59.0	saturated	59.2	59.2	15	638.4	5.32	30.18	69.6	3.24E-04	29.5	
Test Averages/Summary													
2-2	**29.0**	**59.0**	**saturated**	**59.0**	**59.0**	**15**	**79.4**	**5.32**	**30.00**	**69.21**	**3.26E-04**	**29.7**	

Notes:

Start Time: 15:01 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				73.6		0	654.0						
2-3A	29.0	74.0	saturated	73.2	73.2	1	660.8	6.80	44.18	101.9	2.83E-04	25.8	
2-3B	29.0	74.0	saturated	73.3	73.3	3	673.9	6.55	44.28	102.2	2.72E-04	24.8	
2-3C	29.0	74.0	saturated	73.2	73.2	5	687.0	6.55	44.18	101.9	2.73E-04	24.8	
2-3D	29.0	74.0	saturated	73.2	73.2	10	719.9	6.58	44.18	101.9	2.74E-04	25.0	
2-3E	29.0	74.0	saturated	73.2	73.2	15	752.6	6.54	44.18	101.9	2.72E-04	24.8	
Test Averages/Summary													
2-3	**29.0**	**74.0**	**saturated**	**73.3**	**73.3**	**15**	**98.6**	**6.60**	**44.20**	**101.97**	**2.75E-04**	**25.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	66.75
Bottom of Test Interval Depth, ft	77.50

Hydrostatic Pressure (P_0), psi	29.00
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	72.75
Vertical Center of Test Interval (D), ft	67.78
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	521.6
Bottom of Test Interval Elevation, ft	511.5

Start Time: 15:17 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				58.6		0	765.0						
2-4A	29.0	59.0	saturated	58.5	58.5	1	770.3	5.30	29.48	68.0	3.31E-04	30.1	
2-4B	29.0	59.0	saturated	58.4	58.4	3	780.7	5.20	29.38	67.8	3.26E-04	29.7	
2-4C	29.0	59.0	saturated	58.4	58.4	5	791.2	5.25	29.38	67.8	3.29E-04	29.9	
2-4D	29.0	59.0	saturated	58.4	58.4	10	817.1	5.18	29.38	67.8	3.24E-04	29.5	
2-4E	29.0	59.0	saturated	58.4	58.4	15	843.0	5.18	29.38	67.8	3.24E-04	29.5	
Test Averages/Summary													
2-4	**29.0**	**59.0**	**saturated**	**58.5**	**58.5**	**15**	**78.0**	**5.22**	**29.40**	**67.83**	**3.27E-04**	**29.8**	

Notes: Water return out of casing

Start Time: 15:36 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				44.0		0	855.0						
2-5A	29.0	44.0	saturated	44.0	44.0	1	858.5	3.50	14.98	34.6	4.30E-04	39.1	
2-5B	29.0	44.0	saturated	43.9	43.9	3	865.4	3.45	14.88	34.3	4.26E-04	38.8	
2-5C	29.0	44.0	saturated	43.9	43.9	5	872.4	3.50	14.88	34.3	4.33E-04	39.4	
2-5D	29.0	44.0	saturated	43.8	43.8	10	889.7	3.46	14.78	34.1	4.31E-04	39.2	
2-5E	29.0	44.0	saturated	43.8	43.8	15	907.1	3.48	14.78	34.1	4.33E-04	39.4	
Test Averages/Summary													
2-5	**29.0**	**44.0**	**saturated**	**43.9**	**43.9**	**15**	**52.1**	**3.48**	**14.86**	**34.29**	**4.30E-04**	**39.2**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	56.25
Bottom of Test Interval Depth, ft	67.00

Hydrostatic Pressure (P_0), psi	24.80
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	62.25
Vertical Center of Test Interval (D), ft	57.91
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	531.4
Bottom of Test Interval Elevation, ft	521.3

Start Time: 17:20 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				40.0		0	949.4						
3-1A	24.8	39.8	saturated	40.2	40.2	1	949.4	0.00	15.38	35.5	0.00E+00	0.0	
3-1B	24.8	39.8	saturated	40.2	40.2	3	949.4	0.00	15.38	35.5	0.00E+00	0.0	
3-1C	24.8	39.8	saturated	40.3	40.3	5	949.4	0.00	15.48	35.7	0.00E+00	0.0	
3-1D	24.8	39.8	saturated	40.3	40.3	10	949.4	0.00	15.48	35.7	0.00E+00	0.0	
3-1E	24.8	39.8	saturated	40.4	40.4	15	949.4	0.00	15.58	35.9	0.00E+00	0.0	
Test Averages/Summary													
3-1	**24.8**	**39.8**	**saturated**	**40.2**	**40.2**	**15**	**0.0**	**0.00**	**15.46**	**35.67**	**0.00E+00**	**0.0**	

Notes:

Start Time: 17:37 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				49.8		0	949.4						
3-2A	24.8	50.0	saturated	49.9	49.9	1	949.4	0.00	25.08	57.9	0.00E+00	0.0	
3-2B	24.8	50.0	saturated	49.9	49.9	3	949.4	0.00	25.08	57.9	0.00E+00	0.0	
3-2C	24.8	50.0	saturated	49.9	49.9	5	949.4	0.00	25.08	57.9	0.00E+00	0.0	
3-2D	24.8	50.0	saturated	49.9	49.9	10	949.4	0.00	25.08	57.9	0.00E+00	0.0	
3-2E	24.8	50.0	saturated	49.9	49.9	15	949.4	0.00	25.08	57.9	0.00E+00	0.0	
Test Averages/Summary													
3-2	**24.8**	**50.0**	**saturated**	**49.9**	**49.9**	**15**	**0.0**	**0.00**	**25.08**	**57.86**	**0.00E+00**	**0.0**	

Notes:

Start Time: 17:57 — Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				60.8		0	949.4						
3-3A	24.8	60.0	saturated	61.0	61.0	1	949.4	0.00	36.18	83.5	0.00E+00	0.0	
3-3B	24.8	60.0	saturated	61.0	61.0	3	949.4	0.00	36.18	83.5	0.00E+00	0.0	
3-3C	24.8	60.0	saturated	61.0	61.0	5	949.4	0.00	36.18	83.5	0.00E+00	0.0	
3-3D	24.8	60.0	saturated	61.0	61.0	10	949.4	0.00	36.18	83.5	0.00E+00	0.0	
3-3E	24.8	60.0	saturated	61.0	61.0	15	949.4	0.00	36.18	83.5	0.00E+00	0.0	
Test Averages/Summary													
3-3	**24.8**	**60.0**	**saturated**	**61.0**	**61.0**	**15**	**0.0**	**0.00**	**36.18**	**83.47**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer / K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	56.25
Bottom of Test Interval Depth, ft	67.00

Hydrostatic Pressure (P_0), psi	24.80
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	62.25
Vertical Center of Test Interval (D), ft	57.91
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	531.4
Bottom of Test Interval Elevation, ft	521.3

Start Time: 18:14 Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				50.2		0	949.4						
3-4A	24.8	50.0	saturated	50.2	50.2	1	949.4	0.00	25.38	58.6	0.00E+00	0.0	
3-4B	24.8	50.0	saturated	50.2	50.2	3	949.4	0.00	25.38	58.6	0.00E+00	0.0	
3-4C	24.8	50.0	saturated	50.2	50.2	5	949.4	0.00	25.38	58.6	0.00E+00	0.0	
3-4D	24.8	50.0	saturated	50.2	50.2	10	949.4	0.00	25.38	58.6	0.00E+00	0.0	
3-4E	24.8	50.0	saturated	50.2	50.2	15	949.4	0.00	25.38	58.6	0.00E+00	0.0	
Test Averages/Summary													
3-4	**24.8**	**50.0**	**saturated**	**50.2**	**50.2**	**15**	**0.0**	**0.00**	**25.38**	**58.56**	**0.00E+00**	**0.0**	

Notes:

Start Time: 18:32 Packer Pressure, psi: 140

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				40.2		0	949.4						
3-5A	24.8	39.8	saturated	40.2	40.2	1	949.4	0.00	15.38	35.5	0.00E+00	0.0	
3-5B	24.8	39.8	saturated	40.2	40.2	3	949.4	0.00	15.38	35.5	0.00E+00	0.0	
3-5C	24.8	39.8	saturated	40.2	40.2	5	949.4	0.00	15.38	35.5	0.00E+00	0.0	
3-5D	24.8	39.8	saturated	40.2	40.2	10	949.4	0.00	15.38	35.5	0.00E+00	0.0	
3-5E	24.8	39.8	saturated	40.2	40.2	15	949.4	0.00	15.38	35.5	0.00E+00	0.0	
Test Averages/Summary													
3-5	**24.8**	**39.8**	**saturated**	**40.2**	**40.2**	**15**	**0.0**	**0.00**	**15.38**	**35.49**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/20/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	51.25
Bottom of Test Interval Depth, ft	62.00

Hydrostatic Pressure (P_0), psi	22.76
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	57.25
Vertical Center of Test Interval (D), ft	53.21
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	536.1
Bottom of Test Interval Elevation, ft	526.0

Start Time: 08:59 — Packer Pressure, psi: 134

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				33.5		0	954.0						
4-1A	22.8	33.0	saturated	33.6	33.6	1	954.0	0.00	10.82	25.0	0.00E+00	0.0	
4-1B	22.8	33.0	saturated	33.6	33.6	3	954.0	0.00	10.82	25.0	0.00E+00	0.0	
4-1C	22.8	33.0	saturated	33.6	33.6	5	954.0	0.00	10.82	25.0	0.00E+00	0.0	
4-1D	22.8	33.0	saturated	33.7	33.7	10	954.0	0.00	10.92	25.2	0.00E+00	0.0	
4-1E	22.8	33.0	saturated	33.7	33.7	15	954.0	0.00	10.92	25.2	0.00E+00	0.0	
Test Averages/Summary													
4-1	**22.8**	**33.0**	**saturated**	**33.6**	**33.6**	**15**	**0.0**	**0.00**	**10.86**	**25.06**	**0.00E+00**	**0.0**	

Notes:

Start Time: 09:16 — Packer Pressure, psi: 134

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				42.9		0	954.3						
4-2A	22.8	43.0	saturated	42.9	42.9	1	954.3	0.00	20.12	46.4	0.00E+00	0.0	
4-2B	22.8	43.0	saturated	42.9	42.9	3	954.3	0.00	20.12	46.4	0.00E+00	0.0	
4-2C	22.8	43.0	saturated	42.8	42.8	5	954.3	0.00	20.02	46.2	0.00E+00	0.0	
4-2D	22.8	43.0	saturated	42.7	42.7	10	954.3	0.00	19.92	46.0	0.00E+00	0.0	
4-2E	22.8	43.0	saturated	42.6	42.6	15	954.3	0.00	19.82	45.7	0.00E+00	0.0	
Test Averages/Summary													
4-2	**22.8**	**43.0**	**saturated**	**42.8**	**42.8**	**15**	**0.0**	**0.00**	**20.00**	**46.14**	**0.00E+00**	**0.0**	

Notes:

Start Time: 09:33 — Packer Pressure, psi: 134

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				53.4		0	954.4						
4-3A	22.8	53.0	saturated	53.3	53.3	1	954.4	0.00	30.52	70.4	0.00E+00	0.0	
4-3B	22.8	53.0	saturated	53.2	53.2	3	954.4	0.00	30.42	70.2	0.00E+00	0.0	
4-3C	22.8	53.0	saturated	53.2	53.2	5	954.4	0.00	30.42	70.2	0.00E+00	0.0	
4-3D	22.8	53.0	saturated	53.1	53.1	10	954.4	0.00	30.32	70.0	0.00E+00	0.0	
4-3E	22.8	53.0	saturated	53.1	53.1	15	954.4	0.00	30.32	70.0	0.00E+00	0.0	
Test Averages/Summary													
4-3	**22.8**	**53.0**	**saturated**	**53.2**	**53.2**	**15**	**0.0**	**0.00**	**30.40**	**70.14**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/20/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	51.25
Bottom of Test Interval Depth, ft	62.00

Hydrostatic Pressure (P_0), psi	22.76
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	57.25
Vertical Center of Test Interval (D), ft	53.21
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	536.1
Bottom of Test Interval Elevation, ft	526.0

Start Time: 09:49 — Packer Pressure, psi: 134

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				42.9		0	954.4						
4-4A	22.8	43.0	saturated	42.9	42.9	1	954.4	0.00	20.12	46.4	0.00E+00	0.0	
4-4B	22.8	43.0	saturated	42.9	42.9	3	954.4	0.00	20.12	46.4	0.00E+00	0.0	
4-4C	22.8	43.0	saturated	42.9	42.9	5	954.4	0.00	20.12	46.4	0.00E+00	0.0	
4-4D	22.8	43.0	saturated	42.9	42.9	10	954.4	0.00	20.12	46.4	0.00E+00	0.0	
4-4E	22.8	43.0	saturated	42.8	42.8	15	954.4	0.00	20.02	46.2	0.00E+00	0.0	
Test Averages/Summary													
4-4	**22.8**	**43.0**	**saturated**	**42.9**	**42.9**	**15**	**0.0**	**0.00**	**20.10**	**46.38**	**0.00E+00**	**0.0**	

Notes:

Start Time: 10:06 — Packer Pressure, psi: 134

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				33.7		0	954.4						
4-5A	22.8	33.0	saturated	33.8	33.8	1	954.4	0.00	11.02	25.4	0.00E+00	0.0	
4-5B	22.8	33.0	saturated	33.7	33.7	3	954.4	0.00	10.92	25.2	0.00E+00	0.0	
4-5C	22.8	33.0	saturated	33.7	33.7	5	954.4	0.00	10.92	25.2	0.00E+00	0.0	
4-5D	22.8	33.0	saturated	33.7	33.7	10	954.4	0.00	10.92	25.2	0.00E+00	0.0	
4-5E	22.8	33.0	saturated	33.7	33.7	15	954.4	0.00	10.92	25.2	0.00E+00	0.0	
Test Averages/Summary													
4-5	**22.8**	**33.0**	**saturated**	**33.7**	**33.7**	**15**	**0.0**	**0.00**	**10.94**	**25.24**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/20/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	36.75
Bottom of Test Interval Depth, ft	47.50

Hydrostatic Pressure (P_0), psi	16.80
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	42.75
Vertical Center of Test Interval (D), ft	39.58
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	549.8
Bottom of Test Interval Elevation, ft	539.7

Start Time: 10:49 — Packer Pressure, psi: 126

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				25.3		0	962.6						
5-1A	16.8	25.0	saturated	25.3	25.3	1	962.6	0.00	8.48	19.6	0.00E+00	0.0	
5-1B	16.8	25.0	saturated	25.4	25.4	3	962.6	0.00	8.58	19.8	0.00E+00	0.0	
5-1C	16.8	25.0	saturated	25.4	25.4	5	962.6	0.00	8.58	19.8	0.00E+00	0.0	
5-1D	16.8	25.0	saturated	25.4	25.4	10	962.6	0.00	8.58	19.8	0.00E+00	0.0	
5-1E	16.8	25.0	saturated	25.4	25.4	15	962.6	0.00	8.58	19.8	0.00E+00	0.0	
Test Averages/Summary													
5-1	**16.8**	**25.0**	**saturated**	**25.4**	**25.3**	**15**	**0.0**	**0.00**	**8.56**	**19.75**	**0.00E+00**	**0.0**	

Notes: Flow totalizer tested prior to stage. Approximately 0.8 gpm will trigger totalizer, but readings are not accurate

Start Time: 11:07 — Packer Pressure, psi: 126

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				34.5		0	962.8						
5-2A	16.8	34.0	saturated	34.5	34.5	1	962.8	0.00	17.68	40.8	0.00E+00	0.0	
5-2B	16.8	34.0	saturated	34.6	34.6	3	962.8	0.00	17.78	41.0	0.00E+00	0.0	
5-2C	16.8	34.0	saturated	34.6	34.6	5	962.8	0.00	17.78	41.0	0.00E+00	0.0	
5-2D	16.8	34.0	saturated	34.6	34.6	10	962.8	0.00	17.78	41.0	0.00E+00	0.0	
5-2E	16.8	34.0	saturated	34.7	34.7	15	962.8	0.00	17.88	41.3	0.00E+00	0.0	
Test Averages/Summary													
5-2	**16.8**	**34.0**	**saturated**	**34.6**	**34.6**	**15**	**0.0**	**0.00**	**17.78**	**41.02**	**0.00E+00**	**0.0**	

Notes:

Start Time: 11:23 — Packer Pressure, psi: 126

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				43.1		0	963.1						
5-3A	16.8	43.0	saturated	43.1	43.1	1	963.1	0.00	26.28	60.6	0.00E+00	0.0	
5-3B	16.8	43.0	saturated	43.1	43.1	3	963.1	0.00	26.28	60.6	0.00E+00	0.0	
5-3C	16.8	43.0	saturated	43.1	43.1	5	963.1	0.00	26.28	60.6	0.00E+00	0.0	
5-3D	16.8	43.0	saturated	43.2	43.2	10	963.1	0.00	26.38	60.9	0.00E+00	0.0	
5-3E	16.8	43.0	saturated	43.2	43.2	15	963.1	0.00	26.38	60.9	0.00E+00	0.0	
Test Averages/Summary													
5-3	**16.8**	**43.0**	**saturated**	**43.1**	**43.1**	**15**	**0.0**	**0.00**	**26.32**	**60.72**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/20/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	36.75
Bottom of Test Interval Depth, ft	47.50

Hydrostatic Pressure (P_0), psi	16.80
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	42.75
Vertical Center of Test Interval (D), ft	39.58
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	549.8
Bottom of Test Interval Elevation, ft	539.7

Start Time: 11:40 — Packer Pressure, psi: 126

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				34.6		0	963.1						
5-4A	16.8	34.0	saturated	34.6	34.6	1	963.1	0.00	17.78	41.0	0.00E+00	0.0	
5-4B	16.8	34.0	saturated	34.7	34.7	3	963.1	0.00	17.88	41.3	0.00E+00	0.0	
5-4C	16.8	34.0	saturated	34.7	34.7	5	963.1	0.00	17.88	41.3	0.00E+00	0.0	
5-4D	16.8	34.0	saturated	34.7	34.7	10	963.1	0.00	17.88	41.3	0.00E+00	0.0	
5-4E	16.8	34.0	saturated	34.8	34.8	15	963.1	0.00	17.98	41.5	0.00E+00	0.0	
Test Averages/Summary													
5-4	**16.8**	**34.0**	**saturated**	**34.7**	**34.7**	**15**	**0.0**	**0.00**	**17.88**	**41.25**	**0.00E+00**	**0.0**	

Notes:

Start Time: 11:58 — Packer Pressure, psi: 126

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				25.6		0	963.1						
5-5A	16.8	25.0	saturated	25.6	25.6	1	963.1	0.00	8.78	20.3	0.00E+00	0.0	
5-5B	16.8	25.0	saturated	25.6	25.6	3	963.1	0.00	8.78	20.3	0.00E+00	0.0	
5-5C	16.8	25.0	saturated	25.6	25.6	5	963.1	0.00	8.78	20.3	0.00E+00	0.0	
5-5D	16.8	25.0	saturated	25.6	25.6	10	963.1	0.00	8.78	20.3	0.00E+00	0.0	
5-5E	16.8	25.0	saturated	25.6	25.6	15	963.1	0.00	8.78	20.3	0.00E+00	0.0	
Test Averages/Summary													
5-5	**16.8**	**25.0**	**saturated**	**25.6**	**25.6**	**15**	**0.0**	**0.00**	**8.78**	**20.26**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/20/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	26.50
Bottom of Test Interval Depth, ft	37.25

Hydrostatic Pressure (P_0), psi	12.70
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	32.50
Vertical Center of Test Interval (D), ft	29.95
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	559.4
Bottom of Test Interval Elevation, ft	549.3

Start Time: 12:24 — Packer Pressure, psi: 121

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				19.2		0	965.4						
6-1A	12.7	19.0	saturated	19.2	19.2	1	966.1	0.72	6.48	15.0	2.04E-04	18.6	
6-1B	12.7	19.0	saturated	19.3	19.3	3	967.4	0.64	6.58	15.2	1.79E-04	16.3	
6-1C	12.7	19.0	saturated	19.4	19.4	5	968.6	0.62	6.68	15.4	1.71E-04	15.5	
6-1D	12.7	19.0	saturated	19.4	19.4	10	971.7	0.62	6.68	15.4	1.71E-04	15.5	
6-1E	12.7	19.0	saturated	19.5	19.5	15	975.1	0.67	6.78	15.6	1.81E-04	16.5	
Test Averages/Summary													
6-1	**12.7**	**19.0**	**saturated**	**19.3**	**19.3**	**15**	**9.7**	**0.65**	**6.64**	**15.32**	**1.81E-04**	**16.5**	

Notes:

Start Time: 12:41 — Packer Pressure, psi: 121

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				25.8		0	978.0						
6-2A	12.7	26.0	saturated	25.9	25.9	1	979.6	1.58	13.18	30.4	2.20E-04	20.1	
6-2B	12.7	26.0	saturated	26.0	26.0	3	982.7	1.56	13.28	30.6	2.16E-04	19.7	
6-2C	12.7	26.0	saturated	26.1	26.1	5	985.8	1.54	13.38	30.9	2.12E-04	19.3	
6-2D	12.7	26.0	saturated	26.3	26.3	10	993.5	1.54	13.58	31.3	2.08E-04	19.0	
6-2E	12.7	26.0	saturated	26.4	26.4	15	1001.1	1.53	13.68	31.6	2.06E-04	18.7	
Test Averages/Summary													
6-2	**12.7**	**26.0**	**saturated**	**26.1**	**26.1**	**15**	**23.1**	**1.55**	**13.42**	**30.96**	**2.12E-04**	**19.3**	

Notes:

Start Time: 12:58 — Packer Pressure, psi: 121

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				33.4		0	1006.0						
6-3A	12.7	33.0	saturated	33.5	33.5	1	1008.1	2.08	20.78	47.9	1.84E-04	16.8	
6-3B	12.7	33.0	saturated	33.7	33.7	3	1012.2	2.07	20.98	48.4	1.81E-04	16.5	
6-3C	12.7	33.0	saturated	34.0	34.0	5	1016.3	2.04	21.28	49.1	1.76E-04	16.1	
6-3D	12.7	33.0	saturated	34.2	34.2	10	1026.5	2.03	21.48	49.6	1.74E-04	15.9	
6-3E	12.7	33.0	saturated	34.4	34.4	15	1036.6	2.03	21.68	50.0	1.72E-04	15.7	
Test Averages/Summary													
6-3	**12.7**	**33.0**	**saturated**	**33.9**	**33.9**	**15**	**30.6**	**2.05**	**21.24**	**49.01**	**1.78E-04**	**16.2**	

Notes:

Line 5 Replacement Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/20/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-08
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	20
Top of Test Interval Depth, ft	26.50
Bottom of Test Interval Depth, ft	37.25

Hydrostatic Pressure (P_0), psi	12.70
Transducer Zero Reading (R_0)	0.018
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	32.50
Vertical Center of Test Interval (D), ft	29.95
Test Interval Length (L), ft	10.75

Vertical Groundwater Depth (D_{VWL}), ft	1.41
Groundwater Elevation, ft	582.9
Top of Test Interval Elevation, ft	559.4
Bottom of Test Interval Elevation, ft	549.3

Start Time: 13:17 — Packer Pressure, psi: 121

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				26.3		0	1042.0						
6-4A	12.7	26.0	saturated	26.4	26.4	1	1043.5	1.46	13.68	31.6	1.96E-04	17.9	
6-4B	12.7	26.0	saturated	26.4	26.4	3	1046.4	1.46	13.68	31.6	1.96E-04	17.9	
6-4C	12.7	26.0	saturated	26.5	26.5	5	1049.3	1.45	13.78	31.8	1.94E-04	17.7	
6-4D	12.7	26.0	saturated	26.6	26.6	10	1056.6	1.46	13.88	32.0	1.93E-04	17.6	
6-4E	12.7	26.0	saturated	26.6	26.6	15	1063.9	1.46	13.88	32.0	1.93E-04	17.6	
Test Averages/Summary													
6-4	**12.7**	**26.0**	**saturated**	**26.5**	**26.5**	**15**	**21.9**	**1.46**	**13.78**	**31.80**	**1.95E-04**	**17.7**	

Notes:

Start Time: 13:36 — Packer Pressure, psi: 121

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				19.2		0	1069.3						
6-5A	12.7	19.0	saturated	19.2	19.2	1	1069.8	0.46	6.48	15.0	1.31E-04	11.9	
6-5B	12.7	19.0	saturated	19.2	19.2	3	1070.7	0.46	6.48	15.0	1.29E-04	11.8	
6-5C	12.7	19.0	saturated	19.4	19.4	5	1071.7	0.49	6.68	15.4	1.35E-04	12.3	
6-5D	12.7	19.0	saturated	19.4	19.4	10	1074.2	0.50	6.68	15.4	1.39E-04	12.6	
6-5E	12.7	19.0	saturated	19.4	19.4	15	1076.7	0.50	6.68	15.4	1.38E-04	12.6	
Test Averages/Summary													
6-5	**12.7**	**19.0**	**saturated**	**19.3**	**19.3**	**15**	**7.4**	**0.48**	**6.60**	**15.23**	**1.34E-04**	**12.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	06/21/19
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Number of Tests	3
Lattitude	45.78736°N
Longitude	84.77692°W

Top of Rock, ft	4.50
Bottom of Boring, ft	104.00
Depth to Groundwater (D_{WL}),	33.00

Datum Elevation	619.2
Top of Rock Elevation, ft	614.7
Bottom of Hole Elevation, ft	515.2
Groundwater Elevation, ft	586.2

Total Length of Testing, ft	36.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	23.6	38.6	saturated	39.3	39.2	15	13.87	0.97	15.8	36.5	1.03E-04	9.1		
1-2	23.6	53.6	saturated	53.3	53.3	15	21.56	1.45	29.8	68.7	8.14E-05	7.2		
1-3	23.6	68.6	saturated	68.3	68.3	15	30.12	2.01	44.8	103.4	7.49E-05	6.6		
1-4	23.6	53.6	saturated	53.3	53.3	15	21.83	1.46	29.8	68.7	8.19E-05	7.2		
1-5	23.6	38.6	saturated	38.8	38.8	15	7.28	0.49	15.2	35.0	5.42E-05	4.8		
2-1	18.3	33.3	saturated	35.1	35.1	15	71.22	4.70	17.1	39.4	4.61E-04	40.7		
2-2	18.3	48.3	saturated	49.1	49.1	15	96.47	6.46	31.0	71.6	3.48E-04	30.8		
2-3	18.3	63.3	saturated	63.1	63.1	15	90.97	6.12	45.0	103.7	2.28E-04	20.1		
2-4	18.3	48.3	saturated	47.0	47.0	15	63.57	4.26	28.7	66.3	2.48E-04	21.9		
2-5	18.3	33.3	saturated	33.6	33.6	15	40.18	2.67	15.4	35.4	2.91E-04	25.7		
3-1	13.3	28.3	saturated	27.7	27.7	15	249.68	16.65	14.4	33.3	1.93E-03	170.8		
3-2	13.3	43.3	saturated	33.1	33.1	15	366.88	24.49	19.9	45.9	2.06E-03	182.0		
3-3	13.3	28.3	saturated	28.3	28.3	15	250.17	16.67	15.0	34.7	1.86E-03	164.2		
3-4	13.3	21.0	saturated	19.7	19.7	15	134.87	8.97	6.4	14.8	2.33E-03	206.6		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/21/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	81.83
Bottom of Test Interval Depth, ft	94.00

Hydrostatic Pressure (P_0), psi	23.56
Transducer Zero Reading (R_0)	0.012
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	87.83
Vertical Center of Test Interval (D), ft	87.92
Test Interval Length (L), ft	12.17

Depth to Groundwater (D_{WL}), ft	33.00
Groundwater Elevation, ft	586.2
Top of Test Interval Elevation, ft	537.4
Bottom of Test Interval Elevation, ft	525.2

Start Time: 12:45 — Packer Pressure, psi: 165

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				38.6		0	4.0						
1-1A	23.6	38.6	saturated	38.9	38.89	1	5.1	1.08	15.33	35.4	1.18E-04	10.4	
1-1B	23.6	38.6	saturated	39.2	39.19	3	7.2	1.04	15.63	36.1	1.11E-04	9.8	
1-1C	23.6	38.6	saturated	39.5	39.49	5	9.1	0.99	15.93	36.7	1.03E-04	9.2	
1-1D	23.6	38.6	saturated	39.5	39.49	10	13.7	0.91	15.93	36.7	9.58E-05	8.5	
1-1E	23.6	38.6	saturated	39.8	39.79	15	17.9	0.84	16.23	37.4	8.62E-05	7.6	
Test Averages/Summary													
1-1	**23.6**	**38.6**	**saturated**	**39.3**	**39.2**	**15**	**13.9**	**0.97**	**15.81**	**36.47**	**1.03E-04**	**9.1**	

Notes:

Start Time: 13:03 — Packer Pressure, psi: 165

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				52.9		0	23.0						
1-2A	23.6	53.6	saturated	53.0	53.0	1	24.5	1.48	29.43	67.9	8.41E-05	7.4	
1-2B	23.6	53.6	saturated	53.1	53.1	3	27.4	1.46	29.53	68.1	8.27E-05	7.3	
1-2C	23.6	53.6	saturated	53.3	53.3	5	30.3	1.45	29.73	68.6	8.16E-05	7.2	
1-2D	23.6	53.6	saturated	53.5	53.5	10	37.5	1.43	29.93	69.0	8.01E-05	7.1	
1-2E	23.6	53.6	saturated	53.8	53.8	15	44.6	1.42	30.23	69.7	7.85E-05	6.9	
Test Averages/Summary													
1-2	**23.6**	**53.6**	**saturated**	**53.3**	**53.3**	**15**	**21.6**	**1.45**	**29.77**	**68.67**	**8.14E-05**	**7.2**	

Notes:

Start Time: 13:23 — Packer Pressure, psi: 165

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				67.7		0	56.2						
1-3A	23.6	68.6	saturated	67.8	67.8	1	58.2	2.00	44.23	102.0	7.56E-05	6.7	
1-3B	23.6	68.6	saturated	68.2	68.2	3	62.2	2.01	44.63	103.0	7.53E-05	6.7	
1-3C	23.6	68.6	saturated	68.4	68.4	5	66.2	2.00	44.83	103.4	7.46E-05	6.6	
1-3D	23.6	68.6	saturated	68.6	68.6	10	76.3	2.01	45.03	103.9	7.45E-05	6.6	
1-3E	23.6	68.6	saturated	68.9	68.9	15	86.3	2.01	45.33	104.6	7.43E-05	6.6	
Test Averages/Summary													
1-3	**23.6**	**68.6**	**saturated**	**68.3**	**68.3**	**15**	**30.1**	**2.01**	**44.81**	**103.37**	**7.49E-05**	**6.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/21/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	81.83
Bottom of Test Interval Depth, ft	94.00

Hydrostatic Pressure (P_0), psi	23.56
Transducer Zero Reading (R_0)	0.012
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	87.83
Vertical Center of Test Interval (D), ft	87.92
Test Interval Length (L), ft	12.17

Depth to Groundwater (D_{WL}), ft	33.00
Groundwater Elevation, ft	586.2
Top of Test Interval Elevation, ft	537.4
Bottom of Test Interval Elevation, ft	525.2

Start Time: 13:42 — Packer Pressure, psi: 165

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				53.1		0	92.2						
1-4A	23.6	53.6	saturated	53.1	53.1	1	93.6	1.47	29.53	68.1	8.33E-05	7.4	
1-4B	23.6	53.6	saturated	53.2	53.2	3	96.6	1.47	29.63	68.4	8.27E-05	7.3	
1-4C	23.6	53.6	saturated	53.3	53.3	5	99.5	1.46	29.73	68.6	8.19E-05	7.2	
1-4D	23.6	53.6	saturated	53.5	53.5	10	106.7	1.45	29.93	69.0	8.13E-05	7.2	
1-4E	23.6	53.6	saturated	53.7	53.7	15	114.0	1.45	30.13	69.5	8.05E-05	7.1	
Test Averages/Summary													
1-4	**23.6**	**53.6**	**saturated**	**53.3**	**53.3**	**15**	**21.8**	**1.46**	**29.79**	**68.72**	**8.19E-05**	**7.2**	

Notes:

Start Time: 14:00 — Packer Pressure, psi: 165

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				38.7		0	117.0						
1-5A	23.6	38.6	saturated	38.7	38.69	1	117.5	0.52	15.13	34.9	5.75E-05	5.1	
1-5B	23.6	38.6	saturated	38.7	38.69	3	118.5	0.49	15.13	34.9	5.42E-05	4.8	
1-5C	23.6	38.6	saturated	38.8	38.79	5	119.5	0.49	15.23	35.1	5.38E-05	4.8	
1-5D	23.6	38.6	saturated	38.8	38.79	10	121.9	0.48	15.23	35.1	5.32E-05	4.7	
1-5E	23.6	38.6	saturated	38.8	38.79	15	124.3	0.48	15.23	35.1	5.23E-05	4.6	
Test Averages/Summary													
1-5	**23.6**	**38.6**	**saturated**	**38.8**	**38.8**	**15**	**7.3**	**0.49**	**15.19**	**35.04**	**5.42E-05**	**4.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/21/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	69.66
Bottom of Test Interval Depth, ft	81.83

Hydrostatic Pressure (P_0), psi	18.30
Transducer Zero Reading (R_0)	0.012
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	75.66
Vertical Center of Test Interval (D), ft	75.75
Test Interval Length (L), ft	12.17

Depth to Groundwater (D_{WL}), ft	33.00
Groundwater Elevation, ft	586.2
Top of Test Interval Elevation, ft	549.6
Bottom of Test Interval Elevation, ft	537.4

Start Time: 15:10 — Packer Pressure, psi: 158

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				33.5		0	219.9						
2-1A	18.3	33.3	saturated	34.5	34.5	1	224.5	4.60	16.19	37.3	4.75E-04	42.1	
2-1B	18.3	33.3	saturated	34.9	34.9	3	233.6	4.57	16.59	38.3	4.61E-04	40.8	
2-1C	18.3	33.3	saturated	35.6	35.6	5	243.0	4.70	17.29	39.9	4.55E-04	40.2	
2-1D	18.3	33.3	saturated	35.9	35.9	10	266.9	4.78	17.59	40.6	4.54E-04	40.2	
2-1E	18.3	33.3	saturated	36.0	36.0	15	291.1	4.84	17.69	40.8	4.58E-04	40.5	
Test Averages/Summary													
2-1	**18.3**	**33.3**	**saturated**	**35.1**	**35.1**	**15**	**71.2**	**4.70**	**17.07**	**39.38**	**4.61E-04**	**40.7**	

Notes: Very difficult to obtain target press. (Long Delay)

Start Time: 15:28 — Packer Pressure, psi: 158

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				47.7		0	322.1						
2-2A	18.3	48.3	saturated	48.7	48.7	1	328.6	6.50	30.39	70.1	3.58E-04	31.7	
2-2B	18.3	48.3	saturated	49.0	49.0	3	341.7	6.54	30.69	70.8	3.56E-04	31.5	
2-2C	18.3	48.3	saturated	49.5	49.5	5	354.6	6.46	31.19	72.0	3.46E-04	30.7	
2-2D	18.3	48.3	saturated	49.5	49.5	10	386.6	6.40	31.19	72.0	3.43E-04	30.4	
2-2E	18.3	48.3	saturated	50.1	50.1	15	418.6	6.39	31.79	73.3	3.36E-04	29.8	
Test Averages/Summary													
2-2	**18.3**	**48.3**	**saturated**	**49.1**	**49.1**	**15**	**96.5**	**6.46**	**31.05**	**71.63**	**3.48E-04**	**30.8**	

Notes:

Start Time: 15:47 — Packer Pressure, psi: 158

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				62.3		0	452.7						
2-3A	18.3	63.3	saturated	62.8	62.8	1	459.0	6.27	44.49	102.6	2.36E-04	20.9	
2-3B	18.3	63.3	saturated	63.2	63.2	3	471.4	6.20	44.89	103.6	2.31E-04	20.5	
2-3C	18.3	63.3	saturated	63.3	63.3	5	483.7	6.13	44.99	103.8	2.28E-04	20.2	
2-3D	18.3	63.3	saturated	63.6	63.6	10	513.8	6.04	45.29	104.5	2.23E-04	19.7	
2-3E	18.3	63.3	saturated	63.5	63.5	15	543.7	5.97	45.19	104.2	2.21E-04	19.6	
Test Averages/Summary													
2-3	**18.3**	**63.3**	**saturated**	**63.1**	**63.1**	**15**	**91.0**	**6.12**	**44.97**	**103.74**	**2.28E-04**	**20.1**	

Notes: Turned up pump to obtain target press.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/21/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	69.66
Bottom of Test Interval Depth, ft	81.83

Hydrostatic Pressure (P_0), psi	18.30
Transducer Zero Reading (R_0)	0.012
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	75.66
Vertical Center of Test Interval (D), ft	75.75
Test Interval Length (L), ft	12.17

Depth to Groundwater (D_{WL}), ft	33.00
Groundwater Elevation, ft	586.2
Top of Test Interval Elevation, ft	549.6
Bottom of Test Interval Elevation, ft	537.4

Start Time: 16:04 — Packer Pressure, psi: 158

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				46.7		0	556.2						
2-4A	18.3	48.3	saturated	46.9	46.9	1	560.6	4.35	28.59	66.0	2.54E-04	22.5	
2-4B	18.3	48.3	saturated	47.0	47.0	3	569.1	4.24	28.69	66.2	2.47E-04	21.9	
2-4C	18.3	48.3	saturated	47.1	47.1	5	577.6	4.26	28.79	66.4	2.47E-04	21.9	
2-4D	18.3	48.3	saturated	47.1	47.1	10	598.8	4.23	28.79	66.4	2.46E-04	21.8	
2-4E	18.3	48.3	saturated	47.2	47.2	15	619.8	4.21	28.89	66.6	2.44E-04	21.6	
Test Averages/Summary													
2-4	**18.3**	**48.3**	**saturated**	**47.0**	**47.0**	**15**	**63.6**	**4.26**	**28.75**	**66.32**	**2.48E-04**	**21.9**	

Notes: Pump back down to idle.

Start Time: — Packer Pressure, psi: 158

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				33.3		0	646.0						
2-5A	18.3	33.3	saturated	33.3	33.3	3	654.0	2.64	14.99	34.6	2.95E-04	26.1	
2-5B	18.3	33.3	saturated	33.3	33.3	5	659.3	2.65	14.99	34.6	2.96E-04	26.2	
2-5C	18.3	33.3	saturated	34.2	34.2	10	672.6	2.66	15.89	36.7	2.80E-04	24.8	
2-5D	18.3	33.3	saturated	33.9	33.9	15	686.2	2.73	15.59	36.0	2.92E-04	25.9	
Test Averages/Summary													
2-5	**18.3**	**33.3**	**saturated**	**33.6**	**33.6**	**15**	**40.2**	**2.67**	**15.36**	**35.44**	**2.91E-04**	**25.7**	

Notes: Missed the 1 min reading

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/21/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	57.49
Bottom of Test Interval Depth, ft	69.66

Hydrostatic Pressure (P_0), psi	13.26
Transducer Zero Reading (R_0)	0.012
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	63.49
Vertical Center of Test Interval (D), ft	63.58
Test Interval Length (L), ft	12.17

Depth to Groundwater (D_{WL}), ft	33.00
Groundwater Elevation, ft	586.2
Top of Test Interval Elevation, ft	561.7
Bottom of Test Interval Elevation, ft	549.6

Start Time: 17:22 — Packer Pressure, psi: 153

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				27.8		0	945.0						
3-1A	13.3	28.3	saturated	27.7	27.69	1	961.7	16.67	14.43	33.3	1.93E-03	171.0	
3-1B	13.3	28.3	saturated	27.7	27.69	3	995.0	16.67	14.43	33.3	1.93E-03	171.0	
3-1C	13.3	28.3	saturated	27.7	27.69	5	1,028.3	16.65	14.43	33.3	1.93E-03	170.8	
3-1D	13.3	28.3	saturated	27.7	27.69	10	1,111.6	16.65	14.43	33.3	1.93E-03	170.8	
3-1E	13.3	28.3	saturated	27.7	27.69	15	1,194.7	16.63	14.43	33.3	1.93E-03	170.5	
Test Averages/Summary													
3-1	**13.3**	**28.3**	**saturated**	**27.7**	**27.7**	**15**	**249.7**	**16.65**	**14.43**	**33.29**	**1.93E-03**	**170.8**	

Notes: Very high idle on rig pump

Start Time: 17:40 — Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				32.6		0	1,252.8						
3-2A	13.3	43.3	saturated	32.9	32.9	1	1,277.3	24.54	19.63	45.3	2.09E-03	185.0	
3-2B	13.3	43.3	saturated	33.0	33.0	3	1,326.4	24.55	19.73	45.5	2.08E-03	184.2	
3-2C	13.3	43.3	saturated	33.1	33.1	5	1,375.4	24.48	19.83	45.7	2.06E-03	182.7	
3-2D	13.3	43.3	saturated	33.2	33.2	10	1,497.8	24.48	19.93	46.0	2.05E-03	181.8	
3-2E	13.3	43.3	saturated	33.7	33.7	15	1,619.7	24.38	20.43	47.1	2.00E-03	176.6	
Test Averages/Summary													
3-2	**13.3**	**43.3**	**saturated**	**33.1**	**33.1**	**15**	**366.9**	**24.49**	**19.91**	**45.93**	**2.06E-03**	**182.0**	

Notes: Could not obtain target pressure. Water was flowing around casing. Increased packer pressure to 200 psi

Start Time: 17:58 — Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				28.2		0	1,664.8						
3-3A	13.3	28.3	saturated	28.2	28.2	1	1,681.4	16.61	14.93	34.4	1.86E-03	164.7	
3-3B	13.3	28.3	saturated	28.2	28.2	3	1,714.6	16.62	14.93	34.4	1.86E-03	164.7	
3-3C	13.3	28.3	saturated	28.3	28.3	5	1,748.1	16.76	15.03	34.7	1.86E-03	165.0	
3-3D	13.3	28.3	saturated	28.4	28.4	10	1,831.6	16.69	15.13	34.9	1.85E-03	163.3	
3-3E	13.3	28.3	saturated	28.4	28.4	15	1,914.9	16.67	15.13	34.9	1.84E-03	163.1	
Test Averages/Summary													
3-3	**13.3**	**28.3**	**saturated**	**28.3**	**28.3**	**15**	**250.2**	**16.67**	**15.03**	**34.67**	**1.86E-03**	**164.2**	

Notes: Could not step up pressure twice due to high flow rate and maximum achievable transducer pressure of approx. 33-34 psi. No flow around casing.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/21/2019
WSP Personnel	K. Hanson
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-09
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	57.49
Bottom of Test Interval Depth, ft	69.66

Hydrostatic Pressure (P_0), psi	13.26
Transducer Zero Reading (R_0)	0.012
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	63.49
Vertical Center of Test Interval (D), ft	63.58
Test Interval Length (L), ft	12.17

Depth to Groundwater (D_{WL}), ft	33.00
Groundwater Elevation, ft	586.2
Top of Test Interval Elevation, ft	561.7
Bottom of Test Interval Elevation, ft	549.6

Start Time: 18:17 Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				19.6		0	2,008.4						
3-4A	13.3	21.0	saturated	19.6	19.6	1	2,017.2	8.85	6.33	14.6	2.34E-03	207.0	
3-4B	13.3	21.0	saturated	19.7	19.7	3	2,035.2	9.00	6.43	14.8	2.34E-03	207.1	
3-4C	13.3	21.0	saturated	19.7	19.7	5	2,053.2	9.02	6.43	14.8	2.35E-03	207.8	
3-4D	13.3	21.0	saturated	19.7	19.7	10	2,098.2	8.98	6.43	14.8	2.34E-03	206.8	
3-4E	13.3	21.0	saturated	19.8	19.8	15	2,143.2	9.01	6.53	15.1	2.31E-03	204.4	
Test Averages/Summary													
3-4	**13.3**	**21.0**	**saturated**	**19.7**	**19.7**	**15**	**134.9**	**8.97**	**6.43**	**14.83**	**2.33E-03**	**206.6**	

Notes: Added stage to obtain additional data.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	06/23/19
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Number of Tests	3
Lattitude	45.78545°N
Longitude	84.77588°W

Top of Rock, ft	13.00
Bottom of Boring, ft	110.00
Depth to Groundwater (D_{WL}),	72.00

Datum Elevation	662.6
Top of Rock Elevation, ft	649.6
Bottom of Hole Elevation, ft	552.6
Groundwater Elevation, ft	590.6

Total Length of Testing, ft	33.00
Boring Angle from Vertical, °	0.00
Borehole Diameter, ft	0.51

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	11.8	32.0	saturated	32.5	32.5	15	17.80	1.16	20.74	47.8	9.00E-05	9.2		
1-2	11.8	42.0	saturated	43.4	43.4	15	30.90	2.09	31.92	73.6	1.05E-04	10.7		
1-3	11.8	57.0	saturated	58.3	58.3	15	39.30	2.68	47.10	108.7	9.17E-05	9.3		
1-4	11.8	42.0	saturated	42.8	42.8	15	25.80	1.72	31.04	71.6	8.91E-05	9.1		
1-5	11.8	32.0	saturated	32.8	32.8	15	18.50	1.23	20.98	48.4	9.41E-05	9.6		
2-1	7.2	22.2	saturated	22.9	22.9	15	19.50	1.30	15.76	36.4	1.32E-04	13.5		
2-2	7.2	37.2	saturated	37.8	37.8	15	26.20	1.75	30.66	70.7	9.13E-05	9.3		
2-3	7.2	52.2	saturated	53.9	53.9	15	34.90	2.34	46.92	108.2	7.99E-05	8.2		
2-4	7.2	37.2	saturated	37.4	37.4	15	23.30	1.57	30.20	69.7	8.32E-05	8.5		
2-5	7.2	22.2	saturated	21.1	21.1	15	7.20	0.50	13.88	32.0	5.82E-05	5.9		
3-1	2.6	17.6	unsaturated	19.7	19.7	15	35.00	2.34	17.24	39.8	1.40E-04	22.2		
3-2	2.6	32.6	unsaturated	34.2	34.2	15	52.60	3.49	32.16	74.2	1.08E-04	17.7		
3-3	2.6	47.6	unsaturated	45.9	45.9	15	55.30	3.73	43.58	100.5	8.39E-05	14.0		
3-4	2.6	32.6	unsaturated	31.1	31.1	15	40.60	2.72	28.34	65.4	9.56E-05	15.7		
3-5	2.6	17.6	unsaturated	18.0	18.0	15	27.20	1.83	15.30	35.3	1.25E-04	19.6		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/22/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Test Number	1
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	92.00
Bottom of Test Interval Depth, ft	103.00

Hydrostatic Pressure (P_0), psi	11.80
Transducer Zero Reading (R_0)	
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	98.00
Vertical Center of Test Interval (D), ft	97.50
Test Interval Length (L), ft	11.00

Vertical Groundwater Depth(D_{WL}), ft	72.00
Groundwater Elevation, ft	590.6
Top of Test Interval Elevation, ft	570.6
Bottom of Test Interval Elevation, ft	559.6

Start Time: 13:00 — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0	20.5						
1-1A	11.8	32.0	saturated	32.4	32.4	1	21.6	1.10	20.60	47.5	8.56E-05	8.7	
1-1B	11.8	32.0	saturated	32.4	32.4	3	23.9	1.15	20.60	47.5	8.95E-05	9.1	
1-1C	11.8	32.0	saturated	32.4	32.4	5	26.2	1.15	20.60	47.5	8.95E-05	9.1	
1-1D	11.8	32.0	saturated	32.6	32.6	10	32.2	1.20	20.80	48.0	9.25E-05	9.4	
1-1E	11.8	32.0	saturated	32.9	32.9	15	38.3	1.22	21.10	48.7	9.27E-05	9.5	
Test Averages/Summary													
1-1	**11.8**	**32.0**	**saturated**	**32.5**	**32.5**	**15**	**17.8**	**1.16**	**20.74**	**47.85**	**9.00E-05**	**9.2**	

Notes:

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				41.8		0	46.0						
1-2A	11.8	42.0	saturated	42.8	42.8	1	48.2	2.20	31.00	71.5	1.14E-04	11.6	
1-2B	11.8	42.0	saturated	43.4	43.4	3	52.4	2.10	31.60	72.9	1.07E-04	10.9	
1-2C	11.8	42.0	saturated	43.5	43.5	5	56.6	2.10	31.70	73.1	1.06E-04	10.8	
1-2D	11.8	42.0	saturated	44.2	44.2	10	66.7	2.02	32.40	74.7	1.00E-04	10.2	
1-2E	11.8	42.0	saturated	44.7	44.7	15	76.9	2.04	32.90	75.9	9.94E-05	10.2	
Test Averages/Summary													
1-2	**11.8**	**42.0**	**saturated**	**43.4**	**43.4**	**15**	**30.9**	**2.09**	**31.92**	**73.64**	**1.05E-04**	**10.7**	

Notes:

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				55.5		0	84.0						
1-3A	11.8	57.0	saturated	55.6	55.6	1	86.9	2.90	43.80	101.0	1.06E-04	10.8	
1-3B	11.8	57.0	saturated	57.8	57.8	3	92.4	2.75	46.00	106.1	9.58E-05	9.8	
1-3C	11.8	57.0	saturated	60.2	60.2	5	97.7	2.65	48.40	111.7	8.78E-05	9.0	
1-3D	11.8	57.0	saturated	60.3	60.3	10	110.2	2.50	48.50	111.9	8.26E-05	8.4	
1-3E	11.8	57.0	saturated	60.6	60.6	15	123.3	2.62	48.80	112.6	8.61E-05	8.8	
Test Averages/Summary													
1-3	**11.8**	**57.0**	**saturated**	**58.3**	**58.3**	**15**	**39.3**	**2.68**	**47.10**	**108.66**	**9.17E-05**	**9.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/22/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Test Number	1
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	92.00
Bottom of Test Interval Depth, ft	103.00

Hydrostatic Pressure (P_0), psi	11.80
Transducer Zero Reading (R_0)	
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	98.00
Vertical Center of Test Interval (D), ft	97.50
Test Interval Length (L), ft	11.00

Vertical Groundwater Depth(D_{WL}), ft	72.00
Groundwater Elevation, ft	590.6
Top of Test Interval Elevation, ft	570.6
Bottom of Test Interval Elevation, ft	559.6

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				42.4		0	136.0						
1-4A	11.8	42.0	saturated	42.4	42.4	1	137.7	1.70	30.60	70.6	8.91E-05	9.1	
1-4B	11.8	42.0	saturated	42.6	42.6	3	141.2	1.75	30.80	71.1	9.11E-05	9.3	
1-4C	11.8	42.0	saturated	42.7	42.7	5	144.7	1.75	30.90	71.3	9.08E-05	9.3	
1-4D	11.8	42.0	saturated	43.1	43.1	10	153.2	1.70	31.30	72.2	8.71E-05	8.9	
1-4E	11.8	42.0	saturated	43.4	43.4	15	161.8	1.72	31.60	72.9	8.73E-05	8.9	
Test Averages/Summary													
1-4	**11.8**	**42.0**	**saturated**	**42.8**	**42.8**	**15**	**25.8**	**1.72**	**31.04**	**71.61**	**8.91E-05**	**9.1**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				32.6		0	166.0						
1-5A	11.8	32.0	saturated	32.7	32.7	1	167.2	1.20	20.90	48.2	9.21E-05	9.4	
1-5B	11.8	32.0	saturated	32.7	32.7	3	169.7	1.25	20.90	48.2	9.59E-05	9.8	
1-5C	11.8	32.0	saturated	32.8	32.8	5	172.2	1.25	21.00	48.4	9.54E-05	9.7	
1-5D	11.8	32.0	saturated	32.8	32.8	10	178.4	1.24	21.00	48.4	9.47E-05	9.7	
1-5E	11.8	32.0	saturated	32.9	32.9	15	184.5	1.22	21.10	48.7	9.27E-05	9.5	
Test Averages/Summary													
1-5	**11.8**	**32.0**	**saturated**	**32.8**	**32.8**	**15**	**18.5**	**1.23**	**20.98**	**48.40**	**9.41E-05**	**9.6**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/22/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Test Number	2
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	81.00
Bottom of Test Interval Depth, ft	92.00

Hydrostatic Pressure (P_0), psi	7.20
Transducer Zero Reading (R_0)	
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	87.00
Vertical Center of Test Interval (D), ft	86.50
Test Interval Length (L), ft	11.00

Vertical Groundwater Depth(D_{WL}), ft	72.00
Groundwater Elevation, ft	590.6
Top of Test Interval Elevation, ft	581.6
Bottom of Test Interval Elevation, ft	570.6

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				22.5		0	194.0						
2-1A	7.2	22.2	saturated	22.7	22.7	1	195.3	1.30	15.50	35.8	1.34E-04	13.7	
2-1B	7.2	22.2	saturated	22.8	22.8	3	197.9	1.30	15.60	36.0	1.34E-04	13.6	
2-1C	7.2	22.2	saturated	22.9	22.9	5	200.5	1.30	15.70	36.2	1.33E-04	13.6	
2-1D	7.2	22.2	saturated	23.0	23.0	10	207.1	1.32	15.80	36.5	1.34E-04	13.7	
2-1E	7.2	22.2	saturated	23.4	23.4	15	213.5	1.28	16.20	37.4	1.27E-04	12.9	
Test Averages/Summary													
2-1	**7.2**	**22.2**	**saturated**	**22.9**	**22.9**	**15**	**19.5**	**1.30**	**15.76**	**36.36**	**1.32E-04**	**13.5**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				37.3		0	226.2						
2-2A	7.2	37.2	saturated	37.2	37.2	1	227.9	1.70	30.00	69.2	9.09E-05	9.3	
2-2B	7.2	37.2	saturated	37.5	37.5	3	231.5	1.80	30.30	69.9	9.52E-05	9.7	
2-2C	7.2	37.2	saturated	37.8	37.8	5	235.0	1.75	30.60	70.6	9.17E-05	9.4	
2-2D	7.2	37.2	saturated	38.2	38.2	10	243.8	1.76	31.00	71.5	9.10E-05	9.3	
2-2E	7.2	37.2	saturated	38.6	38.6	15	252.4	1.72	31.40	72.4	8.78E-05	9.0	
Test Averages/Summary													
2-2	**7.2**	**37.2**	**saturated**	**37.8**	**37.8**	**15**	**26.2**	**1.75**	**30.66**	**70.73**	**9.13E-05**	**9.3**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				53.0		0	266.0						
2-3A	7.2	52.2	saturated	53.3	53.3	1	268.4	2.40	46.10	106.4	8.35E-05	8.5	
2-3B	7.2	52.2	saturated	53.4	53.4	3	273.1	2.35	46.20	106.6	8.16E-05	8.3	
2-3C	7.2	52.2	saturated	54.0	54.0	5	277.7	2.30	46.80	108.0	7.88E-05	8.0	
2-3D	7.2	52.2	saturated	54.6	54.6	10	289.4	2.34	47.40	109.4	7.91E-05	8.1	
2-3E	7.2	52.2	saturated	55.3	55.3	15	300.9	2.30	48.10	111.0	7.67E-05	7.8	
Test Averages/Summary													
2-3	**7.2**	**52.2**	**saturated**	**53.9**	**53.9**	**15**	**34.9**	**2.34**	**46.92**	**108.24**	**7.99E-05**	**8.2**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/22/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Test Number	2
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	81.00
Bottom of Test Interval Depth, ft	92.00

Hydrostatic Pressure (P_0), psi	7.20
Transducer Zero Reading (R_0)	
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	87.00
Vertical Center of Test Interval (D), ft	86.50
Test Interval Length (L), ft	11.00

Vertical Groundwater Depth(D_{WL}), ft	72.00
Groundwater Elevation, ft	590.6
Top of Test Interval Elevation, ft	581.6
Bottom of Test Interval Elevation, ft	570.6

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				37.1		0	310.0						
2-4A	7.2	37.2	saturated	37.1	37.1	1	311.6	1.60	29.90	69.0	8.58E-05	8.8	
2-4B	7.2	37.2	saturated	37.2	37.2	3	314.7	1.55	30.00	69.2	8.28E-05	8.5	
2-4C	7.2	37.2	saturated	37.3	37.3	5	317.9	1.60	30.10	69.4	8.52E-05	8.7	
2-4D	7.2	37.2	saturated	37.6	37.6	10	325.6	1.54	30.40	70.1	8.12E-05	8.3	
2-4E	7.2	37.2	saturated	37.8	37.8	15	333.3	1.54	30.60	70.6	8.07E-05	8.2	
Test Averages/Summary													
2-4	**7.2**	**37.2**	**saturated**	**37.4**	**37.4**	**15**	**23.3**	**1.57**	**30.20**	**69.67**	**8.32E-05**	**8.5**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				21.2		0	347.0						
2-5A	7.2	22.2	saturated	21.2	21.2	1	347.6	0.60	14.00	32.3	6.87E-05	7.0	
2-5B	7.2	22.2	saturated	21.1	21.1	3	348.6	0.50	13.90	32.1	5.77E-05	5.9	
2-5C	7.2	22.2	saturated	21.1	21.1	5	349.6	0.50	13.90	32.1	5.77E-05	5.9	
2-5D	7.2	22.2	saturated	21.0	21.0	10	352.0	0.48	13.80	31.8	5.58E-05	5.7	
2-5E	7.2	22.2	saturated	21.0	21.0	15	354.2	0.44	13.80	31.8	5.11E-05	5.2	
Test Averages/Summary													
2-5	**7.2**	**22.2**	**saturated**	**21.1**	**21.1**	**15**	**7.2**	**0.50**	**13.88**	**32.02**	**5.82E-05**	**5.9**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Test Number	3
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	70.00
Bottom of Test Interval Depth, ft	81.00

Hydrostatic Pressure (P_0), psi	2.60
Transducer Zero Reading (R_0)	
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	76.00
Vertical Center of Test Interval (D), ft	75.50
Test Interval Length (L), ft	11.00

Vertical Groundwater Depth(D_{WL}), ft	72.00
Groundwater Elevation, ft	590.6
Top of Test Interval Elevation, ft	592.6
Bottom of Test Interval Elevation, ft	581.6

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				19.1		0	379.0						
3-1A	2.6	17.6	unsaturated	19.3	19.3	1	381.4	2.40	16.70	38.5	1.49E-04	23.5	
3-1B	2.6	17.6	unsaturated	19.9	19.9	3	386.0	2.30	17.30	39.9	1.37E-04	21.8	
3-1C	2.6	17.6	unsaturated	19.7	19.7	5	390.6	2.30	17.10	39.4	1.39E-04	22.0	
3-1D	2.6	17.6	unsaturated	20.0	20.0	10	402.2	2.32	17.40	40.1	1.38E-04	21.8	
3-1E	2.6	17.6	unsaturated	20.3	20.3	15	414.0	2.36	17.70	40.8	1.37E-04	21.8	
Test Averages/Summary													
3-1	**2.6**	**17.6**	**unsaturated**	**19.7**	**19.7**	**15**	**35.0**	**2.34**	**17.24**	**39.77**	**1.40E-04**	**22.2**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				31.4		0	429.0						
3-2A	2.6	32.6	unsaturated	31.7	31.7	1	432.5	3.50	29.10	67.1	1.20E-04	19.7	
3-2B	2.6	32.6	unsaturated	32.6	32.6	3	439.3	3.40	30.00	69.2	1.13E-04	18.6	
3-2C	2.6	32.6	unsaturated	33.5	33.5	5	446.2	3.45	30.90	71.3	1.11E-04	18.3	
3-2D	2.6	32.6	unsaturated	36.0	36.0	10	463.7	3.50	33.40	77.1	1.04E-04	17.2	
3-2E	2.6	32.6	unsaturated	40.0	40.0	15	481.6	3.58	37.40	86.3	9.43E-05	15.7	
Test Averages/Summary													
3-2	**2.6**	**32.6**	**unsaturated**	**34.2**	**34.2**	**15**	**52.6**	**3.49**	**32.16**	**74.19**	**1.08E-04**	**17.7**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				44.5		0	506.0						
3-3A	2.6	47.6	unsaturated	45.3	45.3	1	509.9	3.90	42.70	98.5	8.95E-05	15.0	
3-3B	2.6	47.6	unsaturated	45.8	45.8	3	517.4	3.75	43.20	99.7	8.51E-05	14.2	
3-3C	2.6	47.6	unsaturated	46.6	46.6	5	524.8	3.70	44.00	101.5	8.23E-05	13.8	
3-3D	2.6	47.6	unsaturated	46.2	46.2	10	543.0	3.64	43.60	100.6	8.18E-05	13.7	
3-3E	2.6	47.6	unsaturated	47.0	47.0	15	561.3	3.66	44.40	102.4	8.07E-05	13.5	
Test Averages/Summary													
3-3	**2.6**	**47.6**	**unsaturated**	**45.9**	**45.9**	**15**	**55.3**	**3.73**	**43.58**	**100.54**	**8.39E-05**	**14.0**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/19/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Osterberg

Boring ID	BH19-10
Test Number	3
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	70.00
Bottom of Test Interval Depth, ft	81.00

Hydrostatic Pressure (P_0), psi	2.60
Transducer Zero Reading (R_0)	
Dist from Top Packer to Transducer, ft	6.0
Transducer Depth, ft	76.00
Vertical Center of Test Interval (D), ft	75.50
Test Interval Length (L), ft	11.00

Vertical Groundwater Depth(D_{WL}), ft	72.00
Groundwater Elevation, ft	590.6
Top of Test Interval Elevation, ft	592.6
Bottom of Test Interval Elevation, ft	581.6

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				31.6		0	580.0						
3-4A	2.6	32.6	unsaturated	31.5	31.5	1	582.7	2.70	28.90	66.7	9.31E-05	15.3	
3-4B	2.6	32.6	unsaturated	31.3	31.3	3	588.3	2.80	28.70	66.2	9.72E-05	16.0	
3-4C	2.6	32.6	unsaturated	31.2	31.2	5	593.7	2.70	28.60	66.0	9.41E-05	15.5	
3-4D	2.6	32.6	unsaturated	30.7	30.7	10	607.2	2.70	28.10	64.8	9.59E-05	15.7	
3-4E	2.6	32.6	unsaturated	30.0	30.0	15	620.6	2.68	27.40	63.2	9.77E-05	16.0	
Test Averages/Summary													
3-4	**2.6**	**32.6**	**unsaturated**	**31.1**	**31.1**	**15**	**40.6**	**2.72**	**28.34**	**65.38**	**9.56E-05**	**15.7**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				18.2		0	633.0						
3-5A	2.6	17.6	unsaturated	18.1	18.1	1	634.9	1.90	15.50	35.8	1.28E-04	20.1	
3-5B	2.6	17.6	unsaturated	18.1	18.1	3	638.6	1.85	15.50	35.8	1.25E-04	19.5	
3-5C	2.6	17.6	unsaturated	17.9	17.9	5	642.2	1.80	15.30	35.3	1.23E-04	19.3	
3-5D	2.6	17.6	unsaturated	17.9	17.9	10	651.3	1.82	15.30	35.3	1.24E-04	19.5	
3-5E	2.6	17.6	unsaturated	17.5	17.5	15	660.2	1.78	14.90	34.4	1.25E-04	19.6	
Test Averages/Summary													
3-5	**2.6**	**17.6**	**unsaturated**	**18.0**	**18.0**	**15**	**27.2**	**1.83**	**15.30**	**35.30**	**1.25E-04**	**19.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	06/25/19
WSP Personnel	D. Mein, K. Williams, C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond, C Barden,

Boring ID	BH19-15
Number of Tests	10
Lattitude	45.83538°N
Longitude	84.75837°W

Top of Rock, ft	103.00
Bottom of Boring, ft	228.00
Depth to Groundwater (D_{WL}), ft	16.83

Datum Elevation	598.6
Top of Rock Elevation, ft	495.6
Bottom of Hole Elevation, ft	370.6
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	105.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	86.9	101.9	saturated	100.5	100.5	15	13.44	0.93	13.7	31.5	1.30E-04	11.6			
1-2	86.9	116.9	saturated	121.4	121.4	15	29.60	2.01	35.3	81.5	1.07E-04	9.8			
1-3	86.9	131.9	saturated	134.4	134.4	15	26.61	1.79	47.9	110.5	7.01E-05	6.4			
1-4	86.9	116.9	saturated	118.7	118.7	15	19.01	1.26	32.1	74.0	7.39E-05	6.8			
1-5	86.9	101.9	saturated	101.5	101.5	15	4.56	0.29	14.7	33.8	3.65E-05	3.4			
2-1	82.2	97.2	saturated	97.6	97.6	15	0.00	0.00	15.0	34.6	0.00E+00	0.0		
2-2	82.2	112.2	saturated	115.2	115.2	15	0.00	0.00	33.8	78.0	0.00E+00	0.0		
2-3	82.2	127.2	saturated	128.2	128.2	15	0.00	0.00	46.0	106.1	0.00E+00	0.0		No Flow
2-4	82.2	112.2	saturated	115.3	115.3	15	0.00	0.00	33.6	77.6	0.00E+00	0.0		
2-5	82.2	97.2	saturated	99.2	99.2	15	0.00	0.00	17.2	39.6	0.00E+00	0.0		
3-1	77.8	92.8	saturated	90.8	90.8	15	0.40	0.04	12.5	28.7	6.02E-06	0.6			
3-2	77.8	107.8	saturated	110.0	110.0	15	0.11	0.01	32.3	74.6	5.43E-07	0.1		
3-3	77.8	122.8	saturated	124.9	124.9	15	1.42	0.12	47.2	108.8	4.70E-06	0.4			
3-4	77.8	107.8	saturated	111.5	111.5	15	0.08	0.01	33.6	77.5	4.70E-07	0.0		
3-5	77.8	92.8	saturated	92.8	92.8	15	0.00	0.00	15.0	34.6	0.00E+00	0.0		
4-1	73.1	88.1	saturated	88.6	88.6	15	0.00	0.00	15.2	35.1	0.00E+00	0.0		
4-2	73.1	103.1	saturated	103.9	103.9	15	0.28	0.01	31.1	71.8	6.37E-07	0.1		
4-3	73.1	118.1	saturated	118.7	118.7	15	18.55	1.25	45.7	105.4	5.12E-05	4.7			
4-4	73.1	103.1	saturated	103.5	103.5	15	0.09	0.01	30.5	70.3	5.66E-07	0.1		
4-5	73.1	88.1	saturated	88.4	88.4	15	0.00	0.00	15.4	35.5	0.00E+00	0.0		
5-1	68.6	83.6	saturated	83.8	83.8	15	165.22	11.51	15.4	35.6	1.40E-03	128.0			
5-2	68.6	98.6	saturated	98.2	98.2	15	198.34	13.33	29.8	68.7	8.39E-04	76.8			
5-3	68.6	113.6	saturated	113.6	113.6	15	227.86	15.57	45.3	104.6	6.44E-04	58.9			
5-4	68.6	98.6	saturated	97.8	97.8	15	170.66	11.98	29.3	67.6	7.66E-04	70.1			
5-5	68.6	83.6	saturated	83.6	83.6	15	112.04	7.75	15.0	34.6	9.68E-04	88.6			

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	06/25/19
WSP Personnel	D. Mein, K. Williams, C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond, C Barden,

Boring ID	BH19-15
Number of Tests	10
Lattitude	45.83538°N
Longitude	84.75837°W

Top of Rock, ft	103.00
Bottom of Boring, ft	228.00
Depth to Groundwater (D_{WL}), ft	16.83

Datum Elevation	598.6
Top of Rock Elevation, ft	495.6
Bottom of Hole Elevation, ft	370.6
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	105.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
6-1	64.4	79.4	saturated	79.1	79.1	15	0.00	0.00	14.7	33.8	0.00E+00	0.0		
6-2	64.4	94.4	saturated	95.3	95.3	15	0.00	0.00	31.0	71.5	0.00E+00	0.0		
6-3	64.4	109.4	saturated	108.9	108.9	15	18.00	1.25	44.5	102.6	5.26E-05	4.8		
6-4	64.4	94.4	saturated	94.8	94.8	15	0.02	0.00	30.5	70.3	1.24E-07	0.0		
6-5	64.4	79.4	saturated	78.9	78.9	15	0.00	0.00	14.5	33.6	0.00E+00	0.0		
7-1	59.6	74.6	saturated	74.0	74.0	15	10.87	0.76	14.4	33.2	9.84E-05	9.0		
7-2	59.6	89.6	saturated	89.5	89.5	15	17.77	1.22	29.9	69.1	7.62E-05	7.0		
7-3	59.6	104.6	saturated	104.9	104.9	15	28.42	1.89	45.3	104.5	7.81E-05	7.2		
7-4	59.6	89.6	saturated	90.3	90.3	15	17.48	1.16	30.6	70.7	7.12E-05	6.5		
7-5	59.6	74.6	saturated	75.0	75.0	15	0.24	0.01	15.4	35.6	1.45E-06	0.1		
8-1	53.0	68.0	saturated	69.3	69.3	15	0.00	0.00	16.3	37.5	0.00E+00	0.0		
8-2	53.0	83.0	saturated	85.1	85.1	15	10.50	0.74	32.3	74.5	4.25E-05	3.9		
8-3	53.0	98.0	saturated	97.5	97.5	15	20.10	1.33	44.6	102.8	5.61E-05	5.1		
8-4	53.0	83.0	saturated	83.8	83.8	15	6.70	0.43	30.9	71.2	2.59E-05	2.4		
8-5	53.0	68.0	saturated	68.6	68.6	15	0.00	0.00	15.6	36.0	0.00E+00	0.0		
9-1	50.4	65.4	saturated	67.9	67.9	15	0.00	0.00	17.5	40.3	0.00E+00	0.0		
9-2	50.4	80.4	saturated	80.5	80.5	15	0.00	0.00	30.1	69.5	0.00E+00	0.0		
9-3	50.4	95.4	saturated	96.2	96.2	15	0.00	0.00	45.9	105.8	0.00E+00	0.0		No Flow
9-4	50.4	80.4	saturated	79.8	79.8	15	0.00	0.00	29.4	67.8	0.00E+00	0.0		
9-5	50.4	65.4	saturated	65.0	65.0	15	0.00	0.00	14.6	33.7	0.00E+00	0.0		
10-1	45.7	60.7	saturated	60.5	60.5	15	0.00	0.00	14.8	34.1	0.00E+00	0.0		
10-2	45.7	75.7	saturated	75.6	75.6	15	0.00	0.00	29.9	69.0	0.00E+00	0.0		
10-3	45.7	90.7	saturated	91.2	91.2	15	0.00	0.00	45.6	105.2	0.00E+00	0.0		No Flow
10-4	45.7	75.7	saturated	75.5	75.5	15	0.00	0.00	29.8	68.8	0.00E+00	0.0		
10-5	45.7	60.7	saturated	61.2	61.2	15	0.00	0.00	15.6	36.0	0.00E+00	0.0		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	D. Mein
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	212.50
Bottom of Test Interval Depth, ft	223.00

Hydrostatic Pressure (P_0), psi	86.90
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	217.50
Vertical Center of Test Interval (D), ft	217.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	386.1
Bottom of Test Interval Elevation, ft	375.6

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				100.2		0	3.3						
1-1A	86.9	101.9	saturated	100.4	100.4	1	4.2	0.96	13.48	31.1	1.33E-04	12.2	
1-1B	86.9	101.9	saturated	101.5	101.5	3	6.2	0.98	14.60	33.7	1.26E-04	11.5	
1-1C	86.9	101.9	saturated	102.2	102.2	5	8.1	0.97	15.30	35.3	1.19E-04	10.9	
1-1D	86.9	101.9	saturated	103.1	103.1	10	12.9	0.96	16.20	37.4	1.11E-04	10.1	
1-1E	86.9	101.9	saturated	95.7	95.7	15	16.7	0.76	8.80	20.3	1.62E-04	14.8	
Test Averages/Summary													
1-1	**86.9**	**101.9**	**saturated**	**100.5**	**100.5**	**15**	**13.4**	**0.93**	**13.67**	**31.54**	**1.30E-04**	**11.6**	

Notes:

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				117.0		0	21.4						
1-2A	86.9	116.9	saturated	118.1	118.1	1	23.3	1.91	31.20	72.0	1.15E-04	10.5	
1-2B	86.9	116.9	saturated	119.9	119.9	3	27.5	2.13	33.00	76.1	1.21E-04	11.0	
1-2C	86.9	116.9	saturated	121.3	121.3	5	31.9	2.19	34.40	79.4	1.19E-04	10.9	
1-2D	86.9	116.9	saturated	128.9	128.9	10	42.4	2.10	42.00	96.9	9.36E-05	8.6	
1-2E	86.9	116.9	saturated	122.9	122.9	15	51.0	1.71	36.00	83.0	8.91E-05	8.2	
Test Averages/Summary													
1-2	**86.9**	**116.9**	**saturated**	**121.4**	**121.4**	**15**	**29.6**	**2.01**	**35.32**	**81.47**	**1.07E-04**	**9.8**	

Notes:

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				132.0		0	147.2						
1-3A	86.9	131.9	saturated	131.6	131.6	1	149.1	1.86	44.70	103.1	7.79E-05	7.1	
1-3B	86.9	131.9	saturated	134.1	134.1	3	152.6	1.79	47.20	108.9	7.10E-05	6.5	
1-3C	86.9	131.9	saturated	134.9	134.9	5	156.2	1.77	48.00	110.7	6.91E-05	6.3	
1-3D	86.9	131.9	saturated	136.5	136.5	10	165.0	1.76	49.60	114.4	6.63E-05	6.1	
1-3E	86.9	131.9	saturated	137.0	137.0	15	173.8	1.77	50.10	115.6	6.62E-05	6.1	
Test Averages/Summary													
1-3	**86.9**	**131.9**	**saturated**	**134.4**	**134.4**	**15**	**26.6**	**1.79**	**47.92**	**110.54**	**7.01E-05**	**6.4**	

Notes: Had to increase packer pressure. Pressure spiked abrubtly to 155 and packer system lifted 5'. Abandoned initial test and repeated

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	D. Mein
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	212.50
Bottom of Test Interval Depth, ft	223.00

Hydrostatic Pressure (P_0), psi	86.90
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	217.50
Vertical Center of Test Interval (D), ft	217.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	386.1
Bottom of Test Interval Elevation, ft	375.6

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				117.4		0	179.9						
1-4A	86.9	116.9	saturated	117.8	117.8	1	181.1	1.24	30.90	71.3	7.52E-05	6.9	
1-4B	86.9	116.9	saturated	118.5	118.5	3	183.2	1.03	31.60	72.9	6.10E-05	5.6	
1-4C	86.9	116.9	saturated	118.7	118.7	5	186.2	1.52	31.80	73.4	8.92E-05	8.2	
1-4D	86.9	116.9	saturated	119.6	119.6	10	192.6	1.27	32.70	75.4	7.25E-05	6.6	
1-4E	86.9	116.9	saturated	120.2	120.2	15	198.9	1.27	33.30	76.8	7.14E-05	6.5	
Test Averages/Summary													
1-4	**86.9**	**116.9**	**saturated**	**118.7**	**118.7**	**15**	**19.0**	**1.26**	**32.06**	**73.95**	**7.39E-05**	**6.8**	

Notes:

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				101.2		0	200.3						
1-5A	86.9	101.9	saturated	101.3	101.3	1	200.6	0.24	14.40	33.2	3.12E-05	2.9	
1-5B	86.9	101.9	saturated	101.4	101.4	3	201.1	0.27	14.50	33.4	3.42E-05	3.1	
1-5C	86.9	101.9	saturated	101.4	101.4	5	201.7	0.28	14.50	33.4	3.68E-05	3.4	
1-5D	86.9	101.9	saturated	101.9	101.9	10	203.3	0.32	14.98	34.5	4.00E-05	3.7	
1-5E	86.9	101.9	saturated	101.9	101.9	15	204.9	0.32	15.00	34.6	4.05E-05	3.7	
Test Averages/Summary													
1-5	**86.9**	**101.9**	**saturated**	**101.5**	**101.5**	**15**	**4.6**	**0.29**	**14.67**	**33.85**	**3.65E-05**	**3.4**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	D. Mein
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	202.00
Bottom of Test Interval Depth, ft	212.50

Hydrostatic Pressure (P_0), psi	82.20
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	207.00
Vertical Center of Test Interval (D), ft	207.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	396.6
Bottom of Test Interval Elevation, ft	386.1

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				99.8		0	207.8						
2-1A	82.2	97.2	saturated	97.3	97.3	1	207.8	0.00	15.10	34.8	0.00E+00	0.0	
2-1B	82.2	97.2	saturated	98.2	98.2	3	207.8	0.00	16.00	36.9	0.00E+00	0.0	
2-1C	82.2	97.2	saturated	97.5	97.5	5	207.8	0.00	15.30	35.3	0.00E+00	0.0	
2-1D	82.2	97.2	saturated	96.4	96.4	10	207.8	0.00	14.20	32.8	0.00E+00	0.0	
2-1E	82.2	97.2	saturated	96.6	96.6	15	207.8	0.00	14.40	33.2	0.00E+00	0.0	
Test Averages/Summary													
2-1	**82.2**	**97.2**	**saturated**	**97.6**	**97.6**	**15**	**0.0**	**0.00**	**15.00**	**34.60**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				111.3		0	207.8						
2-2A	82.2	112.2	saturated	116.4	116.4	1	207.8	0.00	34.20	78.9	0.00E+00	0.0	
2-2B	82.2	112.2	saturated	117.3	117.3	3	207.8	0.00	35.10	81.0	0.00E+00	0.0	
2-2C	82.2	112.2	saturated	116.7	116.7	5	207.8	0.00	34.50	79.6	0.00E+00	0.0	
2-2D	82.2	112.2	saturated	114.5	114.5	10	207.8	0.00	32.30	74.5	0.00E+00	0.0	
2-2E	82.2	112.2	saturated	115.2	115.2	15	207.8	0.00	33.00	76.1	0.00E+00	0.0	
Test Averages/Summary													
2-2	**82.2**	**112.2**	**saturated**	**115.2**	**115.2**	**15**	**0.0**	**0.00**	**33.82**	**78.01**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				128.2		0	207.8						
2-3A	82.2	127.2	saturated	127.5	127.5	1	207.8	0.00	45.30	104.5	0.00E+00	0.0	
2-3B	82.2	127.2	saturated	127.4	127.4	3	207.8	0.00	45.20	104.3	0.00E+00	0.0	
2-3C	82.2	127.2	saturated	128.4	128.4	5	207.8	0.00	46.20	106.6	0.00E+00	0.0	
2-3D	82.2	127.2	saturated	128.4	128.4	10	207.8	0.00	46.20	106.6	0.00E+00	0.0	
2-3E	82.2	127.2	saturated	129.3	129.3	15	207.8	0.00	47.10	108.7	0.00E+00	0.0	
Test Averages/Summary													
2-3	**82.2**	**127.2**	**saturated**	**128.2**	**128.2**	**15**	**0.0**	**0.00**	**46.00**	**106.11**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	D. Mein
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	202.00
Bottom of Test Interval Depth, ft	212.50

Hydrostatic Pressure (P_0), psi	82.20
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	207.00
Vertical Center of Test Interval (D), ft	207.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	396.6
Bottom of Test Interval Elevation, ft	386.1

Start Time | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				112.4		0	207.8						
2-4A	82.2	112.2	saturated	115.1	115.1	1	207.8	0.00	32.90	75.9	0.00E+00	0.0	
2-4B	82.2	112.2	saturated	115.8	115.8	3	207.8	0.00	33.60	77.5	0.00E+00	0.0	
2-4C	82.2	112.2	saturated	116.2	116.2	5	207.8	0.00	34.00	78.4	0.00E+00	0.0	
2-4D	82.2	112.2	saturated	116.9	116.9	10	207.8	0.00	34.70	80.0	0.00E+00	0.0	
2-4E	82.2	112.2	saturated	115.2	115.2	15	207.8	0.00	33.00	76.1	0.00E+00	0.0	
Test Averages/Summary													
2-4	**82.2**	**112.2**	**saturated**	**115.3**	**115.3**	**15**	**0.0**	**0.00**	**33.64**	**77.60**	**0.00E+00**	**0.0**	

Notes

Start Time | Packer Pressure, psi: 200

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				98.2		0	207.8						
2-5A	82.2	97.2	saturated	99.5	99.5	1	207.8	0.00	17.30	39.9	0.00E+00	0.0	
2-5B	82.2	97.2	saturated	98.0	98.0	3	207.8	0.00	15.80	36.4	0.00E+00	0.0	
2-5C	82.2	97.2	saturated	102.0	102.0	5	207.8	0.00	19.80	45.7	0.00E+00	0.0	
2-5D	82.2	97.2	saturated	99.7	99.7	10	207.8	0.00	17.50	40.4	0.00E+00	0.0	
2-5E	82.2	97.2	saturated	97.7	97.7	15	207.8	0.00	15.50	35.7	0.00E+00	0.0	
Test Averages/Summary													
2-5	**82.2**	**97.2**	**saturated**	**99.2**	**99.2**	**15**	**0.0**	**0.00**	**17.18**	**39.63**	**0.00E+00**	**0.0**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	191.50
Bottom of Test Interval Depth, ft	202.00

Hydrostatic Pressure (P_0), psi	77.80
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	196.50
Vertical Center of Test Interval (D), ft	196.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	407.1
Bottom of Test Interval Elevation, ft	396.6

Start Time | Packer Pressure, psi: 201

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				93.5		0	211.2						
3-1A	77.8	92.8	saturated	90.3	90.2	2	211.6	0.20	12.45	28.7	3.01E-05	2.8	
3-1B	77.8	92.8	saturated	90.7	90.7	3	211.6	0.00	12.93	29.8	0.00E+00	0.0	
3-1C	77.8	92.8	saturated	88.6	88.6	5	211.6	0.00	10.80	24.9	0.00E+00	0.0	
3-1D	77.8	92.8	saturated	90.7	90.6	11	211.6	0.00	12.85	29.6	0.00E+00	0.0	
3-1E	77.8	92.8	saturated	91.1	91.1	15	211.6	0.00	13.27	30.6	0.00E+00	0.0	
Test Averages/Summary													
3-1	**77.8**	**92.8**	**saturated**	**90.8**	**90.8**	**15**	**0.4**	**0.04**	**12.46**	**28.74**	**6.02E-06**	**0.6**	

Notes: Miscommunication spiked test pressure too high, proceeded to drop pressure back down

Start Time | Packer Pressure, psi: 201

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				109.1		0	212.2						
3-2A	77.8	107.8	saturated	109.1	109.1	1	212.2	0.00	31.31	72.2	0.00E+00	0.0	
3-2B	77.8	107.8	saturated	109.7	109.6	3	212.2	0.00	31.85	73.5	0.00E+00	0.0	
3-2C	77.8	107.8	saturated	113.9	113.9	5	212.3	0.05	36.10	83.3	2.59E-06	0.2	
3-2D	77.8	107.8	saturated	108.6	108.6	10	212.3	0.00	30.84	71.1	1.21E-07	0.0	
3-2E	77.8	107.8	saturated	109.4	109.4	15	212.3	0.00	31.62	72.9	0.00E+00	0.0	
Test Averages/Summary													
3-2	**77.8**	**107.8**	**saturated**	**110.0**	**110.0**	**15**	**0.1**	**0.01**	**32.34**	**74.61**	**5.43E-07**	**0.1**	

Notes:

Start Time | Packer Pressure, psi: 201

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				124.5		0	212.8						
3-3A	77.8	122.8	saturated	125.1	125.1	2	213.0	0.11	47.30	109.1	4.36E-06	0.4	
3-3B	77.8	122.8	saturated	125.4	125.4	3	213.3	0.23	47.57	109.7	9.06E-06	0.8	
3-3C	77.8	122.8	saturated	125.8	125.8	5	213.5	0.10	47.96	110.6	3.90E-06	0.4	
3-3D	77.8	122.8	saturated	124.4	124.4	10	214.2	0.15	46.60	107.5	5.87E-06	0.5	
3-3E	77.8	122.8	saturated	124.3	124.2	15	214.2	0.01	46.45	107.2	3.23E-07	0.0	
Test Averages/Summary													
3-3	**77.8**	**122.8**	**saturated**	**124.9**	**124.9**	**15**	**1.4**	**0.12**	**47.17**	**108.83**	**4.70E-06**	**0.4**	

Notes: Having trouble maintaining pressure. Pressure slowly climbs.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	191.50
Bottom of Test Interval Depth, ft	202.00

Hydrostatic Pressure (P_0), psi	77.80
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	196.50
Vertical Center of Test Interval (D), ft	196.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	407.1
Bottom of Test Interval Elevation, ft	396.6

Start Time: | Packer Pressure, psi: 201

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				112.2		0	214.3						
3-4A	77.8	107.8	saturated	112.4	112.4	1	214.3	0.00	34.55	79.7	0.00E+00	0.0	
3-4B	77.8	107.8	saturated	112.9	112.9	3	214.3	0.00	35.11	81.0	0.00E+00	0.0	
3-4C	77.8	107.8	saturated	109.7	109.6	5	214.3	0.04	31.85	73.5	2.35E-06	0.2	
3-4D	77.8	107.8	saturated	110.9	110.9	10	214.3	0.00	33.08	76.3	0.00E+00	0.0	
3-4E	77.8	107.8	saturated	111.2	111.2	15	214.3	0.00	33.41	77.1	0.00E+00	0.0	
Test Averages/Summary													
3-4	**77.8**	**107.8**	**saturated**	**111.5**	**111.5**	**15**	**0.1**	**0.01**	**33.60**	**77.51**	**4.70E-07**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 201

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				92.8		0	216.4						
3-5A	77.8	92.8	saturated	92.9	92.9	1	216.4	0.00	15.07	34.8	0.00E+00	0.0	
3-5B	77.8	92.8	saturated	92.7	92.7	3	216.4	0.00	14.88	34.3	0.00E+00	0.0	
3-5C	77.8	92.8	saturated	92.7	92.7	5	216.4	0.00	14.92	34.4	0.00E+00	0.0	
3-5D	77.8	92.8	saturated	92.8	92.8	10	216.4	0.00	15.02	34.6	0.00E+00	0.0	
3-5E	77.8	92.8	saturated	93.0	93.0	15	216.4	0.00	15.19	35.0	0.00E+00	0.0	
Test Averages/Summary													
3-5	**77.8**	**92.8**	**saturated**	**92.8**	**92.8**	**15**	**0.0**	**0.00**	**15.01**	**34.63**	**0.00E+00**	**0.0**	

Notes: Added screw valve to the bypass line to have better control.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	181.00
Bottom of Test Interval Depth, ft	191.50

Hydrostatic Pressure (P_0), psi	73.10
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	186.00
Vertical Center of Test Interval (D), ft	186.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	417.6
Bottom of Test Interval Elevation, ft	407.1

Start Time: | Packer Pressure, psi: 192

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				89.7		0	221.5						
4-1A	73.1	88.1	saturated	88.5	88.4	1	221.5	0.00	15.35	35.4	0.00E+00	0.0	
4-1B	73.1	88.1	saturated	88.4	88.4	3	221.5	0.00	15.26	35.2	0.00E+00	0.0	
4-1C	73.1	88.1	saturated	88.3	88.3	5	221.5	0.00	15.21	35.1	0.00E+00	0.0	
4-1D	73.1	88.1	saturated	88.1	88.1	10	221.5	0.00	15.01	34.6	0.00E+00	0.0	
4-1E	73.1	88.1	saturated	88.4	88.4	15	221.5	0.00	15.28	35.2	0.00E+00	0.0	
Test Averages/Summary													
4-1	**73.1**	**88.1**	**saturated**	**88.6**	**88.6**	**15**	**0.0**	**0.00**	**15.22**	**35.11**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 192

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				102.4		0	221.8						
4-2A	73.1	103.1	saturated	102.9	102.9	1	221.8	0.00	29.82	68.8	0.00E+00	0.0	
4-2B	73.1	103.1	saturated	103.4	103.4	3	221.8	0.00	30.28	69.9	0.00E+00	0.0	
4-2C	73.1	103.1	saturated	103.7	103.7	5	221.8	0.00	30.61	70.6	0.00E+00	0.0	
4-2D	73.1	103.1	saturated	107.4	107.4	10	222.0	0.04	34.26	79.0	1.97E-06	0.2	
4-2E	73.1	103.1	saturated	103.8	103.8	15	222.1	0.02	30.73	70.9	1.22E-06	0.1	
Test Averages/Summary													
4-2	**73.1**	**103.1**	**saturated**	**103.9**	**103.9**	**15**	**0.3**	**0.01**	**31.14**	**71.84**	**6.37E-07**	**0.1**	

Notes: During 5-10 min pressure spiked to 111. Between 10 and 15, trying to control pressure.

Start Time: | Packer Pressure, psi: 192

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				118.5		0	224.8						
4-3A	73.1	118.1	saturated	118.1	118.1	1	226.0	1.23	45.00	103.8	5.12E-05	4.7	
4-3B	73.1	118.1	saturated	118.4	118.3	3	228.6	1.30	45.25	104.4	5.36E-05	4.9	
4-3C	73.1	118.1	saturated	118.5	118.5	5	231.2	1.29	45.43	104.8	5.30E-05	4.9	
4-3D	73.1	118.1	saturated	119.2	119.1	10	237.3	1.22	46.05	106.2	4.95E-05	4.5	
4-3E	73.1	118.1	saturated	119.9	119.9	15	243.4	1.21	46.79	107.9	4.86E-05	4.5	
Test Averages/Summary													
4-3	**73.1**	**118.1**	**saturated**	**118.7**	**118.7**	**15**	**18.6**	**1.25**	**45.70**	**105.43**	**5.12E-05**	**4.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	181.00
Bottom of Test Interval Depth, ft	191.50

Hydrostatic Pressure (P_0), psi	73.10
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	186.00
Vertical Center of Test Interval (D), ft	186.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	417.6
Bottom of Test Interval Elevation, ft	407.1

Start Time: | Packer Pressure, psi: 192

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				103.0		0	246.4						
4-4A	73.1	103.1	saturated	103.5	103.5	1	246.4	0.00	30.37	70.1	0.00E+00	0.0	
4-4B	73.1	103.1	saturated	103.9	103.9	3	246.4	0.00	30.77	71.0	0.00E+00	0.0	
4-4C	73.1	103.1	saturated	102.9	102.9	5	246.5	0.05	29.79	68.7	2.83E-06	0.3	
4-4D	73.1	103.1	saturated	103.2	103.2	10	246.5	0.00	30.08	69.4	0.00E+00	0.0	
4-4E	73.1	103.1	saturated	104.4	104.4	15	246.5	0.00	31.34	72.3	0.00E+00	0.0	
Test Averages/Summary													
4-4	**73.1**	**103.1**	**saturated**	**103.5**	**103.5**	**15**	**0.1**	**0.01**	**30.47**	**70.29**	**5.66E-07**	**0.1**	

Notes: Flow stopped for a couple of seconds between 3 and 5 min

Start Time: | Packer Pressure, psi: 192

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				88.1		0	247.0						
4-5A	73.1	88.1	saturated	88.1	88.1	1	247.0	0.00	15.03	34.7	0.00E+00	0.0	
4-5B	73.1	88.1	saturated	88.3	88.3	3	247.0	0.00	15.19	35.0	0.00E+00	0.0	
4-5C	73.1	88.1	saturated	88.4	88.4	5	247.0	0.00	15.27	35.2	0.00E+00	0.0	
4-5D	73.1	88.1	saturated	88.7	88.7	10	247.0	0.00	15.60	36.0	0.00E+00	0.0	
4-5E	73.1	88.1	saturated	89.1	89.1	15	247.0	0.00	15.97	36.8	0.00E+00	0.0	
Test Averages/Summary													
4-5	**73.1**	**88.1**	**saturated**	**88.4**	**88.4**	**15**	**0.0**	**0.00**	**15.41**	**35.55**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	170.50
Bottom of Test Interval Depth, ft	181.00

Hydrostatic Pressure (P_0), psi	68.58
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	175.50
Vertical Center of Test Interval (D), ft	175.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	428.1
Bottom of Test Interval Elevation, ft	417.6

Start Time: | Packer Pressure, psi: 187

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				83.0		0	290.4						
5-1A	68.6	83.6	saturated	83.3	83.3	1	305.2	14.83	14.72	34.0	1.89E-03	172.8	
5-1B	68.6	83.6	saturated	83.6	83.6	3	325.6	10.17	15.02	34.6	1.27E-03	116.1	
5-1C	68.6	83.6	saturated	83.9	83.9	5	347.4	10.93	15.35	35.4	1.33E-03	122.2	
5-1D	68.6	83.6	saturated	84.4	84.4	10	401.5	10.82	15.82	36.5	1.28E-03	117.3	
5-1E	68.6	83.6	saturated	84.8	84.8	15	455.6	10.82	16.25	37.5	1.25E-03	114.3	
Test Averages/Summary													
5-1	**68.6**	**83.6**	**saturated**	**83.8**	**83.8**	**15**	**165.2**	**11.51**	**15.43**	**35.60**	**1.40E-03**	**128.0**	

Notes:

Start Time: | Packer Pressure, psi: 187

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				97.2		0	509.6						
5-2A	68.6	98.6	saturated	97.6	97.6	1.5	532.0	14.95	28.98	66.8	9.66E-04	88.5	
5-2B	68.6	98.6	saturated	97.8	97.8	3	551.6	13.07	29.18	67.3	8.39E-04	76.9	
5-2C	68.6	98.6	saturated	97.8	97.8	5	576.3	12.32	29.21	67.4	7.90E-04	72.3	
5-2D	68.6	98.6	saturated	99.6	99.6	10	643.4	13.43	31.05	71.6	8.10E-04	74.2	
5-2E	68.6	98.6	saturated	99.1	99.1	15	707.9	12.91	30.51	70.4	7.92E-04	72.6	
Test Averages/Summary													
5-2	**68.6**	**98.6**	**saturated**	**98.2**	**98.2**	**15**	**198.3**	**13.33**	**29.78**	**68.71**	**8.39E-04**	**76.8**	

Notes:

Start Time: | Packer Pressure, psi: 187

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				112.2		0	854.6						
5-3A	68.6	113.6	saturated	112.7	112.7	1	872.3	17.76	44.09	101.7	7.54E-04	69.1	
5-3B	68.6	113.6	saturated	113.1	113.1	3	902.4	15.01	44.49	102.6	6.32E-04	57.8	
5-3C	68.6	113.6	saturated	114.3	114.3	5	932.6	15.13	45.73	105.5	6.19E-04	56.7	
5-3D	68.6	113.6	saturated	114.4	114.4	10	1,007.6	15.00	45.78	105.6	6.14E-04	56.2	
5-3E	68.6	113.6	saturated	115.1	115.1	15	1,082.4	14.97	46.53	107.4	6.02E-04	55.2	
Test Averages/Summary													
5-3	**68.6**	**113.6**	**saturated**	**113.6**	**113.6**	**15**	**227.9**	**15.57**	**45.32**	**104.56**	**6.44E-04**	**58.9**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	170.50
Bottom of Test Interval Depth, ft	181.00

Hydrostatic Pressure (P_0), psi	68.58
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	175.50
Vertical Center of Test Interval (D), ft	175.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	428.1
Bottom of Test Interval Elevation, ft	417.6

Start Time: | Packer Pressure, psi: 187

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				97.5		0	1,133.4						
5-4A	68.6	98.6	saturated	97.5	97.5	1	1,148.5	15.16	28.93	66.7	9.81E-04	89.9	
5-4B	68.6	98.6	saturated	97.6	97.6	3	1,170.7	11.10	29.04	67.0	7.16E-04	65.6	
5-4C	68.6	98.6	saturated	97.7	97.7	5	1,194.0	11.65	29.10	67.1	7.50E-04	68.7	
5-4D	68.6	98.6	saturated	98.0	98.0	10	1,248.5	10.89	29.46	68.0	6.92E-04	63.4	
5-4E	68.6	98.6	saturated	98.6	98.6	15	1,304.0	11.11	30.02	69.3	6.93E-04	63.5	
Test Averages/Summary													
5-4	**68.6**	**98.6**	**saturated**	**97.8**	**97.8**	**15**	**170.7**	**11.98**	**29.31**	**67.61**	**7.66E-04**	**70.1**	

Notes:

Start Time: | Packer Pressure, psi: 187

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				83.6		0	1,327.6						
5-5A	68.6	83.6	saturated	83.5	83.5	1	1,337.0	9.47	14.92	34.4	1.19E-03	108.8	
5-5B	68.6	83.6	saturated	83.6	83.6	3	1,351.5	7.24	14.97	34.5	9.05E-04	82.9	
5-5C	68.6	83.6	saturated	83.5	83.5	5	1,366.2	7.36	14.95	34.5	9.22E-04	84.4	
5-5D	68.6	83.6	saturated	83.6	83.6	10	1,403.1	7.37	14.97	34.5	9.22E-04	84.5	
5-5E	68.6	83.6	saturated	83.7	83.7	15	1,439.6	7.30	15.15	34.9	9.03E-04	82.7	
Test Averages/Summary													
5-5	**68.6**	**83.6**	**saturated**	**83.6**	**83.6**	**15**	**112.0**	**7.75**	**14.99**	**34.59**	**9.68E-04**	**88.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	160.00
Bottom of Test Interval Depth, ft	170.50

Hydrostatic Pressure (P_0), psi	64.41
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	165.00
Vertical Center of Test Interval (D), ft	165.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	438.6
Bottom of Test Interval Elevation, ft	428.1

Start Time: | Packer Pressure, psi: 183

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				79.1		0	1,443.2						
6-1A	64.4	79.4	saturated	79.2	79.2	1	1,443.2	0.00	14.83	34.2	0.00E+00	0.0	
6-1B	64.4	79.4	saturated	78.8	78.8	3	1,443.2	0.00	14.42	33.3	0.00E+00	0.0	
6-1C	64.4	79.4	saturated	79.4	79.4	6	1,443.2	0.00	14.95	34.5	0.00E+00	0.0	
6-1D	64.4	79.4	saturated	78.9	78.9	10	1,443.2	0.00	14.51	33.5	0.00E+00	0.0	
6-1E	64.4	79.4	saturated	79.0	79.0	15	1,443.2	0.00	14.60	33.7	0.00E+00	0.0	
Test Averages/Summary													
6-1	**64.4**	**79.4**	**saturated**	**79.1**	**79.1**	**15**	**0.0**	**0.00**	**14.66**	**33.82**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 183

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				94.8		0	1,443.6						
6-2A	64.4	94.4	saturated	95.0	95.0	1	1,443.6	0.00	30.57	70.5	0.00E+00	0.0	
6-2B	64.4	94.4	saturated	95.1	95.1	3	1,443.6	0.00	30.73	70.9	0.00E+00	0.0	
6-2C	64.4	94.4	saturated	95.2	95.2	5	1,443.6	0.00	30.77	71.0	0.00E+00	0.0	
6-2D	64.4	94.4	saturated	95.6	95.6	10	1,443.6	0.00	31.23	72.0	0.00E+00	0.0	
6-2E	64.4	94.4	saturated	96.1	96.1	15	1,443.6	0.00	31.72	73.2	0.00E+00	0.0	
Test Averages/Summary													
6-2	**64.4**	**94.4**	**saturated**	**95.3**	**95.3**	**15**	**0.0**	**0.00**	**31.00**	**71.52**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 183

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				108.9		0	1,446.4						
6-3A	64.4	109.4	saturated	108.9	108.9	1	1,447.8	1.43	44.50	102.6	6.02E-05	5.5	
6-3B	64.4	109.4	saturated	108.4	108.4	3	1,450.4	1.28	44.02	101.6	5.47E-05	5.0	
6-3C	64.4	109.4	saturated	108.7	108.7	5	1,452.8	1.21	44.28	102.2	5.10E-05	4.7	
6-3D	64.4	109.4	saturated	108.7	108.7	10	1,458.7	1.18	44.30	102.2	4.97E-05	4.6	
6-3E	64.4	109.4	saturated	109.6	109.6	15	1,464.4	1.14	45.16	104.2	4.74E-05	4.3	
Test Averages/Summary													
6-3	**64.4**	**109.4**	**saturated**	**108.9**	**108.9**	**15**	**18.0**	**1.25**	**44.45**	**102.55**	**5.26E-05**	**4.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	160.00
Bottom of Test Interval Depth, ft	170.50

Hydrostatic Pressure (P_0), psi	64.41
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	165.00
Vertical Center of Test Interval (D), ft	165.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	438.6
Bottom of Test Interval Elevation, ft	428.1

Start Time: | Packer Pressure, psi: 183

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				94.6		0	1,464.7						
6-4A	64.4	94.4	saturated	94.7	94.7	2	1,464.7	0.01	30.30	69.9	6.18E-07	0.1	
6-4B	64.4	94.4	saturated	94.6	94.6	3	1,464.7	0.00	30.23	69.7	0.00E+00	0.0	
6-4C	64.4	94.4	saturated	95.0	95.0	5	1,464.7	0.00	30.59	70.6	0.00E+00	0.0	
6-4D	64.4	94.4	saturated	95.0	95.0	10	1,464.7	0.00	30.60	70.6	0.00E+00	0.0	
6-4E	64.4	94.4	saturated	95.0	95.0	15	1,464.7	0.00	30.57	70.5	0.00E+00	0.0	
Test Averages/Summary													
6-4	**64.4**	**94.4**	**saturated**	**94.8**	**94.8**	**15**	**0.0**	**0.00**	**30.46**	**70.26**	**1.24E-07**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 183

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				78.8		0	1,464.9						
6-5A	64.4	79.4	saturated	78.8	78.8	1	1,464.9	0.00	14.40	33.2	0.00E+00	0.0	
6-5B	64.4	79.4	saturated	78.8	78.8	3	1,464.9	0.00	14.40	33.2	0.00E+00	0.0	
6-5C	64.4	79.4	saturated	78.9	78.9	5	1,464.9	0.00	14.46	33.4	0.00E+00	0.0	
6-5D	64.4	79.4	saturated	79.1	79.1	10	1,464.9	0.00	14.70	33.9	0.00E+00	0.0	
6-5E	64.4	79.4	saturated	79.2	79.2	15	1,464.9	0.00	14.76	34.0	0.00E+00	0.0	
Test Averages/Summary													
6-5	**64.4**	**79.4**	**saturated**	**78.9**	**78.9**	**15**	**0.0**	**0.00**	**14.54**	**33.55**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	7
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	149.50
Bottom of Test Interval Depth, ft	160.00

Hydrostatic Pressure (P_0), psi	59.56
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	154.50
Vertical Center of Test Interval (D), ft	154.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	449.1
Bottom of Test Interval Elevation, ft	438.6

Start Time: | Packer Pressure, psi: 178

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				74.1		0	1,468.4						
7-1A	59.6	74.6	saturated	74.2	74.2	1	1,469.3	0.86	14.67	33.8	1.10E-04	10.1	
7-1B	59.6	74.6	saturated	73.2	73.2	3	1,470.8	0.75	13.69	31.6	1.03E-04	9.4	
7-1C	59.6	74.6	saturated	73.9	73.9	5	1,472.3	0.78	14.35	33.1	1.02E-04	9.3	
7-1D	59.6	74.6	saturated	74.4	74.3	10	1,476.1	0.76	14.79	34.1	9.57E-05	8.8	
7-1E	59.6	74.6	saturated	74.1	74.0	15	1,479.3	0.63	14.49	33.4	8.19E-05	7.5	
Test Averages/Summary													
7-1	**59.6**	**74.6**	**saturated**	**74.0**	**74.0**	**15**	**10.9**	**0.76**	**14.40**	**33.21**	**9.84E-05**	**9.0**	

Notes:

Start Time: | Packer Pressure, psi: 178

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				89.6		0	1,483.4						
7-2A	59.6	89.6	saturated	89.2	89.2	1	1,484.8	1.33	29.68	68.5	8.39E-05	7.7	
7-2B	59.6	89.6	saturated	89.5	89.5	3	1,487.2	1.21	29.93	69.0	7.54E-05	6.9	
7-2C	59.6	89.6	saturated	89.7	89.7	5	1,489.6	1.24	30.15	69.5	7.70E-05	7.1	
7-2D	59.6	89.6	saturated	89.4	89.4	10	1,495.5	1.17	29.80	68.7	7.34E-05	6.7	
7-2E	59.6	89.6	saturated	89.7	89.7	15	1,501.2	1.14	30.12	69.5	7.10E-05	6.5	
Test Averages/Summary													
7-2	**59.6**	**89.6**	**saturated**	**89.5**	**89.5**	**15**	**17.8**	**1.22**	**29.93**	**69.06**	**7.62E-05**	**7.0**	

Notes:

Start Time: | Packer Pressure, psi: 178

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				105.3		0	1,510.1						
7-3A	59.6	104.6	saturated	105.5	105.5	1	1,512.1	1.91	45.95	106.0	7.78E-05	7.1	
7-3B	59.6	104.6	saturated	104.7	104.7	3	1,515.8	1.89	45.11	104.1	7.87E-05	7.2	
7-3C	59.6	104.6	saturated	105.5	105.5	5	1,519.5	1.83	45.95	106.0	7.46E-05	6.8	
7-3D	59.6	104.6	saturated	105.3	105.3	10	1,528.9	1.88	45.74	105.5	7.71E-05	7.1	
7-3E	59.6	104.6	saturated	103.3	103.3	15	1,538.6	1.93	43.78	101.0	8.25E-05	7.6	
Test Averages/Summary													
7-3	**59.6**	**104.6**	**saturated**	**104.9**	**104.9**	**15**	**28.4**	**1.89**	**45.30**	**104.52**	**7.81E-05**	**7.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-15
Test Number	7
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	149.50
Bottom of Test Interval Depth, ft	160.00

Hydrostatic Pressure (P_0), psi	59.56
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	154.50
Vertical Center of Test Interval (D), ft	154.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	449.1
Bottom of Test Interval Elevation, ft	438.6

Start Time: | Packer Pressure, psi: 178

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				90.7		0	1,542.3						
7-4A	59.6	89.6	saturated	90.7	90.7	1	1,543.6	1.23	31.14	71.8	7.40E-05	6.8	
7-4B	59.6	89.6	saturated	89.8	89.8	3	1,545.9	1.18	30.24	69.8	7.31E-05	6.7	
7-4C	59.6	89.6	saturated	89.8	89.8	5	1,548.0	1.06	30.21	69.7	6.57E-05	6.0	
7-4D	59.6	89.6	saturated	90.1	90.1	10	1,554.0	1.19	30.54	70.5	7.28E-05	6.7	
7-4E	59.6	89.6	saturated	90.6	90.6	15	1,559.8	1.17	31.07	71.7	7.03E-05	6.4	
Test Averages/Summary													
7-4	**59.6**	**89.6**	**saturated**	**90.3**	**90.3**	**15**	**17.5**	**1.16**	**30.64**	**70.69**	**7.12E-05**	**6.5**	

Notes:

Start Time: | Packer Pressure, psi: 178

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				75.1		0	1,560.0						
7-5A	59.6	74.6	saturated	74.9	74.9	1	1,560.0	0.00	15.35	35.4	0.00E+00	0.0	
7-5B	59.6	74.6	saturated	75.0	75.0	3	1,560.0	0.01	15.42	35.6	1.21E-06	0.1	
7-5C	59.6	74.6	saturated	74.7	74.7	5	1,560.0	0.01	15.18	35.0	1.23E-06	0.1	
7-5D	59.6	74.6	saturated	75.2	75.2	10	1,560.2	0.02	15.66	36.1	2.87E-06	0.3	
7-5E	59.6	74.6	saturated	75.1	75.1	15	1,560.2	0.02	15.57	35.9	1.92E-06	0.2	
Test Averages/Summary													
7-5	**59.6**	**74.6**	**saturated**	**75.0**	**75.0**	**15**	**0.2**	**0.01**	**15.44**	**35.62**	**1.45E-06**	**0.1**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	8
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	139.00
Bottom of Test Interval Depth, ft	149.50

Hydrostatic Pressure (P_0), psi	53.00
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	144.00
Vertical Center of Test Interval (D), ft	144.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	459.6
Bottom of Test Interval Elevation, ft	449.1

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0	1,526.8						
8-1A	53.0	68.0	saturated	69.0	69.0	1	1,526.8	0.00	16.00	36.9	0.00E+00	0.0	
8-1B	53.0	68.0	saturated	69.0	69.0	3	1,526.8	0.00	16.00	36.9	0.00E+00	0.0	
8-1C	53.0	68.0	saturated	69.3	69.3	5	1,526.8	0.00	16.30	37.6	0.00E+00	0.0	
8-1D	53.0	68.0	saturated	69.4	69.4	10	1,526.8	0.00	16.40	37.8	0.00E+00	0.0	
8-1E	53.0	68.0	saturated	69.7	69.7	15	1,526.8	0.00	16.70	38.5	0.00E+00	0.0	
Test Averages/Summary													
8-1	**53.0**	**68.0**	**saturated**	**69.3**	**69.3**	**15**	**0.0**	**0.00**	**16.28**	**37.55**	**0.00E+00**	**0.0**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				84.1		0	1,566.8						
8-2A	53.0	83.0	saturated	84.5	84.5	1	1,567.5	0.70	31.50	72.7	4.16E-05	3.8	
8-2B	53.0	83.0	saturated	84.7	84.7	3	1,569.1	0.80	31.70	73.1	4.73E-05	4.3	
8-2C	53.0	83.0	saturated	89.5	89.5	5	1,570.9	0.90	36.50	84.2	4.62E-05	4.2	
8-2D	53.0	83.0	saturated	83.8	83.8	10	1,574.4	0.70	30.80	71.0	4.26E-05	3.9	
8-2E	53.0	83.0	saturated	84.0	84.0	15	1,577.3	0.58	31.00	71.5	3.50E-05	3.2	
Test Averages/Summary													
8-2	**53.0**	**83.0**	**saturated**	**85.1**	**85.1**	**15**	**10.5**	**0.74**	**32.30**	**74.51**	**4.25E-05**	**3.9**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				97.0		0	1,588.5						
8-3A	53.0	98.0	saturated	97.2	97.2	1	1,589.6	1.10	44.20	102.0	4.66E-05	4.3	
8-3B	53.0	98.0	saturated	98.2	98.2	3	1,592.6	1.50	45.20	104.3	6.22E-05	5.7	
8-3C	53.0	98.0	saturated	96.4	96.4	5	1,595.5	1.45	43.40	100.1	6.26E-05	5.7	
8-3D	53.0	98.0	saturated	98.6	98.6	10	1,602.1	1.32	45.60	105.2	5.42E-05	5.0	
8-3E	53.0	98.0	saturated	97.4	97.4	15	1,608.6	1.30	44.40	102.4	5.48E-05	5.0	
Test Averages/Summary													
8-3	**53.0**	**98.0**	**saturated**	**97.5**	**97.5**	**15**	**20.1**	**1.33**	**44.56**	**102.79**	**5.61E-05**	**5.1**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	8
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	139.00
Bottom of Test Interval Depth, ft	149.50

Hydrostatic Pressure (P_0), psi	53.00
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	144.00
Vertical Center of Test Interval (D), ft	144.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	459.6
Bottom of Test Interval Elevation, ft	449.1

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				83.4		0	1,609.8						
8-4A	53.0	83.0	saturated	83.3	83.3	1	1,610.2	0.40	30.30	69.9	2.47E-05	2.3	
8-4B	53.0	83.0	saturated	83.2	83.2	3	1,610.9	0.35	30.20	69.7	2.17E-05	2.0	
8-4C	53.0	83.0	saturated	84.1	84.1	5	1,611.8	0.45	31.10	71.7	2.71E-05	2.5	
8-4D	53.0	83.0	saturated	84.1	84.1	10	1,614.5	0.54	31.10	71.7	3.25E-05	3.0	
8-4E	53.0	83.0	saturated	84.7	84.7	15	1,616.5	0.40	31.70	73.1	2.36E-05	2.2	
Test Averages/Summary													
8-4	**53.0**	**83.0**	**saturated**	**83.8**	**83.8**	**15**	**6.7**	**0.43**	**30.88**	**71.23**	**2.59E-05**	**2.4**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				68.5		0	1,616.6						
8-5A	53.0	68.0	saturated	68.5	68.5	1	1,616.6	0.00	15.50	35.7	0.00E+00	0.0	
8-5B	53.0	68.0	saturated	68.5	68.5	3	1,616.6	0.00	15.50	35.7	0.00E+00	0.0	
8-5C	53.0	68.0	saturated	68.6	68.6	5	1,616.6	0.00	15.60	36.0	0.00E+00	0.0	
8-5D	53.0	68.0	saturated	68.7	68.7	10	1,616.6	0.00	15.70	36.2	0.00E+00	0.0	
8-5E	53.0	68.0	saturated	68.8	68.8	15	1,616.6	0.00	15.80	36.4	0.00E+00	0.0	
Test Averages/Summary													
8-5	**53.0**	**68.0**	**saturated**	**68.6**	**68.6**	**15**	**0.0**	**0.00**	**15.62**	**36.03**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	9
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	128.50
Bottom of Test Interval Depth, ft	139.00

Hydrostatic Pressure (P_0), psi	50.44
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	133.50
Vertical Center of Test Interval (D), ft	133.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	470.1
Bottom of Test Interval Elevation, ft	459.6

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				67.7		0	1,618.2						
9-1A	50.4	65.4	saturated	67.8	67.8	1	1,618.2	0.00	17.36	40.0	0.00E+00	0.0	
9-1B	50.4	65.4	saturated	67.9	67.9	3	1,618.2	0.00	17.46	40.3	0.00E+00	0.0	
9-1C	50.4	65.4	saturated	67.8	67.8	5	1,618.2	0.00	17.36	40.0	0.00E+00	0.0	
9-1D	50.4	65.4	saturated	68.0	68.0	10	1,618.2	0.00	17.56	40.5	0.00E+00	0.0	
9-1E	50.4	65.4	saturated	68.1	68.1	15	1,618.2	0.00	17.66	40.7	0.00E+00	0.0	
Test Averages/Summary													
9-1	**50.4**	**65.4**	**saturated**	**67.9**	**67.9**	**15**	**0.0**	**0.00**	**17.48**	**40.32**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.1		0	1,618.6						
9-2A	50.4	80.4	saturated	80.2	80.2	1	1,618.6	0.00	29.76	68.6	0.00E+00	0.0	
9-2B	50.4	80.4	saturated	80.4	80.4	3	1,618.6	0.00	29.96	69.1	0.00E+00	0.0	
9-2C	50.4	80.4	saturated	80.5	80.5	5	1,618.6	0.00	30.06	69.3	0.00E+00	0.0	
9-2D	50.4	80.4	saturated	80.6	80.6	10	1,618.6	0.00	30.16	69.6	0.00E+00	0.0	
9-2E	50.4	80.4	saturated	81.2	81.2	15	1,618.6	0.00	30.76	71.0	0.00E+00	0.0	
Test Averages/Summary													
9-2	**50.4**	**80.4**	**saturated**	**80.5**	**80.5**	**15**	**0.0**	**0.00**	**30.14**	**69.52**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				95.8		0	1,618.7						
9-3A	50.4	95.4	saturated	96.2	96.2	1	1,618.7	0.00	45.76	105.6	0.00E+00	0.0	
9-3B	50.4	95.4	saturated	96.3	96.3	3	1,618.7	0.00	45.86	105.8	0.00E+00	0.0	
9-3C	50.4	95.4	saturated	95.6	95.6	5	1,618.7	0.00	45.16	104.2	0.00E+00	0.0	
9-3D	50.4	95.4	saturated	96.5	96.5	10	1,618.7	0.00	46.06	106.3	0.00E+00	0.0	
9-3E	50.4	95.4	saturated	96.9	96.9	15	1,618.7	0.00	46.46	107.2	0.00E+00	0.0	
Test Averages/Summary													
9-3	**50.4**	**95.4**	**saturated**	**96.2**	**96.2**	**15**	**0.0**	**0.00**	**45.86**	**105.79**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/24/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	9
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	128.50
Bottom of Test Interval Depth, ft	139.00

Hydrostatic Pressure (P_0), psi	50.44
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	133.50
Vertical Center of Test Interval (D), ft	133.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	470.1
Bottom of Test Interval Elevation, ft	459.6

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				79.6		0	1,618.7						
9-4A	50.4	80.4	saturated	79.5	79.5	1	1,618.7	0.00	29.06	67.0	0.00E+00	0.0	
9-4B	50.4	80.4	saturated	79.7	79.7	3	1,618.7	0.00	29.26	67.5	0.00E+00	0.0	
9-4C	50.4	80.4	saturated	79.8	79.8	5	1,618.7	0.00	29.36	67.7	0.00E+00	0.0	
9-4D	50.4	80.4	saturated	80.0	80.0	10	1,618.7	0.00	29.56	68.2	0.00E+00	0.0	
9-4E	50.4	80.4	saturated	80.2	80.2	15	1,618.7	0.00	29.76	68.6	0.00E+00	0.0	
Test Averages/Summary													
9-4	**50.4**	**80.4**	**saturated**	**79.8**	**79.8**	**15**	**0.0**	**0.00**	**29.40**	**67.82**	**0.00E+00**	**0.0**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				64.9		0	1,618.7						
9-5A	50.4	65.4	saturated	65.0	65.0	1	1,618.7	0.00	14.56	33.6	0.00E+00	0.0	
9-5B	50.4	65.4	saturated	65.1	65.1	3	1,618.7	0.00	14.66	33.8	0.00E+00	0.0	
9-5C	50.4	65.4	saturated	65.1	65.1	5	1,618.7	0.00	14.66	33.8	0.00E+00	0.0	
9-5D	50.4	65.4	saturated	65.1	65.1	10	1,618.7	0.00	14.66	33.8	0.00E+00	0.0	
9-5E	50.4	65.4	saturated	65.0	65.0	15	1,618.7	0.00	14.56	33.6	0.00E+00	0.0	
Test Averages/Summary													
9-5	**50.4**	**65.4**	**saturated**	**65.0**	**65.0**	**15**	**0.0**	**0.00**	**14.62**	**33.72**	**0.00E+00**	**0.0**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/25/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	10
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	118.00
Bottom of Test Interval Depth, ft	128.50

Hydrostatic Pressure (P_0), psi	45.74
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	123.00
Vertical Center of Test Interval (D), ft	123.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	480.6
Bottom of Test Interval Elevation, ft	470.1

Start Time: 12:15 — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				60.5		0	1,619.1						
10-1A	45.7	60.7	saturated	60.5	60.5	1	1,619.1	0.00	14.76	34.0	0.00E+00	0.0	
10-1B	45.7	60.7	saturated	60.4	60.4	3	1,619.1	0.00	14.66	33.8	0.00E+00	0.0	
10-1C	45.7	60.7	saturated	60.7	60.7	5	1,619.1	0.00	14.96	34.5	0.00E+00	0.0	
10-1D	45.7	60.7	saturated	60.7	60.7	10	1,619.1	0.00	14.96	34.5	0.00E+00	0.0	
10-1E	45.7	60.7	saturated	60.3	60.3	15	1,619.1	0.00	14.56	33.6	0.00E+00	0.0	
Test Averages/Summary													
10-1	**45.7**	**60.7**	**saturated**	**60.5**	**60.5**	**15**	**0.0**	**0.00**	**14.78**	**34.09**	**0.00E+00**	**0.0**	

Notes:

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				75.1		0	1,619.5						
10-2A	45.7	75.7	saturated	75.2	75.2	1	1,619.5	0.00	29.46	68.0	0.00E+00	0.0	
10-2B	45.7	75.7	saturated	75.4	75.4	3	1,619.5	0.00	29.66	68.4	0.00E+00	0.0	
10-2C	45.7	75.7	saturated	75.6	75.6	5	1,619.5	0.00	29.86	68.9	0.00E+00	0.0	
10-2D	45.7	75.7	saturated	75.9	75.9	10	1,619.5	0.00	30.16	69.6	0.00E+00	0.0	
10-2E	45.7	75.7	saturated	76.2	76.2	15	1,619.5	0.00	30.46	70.3	0.00E+00	0.0	
Test Averages/Summary													
10-2	**45.7**	**75.7**	**saturated**	**75.6**	**75.6**	**15**	**0.0**	**0.00**	**29.92**	**69.02**	**0.00E+00**	**0.0**	

Notes:

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				90.5		0	1,620.0						
10-3A	45.7	90.7	saturated	90.6	90.6	1	1,620.0	0.00	44.86	103.5	0.00E+00	0.0	
10-3B	45.7	90.7	saturated	90.9	90.9	3	1,620.0	0.00	45.16	104.2	0.00E+00	0.0	
10-3C	45.7	90.7	saturated	91.3	91.3	5	1,620.0	0.00	45.56	105.1	0.00E+00	0.0	
10-3D	45.7	90.7	saturated	91.8	91.8	10	1,620.0	0.00	46.06	106.3	0.00E+00	0.0	
10-3E	45.7	90.7	saturated	92.1	92.1	15	1,620.0	0.00	46.36	106.9	0.00E+00	0.0	
Test Averages/Summary													
10-3	**45.7**	**90.7**	**saturated**	**91.2**	**91.2**	**15**	**0.0**	**0.00**	**45.60**	**105.19**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	6/25/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-15
Test Number	10
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	118.00
Bottom of Test Interval Depth, ft	128.50

Hydrostatic Pressure (P_0), psi	45.74
Transducer Zero Reading (R_0)	0.004
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	123.00
Vertical Center of Test Interval (D), ft	123.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.83
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	480.6
Bottom of Test Interval Elevation, ft	470.1

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				75.3		0	1,620.0						
10-4A	45.7	75.7	saturated	75.2	75.2	1	1,620.0	0.00	29.46	68.0	0.00E+00	0.0	
10-4B	45.7	75.7	saturated	75.4	75.4	3	1,620.0	0.00	29.66	68.4	0.00E+00	0.0	
10-4C	45.7	75.7	saturated	75.5	75.5	5	1,620.0	0.00	29.76	68.6	0.00E+00	0.0	
10-4D	45.7	75.7	saturated	75.8	75.8	10	1,620.0	0.00	30.06	69.3	0.00E+00	0.0	
10-4E	45.7	75.7	saturated	76.0	76.0	15	1,620.0	0.00	30.26	69.8	0.00E+00	0.0	
Test Averages/Summary													
10-4	**45.7**	**75.7**	**saturated**	**75.5**	**75.5**	**15**	**0.0**	**0.00**	**29.84**	**68.83**	**0.00E+00**	**0.0**	

Notes

Start Time | Packer Pressure, psi

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				60.4		0	1,620.0						
10-5A	45.7	60.7	saturated	60.8	60.8	1	1,620.0	0.00	15.06	34.7	0.00E+00	0.0	
10-5B	45.7	60.7	saturated	61.1	61.1	3	1,620.0	0.00	15.36	35.4	0.00E+00	0.0	
10-5C	45.7	60.7	saturated	61.4	61.4	5	1,620.0	0.00	15.66	36.1	0.00E+00	0.0	
10-5D	45.7	60.7	saturated	61.6	61.6	10	1,620.0	0.00	15.86	36.6	0.00E+00	0.0	
10-5E	45.7	60.7	saturated	61.8	61.8	15	1,620.0	0.00	16.06	37.0	0.00E+00	0.0	
Test Averages/Summary													
10-5	**45.7**	**60.7**	**saturated**	**61.2**	**61.2**	**15**	**0.0**	**0.00**	**15.60**	**35.98**	**0.00E+00**	**0.0**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/03/19
WSP Personnel	K. Williams, C. Fischer
Subcontractor	Cascade Drilling
Driller	C. Barden, S. Parks

Boring ID	BH19-16
Number of Tests	4
Lattitude	45.83164°N
Longitude	84.76097°W

Top of Rock, ft	110.00
Bottom of Boring, ft	328.50
Depth to Groundwater (D_{WL}),	18.20

Datum Elevation	600.0
Top of Rock Elevation, ft	490.0
Bottom of Hole Elevation, ft	271.5
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	42.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	119.2	134.2	saturated	135.1	135.1	15	25.08	1.65	15.9	36.7	1.94E-04	17.7		
1-2	119.2	149.2	saturated	152.6	152.6	15	79.42	5.48	33.5	77.3	3.06E-04	28.1		
1-3	119.2	164.2	saturated	164.2	164.2	15	124.11	8.16	44.8	103.3	3.41E-04	31.3		
1-4	119.2	149.2	saturated	148.8	148.8	15	94.18	6.39	29.5	68.1	4.05E-04	37.1		
1-5	119.2	134.2	saturated	134.8	134.8	15	60.29	4.02	15.6	35.9	4.84E-04	44.3		
2-1	115.2	130.2	saturated	129.9	129.9	16	0.00	0.00	14.8	34.1	0.00E+00	0.0		
2-2	115.2	145.2	saturated	145.5	145.5	15	0.00	0.00	30.4	70.2	0.00E+00	0.0		
2-3	115.2	160.2	saturated	159.9	159.9	15	0.00	0.00	44.6	102.9	0.00E+00	0.0		No Flow
2-4	115.2	145.2	saturated	145.6	145.6	15	0.00	0.00	30.4	70.1	0.00E+00	0.0		
2-5	115.2	130.2	saturated	129.3	129.3	15	0.00	0.00	13.9	32.2	0.00E+00	0.0		
3-1	110.1	125.1	saturated	124.6	124.6	15	5.88	0.43	14.2	32.8	5.70E-05	5.2		
3-2	110.1	140.1	saturated	140.4	140.4	15	19.41	1.38	30.4	70.0	8.56E-05	7.8		
3-3	110.1	155.1	saturated	154.2	154.2	15	36.14	2.41	43.8	101.0	1.03E-04	9.4		
3-4	110.1	140.1	saturated	140.3	140.3	15	25.04	1.73	30.1	69.5	1.08E-04	9.9		
3-5	110.1	125.1	saturated	125.8	125.8	15	11.09	0.75	15.7	36.3	8.94E-05	8.2		
4-1	106.0	121.0	saturated	121.0	121.0	15	190.98	12.67	15.1	34.9	1.57E-03	143.7		
4-2	106.0	136.0	saturated	137.7	137.7	15	305.80	19.99	32.0	73.7	1.17E-03	107.3		
4-3	106.0	151.0	saturated	150.1	150.1	15	333.20	22.21	44.2	102.0	9.41E-04	86.2		
4-4	106.0	136.0	saturated	137.0	137.0	15	272.70	17.87	31.0	71.6	1.08E-03	98.8		
4-5	106.0	121.0	saturated	121.5	121.5	15	165.20	11.05	15.6	36.1	1.32E-03	121.2		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-16
Test Number	1
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	289.75
Bottom of Test Interval Depth, ft	300.25

Hydrostatic Pressure (P_0), psi	119.20
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	294.25
Vertical Center of Test Interval (D), ft	295.00
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	310.2
Bottom of Test Interval Elevation, ft	299.7

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				135.2		0	1,732.5						
1-1A	119.2	134.2	saturated	136.0	136.0	1	1,734.1	1.56	16.82	38.8	1.74E-04	15.9	
1-1B	119.2	134.2	saturated	135.5	135.5	3	1,737.5	1.68	16.29	37.6	1.93E-04	17.7	
1-1C	119.2	134.2	saturated	134.5	134.5	5	1,740.7	1.61	15.29	35.3	1.97E-04	18.1	
1-1D	119.2	134.2	saturated	134.8	134.8	10	1,748.8	1.63	15.57	35.9	1.96E-04	17.9	
1-1E	119.2	134.2	saturated	134.9	134.9	15	1,757.6	1.76	15.68	36.2	2.10E-04	19.3	
Test Averages/Summary													
1-1	**119.2**	**134.2**	**saturated**	**135.1**	**135.1**	**15**	**25.1**	**1.65**	**15.93**	**36.75**	**1.94E-04**	**17.7**	

Notes:

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				152.1		0	1,786.2						
1-2A	119.2	149.2	saturated	152.1	152.1	1	1,792.4	6.18	32.89	75.9	3.52E-04	32.2	
1-2B	119.2	149.2	saturated	152.2	152.2	3	1,802.3	4.95	33.04	76.2	2.81E-04	25.7	
1-2C	119.2	149.2	saturated	153.2	153.2	5	1,814.3	5.98	34.03	78.5	3.29E-04	30.1	
1-2D	119.2	149.2	saturated	153.4	153.4	10	1,840.0	5.14	34.22	78.9	2.81E-04	25.7	
1-2E	119.2	149.2	saturated	152.4	152.5	15	1,865.7	5.14	33.25	76.7	2.89E-04	26.5	
Test Averages/Summary													
1-2	**119.2**	**149.2**	**saturated**	**152.6**	**152.6**	**15**	**79.4**	**5.48**	**33.49**	**77.25**	**3.06E-04**	**28.1**	

Notes:

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				165.2		0	1,887.2						
1-3A	119.2	164.2	saturated	164.9	164.9	1	1,895.2	8.00	45.72	105.5	3.28E-04	30.0	
1-3B	119.2	164.2	saturated	164.9	165.0	3	1,911.7	8.27	45.75	105.5	3.39E-04	31.0	
1-3C	119.2	164.2	saturated	161.4	161.4	5	1,927.1	7.68	42.21	97.4	3.41E-04	31.2	
1-3D	119.2	164.2	saturated	164.6	164.6	10	1,967.7	8.11	45.44	104.8	3.34E-04	30.6	
1-3E	119.2	164.2	saturated	163.9	163.9	15	2,011.3	8.73	44.67	103.1	3.66E-04	33.5	
Test Averages/Summary													
1-3	**119.2**	**164.2**	**saturated**	**164.2**	**164.2**	**15**	**124.1**	**8.16**	**44.76**	**103.25**	**3.41E-04**	**31.3**	

Notes: Pressure drop between 3-5 min

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-16
Test Number	1
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	289.75
Bottom of Test Interval Depth, ft	300.25

Hydrostatic Pressure (P_0), psi	119.20
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	294.25
Vertical Center of Test Interval (D), ft	295.00
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	310.2
Bottom of Test Interval Elevation, ft	299.7

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				149.4		0	2,025.3						
1-4A	119.2	149.2	saturated	148.7	148.7	1	2,032.3	7.04	29.50	68.1	4.47E-04	40.9	
1-4B	119.2	149.2	saturated	148.7	148.7	3	2,044.8	6.25	29.54	68.2	3.96E-04	36.3	
1-4C	119.2	149.2	saturated	148.2	148.2	5	2,057.2	6.21	29.00	66.9	4.01E-04	36.7	
1-4D	119.2	149.2	saturated	148.8	148.8	10	2,088.3	6.22	29.58	68.2	3.94E-04	36.1	
1-4E	119.2	149.2	saturated	149.1	149.1	15	2,119.5	6.23	29.95	69.1	3.89E-04	35.7	
Test Averages/Summary													
1-4	**119.2**	**149.2**	**saturated**	**148.8**	**148.8**	**15**	**94.2**	**6.39**	**29.51**	**68.09**	**4.05E-04**	**37.1**	

Notes:

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				134.8		0	2,129.7						
1-5A	119.2	134.2	saturated	134.8	134.8	1	2,133.7	4.04	15.57	35.9	4.86E-04	44.5	
1-5B	119.2	134.2	saturated	134.7	134.7	3	2,141.7	4.01	15.49	35.7	4.85E-04	44.4	
1-5C	119.2	134.2	saturated	134.7	134.7	5	2,149.8	4.02	15.53	35.8	4.85E-04	44.4	
1-5D	119.2	134.2	saturated	134.7	134.8	10	2,169.9	4.02	15.56	35.9	4.83E-04	44.3	
1-5E	119.2	134.2	saturated	134.8	134.8	15	2,190.0	4.02	15.64	36.1	4.81E-04	44.1	
Test Averages/Summary													
1-5	**119.2**	**134.2**	**saturated**	**134.8**	**134.8**	**15**	**60.3**	**4.02**	**15.56**	**35.90**	**4.84E-04**	**44.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-16
Test Number	2
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	279.25
Bottom of Test Interval Depth, ft	289.75

Hydrostatic Pressure (P_0), psi	115.22
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	283.75
Vertical Center of Test Interval (D), ft	284.50
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	320.7
Bottom of Test Interval Elevation, ft	310.2

Start Time: | Packer Pressure, psi: 242

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				129.6		0	2,194.2						
2-1A	115.2	130.2	saturated	129.5	129.5	1	2,194.2	0.00	14.30	33.0	0.00E+00	0.0	
2-1B	115.2	130.2	saturated	130.4	130.5	3	2,194.2	0.00	15.23	35.1	0.00E+00	0.0	
2-1C	115.2	130.2	saturated	130.7	130.7	5	2,194.2	0.00	15.50	35.8	0.00E+00	0.0	
2-1D	115.2	130.2	saturated	128.7	128.7	10	2,194.2	0.00	13.45	31.0	0.00E+00	0.0	
2-1E	115.2	130.2	saturated	130.6	130.6	16	2,194.2	0.00	15.38	35.5	0.00E+00	0.0	
Test Averages/Summary													
2-1	**115.2**	**130.2**	**saturated**	**129.9**	**129.9**	**16**	**0.0**	**0.00**	**14.77**	**34.08**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 242

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				145.0		0	2,194.4						
2-2A	115.2	145.2	saturated	145.4	145.4	1	2,194.4	0.00	30.23	69.7	0.00E+00	0.0	
2-2B	115.2	145.2	saturated	145.6	145.7	3	2,194.4	0.00	30.44	70.2	0.00E+00	0.0	
2-2C	115.2	145.2	saturated	145.5	145.5	5	2,194.4	0.00	30.32	69.9	0.00E+00	0.0	
2-2D	115.2	145.2	saturated	145.7	145.7	10	2,194.4	0.00	30.48	70.3	0.00E+00	0.0	
2-2E	115.2	145.2	saturated	145.8	145.8	15	2,194.4	0.00	30.62	70.6	0.00E+00	0.0	
Test Averages/Summary													
2-2	**115.2**	**145.2**	**saturated**	**145.5**	**145.5**	**15**	**0.0**	**0.00**	**30.42**	**70.18**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 242

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				160.6		0	2,194.4						
2-3A	115.2	160.2	saturated	160.4	160.4	1	2,194.4	0.00	45.18	104.2	0.00E+00	0.0	
2-3B	115.2	160.2	saturated	160.5	160.6	3	2,194.4	0.00	45.34	104.6	0.00E+00	0.0	
2-3C	115.2	160.2	saturated	161.0	161.0	5	2,194.4	0.00	45.76	105.6	0.00E+00	0.0	
2-3D	115.2	160.2	saturated	160.6	160.6	10	2,194.4	0.00	45.41	104.8	0.00E+00	0.0	
2-3E	115.2	160.2	saturated	156.5	156.6	15	2,194.4	0.00	41.34	95.4	0.00E+00	0.0	
Test Averages/Summary													
2-3	**115.2**	**160.2**	**saturated**	**159.9**	**159.9**	**15**	**0.0**	**0.00**	**44.60**	**102.90**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-16
Test Number	2
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	279.25
Bottom of Test Interval Depth, ft	289.75

Hydrostatic Pressure (P_0), psi	115.22
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	283.75
Vertical Center of Test Interval (D), ft	284.50
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	320.7
Bottom of Test Interval Elevation, ft	310.2

Start Time: | Packer Pressure, psi: 242

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				146.0		0	2,194.4						
2-4A	115.2	145.2	saturated	145.7	145.7	1	2,194.4	0.00	30.52	70.4	0.00E+00	0.0	
2-4B	115.2	145.2	saturated	145.5	145.5	3	2,194.4	0.00	30.26	69.8	0.00E+00	0.0	
2-4C	115.2	145.2	saturated	146.0	146.0	5	2,194.4	0.00	30.78	71.0	0.00E+00	0.0	
2-4D	115.2	145.2	saturated	145.1	145.2	10	2,194.4	0.00	29.94	69.1	0.00E+00	0.0	
2-4E	115.2	145.2	saturated	145.5	145.5	15	2,194.4	0.00	30.32	70.0	0.00E+00	0.0	
Test Averages/Summary													
2-4	**115.2**	**145.2**	**saturated**	**145.6**	**145.6**	**15**	**0.0**	**0.00**	**30.37**	**70.05**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 242

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				129.8		0	2,194.4						
2-5A	115.2	130.2	saturated	129.2	129.2	1	2,194.4	0.00	14.02	32.3	0.00E+00	0.0	
2-5B	115.2	130.2	saturated	129.1	129.1	3	2,194.4	0.00	13.86	32.0	0.00E+00	0.0	
2-5C	115.2	130.2	saturated	129.1	129.1	5	2,194.4	0.00	13.90	32.1	0.00E+00	0.0	
2-5D	115.2	130.2	saturated	129.1	129.1	10	2,194.4	0.00	13.93	32.1	0.00E+00	0.0	
2-5E	115.2	130.2	saturated	129.2	129.2	15	2,194.4	0.00	14.01	32.3	0.00E+00	0.0	
Test Averages/Summary													
2-5	**115.2**	**130.2**	**saturated**	**129.3**	**129.3**	**15**	**0.0**	**0.00**	**13.94**	**32.16**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-16
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	268.75
Bottom of Test Interval Depth, ft	279.25

Hydrostatic Pressure (P_0), psi	110.11
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	273.25
Vertical Center of Test Interval (D), ft	274.00
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	331.2
Bottom of Test Interval Elevation, ft	320.7

Start Time: | Packer Pressure, psi: 237

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				125.7		0	2,198.0						
3-1A	110.1	125.1	saturated	125.9	125.9	1	2,198.8	0.72	15.77	36.4	8.55E-05	7.8	
3-1B	110.1	125.1	saturated	121.6	121.6	3	2,199.8	0.49	11.52	26.6	8.05E-05	7.4	
3-1C	110.1	125.1	saturated	123.6	123.6	5	2,200.1	0.18	13.52	31.2	2.56E-05	2.3	
3-1D	110.1	125.1	saturated	125.0	125.0	10	2,201.8	0.33	14.90	34.4	4.12E-05	3.8	
3-1E	110.1	125.1	saturated	125.5	125.5	15	2,203.9	0.43	15.42	35.6	5.25E-05	4.8	
Test Averages/Summary													
3-1	**110.1**	**125.1**	**saturated**	**124.6**	**124.6**	**15**	**5.9**	**0.43**	**14.23**	**32.82**	**5.70E-05**	**5.2**	

Notes: Overcorrected a pressure spike during 1-3 min interval

Start Time: | Packer Pressure, psi: 237

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				140.2		0	2,205.7						
3-2A	110.1	140.1	saturated	139.5	139.5	1	2,207.4	1.68	29.42	67.9	1.07E-04	9.8	
3-2B	110.1	140.1	saturated	140.3	140.3	3	2,210.5	1.56	30.20	69.7	9.67E-05	8.9	
3-2C	110.1	140.1	saturated	141.4	141.4	5	2,213.1	1.27	31.32	72.3	7.56E-05	6.9	
3-2D	110.1	140.1	saturated	140.0	140.0	10	2,219.1	1.21	29.87	68.9	7.60E-05	7.0	
3-2E	110.1	140.1	saturated	141.1	141.1	15	2,225.2	1.20	30.99	71.5	7.28E-05	6.7	
Test Averages/Summary													
3-2	**110.1**	**140.1**	**saturated**	**140.4**	**140.4**	**15**	**19.4**	**1.38**	**30.36**	**70.04**	**8.56E-05**	**7.8**	

Notes:

Start Time: | Packer Pressure, psi: 237

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				155.6		0	2,228.5						
3-3A	110.1	155.1	saturated	155.7	155.7	1	2,231.1	2.68	45.61	105.2	1.10E-04	10.1	
3-3B	110.1	155.1	saturated	154.8	154.8	3	2,235.3	2.09	44.71	103.1	8.75E-05	8.0	
3-3C	110.1	155.1	saturated	151.9	152.0	5	2,240.1	2.39	41.86	96.6	1.07E-04	9.8	
3-3D	110.1	155.1	saturated	154.3	154.3	10	2,252.3	2.45	44.22	102.0	1.04E-04	9.5	
3-3E	110.1	155.1	saturated	152.6	152.6	15	2,264.6	2.45	42.53	98.1	1.08E-04	9.9	
Test Averages/Summary													
3-3	**110.1**	**155.1**	**saturated**	**154.2**	**154.2**	**15**	**36.1**	**2.41**	**43.78**	**101.01**	**1.03E-04**	**9.4**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-16
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	268.75
Bottom of Test Interval Depth, ft	279.25

Hydrostatic Pressure (P_0), psi	110.11
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	273.25
Vertical Center of Test Interval (D), ft	274.00
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	331.2
Bottom of Test Interval Elevation, ft	320.7

Start Time: | Packer Pressure, psi: 237

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				140.6		0	2,266.2						
3-4A	110.1	140.1	saturated	140.1	140.1	1	2,268.2	2.00	30.02	69.2	1.25E-04	11.4	
3-4B	110.1	140.1	saturated	141.0	141.0	3	2,271.9	1.84	30.87	71.2	1.12E-04	10.2	
3-4C	110.1	140.1	saturated	140.3	140.3	5	2,275.0	1.59	30.18	69.6	9.87E-05	9.0	
3-4D	110.1	140.1	saturated	139.8	139.8	10	2,283.4	1.66	29.68	68.5	1.05E-04	9.6	
3-4E	110.1	140.1	saturated	140.0	140.0	15	2,291.2	1.57	29.92	69.0	9.84E-05	9.0	
Test Averages/Summary													
3-4	**110.1**	**140.1**	**saturated**	**140.3**	**140.3**	**15**	**25.0**	**1.73**	**30.13**	**69.51**	**1.08E-04**	**9.9**	

Notes:

Start Time: | Packer Pressure, psi: 237

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				125.7		0	2,293.7						
3-5A	110.1	125.1	saturated	125.7	125.8	1	2,294.5	0.80	15.65	36.1	9.57E-05	8.8	
3-5B	110.1	125.1	saturated	125.8	125.8	3	2,295.9	0.69	15.70	36.2	8.29E-05	7.6	
3-5C	110.1	125.1	saturated	125.9	125.9	5	2,297.5	0.81	15.78	36.4	9.55E-05	8.7	
3-5D	110.1	125.1	saturated	125.9	125.9	10	2,301.4	0.78	15.82	36.5	9.23E-05	8.5	
3-5E	110.1	125.1	saturated	125.8	125.8	15	2,304.8	0.68	15.72	36.3	8.08E-05	7.4	
Test Averages/Summary													
3-5	**110.1**	**125.1**	**saturated**	**125.8**	**125.8**	**15**	**11.1**	**0.75**	**15.74**	**36.30**	**8.94E-05**	**8.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams, C. Fischer
Subcontractor	Cascade Drilling
Driller	C. Barden, S. Parks

Boring ID	BH19-16
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	258.25
Bottom of Test Interval Depth, ft	268.75

Hydrostatic Pressure (P_0), psi	105.96
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	262.75
Vertical Center of Test Interval (D), ft	263.50
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	341.7
Bottom of Test Interval Elevation, ft	331.2

Start Time: | Packer Pressure, psi: 232

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				120.6		0	2,377.6						
4-1A	106.0	121.0	saturated	120.8	120.8	1	2,390.0	12.45	14.84	34.2	1.57E-03	143.9	
4-1B	106.0	121.0	saturated	120.8	120.9	3	2,416.6	13.30	14.91	34.4	1.67E-03	153.0	
4-1C	106.0	121.0	saturated	121.4	121.4	5	2,440.7	12.05	15.45	35.6	1.46E-03	133.8	
4-1D	106.0	121.0	saturated	121.2	121.2	10	2,504.9	12.82	15.28	35.2	1.57E-03	144.0	
4-1E	106.0	121.0	saturated	121.1	121.1	15	2,568.6	12.74	15.19	35.0	1.57E-03	143.9	
Test Averages/Summary													
4-1	**106.0**	**121.0**	**saturated**	**121.0**	**121.0**	**15**	**191.0**	**12.67**	**15.13**	**34.91**	**1.57E-03**	**143.7**	

Notes: Packer inflated and holding pressure. Water return in the casing. Shift change after end of test.

Start Time: | Packer Pressure, psi: 232

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				136.8		0	2,648.0						
4-2A	106.0	136.0	saturated	137.6	137.6	1	2,665.8	17.80	31.66	73.0	1.05E-03	96.4	
4-2B	106.0	136.0	saturated	137.2	137.2	3	2,706.8	20.50	31.26	72.1	1.23E-03	112.5	
4-2C	106.0	136.0	saturated	138.1	138.1	5	2,747.6	20.40	32.16	74.2	1.19E-03	108.8	
4-2D	106.0	136.0	saturated	139.0	139.0	10	2,849.3	20.34	33.06	76.3	1.15E-03	105.5	
4-2E	106.0	136.0	saturated	137.6	137.6	15	2,953.8	20.90	31.66	73.0	1.24E-03	113.2	
Test Averages/Summary													
4-2	**106.0**	**136.0**	**saturated**	**137.7**	**137.7**	**15**	**305.8**	**19.99**	**31.96**	**73.73**	**1.17E-03**	**107.3**	

Notes: Water return in casing.

Start Time: | Packer Pressure, psi: 232

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				149.7		0	3,000.0						
4-3A	106.0	151.0	saturated	149.1	149.1	1	3,022.1	22.10	43.16	99.6	9.59E-04	87.8	
4-3B	106.0	151.0	saturated	150.9	150.9	3	3,067.0	22.45	44.96	103.7	9.35E-04	85.7	
4-3C	106.0	151.0	saturated	151.7	151.7	5	3,111.2	22.10	45.76	105.6	9.04E-04	82.8	
4-3D	106.0	151.0	saturated	149.7	149.7	10	3,221.9	22.14	43.76	101.0	9.47E-04	86.8	
4-3E	106.0	151.0	saturated	149.3	149.3	15	3,333.2	22.26	43.36	100.0	9.61E-04	88.1	
Test Averages/Summary													
4-3	**106.0**	**151.0**	**saturated**	**150.1**	**150.1**	**15**	**333.2**	**22.21**	**44.20**	**101.97**	**9.41E-04**	**86.2**	

Notes: Water return in casing.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/3/2019
WSP Personnel	K. Williams, C. Fischer
Subcontractor	Cascade Drilling
Driller	C. Barden, S. Parks

Boring ID	BH19-16
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	258.25
Bottom of Test Interval Depth, ft	268.75

Hydrostatic Pressure (P_0), psi	105.96
Transducer Zero Reading (R_0)	-0.015
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	262.75
Vertical Center of Test Interval (D), ft	263.50
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.20
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	341.7
Bottom of Test Interval Elevation, ft	331.2

Start Time: | Packer Pressure, psi: 232

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				137.0		0	3,385.4						
4-4A	106.0	136.0	saturated	137.4	137.4	1	3,401.2	15.80	31.46	72.6	9.41E-04	86.2	
4-4B	106.0	136.0	saturated	137.0	137.0	3	3,437.6	18.20	31.06	71.7	1.10E-03	100.5	
4-4C	106.0	136.0	saturated	137.2	137.2	5	3,475.1	18.75	31.26	72.1	1.12E-03	102.9	
4-4D	106.0	136.0	saturated	136.8	136.8	10	3,565.8	18.14	30.86	71.2	1.10E-03	100.8	
4-4E	106.0	136.0	saturated	136.5	136.5	15	3,658.1	18.46	30.56	70.5	1.13E-03	103.6	
Test Averages/Summary													
4-4	**106.0**	**136.0**	**saturated**	**137.0**	**137.0**	**15**	**272.7**	**17.87**	**31.04**	**71.61**	**1.08E-03**	**98.8**	

Notes: Water return in casing.

Start Time: | Packer Pressure, psi: 232

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				121.3		0	3,679.0						
4-5A	106.0	121.0	saturated	121.4	121.4	1	3,690.3	11.30	15.46	35.7	1.37E-03	125.4	
4-5B	106.0	121.0	saturated	121.7	121.7	3	3,712.3	11.00	15.76	36.4	1.31E-03	119.7	
4-5C	106.0	121.0	saturated	121.5	121.5	5	3,734.2	10.95	15.56	35.9	1.32E-03	120.7	
4-5D	106.0	121.0	saturated	121.3	121.3	10	3,789.2	11.00	15.36	35.4	1.34E-03	122.8	
4-5E	106.0	121.0	saturated	122.0	122.0	15	3,844.2	11.00	16.06	37.1	1.28E-03	117.5	
Test Averages/Summary													
4-5	**106.0**	**121.0**	**saturated**	**121.5**	**121.5**	**15**	**165.2**	**11.05**	**15.64**	**36.08**	**1.32E-03**	**121.2**	

Notes: Water return in casing.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/12/19
WSP Personnel	C. Fischer, X. You, K. Williams, K. Zeiger
Subcontractor	Cascade Drilling
Driller	S. Parks, C. Barden, M. Bond

Boring ID	BH19-17
Number of Tests	17
Lattitude	45.82875°N
Longitude	84.76084°W

Top of Rock, ft	107.00
Bottom of Boring, ft	378.00
Depth to Groundwater (D_{WL}), ft	17.84

Datum Elevation	599.7
Top of Rock Elevation, ft	492.7
Bottom of Hole Elevation, ft	221.7
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	173.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32 / 0.51

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	151.1	171.1	saturated	171.8	171.8	15	0.00	0.00	20.7	47.7	0.00E+00	0.0		
1-2	151.1	186.1	saturated	187.7	187.7	15	0.00	0.00	36.8	85.0	0.00E+00	0.0		
1-3	151.1	201.1	saturated	200.4	200.4	15	0.00	0.00	49.4	114.0	0.00E+00	0.0		No Flow
1-4	151.1	186.1	saturated	186.3	186.3	15	0.00	0.00	35.4	81.8	0.00E+00	0.0		
1-5	151.1	171.1	saturated	172.2	172.2	15	0.00	0.00	21.5	49.5	0.00E+00	0.0		
2-1	146.6	161.6	saturated	161.8	161.8	15	0.00	0.00	15.2	35.1	0.00E+00	0.0		
2-2	146.6	176.6	saturated	178.3	178.3	15	0.00	0.00	31.8	73.4	0.00E+00	0.0		
2-3	146.6	191.6	saturated	192.5	192.5	15	0.00	0.00	46.0	106.0	0.00E+00	0.0		
2-4	146.6	176.6	saturated	178.2	178.2	15	0.00	0.00	31.9	73.6	0.00E+00	0.0		
2-5	146.6	161.6	saturated	161.8	161.8	15	0.01	0.00	15.3	35.4	1.14E-07	0.0	||||	
3-1	142.0	157.0	saturated	158.6	158.7	15	0.00	0.00	16.8	38.7	0.00E+00	0.0		
3-2	142.0	172.0	saturated	173.0	173.0	15	0.00	0.00	30.9	71.3	0.00E+00	0.0		
3-3	142.0	187.0	saturated	188.9	188.9	15	0.00	0.00	46.9	108.2	0.00E+00	0.0		No Flow
3-4	142.0	172.0	saturated	174.3	174.3	15	0.00	0.00	32.2	74.3	0.00E+00	0.0		
3-5	142.0	157.0	saturated	156.5	156.5	15	0.00	0.00	14.4	33.2	0.00E+00	0.0		
4-1	137.6	152.6	saturated	151.5	151.5	15	0.00	0.00	13.6	31.3	0.00E+00	0.0		
4-2	137.6	167.6	saturated	168.7	168.7	15	0.00	0.00	31.2	72.1	0.00E+00	0.0		
4-3	137.6	182.6	saturated	183.0	183.0	15	0.00	0.00	45.4	104.8	0.00E+00	0.0		No Flow
4-4	137.6	167.6	saturated	167.9	167.9	15	0.00	0.00	30.2	69.8	0.00E+00	0.0		
4-5	137.6	152.6	saturated	152.7	152.7	15	0.00	0.00	15.1	34.9	0.00E+00	0.0		
5-1	133.0	148.0	saturated	149.2	149.2	15	0.01	0.00	16.2	37.4	1.16E-07	0.0		
5-2	133.0	163.0	saturated	165.0	165.0	15	14.82	1.03	32.0	73.8	6.01E-05	5.5	||||||||||||||	
5-3	133.0	178.0	saturated	180.1	180.1	15	18.28	1.23	47.3	109.0	4.88E-05	4.5	||||||||||||	
5-4	133.0	163.0	saturated	163.3	163.3	15	10.20	0.65	30.3	69.9	4.00E-05	3.7	||||||||||	
5-5	133.0	148.0	saturated	149.7	149.7	15	0.00	0.00	16.7	38.6	0.00E+00	0.0		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/12/19
WSP Personnel	C. Fischer, X. You, K. Williams, K. Zeiger
Subcontractor	Cascade Drilling
Driller	S. Parks, C. Barden, M. Bond

Boring ID	BH19-17
Number of Tests	17
Lattitude	45.82875°N
Longitude	84.76084°W

Top of Rock, ft	107.00
Bottom of Boring, ft	378.00
Depth to Groundwater (D_{WL}), ft	17.84

Datum Elevation	599.7
Top of Rock Elevation, ft	492.7
Bottom of Hole Elevation, ft	221.7
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	173.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32 / 0.51

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
6-1	119.1	134.1	saturated	133.8	133.8	15	62.93	4.13	14.5	33.4	5.19E-04	55.8	|||	This test was performed using 6" packers.
6-2	119.1	149.1	saturated	150.3	150.3	15	95.70	7.79	31.6	72.9	4.62E-04	48.3	|||	
6-3	119.1	164.1	saturated	165.5	165.5	17	239.17	15.06	46.5	107.3	5.89E-04	63.4	|||	
6-4	119.1	149.1	saturated	150.1	150.1	15	194.85	13.08	31.2	72.0	7.64E-04	82.0	|||	
6-5	119.1	134.1	saturated	135.2	135.2	15	117.64	7.47	16.2	37.3	8.44E-04	90.6	|||	
7-1	116.2	131.2	saturated	129.5	129.5	15	0.31	0.04	13.1	30.3	6.00E-06	0.7		This test was performed using 6" packers.
7-2	116.2	146.2	saturated	147.5	147.5	15	30.52	2.23	31.7	73.1	1.29E-04	13.8	|||	
7-3	116.2	161.2	saturated	162.8	162.8	15	88.42	6.28	46.7	107.8	2.45E-04	26.3	|||	
7-4	116.2	146.2	saturated	147.5	147.5	15	62.19	4.29	31.4	72.4	2.49E-04	26.8	|||	
7-5	116.2	131.2	saturated	132.1	132.1	15	36.70	2.53	16.0	36.9	2.89E-04	31.0	|||	
8-1	111.5	126.5	saturated	124.2	124.2	15	0.13	0.02	12.4	28.7	2.23E-06	0.3		This test was performed using 6" packers.
8-2	111.5	141.5	saturated	140.5	140.5	15	23.71	1.68	29.2	67.3	1.05E-04	11.3			
8-3	111.5	156.5	saturated	154.3	154.3	16	149.85	8.00	42.5	98.0	3.59E-04	36.9	|||	
8-4	111.5	141.5	saturated	138.9	138.9	15	285.08	20.42	27.2	62.8	1.37E-03	146.9	|||	
8-5	111.5	126.5	saturated	126.5	126.5	15	175.11	11.73	14.8	34.2	1.44E-03	155.0	|||	
9-1	105.5	120.5	saturated	120.1	120.5	15	108.02	7.18	15.0	34.5	8.76E-04	93.9	|||	This test was performed using 6" packers.
9-2	105.5	135.5	saturated	135.0	135.0	15	258.39	16.97	29.8	68.7	1.04E-03	111.6	|||	
9-3	105.5	150.5	saturated	144.1	144.1	15	491.29	32.42	38.9	89.8	1.52E-03	163.0	|||	
9-4	105.5	135.5	saturated	135.7	135.7	15	447.31	29.74	30.6	70.6	1.77E-03	190.2	|||	
9-5	105.5	120.5	saturated	120.3	120.3	15	291.63	19.39	15.2	35.1	2.32E-03	249.8	|||	
10-1	102.0	117.0	saturated	108.9	109.2	15	495.82	33.13	7.6	17.5	7.99E-03	853.4	|||	This test was performed using 6" packers. Free flow achieved on first stage

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/12/19
WSP Personnel	C. Fischer, X. You, K. Williams, K. Zeiger
Subcontractor	Cascade Drilling
Driller	S. Parks, C. Barden, M. Bond

Boring ID	BH19-17
Number of Tests	17
Lattitude	45.82875°N
Longitude	84.76084°W

Top of Rock, ft	107.00
Bottom of Boring, ft	378.00
Depth to Groundwater (D_{WL}), ft	17.84

Datum Elevation	599.7
Top of Rock Elevation, ft	492.7
Bottom of Hole Elevation, ft	221.7
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	173.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32 / 0.51

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
11-1	77.2	92.2	saturated	92.9	92.9	15	24.40	1.63	15.9	36.7	1.93E-04	17.6		
11-2	77.2	107.2	saturated	108.6	108.6	15	44.00	2.93	31.6	72.8	1.74E-04	15.9		
11-3	77.2	122.2	saturated	120.1	120.1	15	75.60	5.03	42.7	98.6	2.20E-04	20.2		
11-4	77.2	107.2	saturated	108.6	108.6	15	61.30	4.10	31.5	72.7	2.44E-04	22.3		
11-5	77.2	92.2	saturated	93.4	93.4	15	37.30	2.46	16.3	37.5	2.83E-04	26.0		
12-1	73.3	88.3	saturated	89.0	88.9	15	118.20	7.98	15.8	36.4	9.47E-04	86.8		
12-2	73.3	103.3	saturated	103.6	103.6	15	187.00	12.54	30.4	70.2	7.72E-04	70.7		
12-3	73.3	118.3	saturated	118.5	118.5	15	245.30	16.54	45.2	104.3	6.85E-04	62.7		
12-4	73.3	103.3	saturated	103.7	103.7	15	190.70	12.73	30.5	70.5	7.81E-04	71.5		
12-5	73.3	88.3	saturated	88.0	88.0	15	118.20	7.90	14.6	33.8	1.01E-03	92.5		
13-1	68.4	83.4	saturated	82.7	82.7	15	46.60	3.10	14.4	33.1	4.05E-04	37.1		
13-2	68.4	98.4	saturated	97.7	97.7	15	91.50	5.98	29.1	67.1	3.85E-04	35.3		Packer assembly hit an obstruction 1' above target depth.
13-3	68.4	113.4	saturated	113.2	113.2	15	141.06	9.37	44.9	103.5	3.91E-04	35.8		
13-4	68.4	98.4	saturated	98.8	98.8	15	105.18	7.10	30.4	70.0	4.38E-04	40.1		
13-5	68.4	83.4	saturated	83.8	83.8	15	63.96	4.30	15.4	35.4	5.25E-04	48.1		
14-1	64.4	79.4	saturated	79.6	79.6	15	31.55	2.16	15.2	35.2	2.66E-04	24.4		
14-2	64.4	94.4	saturated	94.0	94.0	15	50.43	3.45	29.6	68.3	2.18E-04	20.0		
14-3	64.4	109.4	saturated	109.2	109.2	15	74.57	4.88	44.8	103.3	2.04E-04	18.7		
14-4	64.4	94.4	saturated	94.2	94.2	15	54.71	3.68	29.8	68.8	2.31E-04	21.2		
14-5	64.4	79.4	saturated	79.4	79.4	15	32.89	2.21	15.0	34.7	2.75E-04	25.2		
15-1	59.7	74.7	saturated	75.3	75.3	15	62.86	4.31	15.6	36.1	5.16E-04	47.2		
15-2	59.7	89.7	saturated	90.8	90.8	15.5	99.49	6.44	30.9	71.3	3.90E-04	35.7		
15-3	59.7	104.7	saturated	105.1	105.1	15	127.74	8.58	45.4	104.7	3.54E-04	32.4		
15-4	59.7	89.7	saturated	90.8	90.8	15	94.69	6.33	31.1	71.7	3.81E-04	34.9		
15-5	59.7	74.7	saturated	75.2	75.2	15	59.50	4.03	15.5	35.7	4.87E-04	44.6		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/12/19
WSP Personnel	C. Fischer, X. You, K. Williams, K. Zeiger
Subcontractor	Cascade Drilling
Driller	S. Parks, C. Barden, M. Bond

Boring ID	BH19-17
Number of Tests	17
Lattitude	45.82875°N
Longitude	84.76084°W

Top of Rock, ft	107.00
Bottom of Boring, ft	378.00
Depth to Groundwater (D_{WL}), ft	17.84

Datum Elevation	599.7
Top of Rock Elevation, ft	492.7
Bottom of Hole Elevation, ft	221.7
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	173.00
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32 / 0.51

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
16-1	55.1	70.1	saturated	69.5	69.5	15	0.00	0.00	14.4	33.3	0.00E+00	0.0		
16-2	55.1	85.1	saturated	85.2	85.2	15	2.64	0.22	29.9	69.0	1.37E-05	1.3		
16-3	55.1	100.1	saturated	100.0	100.0	15	14.55	1.00	45.0	103.9	4.15E-05	3.8		
16-4	55.1	85.1	saturated	84.9	84.9	15	1.31	0.10	29.5	68.1	6.56E-06	0.6		
16-5	55.1	70.1	saturated	70.0	70.0	15	0.00	0.00	15.0	34.5	0.00E+00	0.0		
17-1	50.6	60.0	saturated	60.3	60.3	15	0.00	0.00	9.6	22.2	0.00E+00	0.0		
17-2	50.6	70.0	saturated	70.4	70.4	15	0.00	0.00	19.8	45.7	0.00E+00	0.0		
17-3	50.6	80.0	saturated	80.0	80.0	15	3.07	0.21	29.4	67.9	1.37E-05	1.2		
17-4	50.6	70.0	saturated	70.2	70.2	15	0.01	0.00	19.6	45.3	3.66E-08	0.0		
17-5	50.6	60.0	saturated	59.2	59.2	15	0.00	0.00	8.6	19.8	0.00E+00	0.0		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/8/2019
WSP Personnel	X. You, K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden /

Boring ID	BH19-17
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	357.00
Bottom of Test Interval Depth, ft	367.50

Hydrostatic Pressure (P_0), psi	151.05
Transducer Zero Reading (R_0)	-0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	362.00
Vertical Center of Test Interval (D), ft	362.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	242.7
Bottom of Test Interval Elevation, ft	232.2

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				172.4		0	6,671.3						
1-1A	151.1	171.1	saturated	172.2	172.2	1	6,671.3	0.00	21.17	48.8	0.00E+00	0.0	
1-1B	151.1	171.1	saturated	171.6	171.6	3	6,671.3	0.00	20.57	47.4	0.00E+00	0.0	
1-1C	151.1	171.1	saturated	171.5	171.5	5	6,671.3	0.00	20.47	47.2	0.00E+00	0.0	
1-1D	151.1	171.1	saturated	171.5	171.5	10	6,671.3	0.00	20.47	47.2	0.00E+00	0.0	
1-1E	151.1	171.1	saturated	171.8	171.8	15	6,671.3	0.00	20.77	47.9	0.00E+00	0.0	
Test Averages/Summary													
1-1	**151.1**	**171.1**	**saturated**	**171.8**	**171.8**	**15**	**0.0**	**0.00**	**20.69**	**47.72**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				186.8		0	6,671.3						
1-2A	151.1	186.1	saturated	187.2	187.2	1	6,671.3	0.00	36.17	83.4	0.00E+00	0.0	
1-2B	151.1	186.1	saturated	187.2	187.2	3	6,671.3	0.00	36.17	83.4	0.00E+00	0.0	
1-2C	151.1	186.1	saturated	187.8	187.8	5	6,671.3	0.00	36.77	84.8	0.00E+00	0.0	
1-2D	151.1	186.1	saturated	188.5	188.5	10	6,671.3	0.00	37.47	86.4	0.00E+00	0.0	
1-2E	151.1	186.1	saturated	188.6	188.6	15	6,671.3	0.00	37.57	86.7	0.00E+00	0.0	
Test Averages/Summary													
1-2	**151.1**	**186.1**	**saturated**	**187.7**	**187.7**	**15**	**0.0**	**0.00**	**36.83**	**84.96**	**0.00E+00**	**0.0**	

Notes: Shift change between stage 2 and 3

Start Time: 07:45 | Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				200.3		0	6,671.3						
1-3A	151.1	201.1	saturated	200.7	200.7	1	6,671.3	0.00	49.67	114.6	0.00E+00	0.0	
1-3B	151.1	201.1	saturated	200.7	200.7	3	6,671.3	0.00	49.67	114.6	0.00E+00	0.0	
1-3C	151.1	201.1	saturated	200.1	200.1	5	6,671.3	0.00	49.07	113.2	0.00E+00	0.0	
1-3D	151.1	201.1	saturated	200.7	200.7	10	6,671.3	0.00	49.67	114.6	0.00E+00	0.0	
1-3E	151.1	201.1	saturated	200.0	200.0	15	6,671.3	0.00	48.97	113.0	0.00E+00	0.0	
Test Averages/Summary													
1-3	**151.1**	**201.1**	**saturated**	**200.4**	**200.4**	**15**	**0.0**	**0.00**	**49.41**	**113.98**	**0.00E+00**	**0.0**	

Notes: Shift change between stage 2 and 3

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/8/2019
WSP Personnel	X. You, K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden /

Boring ID	BH19-17
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	357.00
Bottom of Test Interval Depth, ft	367.50

Hydrostatic Pressure (P_0), psi	151.05
Transducer Zero Reading (R_0)	-0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	362.00
Vertical Center of Test Interval (D), ft	362.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	242.7
Bottom of Test Interval Elevation, ft	232.2

Start Time: 08:05 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				185.6		0	6,671.3						
1-4A	151.1	186.1	saturated	186.0	186.0	1	6,671.3	0.00	34.98	80.7	0.00E+00	0.0	
1-4B	151.1	186.1	saturated	186.2	186.2	3	6,671.3	0.00	35.16	81.1	0.00E+00	0.0	
1-4C	151.1	186.1	saturated	186.5	186.5	5	6,671.3	0.00	35.45	81.8	0.00E+00	0.0	
1-4D	151.1	186.1	saturated	187.0	187.0	10	6,671.3	0.00	35.96	83.0	0.00E+00	0.0	
1-4E	151.1	186.1	saturated	186.7	186.8	15	6,671.3	0.00	35.71	82.4	0.00E+00	0.0	
Test Averages/Summary													
1-4	**151.1**	**186.1**	**saturated**	**186.3**	**186.3**	**15**	**0.0**	**0.00**	**35.45**	**81.78**	**0.00E+00**	**0.0**	

Notes:

Start Time: 08:25 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				170.9		0	6,671.3						
1-5A	151.1	171.1	saturated	170.2	170.2	1	6,671.3	0.00	19.14	44.2	0.00E+00	0.0	
1-5B	151.1	171.1	saturated	173.9	174.0	3	6,671.3	0.00	22.91	52.9	0.00E+00	0.0	
1-5C	151.1	171.1	saturated	172.5	172.5	5	6,671.3	0.00	21.46	49.5	0.00E+00	0.0	
1-5D	151.1	171.1	saturated	172.8	172.9	10	6,671.3	0.00	21.81	50.3	0.00E+00	0.0	
1-5E	151.1	171.1	saturated	173.0	173.0	15	6,671.3	0.00	21.94	50.6	0.00E+00	0.0	
Test Averages/Summary													
1-5	**151.1**	**171.1**	**saturated**	**172.2**	**172.2**	**15**	**0.0**	**0.00**	**21.45**	**49.49**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/8/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	346.50
Bottom of Test Interval Depth, ft	357.00

Hydrostatic Pressure (P_0), psi	146.63
Transducer Zero Reading (R_0)	-0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	351.50
Vertical Center of Test Interval (D), ft	351.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	253.2
Bottom of Test Interval Elevation, ft	242.7

Start Time: 09:08 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				161.8		0	6,675.8						
2-1A	146.6	161.6	saturated	161.8	161.8	1	6,675.8	0.00	15.17	35.0	0.00E+00	0.0	
2-1B	146.6	161.6	saturated	161.8	161.9	3	6,675.8	0.00	15.22	35.1	0.00E+00	0.0	
2-1C	146.6	161.6	saturated	161.8	161.9	5	6,675.8	0.00	15.22	35.1	0.00E+00	0.0	
2-1D	146.6	161.6	saturated	161.8	161.9	10	6,675.8	0.00	15.23	35.1	0.00E+00	0.0	
2-1E	146.6	161.6	saturated	161.9	161.9	15	6,675.8	0.00	15.24	35.2	0.00E+00	0.0	
Test Averages/Summary													
2-1	**146.6**	**161.6**	**saturated**	**161.8**	**161.8**	**15**	**0.0**	**0.00**	**15.22**	**35.11**	**0.00E+00**	**0.0**	

Notes:

Start Time: 09:25 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				177.9		0	6,676.2						
2-2A	146.6	176.6	saturated	177.9	178.0	1	6,676.2	0.00	31.33	72.3	0.00E+00	0.0	
2-2B	146.6	176.6	saturated	177.9	177.9	3	6,676.2	0.00	31.31	72.2	0.00E+00	0.0	
2-2C	146.6	176.6	saturated	178.6	178.6	5	6,676.2	0.00	32.01	73.8	0.00E+00	0.0	
2-2D	146.6	176.6	saturated	178.8	178.8	10	6,676.2	0.00	32.16	74.2	0.00E+00	0.0	
2-2E	146.6	176.6	saturated	178.9	178.9	15	6,676.2	0.00	32.27	74.4	0.00E+00	0.0	
Test Averages/Summary													
2-2	**146.6**	**176.6**	**saturated**	**178.3**	**178.3**	**15**	**0.0**	**0.00**	**31.81**	**73.40**	**0.00E+00**	**0.0**	

Notes:

Start Time: 09:44 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				192.1		0	6,676.5						
2-3A	146.6	191.6	saturated	192.2	192.2	1	6,676.5	0.00	45.59	105.2	0.00E+00	0.0	
2-3B	146.6	191.6	saturated	192.4	192.4	3	6,676.5	0.00	45.78	105.6	0.00E+00	0.0	
2-3C	146.6	191.6	saturated	192.6	192.6	5	6,676.5	0.00	45.98	106.1	0.00E+00	0.0	
2-3D	146.6	191.6	saturated	192.7	192.7	10	6,676.5	0.00	46.12	106.4	0.00E+00	0.0	
2-3E	146.6	191.6	saturated	192.9	192.9	15	6,676.5	0.00	46.30	106.8	0.00E+00	0.0	
Test Averages/Summary													
2-3	**146.6**	**191.6**	**saturated**	**192.5**	**192.5**	**15**	**0.0**	**0.00**	**45.96**	**106.02**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/8/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	346.50
Bottom of Test Interval Depth, ft	357.00

Hydrostatic Pressure (P_0), psi	146.63
Transducer Zero Reading (R_0)	-0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	351.50
Vertical Center of Test Interval (D), ft	351.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	253.2
Bottom of Test Interval Elevation, ft	242.7

Start Time: 10:01 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				176.7		0	6,676.5						
2-4A	146.6	176.6	saturated	178.9	178.9	1	6,676.5	0.00	32.30	74.5	0.00E+00	0.0	
2-4B	146.6	176.6	saturated	178.2	178.2	3	6,676.5	0.00	31.61	72.9	0.00E+00	0.0	
2-4C	146.6	176.6	saturated	178.5	178.5	5	6,676.5	0.00	31.84	73.5	0.00E+00	0.0	
2-4D	146.6	176.6	saturated	178.5	178.5	10	6,676.5	0.00	31.86	73.5	0.00E+00	0.0	
2-4E	146.6	176.6	saturated	178.5	178.5	15	6,676.5	0.00	31.88	73.5	0.00E+00	0.0	
Test Averages/Summary													
2-4	**146.6**	**176.6**	**saturated**	**178.2**	**178.2**	**15**	**0.0**	**0.00**	**31.90**	**73.59**	**0.00E+00**	**0.0**	

Notes:

Start Time: 10:18 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				160.9		0	6,676.5						
2-5A	146.6	161.6	saturated	161.0	161.0	1	6,676.5	0.00	14.37	33.2	0.00E+00	0.0	
2-5B	146.6	161.6	saturated	160.5	160.5	3	6,676.5	0.00	13.91	32.1	0.00E+00	0.0	
2-5C	146.6	161.6	saturated	163.1	163.1	5	6,676.5	0.00	16.44	37.9	5.70E-07	0.1	
2-5D	146.6	161.6	saturated	162.4	162.4	10	6,676.5	0.00	15.81	36.5	0.00E+00	0.0	
2-5E	146.6	161.6	saturated	162.8	162.8	15	6,676.5	0.00	16.14	37.2	0.00E+00	0.0	
Test Averages/Summary													
2-5	**146.6**	**161.6**	**saturated**	**161.8**	**161.8**	**15**	**0.0**	**0.00**	**15.33**	**35.37**	**1.14E-07**	**0.0**	

Notes: Slight pressure spike between 2-5B and 2-5C. Difficult to keep pressure down.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/9/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	336.00
Bottom of Test Interval Depth, ft	346.50

Hydrostatic Pressure (P_0), psi	142.04
Transducer Zero Reading (R_0)	-0.005
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	341.00
Vertical Center of Test Interval (D), ft	341.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	263.7
Bottom of Test Interval Elevation, ft	253.2

Start Time: 11:00 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				157.7		0	6,676.9						
3-1A	142.0	157.0	saturated	158.8	158.8	1	6,676.9	0.00	16.77	38.7	0.00E+00	0.0	
3-1B	142.0	157.0	saturated	158.8	158.8	3	6,676.9	0.00	16.72	38.6	0.00E+00	0.0	
3-1C	142.0	157.0	saturated	158.6	158.6	5	6,676.9	0.00	16.55	38.2	0.00E+00	0.0	
3-1D	142.0	157.0	saturated	159.0	159.0	10	6,676.9	0.00	16.91	39.0	0.00E+00	0.0	
3-1E	142.0	157.0	saturated	159.1	159.1	15	6,676.9	0.00	17.03	39.3	0.00E+00	0.0	
Test Averages/Summary													
3-1	**142.0**	**157.0**	**saturated**	**158.6**	**158.7**	**15**	**0.0**	**0.00**	**16.80**	**38.75**	**0.00E+00**	**0.0**	

Notes:

Start Time: 11:18 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				173.0		0	6,677.0						
3-2A	142.0	172.0	saturated	172.9	172.9	1	6,677.0	0.00	30.88	71.2	0.00E+00	0.0	
3-2B	142.0	172.0	saturated	172.6	172.6	3	6,677.0	0.00	30.55	70.5	0.00E+00	0.0	
3-2C	142.0	172.0	saturated	172.5	172.5	5	6,677.0	0.00	30.47	70.3	0.00E+00	0.0	
3-2D	142.0	172.0	saturated	173.1	173.1	10	6,677.0	0.00	31.10	71.8	0.00E+00	0.0	
3-2E	142.0	172.0	saturated	173.6	173.6	15	6,677.0	0.00	31.54	72.8	0.00E+00	0.0	
Test Averages/Summary													
3-2	**142.0**	**172.0**	**saturated**	**173.0**	**173.0**	**15**	**0.0**	**0.00**	**30.91**	**71.31**	**0.00E+00**	**0.0**	

Notes:

Start Time: 11:36 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				188.6		0	6,677.0						
3-3A	142.0	187.0	saturated	188.5	188.5	1	6,677.0	0.00	46.44	107.1	0.00E+00	0.0	
3-3B	142.0	187.0	saturated	188.6	188.6	3	6,677.0	0.00	46.59	107.5	0.00E+00	0.0	
3-3C	142.0	187.0	saturated	188.8	188.8	5	6,677.0	0.00	46.72	107.8	0.00E+00	0.0	
3-3D	142.0	187.0	saturated	188.9	188.9	10	6,677.0	0.00	46.90	108.2	0.00E+00	0.0	
3-3E	142.0	187.0	saturated	189.9	189.9	15	6,677.0	0.00	47.89	110.5	0.00E+00	0.0	
Test Averages/Summary													
3-3	**142.0**	**187.0**	**saturated**	**188.9**	**188.9**	**15**	**0.0**	**0.00**	**46.91**	**108.22**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/9/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	336.00
Bottom of Test Interval Depth, ft	346.50

Hydrostatic Pressure (P_0), psi	142.04
Transducer Zero Reading (R_0)	-0.005
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	341.00
Vertical Center of Test Interval (D), ft	341.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	263.7
Bottom of Test Interval Elevation, ft	253.2

Start Time: 11:55 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				174.3		0	6,677.0						
3-4A	142.0	172.0	saturated	174.2	174.2	1	6,677.0	0.00	32.14	74.1	0.00E+00	0.0	
3-4B	142.0	172.0	saturated	174.3	174.3	3	6,677.0	0.00	32.30	74.5	0.00E+00	0.0	
3-4C	142.0	172.0	saturated	174.2	174.2	5	6,677.0	0.00	32.15	74.2	0.00E+00	0.0	
3-4D	142.0	172.0	saturated	174.2	174.2	10	6,677.0	0.00	32.15	74.2	0.00E+00	0.0	
3-4E	142.0	172.0	saturated	174.3	174.3	15	6,677.0	0.00	32.27	74.4	0.00E+00	0.0	
Test Averages/Summary													
3-4	**142.0**	**172.0**	**saturated**	**174.3**	**174.3**	**15**	**0.0**	**0.00**	**32.20**	**74.29**	**0.00E+00**	**0.0**	

Notes: Tried to lower pressure to 172, but it would not maintain around 172. Spiked up and down.

Start Time: 12:15 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				156.5		0	6,677.0						
3-5A	142.0	157.0	saturated	156.6	156.6	1	6,677.0	0.00	14.59	33.7	0.00E+00	0.0	
3-5B	142.0	157.0	saturated	156.6	156.6	3	6,677.0	0.00	14.57	33.6	0.00E+00	0.0	
3-5C	142.0	157.0	saturated	156.6	156.6	5	6,677.0	0.00	14.52	33.5	0.00E+00	0.0	
3-5D	142.0	157.0	saturated	156.3	156.3	10	6,677.0	0.00	14.27	32.9	0.00E+00	0.0	
3-5E	142.0	157.0	saturated	156.1	156.1	15	6,677.0	0.00	14.10	32.5	0.00E+00	0.0	
Test Averages/Summary													
3-5	**142.0**	**157.0**	**saturated**	**156.5**	**156.5**	**15**	**0.0**	**0.00**	**14.41**	**33.24**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/9/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	325.50
Bottom of Test Interval Depth, ft	336.00

Hydrostatic Pressure (P_0), psi	137.57
Transducer Zero Reading (R_0)	-0.005
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	330.50
Vertical Center of Test Interval (D), ft	330.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	274.2
Bottom of Test Interval Elevation, ft	263.7

Start Time: 13:00 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				153.4		0	6,677.3						
4-1A	137.6	152.6	saturated	151.6	151.6	1	6,677.3	0.00	14.05	32.4	0.00E+00	0.0	
4-1B	137.6	152.6	saturated	151.1	151.1	3	6,677.3	0.00	13.54	31.2	0.00E+00	0.0	
4-1C	137.6	152.6	saturated	151.2	151.2	5	6,677.3	0.00	13.58	31.3	0.00E+00	0.0	
4-1D	137.6	152.6	saturated	151.0	151.0	10	6,677.3	0.00	13.43	31.0	0.00E+00	0.0	
4-1E	137.6	152.6	saturated	150.7	150.7	15	6,677.3	0.00	13.16	30.4	0.00E+00	0.0	
Test Averages/Summary													
4-1	**137.6**	**152.6**	**saturated**	**151.5**	**151.5**	**15**	**0.0**	**0.00**	**13.55**	**31.27**	**0.00E+00**	**0.0**	

Notes:

Start Time: 13:19 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				168.1		0	6,677.6						
4-2A	137.6	167.6	saturated	168.2	168.2	1	6,677.6	0.00	30.61	70.6	0.00E+00	0.0	
4-2B	137.6	167.6	saturated	168.4	168.4	3	6,677.6	0.00	30.84	71.2	0.00E+00	0.0	
4-2C	137.6	167.6	saturated	168.5	168.5	5	6,677.6	0.00	30.97	71.5	0.00E+00	0.0	
4-2D	137.6	167.6	saturated	169.2	169.2	10	6,677.6	0.00	31.68	73.1	0.00E+00	0.0	
4-2E	137.6	167.6	saturated	169.7	169.7	15	6,677.6	0.00	32.11	74.1	0.00E+00	0.0	
Test Averages/Summary													
4-2	**137.6**	**167.6**	**saturated**	**168.7**	**168.7**	**15**	**0.0**	**0.00**	**31.24**	**72.08**	**0.00E+00**	**0.0**	

Notes:

Start Time: 13:47 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				183.2		0	6,677.7						
4-3A	137.6	182.6	saturated	182.9	182.9	1	6,677.7	0.00	45.35	104.6	0.00E+00	0.0	
4-3B	137.6	182.6	saturated	182.9	182.9	3	6,677.7	0.00	45.36	104.6	0.00E+00	0.0	
4-3C	137.6	182.6	saturated	183.0	183.0	5	6,677.7	0.00	45.45	104.8	0.00E+00	0.0	
4-3D	137.6	182.6	saturated	183.0	183.0	10	6,677.7	0.00	45.41	104.8	0.00E+00	0.0	
4-3E	137.6	182.6	saturated	183.1	183.1	15	6,677.7	0.00	45.54	105.1	0.00E+00	0.0	
Test Averages/Summary													
4-3	**137.6**	**182.6**	**saturated**	**183.0**	**183.0**	**15**	**0.0**	**0.00**	**45.42**	**104.78**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/9/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	325.50
Bottom of Test Interval Depth, ft	336.00

Hydrostatic Pressure (P_0), psi	137.57
Transducer Zero Reading (R_0)	-0.005
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	330.50
Vertical Center of Test Interval (D), ft	330.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	274.2
Bottom of Test Interval Elevation, ft	263.7

Start Time: 13:53 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				168.2		0	6,677.7						
4-4A	137.6	167.6	saturated	168.1	168.1	1	6,677.7	0.00	30.50	70.4	0.00E+00	0.0	
4-4B	137.6	167.6	saturated	168.0	168.0	3	6,677.7	0.00	30.41	70.2	0.00E+00	0.0	
4-4C	137.6	167.6	saturated	167.8	167.8	5	6,677.7	0.00	30.20	69.7	0.00E+00	0.0	
4-4D	137.6	167.6	saturated	167.8	167.8	10	6,677.7	0.00	30.24	69.8	0.00E+00	0.0	
4-4E	137.6	167.6	saturated	167.4	167.4	15	6,677.7	0.00	29.85	68.9	0.00E+00	0.0	
Test Averages/Summary													
4-4	**137.6**	**167.6**	**saturated**	**167.9**	**167.9**	**15**	**0.0**	**0.00**	**30.24**	**69.76**	**0.00E+00**	**0.0**	

Notes:

Start Time: 14:12 — Packer Pressure, psi: 260

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				152.7		0	6,677.7						
4-5A	137.6	152.6	saturated	152.7	152.7	1	6,677.7	0.00	15.17	35.0	0.00E+00	0.0	
4-5B	137.6	152.6	saturated	152.8	152.8	3	6,677.7	0.00	15.20	35.1	0.00E+00	0.0	
4-5C	137.6	152.6	saturated	152.7	152.7	5	6,677.7	0.00	15.17	35.0	0.00E+00	0.0	
4-5D	137.6	152.6	saturated	152.6	152.6	10	6,677.7	0.00	15.06	34.7	0.00E+00	0.0	
4-5E	137.6	152.6	saturated	152.6	152.6	15	6,677.7	0.00	15.00	34.6	0.00E+00	0.0	
Test Averages/Summary													
4-5	**137.6**	**152.6**	**saturated**	**152.7**	**152.7**	**15**	**0.0**	**0.00**	**15.12**	**34.89**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/9/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	315.00
Bottom of Test Interval Depth, ft	325.50

Hydrostatic Pressure (P_0), psi	133.00
Transducer Zero Reading (R_0)	-0.005
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	320.00
Vertical Center of Test Interval (D), ft	320.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	284.7
Bottom of Test Interval Elevation, ft	274.2

Start Time: 14:48 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				149.0		0	6,629.5						
5-1A	133.0	148.0	saturated	149.0	149.0	1	6,629.5	0.00	16.04	37.0	0.00E+00	0.0	
5-1B	133.0	148.0	saturated	149.1	149.1	3	6,629.5	0.01	16.12	37.2	5.81E-07	0.1	
5-1C	133.0	148.0	saturated	149.2	149.2	5	6,629.5	0.00	16.22	37.4	0.00E+00	0.0	
5-1D	133.0	148.0	saturated	149.4	149.4	10	6,629.5	0.00	16.40	37.8	0.00E+00	0.0	
5-1E	133.0	148.0	saturated	149.4	149.4	15	6,629.5	0.00	16.39	37.8	0.00E+00	0.0	
Test Averages/Summary													
5-1	**133.0**	**148.0**	**saturated**	**149.2**	**149.2**	**15**	**0.0**	**0.00**	**16.23**	**37.44**	**1.16E-07**	**0.0**	

Notes:

Start Time: 15:07 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				165.1		0	6,633.0						
5-2A	133.0	163.0	saturated	165.3	165.3	1	6,634.1	1.11	32.35	74.6	6.43E-05	5.9	
5-2B	133.0	163.0	saturated	165.3	165.3	3	6,636.2	1.08	32.32	74.6	6.23E-05	5.7	
5-2C	133.0	163.0	saturated	165.7	165.7	5	6,638.3	1.06	32.72	75.5	6.07E-05	5.6	
5-2D	133.0	163.0	saturated	163.1	163.1	10	6,643.0	0.94	30.12	69.5	5.85E-05	5.4	
5-2E	133.0	163.0	saturated	165.5	165.5	15	6,647.8	0.95	32.51	75.0	5.46E-05	5.0	
Test Averages/Summary													
5-2	**133.0**	**163.0**	**saturated**	**165.0**	**165.0**	**15**	**14.8**	**1.03**	**32.00**	**73.82**	**6.01E-05**	**5.5**	

Notes: Pressure creeped up to 166 psi then dropped to 163 with slight adjustment.

Start Time: 15:24 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				179.4		0	6,650.6						
5-3A	133.0	178.0	saturated	179.2	179.2	1	6,651.8	1.25	46.25	106.7	5.06E-05	4.6	
5-3B	133.0	178.0	saturated	180.3	180.3	3	6,654.4	1.28	47.31	109.1	5.09E-05	4.7	
5-3C	133.0	178.0	saturated	180.0	180.0	5	6,656.8	1.21	47.00	108.4	4.82E-05	4.4	
5-3D	133.0	178.0	saturated	180.8	180.8	10	6,662.9	1.21	47.76	110.2	4.74E-05	4.3	
5-3E	133.0	178.0	saturated	181.0	181.0	15	6,668.8	1.20	47.98	110.7	4.68E-05	4.3	
Test Averages/Summary													
5-3	**133.0**	**178.0**	**saturated**	**180.1**	**180.1**	**15**	**18.3**	**1.23**	**47.26**	**109.03**	**4.88E-05**	**4.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/9/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	315.00
Bottom of Test Interval Depth, ft	325.50

Hydrostatic Pressure (P_0), psi	133.00
Transducer Zero Reading (R_0)	-0.005
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	320.00
Vertical Center of Test Interval (D), ft	320.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	284.7
Bottom of Test Interval Elevation, ft	274.2

Start Time: 15:40 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				163.0		0	6,669.6						
5-4A	133.0	163.0	saturated	163.0	163.0	1	6,670.2	0.59	30.01	69.2	3.68E-05	3.4	
5-4B	133.0	163.0	saturated	163.0	163.1	3	6,671.4	0.59	30.05	69.3	3.68E-05	3.4	
5-4C	133.0	163.0	saturated	163.0	163.0	5	6,672.6	0.63	29.97	69.1	3.94E-05	3.6	
5-4D	133.0	163.0	saturated	163.3	163.3	10	6,676.1	0.69	30.28	69.9	4.28E-05	3.9	
5-4E	133.0	163.0	saturated	164.3	164.3	15	6,679.8	0.74	31.28	72.2	4.44E-05	4.1	
Test Averages/Summary													
5-4	**133.0**	**163.0**	**saturated**	**163.3**	**163.3**	**15**	**10.2**	**0.65**	**30.32**	**69.95**	**4.00E-05**	**3.7**	

Notes:

Start Time: 15:56 — Packer Pressure, psi: 250

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				149.4		0	6,679.9						
5-5A	133.0	148.0	saturated	149.5	149.5	1	6,679.9	0.00	16.53	38.1	0.00E+00	0.0	
5-5B	133.0	148.0	saturated	149.6	149.6	3	6,679.9	0.00	16.62	38.4	0.00E+00	0.0	
5-5C	133.0	148.0	saturated	149.7	149.7	5	6,679.9	0.00	16.73	38.6	0.00E+00	0.0	
5-5D	133.0	148.0	saturated	149.8	149.8	10	6,679.9	0.00	16.82	38.8	0.00E+00	0.0	
5-5E	133.0	148.0	saturated	150.0	150.0	15	6,679.9	0.00	17.00	39.2	0.00E+00	0.0	
Test Averages/Summary													
5-5	**133.0**	**148.0**	**saturated**	**149.7**	**149.7**	**15**	**0.0**	**0.00**	**16.74**	**38.62**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/10/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	6
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	288.20
Bottom of Test Interval Depth, ft	297.40

Hydrostatic Pressure (P_0), psi	119.10
Transducer Zero Reading (R_0)	-0.004
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	292.20
Vertical Center of Test Interval (D), ft	292.80
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	311.5
Bottom of Test Interval Elevation, ft	302.3

Start Time: 12:10 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				135.0		0	17.6						
6-1A	119.1	134.1	saturated	133.8	133.8	1	22.0	4.39	14.68	33.9	5.45E-04	58.6	
6-1B	119.1	134.1	saturated	132.8	132.8	3	28.6	3.34	13.69	31.6	4.44E-04	47.7	
6-1C	119.1	134.1	saturated	133.7	133.7	5	37.1	4.24	14.63	33.8	5.28E-04	56.7	
6-1D	119.1	134.1	saturated	133.7	133.7	10	59.1	4.41	14.56	33.6	5.52E-04	59.3	
6-1E	119.1	134.1	saturated	133.9	133.9	15	80.5	4.27	14.82	34.2	5.25E-04	56.4	
Test Averages/Summary													
6-1	**119.1**	**134.1**	**saturated**	**133.8**	**133.8**	**15**	**62.9**	**4.13**	**14.48**	**33.40**	**5.19E-04**	**55.8**	

Notes: Pressure spiked and dropped (131-138) repeatedly with constant gpm.

Start Time: 12:28 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				148.3		0	103.8						
6-2A	119.1	149.1	saturated	146.0	146.0	1	114.2	10.36	26.94	62.1	7.01E-04	75.3	
6-2B	119.1	149.1	saturated	149.4	149.4	3	138.1	11.94	30.31	69.9	7.18E-04	77.1	
6-2C	119.1	149.1	saturated	155.2	155.2	5	152.6	7.25	36.13	83.3	3.66E-04	39.3	
6-2D	119.1	149.1	saturated	149.3	149.3	10	170.3	3.55	30.17	69.6	2.14E-04	23.0	
6-2E	119.1	149.1	saturated	153.5	153.5	15	199.5	5.84	34.41	79.4	3.09E-04	33.2	
Test Averages/Summary													
6-2	**119.1**	**149.1**	**saturated**	**150.3**	**150.3**	**15**	**95.7**	**7.79**	**31.59**	**72.88**	**4.62E-04**	**48.3**	

Notes: Pressure spiked (143-159 psi) to 154 psi at 2 min, then to 164 psi at 4min (pressure would not level out).

Start Time: 12:44 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				165.0		0	202.2						
6-3A	119.1	164.1	saturated	167.9	167.9	1	235.1	32.82	48.77	112.5	1.23E-03	131.7	
6-3B	119.1	164.1	saturated	169.7	169.7	3	253.2	9.05	50.57	116.7	3.26E-04	35.0	
6-3C	119.1	164.1	saturated	166.1	166.1	5	271.6	9.24	46.97	108.4	3.58E-04	38.5	
6-3D	119.1	164.1	saturated	164.1	164.1	7	289.8	9.10	45.01	103.8	3.68E-04	39.6	
6-3E	119.1	164.1	saturated	165.2	165.2	12	365.0	15.03	46.09	106.3	5.94E-04	63.8	
6-3F	119.1	164.1	saturated	160.8	160.8	17	441.4	15.16	41.67	96.1	6.63E-04	71.2	
Test Averages/Summary													
6-3	**119.1**	**164.1**	**saturated**	**165.5**	**165.5**	**17**	**239.2**	**15.06**	**46.51**	**107.31**	**5.89E-04**	**63.4**	

Notes: Initial flow possible read wrong. Pressure still spiking/dropping without change in gpm. Big Pressure drop at 7min maybe started too early to level out.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/10/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	6
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	288.20
Bottom of Test Interval Depth, ft	297.40

Hydrostatic Pressure (P_0), psi	119.10
Transducer Zero Reading (R_0)	-0.004
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	292.20
Vertical Center of Test Interval (D), ft	292.80
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	311.5
Bottom of Test Interval Elevation, ft	302.3

Start Time: 13:05 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				149.2		0	469.0						
6-4A	119.1	149.1	saturated	149.5	149.5	1	482.9	13.95	30.39	70.1	8.36E-04	89.9	
6-4B	119.1	149.1	saturated	150.0	150.0	3	507.7	12.42	30.90	71.3	7.32E-04	78.7	
6-4C	119.1	149.1	saturated	150.1	150.1	5	533.8	13.01	31.05	71.6	7.63E-04	82.0	
6-4D	119.1	149.1	saturated	150.8	150.8	10	598.8	13.01	31.70	73.1	7.47E-04	80.3	
6-4E	119.1	149.1	saturated	151.1	151.1	15	663.8	13.00	32.04	73.9	7.39E-04	79.5	
Test Averages/Summary													
6-4	**119.1**	**149.1**	**saturated**	**150.1**	**150.1**	**15**	**194.9**	**13.08**	**31.22**	**72.02**	**7.64E-04**	**82.0**	

Notes:

Start Time: 13:21 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				135.2		0	676.3						
6-5A	119.1	134.1	saturated	135.7	135.7	1	682.4	6.11	16.57	38.2	6.72E-04	72.2	
6-5B	119.1	134.1	saturated	135.0	135.0	3	696.6	7.10	15.91	36.7	8.13E-04	87.4	
6-5C	119.1	134.1	saturated	135.0	135.0	5	712.2	7.80	15.93	36.8	8.92E-04	95.8	
6-5D	119.1	134.1	saturated	135.2	135.2	10	752.5	8.06	16.11	37.2	9.11E-04	97.9	
6-5E	119.1	134.1	saturated	135.3	135.3	15	793.9	8.29	16.23	37.5	9.30E-04	100.0	
Test Averages/Summary													
6-5	**119.1**	**134.1**	**saturated**	**135.2**	**135.2**	**15**	**117.6**	**7.47**	**16.15**	**37.26**	**8.44E-04**	**90.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/10/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	7
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	279.00
Bottom of Test Interval Depth, ft	288.20

Hydrostatic Pressure (P_0), psi	116.21
Transducer Zero Reading (R_0)	-0.025
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	283.00
Vertical Center of Test Interval (D), ft	283.60
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	320.7
Bottom of Test Interval Elevation, ft	311.5

Start Time: 23:42 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				130.2		0	9.2						
7-1A	116.2	131.2	saturated	130.1	130.1	1	9.3	0.15	13.89	32.0	1.97E-05	2.1	
7-1B	116.2	131.2	saturated	129.4	129.4	3	9.4	0.05	13.20	30.4	6.90E-06	0.7	
7-1C	116.2	131.2	saturated	129.1	129.1	5	9.5	0.02	12.92	29.8	2.82E-06	0.3	
7-1D	116.2	131.2	saturated	129.0	129.0	10	9.5	0.00	12.82	29.6	0.00E+00	0.0	
7-1E	116.2	131.2	saturated	129.0	129.1	15	9.5	0.00	12.85	29.6	5.67E-07	0.1	
Test Averages/Summary													
7-1	**116.2**	**131.2**	**saturated**	**129.5**	**129.5**	**15**	**0.3**	**0.04**	**13.13**	**30.29**	**6.00E-06**	**0.7**	

Notes:

Start Time: 00:01 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				145.7		0	14.1						
7-2A	116.2	146.2	saturated	147.1	147.1	1	16.9	2.78	30.87	71.2	1.64E-04	17.6	
7-2B	116.2	146.2	saturated	146.7	146.7	3	22.1	2.61	30.51	70.4	1.56E-04	16.8	
7-2C	116.2	146.2	saturated	147.6	147.6	5	26.3	2.10	31.44	72.5	1.22E-04	13.1	
7-2D	116.2	146.2	saturated	149.5	149.5	10	34.9	1.73	33.32	76.9	9.45E-05	10.2	
7-2E	116.2	146.2	saturated	148.5	148.6	15	44.6	1.94	32.36	74.6	1.09E-04	11.7	
Test Averages/Summary													
7-2	**116.2**	**146.2**	**saturated**	**147.5**	**147.5**	**15**	**30.5**	**2.23**	**31.70**	**73.12**	**1.29E-04**	**13.8**	

Notes: Pressure spiked at 10 min.

Start Time: 00:23 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				162.4		0	65.2						
7-3A	116.2	161.2	saturated	165.1	165.1	1	72.1	6.88	48.87	112.7	2.57E-04	27.6	
7-3B	116.2	161.2	saturated	162.8	162.8	3	87.1	7.54	46.61	107.5	2.95E-04	31.7	
7-3C	116.2	161.2	saturated	161.9	161.9	5	99.4	6.12	45.70	105.4	2.44E-04	26.2	
7-3D	116.2	161.2	saturated	161.3	161.3	10	126.9	5.50	45.09	104.0	2.22E-04	23.9	
7-3E	116.2	161.2	saturated	163.6	163.7	15	153.6	5.35	47.45	109.5	2.05E-04	22.1	
Test Averages/Summary													
7-3	**116.2**	**161.2**	**saturated**	**162.8**	**162.8**	**15**	**88.4**	**6.28**	**46.74**	**107.83**	**2.45E-04**	**26.3**	

Notes: Pressure spiked at 1 min then dropped to 161.8

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/10/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	7
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	279.00
Bottom of Test Interval Depth, ft	288.20

Hydrostatic Pressure (P_0), psi	116.21
Transducer Zero Reading (R_0)	-0.025
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	283.00
Vertical Center of Test Interval (D), ft	283.60
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	320.7
Bottom of Test Interval Elevation, ft	311.5

Start Time: 00:44 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				147.1		0	171.7						
7-4A	116.2	146.2	saturated	147.1	147.1	1	176.5	4.87	30.90	71.3	2.87E-04	30.9	
7-4B	116.2	146.2	saturated	147.6	147.6	3	185.4	4.46	31.37	72.4	2.59E-04	27.8	
7-4C	116.2	146.2	saturated	147.6	147.6	5	193.6	4.09	31.44	72.5	2.37E-04	25.4	
7-4D	116.2	146.2	saturated	147.8	147.8	10	213.6	3.99	31.58	72.8	2.30E-04	24.8	
7-4E	116.2	146.2	saturated	147.9	147.9	15	233.8	4.05	31.70	73.1	2.33E-04	25.0	
Test Averages/Summary													
7-4	**116.2**	**146.2**	**saturated**	**147.5**	**147.5**	**15**	**62.2**	**4.29**	**31.39**	**72.42**	**2.49E-04**	**26.8**	

Notes:

Start Time: 01:03 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				132.0		0	241.5						
7-5A	116.2	131.2	saturated	131.9	131.9	1	244.3	2.78	15.74	36.3	3.22E-04	34.6	
7-5B	116.2	131.2	saturated	131.9	131.9	3	249.4	2.55	15.68	36.2	2.96E-04	31.8	
7-5C	116.2	131.2	saturated	132.3	132.3	5	254.6	2.60	16.09	37.1	2.95E-04	31.7	
7-5D	116.2	131.2	saturated	132.4	132.4	10	266.4	2.36	16.22	37.4	2.65E-04	28.5	
7-5E	116.2	131.2	saturated	132.4	132.4	15	278.2	2.36	16.18	37.3	2.66E-04	28.6	
Test Averages/Summary													
7-5	**116.2**	**131.2**	**saturated**	**132.1**	**132.1**	**15**	**36.7**	**2.53**	**15.98**	**36.86**	**2.89E-04**	**31.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/10/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	8
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	269.80
Bottom of Test Interval Depth, ft	279.00

Hydrostatic Pressure (P_0), psi	111.52
Transducer Zero Reading (R_0)	-0.025
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	273.80
Vertical Center of Test Interval (D), ft	274.40
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	329.9
Bottom of Test Interval Elevation, ft	320.7

Start Time: 03:19 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				125.6		0	283.8						
8-1A	111.5	126.5	saturated	125.4	125.4	1	283.8	0.04	13.93	32.1	5.23E-06	0.6	
8-1B	111.5	126.5	saturated	124.8	124.8	3	283.9	0.02	13.33	30.7	2.73E-06	0.3	
8-1C	111.5	126.5	saturated	124.2	124.3	5	283.9	0.02	12.74	29.4	2.86E-06	0.3	
8-1D	111.5	126.5	saturated	123.0	123.1	10	283.9	0.00	11.55	26.6	3.16E-07	0.0	
8-1E	111.5	126.5	saturated	122.2	122.2	15	283.9	0.00	10.72	24.7	0.00E+00	0.0	
Test Averages/Summary													
8-1	**111.5**	**126.5**	**saturated**	**124.2**	**124.2**	**15**	**0.1**	**0.02**	**12.45**	**28.72**	**2.23E-06**	**0.3**	

Notes: Pressure dropped between 5 and 10 min

Start Time: 03:44 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				139.9		0	293.6						
8-2A	111.5	141.5	saturated	140.0	140.0	1	295.7	2.11	28.47	65.7	1.35E-04	14.5	|
8-2B	111.5	141.5	saturated	140.4	140.4	3	298.9	1.58	28.92	66.7	9.96E-05	10.7	|
8-2C	111.5	141.5	saturated	140.3	140.3	5	302.3	1.73	28.82	66.5	1.09E-04	11.8	|
8-2D	111.5	141.5	saturated	141.0	141.0	10	309.9	1.51	29.51	68.1	9.31E-05	10.0	|
8-2E	111.5	141.5	saturated	141.6	141.6	15	317.3	1.49	30.08	69.4	9.01E-05	9.7	
Test Averages/Summary													
8-2	**111.5**	**141.5**	**saturated**	**140.5**	**140.5**	**15**	**23.7**	**1.68**	**29.16**	**67.26**	**1.05E-04**	**11.3**	|

Notes:

Start Time: 04:01 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				156.4		0	320.2						
8-3A	111.5	156.5	saturated	156.4	156.4	1	322.6	2.38	44.92	103.6	9.65E-05	10.4	|
8-3B	111.5	156.5	saturated	156.9	156.9	3	327.6	2.51	45.36	104.6	1.01E-04	10.8	|
8-3C	111.5	156.5	saturated	157.2	157.2	5	332.2	2.33	45.69	105.4	9.27E-05	10.0	|
8-3D	111.5	156.5	saturated	150.2	150.2	10	354.0	4.35	38.66	89.2	2.05E-04	22.0	||
8-3E	111.5	156.5	saturated	152.1	152.1	14	422.4	17.11	40.59	93.6	7.68E-04	82.5	|||||||
8-3F	111.5	156.5	saturated	151.2	151.2	16	470.0	19.34	39.66	91.5	8.89E-04	95.5	|||||||
Test Averages/Summary													
8-3	**111.5**	**156.5**	**saturated**	**154.3**	**154.3**	**16**	**149.9**	**8.00**	**42.48**	**97.99**	**3.59E-04**	**36.9**	|||

Notes: At 14min pressure dropped to 133. Adjusted pressure back up to 150. Pressure continued dropping and spiking .

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/10/2019
WSP Personnel	X. You
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	8
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	269.80
Bottom of Test Interval Depth, ft	279.00

Hydrostatic Pressure (P_0), psi	111.52
Transducer Zero Reading (R_0)	-0.025
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	273.80
Vertical Center of Test Interval (D), ft	274.40
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	329.9
Bottom of Test Interval Elevation, ft	320.7

Start Time: 04:25 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				139.7		0	525.3						
8-4A	111.5	141.5	saturated	138.0	138.1	1	550.0	24.72	26.55	61.2	1.70E-03	182.3	
8-4B	111.5	141.5	saturated	138.7	138.7	3	591.6	20.81	27.23	62.8	1.39E-03	149.6	
8-4C	111.5	141.5	saturated	139.0	139.0	5	634.3	21.35	27.51	63.5	1.41E-03	152.0	
8-4D	111.5	141.5	saturated	139.0	139.0	10	725.2	18.18	27.50	63.4	1.21E-03	129.5	
8-4E	111.5	141.5	saturated	138.8	138.8	15	810.3	17.02	27.26	62.9	1.14E-03	122.3	
Test Averages/Summary													
8-4	**111.5**	**141.5**	**saturated**	**138.9**	**138.9**	**15**	**285.1**	**20.42**	**27.21**	**62.76**	**1.37E-03**	**146.9**	

Notes:

Start Time: 04:42 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				127.7		0	829.9						
8-5A	111.5	126.5	saturated	126.8	126.9	1	840.8	10.91	15.34	35.4	1.30E-03	139.3	
8-5B	111.5	126.5	saturated	125.9	126.0	3	870.0	14.58	14.45	33.3	1.84E-03	197.5	
8-5C	111.5	126.5	saturated	126.0	126.0	5	890.4	10.23	14.48	33.4	1.29E-03	138.3	
8-5D	111.5	126.5	saturated	126.4	126.4	10	947.7	11.45	14.93	34.4	1.40E-03	150.2	
8-5E	111.5	126.5	saturated	126.4	126.4	15	1,005.0	11.47	14.89	34.3	1.40E-03	150.8	
Test Averages/Summary													
8-5	**111.5**	**126.5**	**saturated**	**126.5**	**126.5**	**15**	**175.1**	**11.73**	**14.81**	**34.17**	**1.44E-03**	**155.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/12/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	9
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	260.60
Bottom of Test Interval Depth, ft	269.80

Hydrostatic Pressure (P_0), psi	105.50
Transducer Zero Reading (R_0)	-0.356
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	264.60
Vertical Center of Test Interval (D), ft	265.20
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	339.1
Bottom of Test Interval Elevation, ft	329.9

Start Time: | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				120.1		0	1,030.7						
9-1A	105.5	120.5	saturated	120.1	120.4	1	1,038.2	7.48	14.91	34.4	9.14E-04	98.2	
9-1B	105.5	120.5	saturated	120.6	121.0	3	1,052.3	7.04	15.45	35.6	8.30E-04	89.2	
9-1C	105.5	120.5	saturated	120.7	121.1	5	1,066.0	6.85	15.56	35.9	8.02E-04	86.2	
9-1D	105.5	120.5	saturated	119.4	119.7	10	1,103.3	7.48	14.25	32.9	9.56E-04	102.7	
9-1E	105.5	120.5	saturated	119.9	120.2	15	1,138.7	7.08	14.71	33.9	8.77E-04	94.2	
Test Averages/Summary													
9-1	**105.5**	**120.5**	**saturated**	**120.1**	**120.5**	**15**	**108.0**	**7.18**	**14.98**	**34.55**	**8.76E-04**	**93.9**	

Notes:

Start Time: | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				135.6		0	1,193.2						
9-2A	105.5	135.5	saturated	134.5	134.9	1	1,208.9	15.73	29.35	67.7	9.76E-04	104.9	
9-2B	105.5	135.5	saturated	134.8	135.1	3	1,245.8	18.42	29.64	68.4	1.13E-03	121.7	
9-2C	105.5	135.5	saturated	135.4	135.7	5	1,277.5	15.86	30.25	69.8	9.55E-04	102.7	
9-2D	105.5	135.5	saturated	134.7	135.0	10	1,363.8	17.27	29.52	68.1	1.07E-03	114.5	
9-2E	105.5	135.5	saturated	135.2	135.5	15	1,451.6	17.55	30.03	69.3	1.06E-03	114.4	
Test Averages/Summary													
9-2	**105.5**	**135.5**	**saturated**	**135.0**	**135.0**	**15**	**258.4**	**16.97**	**29.76**	**68.65**	**1.04E-03**	**111.6**	

Notes: Pressure fluctuated ~1.2 psi throught test.

Start Time: | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				144.1		0	1,611.5						
9-3A	105.5	150.5	saturated	145.7	146.0	1	1,642.8	31.24	40.52	93.5	1.40E-03	150.9	
9-3B	105.5	150.5	saturated	146.0	146.4	3	1,708.0	32.59	40.86	94.3	1.45E-03	156.2	
9-3C	105.5	150.5	saturated	144.7	145.0	5	1,772.3	32.19	39.52	91.2	1.48E-03	159.4	
9-3D	105.5	150.5	saturated	143.1	143.5	10	1,942.9	34.11	38.00	87.7	1.64E-03	175.8	
9-3E	105.5	150.5	saturated	140.9	141.3	15	2,102.8	31.99	35.81	82.6	1.63E-03	174.9	
Test Averages/Summary													
9-3	**105.5**	**150.5**	**saturated**	**144.1**	**144.1**	**15**	**491.3**	**32.42**	**38.94**	**89.84**	**1.52E-03**	**163.0**	

Notes: Attempted to pressurize and pressure fluctuated too much. Adjusted setup. Attempted test with pump at max with bypass 100% closed and could not achieve target pressure.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/12/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	9
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	260.60
Bottom of Test Interval Depth, ft	269.80

Hydrostatic Pressure (P_0), psi	105.50
Transducer Zero Reading (R_0)	-0.356
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	264.60
Vertical Center of Test Interval (D), ft	265.20
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	339.1
Bottom of Test Interval Elevation, ft	329.9

Start Time: | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				135.3		0	2,177.7						
9-4A	105.5	135.5	saturated	135.9	136.2	1	2,207.0	29.23	30.74	70.9	1.73E-03	186.2	
9-4B	105.5	135.5	saturated	135.9	136.2	3	2,267.0	30.00	30.71	70.8	1.78E-03	191.3	
9-4C	105.5	135.5	saturated	135.7	136.1	5	2,326.5	29.77	30.58	70.5	1.77E-03	190.6	
9-4D	105.5	135.5	saturated	135.9	136.2	10	2,475.4	29.78	30.73	70.9	1.77E-03	189.8	
9-4E	105.5	135.5	saturated	135.4	135.8	15	2,625.0	29.92	30.28	69.8	1.80E-03	193.5	
Test Averages/Summary													
9-4	**105.5**	**135.5**	**saturated**	**135.7**	**135.7**	**15**	**447.3**	**29.74**	**30.61**	**70.61**	**1.77E-03**	**190.2**	

Notes:

Start Time: | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				120.3		0	2,675.9						
9-5A	105.5	120.5	saturated	120.4	120.8	1	2,694.6	18.67	15.27	35.2	2.23E-03	239.4	
9-5B	105.5	120.5	saturated	120.4	120.7	3	2,735.2	20.30	15.21	35.1	2.43E-03	261.3	
9-5C	105.5	120.5	saturated	120.4	120.7	5	2,773.6	19.22	15.22	35.1	2.30E-03	247.2	
9-5D	105.5	120.5	saturated	120.4	120.7	10	2,869.9	19.26	15.23	35.1	2.30E-03	247.5	
9-5E	105.5	120.5	saturated	120.2	120.6	15	2,967.6	19.53	15.08	34.8	2.36E-03	253.6	
Test Averages/Summary													
9-5	**105.5**	**120.5**	**saturated**	**120.3**	**120.3**	**15**	**291.6**	**19.39**	**15.20**	**35.07**	**2.32E-03**	**249.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/12/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	M. Bond

Boring ID	BH19-17
Test Number	10
Borehole Diameter, ft	0.51
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	251.60
Bottom of Test Interval Depth, ft	260.80

Hydrostatic Pressure (P_0), psi	102.00
Transducer Zero Reading (R_0)	-0.356
Dist from Top Packer to Transducer, ft	4.0
Transducer Depth, ft	255.60
Vertical Center of Test Interval (D), ft	256.20
Test Interval Length (L), ft	9.20

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	348.1
Bottom of Test Interval Elevation, ft	338.9

Start Time: | Packer Pressure, psi: 220

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				107.1		0	59.8						
10-1A	102.0	117.0	saturated	108.3	108.6	1	93.5	33.67	6.63	15.3	9.26E-03	994.8	
10-1B	102.0	117.0	saturated	109.1	109.5	3	159.8	33.14	7.46	17.2	8.09E-03	869.4	
10-1C	102.0	117.0	saturated	109.3	109.7	5	225.4	32.80	7.67	17.7	7.79E-03	836.8	
10-1D	102.0	117.0	saturated	109.8	110.1	10	398.8	34.68	8.13	18.7	7.78E-03	835.5	
10-1E	102.0	117.0	saturated	109.8	110.1	15	555.7	31.37	8.12	18.7	7.04E-03	756.7	
Test Averages/Summary													
10-1	**102.0**	**117.0**	**saturated**	**108.9**	**109.2**	**15**	**495.8**	**33.13**	**7.60**	**17.54**	**7.99E-03**	**853.4**	

Notes: Pump running at max capacity. Water return in casing began at 10 min mark. Abandonded remaining test for this interval.

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0							
						1							
						3							
						5							
						10							
						15							
Test Averages/Summary													

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
						0							
						1							
						3							
						5							
						10							
						15							
Test Averages/Summary													

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/6/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	S. Parks

Boring ID	BH19-17
Test Number	11
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.00
Bottom of Test Interval Depth, ft	203.50

Hydrostatic Pressure (P_0), psi	77.19
Transducer Zero Reading (R_0)	-0.009
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	198.00
Vertical Center of Test Interval (D), ft	198.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	406.7
Bottom of Test Interval Elevation, ft	396.2

Start Time: 12:25 — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				91.8		0	6,376.0						
11-1A	77.2	92.2	saturated	92.2	92.2	1	6,377.6	1.60	15.02	34.6	1.99E-04	18.3	
11-1B	77.2	92.2	saturated	92.8	92.8	3	6,381.1	1.75	15.62	36.0	2.10E-04	19.2	
11-1C	77.2	92.2	saturated	93.0	93.0	5	6,384.3	1.60	15.82	36.5	1.89E-04	17.4	
11-1D	77.2	92.2	saturated	93.5	93.5	10	6,392.4	1.62	16.32	37.6	1.86E-04	17.0	
11-1E	77.2	92.2	saturated	93.9	93.9	15	6,400.4	1.60	16.72	38.6	1.79E-04	16.4	
Test Averages/Summary													
11-1	**77.2**	**92.2**	**saturated**	**92.9**	**92.9**	**15**	**24.4**	**1.63**	**15.90**	**36.68**	**1.93E-04**	**17.6**	

Notes:

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				108.1		0	6,414.0						
11-2A	77.2	107.2	saturated	108.3	108.3	1	6,416.9	2.90	31.12	71.8	1.75E-04	16.0	
11-2B	77.2	107.2	saturated	108.4	108.4	3	6,422.7	2.90	31.22	72.0	1.74E-04	15.9	
11-2C	77.2	107.2	saturated	108.9	108.9	5	6,428.6	2.95	31.72	73.2	1.74E-04	16.0	
11-2D	77.2	107.2	saturated	109.0	109.0	10	6,443.3	2.94	31.82	73.4	1.73E-04	15.8	
11-2E	77.2	107.2	saturated	109.1	109.1	15	6,458.0	2.94	31.92	73.6	1.72E-04	15.8	
Test Averages/Summary													
11-2	**77.2**	**107.2**	**saturated**	**108.6**	**108.6**	**15**	**44.0**	**2.93**	**31.56**	**72.81**	**1.74E-04**	**15.9**	

Notes:

Start Time: — Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				120.8		0	6,474.0						
11-3A	77.2	122.2	saturated	120.0	120.0	1	6,479.0	5.00	42.82	98.8	2.19E-04	20.0	
11-3B	77.2	122.2	saturated	119.6	119.6	3	6,489.1	5.05	42.42	97.9	2.23E-04	20.4	
11-3C	77.2	122.2	saturated	119.6	119.6	5	6,499.1	5.00	42.42	97.9	2.21E-04	20.2	
11-3D	77.2	122.2	saturated	120.2	120.2	10	6,524.3	5.04	43.02	99.2	2.19E-04	20.1	
11-3E	77.2	122.2	saturated	120.2	120.2	15	6,549.6	5.06	43.02	99.2	2.20E-04	20.2	
Test Averages/Summary													
11-3	**77.2**	**122.2**	**saturated**	**120.1**	**120.1**	**15**	**75.6**	**5.03**	**42.74**	**98.60**	**2.20E-04**	**20.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/6/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	S. Parks

Boring ID	BH19-17
Test Number	11
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.00
Bottom of Test Interval Depth, ft	203.50

Hydrostatic Pressure (P_0), psi	77.19
Transducer Zero Reading (R_0)	-0.009
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	198.00
Vertical Center of Test Interval (D), ft	198.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	406.7
Bottom of Test Interval Elevation, ft	396.2

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				107.9		0	6,559.0						
11-4A	77.2	107.2	saturated	108.3	108.3	1	6,563.2	4.20	31.12	71.8	2.53E-04	23.2	
11-4B	77.2	107.2	saturated	108.6	108.6	3	6,571.4	4.10	31.42	72.5	2.44E-04	22.4	
11-4C	77.2	107.2	saturated	108.8	108.8	5	6,579.5	4.05	31.62	72.9	2.40E-04	22.0	
11-4D	77.2	107.2	saturated	109.0	109.0	10	6,599.8	4.06	31.82	73.4	2.39E-04	21.9	
11-4E	77.2	107.2	saturated	108.8	108.8	15	6,620.3	4.10	31.62	72.9	2.43E-04	22.2	
Test Averages/Summary													
11-4	**77.2**	**107.2**	**saturated**	**108.6**	**108.6**	**15**	**61.3**	**4.10**	**31.52**	**72.71**	**2.44E-04**	**22.3**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				93.2		0	6,626.0						
11-5A	77.2	92.2	saturated	93.3	93.3	1	6,628.6	2.60	16.12	37.2	3.02E-04	27.7	
11-5B	77.2	92.2	saturated	93.2	93.2	3	6,633.7	2.55	16.02	37.0	2.98E-04	27.3	
11-5C	77.2	92.2	saturated	93.4	93.4	5	6,637.8	2.05	16.22	37.4	2.37E-04	21.7	
11-5D	77.2	92.2	saturated	93.6	93.6	10	6,650.5	2.54	16.42	37.9	2.90E-04	26.5	
11-5E	77.2	92.2	saturated	93.7	93.7	15	6,663.3	2.56	16.52	38.1	2.90E-04	26.6	
Test Averages/Summary													
11-5	**77.2**	**92.2**	**saturated**	**93.4**	**93.4**	**15**	**37.3**	**2.46**	**16.26**	**37.51**	**2.83E-04**	**26.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	S. Parks

Boring ID	BH19-17
Test Number	12
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.50
Bottom of Test Interval Depth, ft	194.00

Hydrostatic Pressure (P_0), psi	73.28
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	188.50
Vertical Center of Test Interval (D), ft	188.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	416.2
Bottom of Test Interval Elevation, ft	405.7

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				88.3		0	3,890.0						
12-1A	73.3	88.3	saturated	89.7	89.7	1	3,898.3	8.30	16.40	37.8	9.48E-04	86.8	
12-1B	73.3	88.3	saturated	88.8	88.8	3	3,914.3	8.00	15.50	35.8	9.67E-04	88.5	
12-1C	73.3	88.3	saturated	88.9	88.9	5	3,930.4	8.05	15.60	36.0	9.66E-04	88.5	
12-1D	73.3	88.3	saturated	89.0	89.0	10	3,969.1	7.74	15.70	36.2	9.23E-04	84.6	
12-1E	73.3	88.3	saturated	89.0	89.0	15	4,008.2	7.82	15.70	36.2	9.33E-04	85.4	
Test Averages/Summary													
12-1	**73.3**	**88.3**	**saturated**	**89.0**	**88.9**	**15**	**118.2**	**7.98**	**15.78**	**36.40**	**9.47E-04**	**86.8**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				102.8		0	4,062.0						
12-2A	73.3	103.3	saturated	103.4	103.4	1	4,074.7	12.70	30.10	69.4	7.90E-04	72.4	
12-2B	73.3	103.3	saturated	103.8	103.8	3	4,100.2	12.75	30.50	70.4	7.83E-04	71.7	
12-2C	73.3	103.3	saturated	103.7	103.7	5	4,125.1	12.45	30.40	70.1	7.67E-04	70.3	
12-2D	73.3	103.3	saturated	104.2	104.2	10	4,175.5	10.08	30.90	71.3	6.11E-04	56.0	
12-2E	73.3	103.3	saturated	103.5	103.5	15	4,249.0	14.70	30.20	69.7	9.12E-04	83.5	
Test Averages/Summary													
12-2	**73.3**	**103.3**	**saturated**	**103.6**	**103.6**	**15**	**187.0**	**12.54**	**30.42**	**70.18**	**7.72E-04**	**70.7**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				118.3		0	4,322.0						
12-3A	73.3	118.3	saturated	119.3	119.3	1	4,339.2	17.20	46.00	106.1	7.00E-04	64.1	
12-3B	73.3	118.3	saturated	118.3	118.3	3	4,371.9	16.35	45.00	103.8	6.80E-04	62.3	
12-3C	73.3	118.3	saturated	118.7	118.7	5	4,405.4	16.75	45.40	104.7	6.91E-04	63.3	
12-3D	73.3	118.3	saturated	118.5	118.5	10	4,485.7	16.06	45.20	104.3	6.65E-04	60.9	
12-3E	73.3	118.3	saturated	117.8	117.8	15	4,567.3	16.32	44.50	102.7	6.87E-04	62.9	
Test Averages/Summary													
12-3	**73.3**	**118.3**	**saturated**	**118.5**	**118.5**	**15**	**245.3**	**16.54**	**45.22**	**104.32**	**6.85E-04**	**62.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	C. Fischer
Subcontractor	Cascade Drilling
Driller	S. Parks

Boring ID	BH19-17
Test Number	12
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.50
Bottom of Test Interval Depth, ft	194.00

Hydrostatic Pressure (P_0), psi	73.28
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	188.50
Vertical Center of Test Interval (D), ft	188.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	416.2
Bottom of Test Interval Elevation, ft	405.7

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				103.2		0	4,617.0						
12-4A	73.3	103.3	saturated	103.4	103.4	1	4,629.9	12.90	30.10	69.4	8.03E-04	73.5	
12-4B	73.3	103.3	saturated	103.6	103.6	3	4,655.0	12.55	30.30	69.9	7.76E-04	71.0	
12-4C	73.3	103.3	saturated	103.8	103.8	5	4,680.6	12.80	30.50	70.4	7.86E-04	72.0	
12-4D	73.3	103.3	saturated	104.1	104.1	10	4,744.1	12.70	30.80	71.1	7.72E-04	70.7	
12-4E	73.3	103.3	saturated	104.3	104.3	15	4,807.7	12.72	31.00	71.5	7.68E-04	70.4	
Test Averages/Summary													
12-4	**73.3**	**103.3**	**saturated**	**103.7**	**103.7**	**15**	**190.7**	**12.73**	**30.54**	**70.46**	**7.81E-04**	**71.5**	

Notes:

Start Time: | Packer Pressure, psi:

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				88.2		0	4,835.0						
12-5A	73.3	88.3	saturated	87.7	87.7	1	4,843.0	8.00	14.40	33.2	1.04E-03	95.3	
12-5B	73.3	88.3	saturated	87.9	87.9	3	4,858.9	7.95	14.60	33.7	1.02E-03	93.4	
12-5C	73.3	88.3	saturated	88.1	88.1	5	4,874.5	7.80	14.80	34.1	9.87E-04	90.4	
12-5D	73.3	88.3	saturated	87.9	87.9	10	4,913.8	7.86	14.60	33.7	1.01E-03	92.3	
12-5E	73.3	88.3	saturated	88.1	88.1	15	4,953.2	7.88	14.80	34.1	9.97E-04	91.3	
Test Averages/Summary													
12-5	**73.3**	**88.3**	**saturated**	**88.0**	**88.0**	**15**	**118.2**	**7.90**	**14.64**	**33.77**	**1.01E-03**	**92.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	C. Fischer, K. Williams
Subcontractor	Cascade Drilling
Driller	S. Parks, C. Barden

Boring ID	BH19-17
Test Number	13
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	172.00
Bottom of Test Interval Depth, ft	182.50

Hydrostatic Pressure (P_0), psi	68.40
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	177.00
Vertical Center of Test Interval (D), ft	177.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	427.7
Bottom of Test Interval Elevation, ft	417.2

Start Time: | Packer Pressure, psi: 150

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				82.3		0	4,992.0						
13-1A	68.4	83.4	saturated	82.4	82.4	1	4,995.1	3.10	13.98	32.3	4.15E-04	38.0	
13-1B	68.4	83.4	saturated	82.5	82.5	3	5,001.3	3.10	14.08	32.5	4.12E-04	37.8	
13-1C	68.4	83.4	saturated	82.7	82.7	5	5,007.5	3.10	14.28	33.0	4.06E-04	37.2	
13-1D	68.4	83.4	saturated	83.0	83.0	10	5,023.0	3.10	14.58	33.6	3.98E-04	36.5	
13-1E	68.4	83.4	saturated	83.3	83.3	15	5,038.6	3.12	14.88	34.3	3.93E-04	36.0	
Test Averages/Summary													
13-1	**68.4**	**83.4**	**saturated**	**82.7**	**82.7**	**15**	**46.6**	**3.10**	**14.36**	**33.14**	**4.05E-04**	**37.1**	

Notes:

Start Time: | Packer Pressure, psi: 150

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				98.8		0	5,056.1						
13-2A	68.4	98.4	saturated	97.5	97.5	1	5,062.0	5.90	29.08	67.1	3.80E-04	34.8	
13-2B	68.4	98.4	saturated	95.6	95.6	3	5,073.6	5.80	27.18	62.7	4.00E-04	36.6	
13-2C	68.4	98.4	saturated	98.3	98.3	5	5,085.0	5.70	29.88	68.9	3.57E-04	32.7	
13-2D	68.4	98.4	saturated	97.9	97.9	10	5,115.9	6.18	29.48	68.0	3.93E-04	36.0	
13-2E	68.4	98.4	saturated	98.3	98.3	15	5,147.6	6.34	29.88	68.9	3.97E-04	36.4	
Test Averages/Summary													
13-2	**68.4**	**98.4**	**saturated**	**97.7**	**97.7**	**15**	**91.5**	**5.98**	**29.10**	**67.14**	**3.85E-04**	**35.3**	

Notes: Shift change occurred after test.

Start Time: | Packer Pressure, psi: 150

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				113.0		0	5,203.3						
13-3A	68.4	113.4	saturated	113.7	113.7	1	5,212.8	9.46	45.33	104.6	3.91E-04	35.8	
13-3B	68.4	113.4	saturated	113.5	113.5	3	5,231.7	9.46	45.05	103.9	3.93E-04	36.0	
13-3C	68.4	113.4	saturated	112.8	112.8	5	5,249.6	8.95	44.42	102.5	3.77E-04	34.6	
13-3D	68.4	113.4	saturated	113.4	113.4	10	5,297.2	9.53	44.95	103.7	3.97E-04	36.4	
13-3E	68.4	113.4	saturated	113.0	113.0	15	5,344.4	9.42	44.55	102.8	3.96E-04	36.3	
Test Averages/Summary													
13-3	**68.4**	**113.4**	**saturated**	**113.2**	**113.2**	**15**	**141.1**	**9.37**	**44.86**	**103.49**	**3.91E-04**	**35.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	C. Fischer, K. Williams
Subcontractor	Cascade Drilling
Driller	S. Parks, C. Barden

Boring ID	BH19-17
Test Number	13
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	172.00
Bottom of Test Interval Depth, ft	182.50

Hydrostatic Pressure (P_0), psi	68.40
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	177.00
Vertical Center of Test Interval (D), ft	177.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	427.7
Bottom of Test Interval Elevation, ft	417.2

Start Time: | Packer Pressure, psi: 150

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				98.8		0	5,376.6						
13-4A	68.4	98.4	saturated	98.9	98.9	1	5,384.3	7.64	30.52	70.4	4.69E-04	42.9	
13-4B	68.4	98.4	saturated	98.8	98.8	3	5,399.8	7.74	30.36	70.0	4.77E-04	43.7	
13-4C	68.4	98.4	saturated	98.7	98.6	5	5,412.1	6.14	30.24	69.8	3.81E-04	34.9	
13-4D	68.4	98.4	saturated	98.8	98.8	10	5,447.8	7.14	30.39	70.1	4.40E-04	40.3	
13-4E	68.4	98.4	saturated	98.7	98.7	15	5,481.8	6.81	30.29	69.9	4.21E-04	38.6	
Test Averages/Summary													
13-4	**68.4**	**98.4**	**saturated**	**98.8**	**98.8**	**15**	**105.2**	**7.10**	**30.36**	**70.04**	**4.38E-04**	**40.1**	

Notes:

Start Time: | Packer Pressure, psi: 150

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				83.7		0	5,500.5						
13-5A	68.4	83.4	saturated	83.7	83.7	1	5,504.9	4.39	15.31	35.3	5.37E-04	49.2	
13-5B	68.4	83.4	saturated	83.7	83.7	3	5,513.3	4.20	15.32	35.4	5.13E-04	47.0	
13-5C	68.4	83.4	saturated	83.9	83.9	5	5,522.3	4.50	15.49	35.7	5.44E-04	49.8	
13-5D	68.4	83.4	saturated	83.8	83.8	10	5,543.3	4.22	15.42	35.6	5.12E-04	46.9	
13-5E	68.4	83.4	saturated	83.7	83.7	15	5,564.4	4.22	15.28	35.2	5.17E-04	47.4	
Test Averages/Summary													
13-5	**68.4**	**83.4**	**saturated**	**83.8**	**83.8**	**15**	**64.0**	**4.30**	**15.37**	**35.45**	**5.25E-04**	**48.1**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	14
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	161.50
Bottom of Test Interval Depth, ft	172.00

Hydrostatic Pressure (P_0), psi	64.39
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	166.50
Vertical Center of Test Interval (D), ft	166.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	438.2
Bottom of Test Interval Elevation, ft	427.7

Start Time: | Packer Pressure, psi: 145

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				79.4		0	5,571.7						
14-1A	64.4	79.4	saturated	79.7	79.7	1	5,574.2	2.47	15.30	35.3	3.02E-04	27.7	
14-1B	64.4	79.4	saturated	79.5	79.5	3	5,578.4	2.11	15.10	34.8	2.62E-04	24.0	
14-1C	64.4	79.4	saturated	79.7	79.7	5	5,582.6	2.11	15.34	35.4	2.57E-04	23.5	
14-1D	64.4	79.4	saturated	79.6	79.6	10	5,593.2	2.12	15.20	35.1	2.61E-04	23.9	
14-1E	64.4	79.4	saturated	79.6	79.6	15	5,603.2	2.01	15.24	35.1	2.47E-04	22.7	
Test Averages/Summary													
14-1	**64.4**	**79.4**	**saturated**	**79.6**	**79.6**	**15**	**31.6**	**2.16**	**15.24**	**35.15**	**2.66E-04**	**24.4**	

Notes:

Start Time: | Packer Pressure, psi: 145

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				93.9		0	5,607.1						
14-2A	64.4	94.4	saturated	95.0	95.0	1	5,610.9	3.81	30.63	70.7	2.33E-04	21.3	
14-2B	64.4	94.4	saturated	93.6	93.6	3	5,617.9	3.49	29.21	67.4	2.24E-04	20.5	
14-2C	64.4	94.4	saturated	93.9	93.9	5	5,624.7	3.39	29.53	68.1	2.15E-04	19.7	
14-2D	64.4	94.4	saturated	93.5	93.5	10	5,641.2	3.30	29.07	67.1	2.13E-04	19.5	
14-2E	64.4	94.4	saturated	94.0	94.0	15	5,657.5	3.27	29.61	68.3	2.07E-04	19.0	
Test Averages/Summary													
14-2	**64.4**	**94.4**	**saturated**	**94.0**	**94.0**	**15**	**50.4**	**3.45**	**29.61**	**68.31**	**2.18E-04**	**20.0**	

Notes:

Start Time: | Packer Pressure, psi: 145

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				109.2		0	5,665.5						
14-3A	64.4	109.4	saturated	110.6	110.6	1	5,670.0	4.52	46.18	106.5	1.83E-04	16.8	
14-3B	64.4	109.4	saturated	108.1	108.0	3	5,680.3	5.13	43.66	100.7	2.20E-04	20.2	
14-3C	64.4	109.4	saturated	109.4	109.3	5	5,689.6	4.67	44.95	103.7	1.95E-04	17.8	
14-3D	64.4	109.4	saturated	109.6	109.6	10	5,714.6	4.98	45.20	104.3	2.06E-04	18.9	
14-3E	64.4	109.4	saturated	108.3	108.3	15	5,740.1	5.11	43.87	101.2	2.18E-04	20.0	
Test Averages/Summary													
14-3	**64.4**	**109.4**	**saturated**	**109.2**	**109.2**	**15**	**74.6**	**4.88**	**44.77**	**103.29**	**2.04E-04**	**18.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	14
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	161.50
Bottom of Test Interval Depth, ft	172.00

Hydrostatic Pressure (P_0), psi	64.39
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	166.50
Vertical Center of Test Interval (D), ft	166.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	438.2
Bottom of Test Interval Elevation, ft	427.7

Start Time: | Packer Pressure, psi: 145

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				94.3		0	5,748.4						
14-4A	64.4	94.4	saturated	94.3	94.3	1	5,752.2	3.78	29.90	69.0	2.37E-04	21.7	
14-4B	64.4	94.4	saturated	94.3	94.3	3	5,759.1	3.46	29.88	68.9	2.17E-04	19.9	
14-4C	64.4	94.4	saturated	94.6	94.6	5	5,767.0	3.92	30.17	69.6	2.43E-04	22.3	
14-4D	64.4	94.4	saturated	94.1	94.1	10	5,785.1	3.62	29.71	68.5	2.28E-04	20.9	
14-4E	64.4	94.4	saturated	93.9	93.9	15	5,803.1	3.61	29.53	68.1	2.29E-04	21.0	
Test Averages/Summary													
14-4	**64.4**	**94.4**	**saturated**	**94.2**	**94.2**	**15**	**54.7**	**3.68**	**29.84**	**68.83**	**2.31E-04**	**21.2**	

Notes:

Start Time: | Packer Pressure, psi: 145

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				79.3		0	5,806.4						
14-5A	64.4	79.4	saturated	79.4	79.4	1.5	5,810.0	2.39	15.01	34.6	2.99E-04	27.3	
14-5B	64.4	79.4	saturated	79.3	79.3	3	5,813.1	2.06	14.87	34.3	2.59E-04	23.8	
14-5C	64.4	79.4	saturated	79.3	79.3	5	5,817.5	2.22	14.90	34.4	2.80E-04	25.6	
14-5D	64.4	79.4	saturated	79.5	79.5	10	5,828.6	2.21	15.11	34.9	2.74E-04	25.1	
14-5E	64.4	79.4	saturated	79.7	79.7	15	5,839.3	2.14	15.28	35.3	2.62E-04	24.0	
Test Averages/Summary													
14-5	**64.4**	**79.4**	**saturated**	**79.4**	**79.4**	**15**	**32.9**	**2.21**	**15.03**	**34.69**	**2.75E-04**	**25.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	15
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	151.00
Bottom of Test Interval Depth, ft	161.50

Hydrostatic Pressure (P_0), psi	59.75
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	156.00
Vertical Center of Test Interval (D), ft	156.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	448.7
Bottom of Test Interval Elevation, ft	438.2

Start Time: | Packer Pressure, psi: 125

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				74.7		0	5,850.2						
15-1A	59.7	74.7	saturated	75.7	75.6	1	5,854.8	4.58	15.89	36.7	5.40E-04	49.4	
15-1B	59.7	74.7	saturated	75.3	75.3	3	5,863.9	4.55	15.51	35.8	5.49E-04	50.3	
15-1C	59.7	74.7	saturated	75.6	75.6	5	5,872.5	4.30	15.81	36.5	5.09E-04	46.6	
15-1D	59.7	74.7	saturated	75.6	75.6	10	5,893.3	4.16	15.88	36.6	4.91E-04	44.9	
15-1E	59.7	74.7	saturated	74.9	74.9	15	5,913.0	3.95	15.13	34.9	4.89E-04	44.8	
Test Averages/Summary													
15-1	**59.7**	**74.7**	**saturated**	**75.3**	**75.3**	**15**	**62.9**	**4.31**	**15.65**	**36.10**	**5.16E-04**	**47.2**	

Notes:

Start Time: | Packer Pressure, psi: 125

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				91.2		0	5,930.8						
15-2A	59.7	89.7	saturated	90.8	90.8	2	5,945.2	7.18	31.03	71.6	4.33E-04	39.7	
15-2B	59.7	89.7	saturated	90.0	90.0	3	5,951.0	5.79	30.23	69.7	3.59E-04	32.9	
15-2C	59.7	89.7	saturated	91.2	91.2	5	5,964.3	6.67	31.40	72.4	3.98E-04	36.4	
15-2D	59.7	89.7	saturated	90.8	90.8	10	5,995.5	6.24	31.03	71.6	3.76E-04	34.5	
15-2E	59.7	89.7	saturated	90.6	90.6	15.5	6,030.3	6.33	30.85	71.2	3.84E-04	35.2	
Test Averages/Summary													
15-2	**59.7**	**89.7**	**saturated**	**90.8**	**90.8**	**15.5**	**99.5**	**6.44**	**30.91**	**71.31**	**3.90E-04**	**35.7**	

Notes:

Start Time: | Packer Pressure, psi: 125

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				105.0		0	6,040.4						
15-3A	59.7	104.7	saturated	104.0	104.0	1	6,049.2	8.80	44.21	102.0	3.73E-04	34.1	
15-3B	59.7	104.7	saturated	105.7	105.7	3	6,066.6	8.72	45.92	105.9	3.55E-04	32.6	
15-3C	59.7	104.7	saturated	106.0	105.9	5	6,083.6	8.48	46.19	106.6	3.44E-04	31.5	
15-3D	59.7	104.7	saturated	104.7	104.7	10	6,126.8	8.64	44.96	103.7	3.60E-04	33.0	
15-3E	59.7	104.7	saturated	105.5	105.4	15	6,168.1	8.27	45.69	105.4	3.39E-04	31.0	
Test Averages/Summary													
15-3	**59.7**	**104.7**	**saturated**	**105.1**	**105.1**	**15**	**127.7**	**8.58**	**45.39**	**104.72**	**3.54E-04**	**32.4**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	15
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	151.00
Bottom of Test Interval Depth, ft	161.50

Hydrostatic Pressure (P_0), psi	59.75
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	156.00
Vertical Center of Test Interval (D), ft	156.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	448.7
Bottom of Test Interval Elevation, ft	438.2

Start Time: | Packer Pressure, psi: 125

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				90.7		0	6,176.5						
15-4A	59.7	89.7	saturated	91.0	90.9	1	6,182.8	6.33	31.19	72.0	3.80E-04	34.8	
15-4B	59.7	89.7	saturated	90.8	90.7	3	6,195.7	6.43	31.00	71.5	3.88E-04	35.6	
15-4C	59.7	89.7	saturated	90.8	90.8	5	6,208.4	6.35	31.02	71.6	3.83E-04	35.1	
15-4D	59.7	89.7	saturated	90.7	90.7	10	6,239.6	6.24	30.93	71.4	3.78E-04	34.6	
15-4E	59.7	89.7	saturated	91.1	91.1	15	6,271.2	6.32	31.32	72.3	3.78E-04	34.6	
Test Averages/Summary													
15-4	**59.7**	**89.7**	**saturated**	**90.8**	**90.8**	**15**	**94.7**	**6.33**	**31.09**	**71.73**	**3.81E-04**	**34.9**	

Notes:

Start Time: | Packer Pressure, psi: 125

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				75.1		0	6,275.1						
15-5A	59.7	74.7	saturated	75.1	75.1	1	6,279.6	4.47	15.32	35.3	5.46E-04	50.0	
15-5B	59.7	74.7	saturated	75.1	75.1	3	6,287.4	3.90	15.36	35.4	4.75E-04	43.6	
15-5C	59.7	74.7	saturated	75.3	75.3	5	6,295.1	3.88	15.57	35.9	4.67E-04	42.7	
15-5D	59.7	74.7	saturated	75.3	75.3	10	6,315.1	4.00	15.52	35.8	4.82E-04	44.2	
15-5E	59.7	74.7	saturated	75.4	75.4	15	6,334.6	3.90	15.64	36.1	4.67E-04	42.7	
Test Averages/Summary													
15-5	**59.7**	**74.7**	**saturated**	**75.2**	**75.2**	**15**	**59.5**	**4.03**	**15.48**	**35.72**	**4.87E-04**	**44.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	16
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	140.50
Bottom of Test Interval Depth, ft	151.00

Hydrostatic Pressure (P_0), psi	55.09
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	145.50
Vertical Center of Test Interval (D), ft	145.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	459.2
Bottom of Test Interval Elevation, ft	448.7

Start Time: | Packer Pressure, psi: 110

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				69.1		0	6,338.1						
16-1A	55.1	70.1	saturated	69.2	69.2	1	6,338.1	0.00	14.14	32.6	0.00E+00	0.0	
16-1B	55.1	70.1	saturated	69.4	69.4	3	6,338.1	0.00	14.31	33.0	0.00E+00	0.0	
16-1C	55.1	70.1	saturated	69.5	69.5	5	6,338.1	0.00	14.40	33.2	0.00E+00	0.0	
16-1D	55.1	70.1	saturated	69.7	69.7	10	6,338.1	0.00	14.61	33.7	0.00E+00	0.0	
16-1E	55.1	70.1	saturated	69.9	69.9	15	6,338.1	0.00	14.78	34.1	0.00E+00	0.0	
Test Averages/Summary													
16-1	**55.1**	**70.1**	**saturated**	**69.5**	**69.5**	**15**	**0.0**	**0.00**	**14.45**	**33.33**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 110

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				85.9		0	6,339.6						
16-2A	55.1	85.1	saturated	85.7	85.7	1	6,340.0	0.38	30.64	70.7	2.32E-05	2.1	
16-2B	55.1	85.1	saturated	82.0	82.0	3	6,340.4	0.18	26.93	62.1	1.29E-05	1.2	
16-2C	55.1	85.1	saturated	86.3	86.3	5	6,340.9	0.26	31.22	72.0	1.53E-05	1.4	
16-2D	55.1	85.1	saturated	85.4	85.4	10	6,341.7	0.16	30.27	69.8	9.77E-06	0.9	
16-2E	55.1	85.1	saturated	85.7	85.7	15	6,342.3	0.12	30.58	70.6	7.23E-06	0.7	
Test Averages/Summary													
16-2	**55.1**	**85.1**	**saturated**	**85.2**	**85.2**	**15**	**2.6**	**0.22**	**29.93**	**69.05**	**1.37E-05**	**1.3**	

Notes: Overcorrected pressure spike between 16-2A and 16-2B.

Start Time: | Packer Pressure, psi: 110

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				99.4		0	6,343.5						
16-3A	55.1	100.1	saturated	99.6	99.6	1	6,344.5	1.02	44.47	102.6	4.30E-05	3.9	
16-3B	55.1	100.1	saturated	99.7	99.7	3	6,346.6	1.03	44.63	103.0	4.34E-05	4.0	
16-3C	55.1	100.1	saturated	100.2	100.1	5	6,348.8	1.08	45.06	103.9	4.47E-05	4.1	
16-3D	55.1	100.1	saturated	100.6	100.6	10	6,353.6	0.96	45.50	105.0	3.95E-05	3.6	
16-3E	55.1	100.1	saturated	100.7	100.7	15	6,358.1	0.90	45.59	105.2	3.71E-05	3.4	
Test Averages/Summary													
16-3	**55.1**	**100.1**	**saturated**	**100.0**	**100.0**	**15**	**14.5**	**1.00**	**45.05**	**103.93**	**4.15E-05**	**3.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	16
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	140.50
Bottom of Test Interval Depth, ft	151.00

Hydrostatic Pressure (P_0), psi	55.09
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	145.50
Vertical Center of Test Interval (D), ft	145.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	459.2
Bottom of Test Interval Elevation, ft	448.7

Start Time: | Packer Pressure, psi: 110

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				86.2		0	6,359.0						
16-4A	55.1	85.1	saturated	84.4	84.4	1	6,359.1	0.13	29.32	67.6	8.30E-06	0.8	III
16-4B	55.1	85.1	saturated	84.6	84.6	3	6,359.4	0.13	29.48	68.0	8.26E-06	0.8	III
16-4C	55.1	85.1	saturated	84.6	84.6	5	6,359.6	0.12	29.51	68.1	7.62E-06	0.7	III
16-4D	55.1	85.1	saturated	84.5	84.5	10	6,360.0	0.08	29.39	67.8	5.35E-06	0.5	II
16-4E	55.1	85.1	saturated	84.9	84.9	15	6,360.3	0.05	29.82	68.8	3.27E-06	0.3	I
Test Averages/Summary													
16-4	**55.1**	**85.1**	**saturated**	**84.9**	**84.9**	**15**	**1.3**	**0.10**	**29.50**	**68.06**	**6.56E-06**	**0.6**	II

Notes:

Start Time: | Packer Pressure, psi: 110

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				69.9		0	6,360.3						
16-5A	55.1	70.1	saturated	69.9	69.9	1	6,360.3	0.00	14.80	34.2	0.00E+00	0.0	
16-5B	55.1	70.1	saturated	70.0	70.0	3	6,360.3	0.00	14.89	34.4	0.00E+00	0.0	
16-5C	55.1	70.1	saturated	70.0	70.0	5	6,360.3	0.00	14.90	34.4	0.00E+00	0.0	
16-5D	55.1	70.1	saturated	70.2	70.1	10	6,360.3	0.00	15.05	34.7	0.00E+00	0.0	
16-5E	55.1	70.1	saturated	70.2	70.2	15	6,360.3	0.00	15.13	34.9	0.00E+00	0.0	
Test Averages/Summary													
16-5	**55.1**	**70.1**	**saturated**	**70.0**	**70.0**	**15**	**0.0**	**0.00**	**14.96**	**34.50**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	17
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	130.00
Bottom of Test Interval Depth, ft	140.50

Hydrostatic Pressure (P_0), psi	50.58
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	135.00
Vertical Center of Test Interval (D), ft	135.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	469.7
Bottom of Test Interval Elevation, ft	459.2

Start Time: | Packer Pressure, psi: 90

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				60.7		0	6,361.8						
17-1A	50.6	60.0	saturated	60.7	60.7	1	6,361.8	0.00	10.14	23.4	0.00E+00	0.0	
17-1B	50.6	60.0	saturated	60.0	60.0	3	6,361.8	0.00	9.38	21.6	0.00E+00	0.0	
17-1C	50.6	60.0	saturated	60.0	60.0	5	6,361.8	0.00	9.45	21.8	0.00E+00	0.0	
17-1D	50.6	60.0	saturated	60.1	60.1	10	6,361.8	0.00	9.55	22.0	0.00E+00	0.0	
17-1E	50.6	60.0	saturated	60.3	60.3	15	6,361.8	0.00	9.70	22.4	0.00E+00	0.0	
Test Averages/Summary													
17-1	**50.6**	**60.0**	**saturated**	**60.3**	**60.3**	**15**	**0.0**	**0.00**	**9.64**	**22.24**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 90

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				70.6		0	6,362.5						
17-2A	50.6	70.0	saturated	70.5	70.5	1	6,362.5	0.00	19.94	46.0	0.00E+00	0.0	
17-2B	50.6	70.0	saturated	70.5	70.5	3	6,362.5	0.00	19.91	45.9	0.00E+00	0.0	
17-2C	50.6	70.0	saturated	70.7	70.6	5	6,362.5	0.00	20.07	46.3	0.00E+00	0.0	
17-2D	50.6	70.0	saturated	70.1	70.1	10	6,362.5	0.00	19.51	45.0	0.00E+00	0.0	
17-2E	50.6	70.0	saturated	70.2	70.2	15	6,362.5	0.00	19.61	45.2	0.00E+00	0.0	
Test Averages/Summary													
17-2	**50.6**	**70.0**	**saturated**	**70.4**	**70.4**	**15**	**0.0**	**0.00**	**19.81**	**45.69**	**0.00E+00**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 90

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.1		0	6,364.6						
17-3A	50.6	80.0	saturated	79.6	79.6	1	6,364.9	0.25	29.03	67.0	1.61E-05	1.5	
17-3B	50.6	80.0	saturated	79.6	79.6	3	6,365.4	0.24	28.98	66.9	1.55E-05	1.4	
17-3C	50.6	80.0	saturated	79.8	79.7	5	6,365.7	0.19	29.16	67.3	1.22E-05	1.1	
17-3D	50.6	80.0	saturated	80.5	80.5	10	6,366.8	0.20	29.88	68.9	1.28E-05	1.2	
17-3E	50.6	80.0	saturated	80.8	80.7	15	6,367.7	0.19	30.16	69.6	1.17E-05	1.1	
Test Averages/Summary													
17-3	**50.6**	**80.0**	**saturated**	**80.0**	**80.0**	**15**	**3.1**	**0.21**	**29.44**	**67.92**	**1.37E-05**	**1.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/5/2019
WSP Personnel	K. Williams
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-17
Test Number	17
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	130.00
Bottom of Test Interval Depth, ft	140.50

Hydrostatic Pressure (P_0), psi	50.58
Transducer Zero Reading (R_0)	0.016
Dist from Top Packer to Transducer, ft	5.0
Transducer Depth, ft	135.00
Vertical Center of Test Interval (D), ft	135.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	17.84
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	469.7
Bottom of Test Interval Elevation, ft	459.2

Start Time: | Packer Pressure, psi: 90

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				70.0		0	6,367.7						
17-4A	50.6	70.0	saturated	70.1	70.1	1	6,367.7	0.00	19.51	45.0	0.00E+00	0.0	
17-4B	50.6	70.0	saturated	70.3	70.2	3	6,367.7	0.00	19.65	45.3	0.00E+00	0.0	
17-4C	50.6	70.0	saturated	70.4	70.4	5	6,367.7	0.00	19.80	45.7	0.00E+00	0.0	
17-4D	50.6	70.0	saturated	71.1	71.0	10	6,367.7	0.00	20.46	47.2	1.83E-07	0.0	
17-4E	50.6	70.0	saturated	69.3	69.2	15	6,367.7	0.00	18.66	43.0	0.00E+00	0.0	
Test Averages/Summary													
17-4	**50.6**	**70.0**	**saturated**	**70.2**	**70.2**	**15**	**0.0**	**0.00**	**19.62**	**45.26**	**3.66E-08**	**0.0**	

Notes:

Start Time: | Packer Pressure, psi: 90

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				59.1		0	6,368.1						
17-5A	50.6	60.0	saturated	59.1	59.0	1	6,368.1	0.00	8.47	19.5	0.00E+00	0.0	
17-5B	50.6	60.0	saturated	59.2	59.1	3	6,368.1	0.00	8.56	19.7	0.00E+00	0.0	
17-5C	50.6	60.0	saturated	59.2	59.2	5	6,368.1	0.00	8.58	19.8	0.00E+00	0.0	
17-5D	50.6	60.0	saturated	59.2	59.2	10	6,368.1	0.00	8.62	19.9	0.00E+00	0.0	
17-5E	50.6	60.0	saturated	59.3	59.3	15	6,368.1	0.00	8.67	20.0	0.00E+00	0.0	
Test Averages/Summary													
17-5	**50.6**	**60.0**	**saturated**	**59.2**	**59.2**	**15**	**0.0**	**0.00**	**8.58**	**19.79**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	10/27/19
WSP Personel	C. Zhang
Driller	Fugro
Operator	T. Brindle/A. Fudge
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	11.8
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-19
Number of Tests	1
Lattitude	45.82346°N
Longitude	84.76282°W

Top of Rock, ft	63.6
Bottom of Boring, ft	200.3
Lake Depth, ft	135.2

Datum (Mudline) Elevation	446.5
Top of Rock Elevation, ft	382.9
Bottom of Hole Elevation, ft	246.2
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.0	14.5	Saturated	0.4	0.1	109.3	0.4	0.1	24.1	55.7	6.78E-06	0.7		
1-2	2.0	29.0	Saturated	14.3	3.8	109.3	0.8	0.2	38.6	89.1	8.37E-06	0.8		
1-3	3.0	43.5	Saturated	47.0	12.4	109.3	3.0	0.8	53.0	122.4	2.35E-05	2.3		
1-4	2.0	29.0	Saturated	15.1	4.0	109.3	1.1	0.3	38.6	89.1	1.19E-05	1.2		
1-5	1.0	14.5	Saturated	7.4	2.0	109.3	0.5	0.1	24.1	55.7	8.30E-06	0.8		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	10/27/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	T. Brindle/A. Fudge

Boring ID	BH19-19
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	111.2
Bottom of Test Interval Depth, ft	122.9

Estimated Hydrostatic Pressure, psi	109.3
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	117.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	135.2		
Datum (Mudline) Elevation, ft	446.5		
Top of Test Interval Elevation, ft	335.3		
Bottom of Test Interval Elevation, ft	323.6		
Rubber Hose Length, ft	52.5		
# of NQ Rods	21	# of HWY Rods	8

Note:

Start Time: 08:22 | Stage/Packer Pressure, bar: 40 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				34885.1	9209.7	0							
1-1A	1.0	14.5	Saturated	34885.5	9209.8	1	0.4	0.1	24.1	55.7	6.78E-06	0.7	
1-1B	1.0	14.5	Saturated	34883.6	9209.3	3	(1.0)	(0.3)					
1-1C	1.0	14.5	Saturated	34882.9	9209.1	5	(0.3)	(0.1)					
1-1D	1.0	14.5	Saturated	34881.9	9208.8	10	(0.2)	(0.1)					
1-1E	1.0	14.5	Saturated	34878.9	9208.0	15	(0.6)	(0.2)					
Test Averages/Summary													
1-1	**1.0**	**14.5**	**Saturated**	**0.4**	**0.1**	**15**	**0.4**	**0.1**	**24.1**	**55.7**	**6.78E-06**	**0.7**	

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Start Time: 08:38 | Stage/Packer Pressure, bar: 35 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				34879.6	9208.2	0							
1-2A	2.0	29.0	Saturated	34880.0	9208.3	1	0.4	0.1	38.6	89.1	4.23E-06	0.4	
1-2B	2.0	29.0	Saturated	34881.6	9208.7	4	0.5	0.1	38.6	89.1	5.64E-06	0.6	
1-2C	2.0	29.0	Saturated	34882.3	9208.9	5	0.7	0.2	38.6	89.1	7.41E-06	0.7	
1-2D	2.0	29.0	Saturated	34888.8	9210.6	10	1.3	0.3	38.6	89.1	1.38E-05	1.4	
1-2E	2.0	29.0	Saturated	34893.9	9212.0	15	1.0	0.3	38.6	89.1	1.08E-05	1.1	
Test Averages/Summary													
1-2	**2.0**	**29.0**	**Saturated**	**14.3**	**3.8**	**15**	**0.8**	**0.2**	**38.6**	**89.1**	**8.37E-06**	**0.8**	

Notes:

Start Time: 08:54 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				34896.9	9212.8	0							
1-3A	3.0	43.5	Saturated	34899.6	9213.5	1	2.7	0.7	53.0	122.4	2.08E-05	2.1	
1-3B	3.0	43.5	Saturated	34905.9	9215.2	3	3.2	0.8	53.0	122.4	2.43E-05	2.4	
1-3C	3.0	43.5	Saturated	34911.9	9216.7	5	3.0	0.8	53.0	122.4	2.31E-05	2.3	
1-3D	3.0	43.5	Saturated	34926.9	9220.7	10	3.0	0.8	53.0	122.4	2.31E-05	2.3	
1-3E	3.0	43.5	Saturated	34943.9	9225.2	15	3.4	0.9	53.0	122.4	2.62E-05	2.6	
Test Averages/Summary													
1-3	**3.0**	**43.5**	**Saturated**	**47.0**	**12.4**	**15**	**3.0**	**0.8**	**53.0**	**122.4**	**2.35E-05**	**2.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	10/27/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	T. Brindle/A. Fudge

Boring ID	BH19-19
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	111.2
Bottom of Test Interval Depth, ft	122.9

Estimated Hydrostatic Pressure, psi	109.3
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	117.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	135.2		
Datum (Mudline) Elevation, ft	446.5		
Top of Test Interval Elevation, ft	335.3		
Bottom of Test Interval Elevation, ft	323.6		
Rubber Hose Length, ft	52.5		
# of NQ Rods	21	# of HWY Rods	8

Note:

Start Time: 09:10 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
				34946.2	9225.8	0						
1-4A	2.0	29.0	Saturated	34947.8	9226.2	1	1.6	0.4	38.6	89.1	1.69E-05	1.7
1-4B	2.0	29.0	Saturated	34950.4	9226.9	3	1.3	0.3	38.6	89.1	1.38E-05	1.4
1-4C	2.0	29.0	Saturated	34952.2	9227.4	5	0.9	0.2	38.6	89.1	9.52E-06	0.9
1-4D	2.0	29.0	Saturated	34957.0	9228.6	10	1.0	0.3	38.6	89.1	1.02E-05	1.0
1-4E	2.0	29.0	Saturated	34961.3	9229.8	15	0.9	0.2	38.6	89.1	9.10E-06	0.9
Test Averages/Summary												
1-4	**2.0**	**29.0**	**Saturated**	**15.1**	**4.0**	**15**	**1.1**	**0.3**	**38.6**	**89.1**	**1.19E-05**	**1.2**

Notes:

Start Time: 09:28 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
				34961.6	9229.9	0						
1-5A	1.0	14.5	Saturated	34962.1	9230.0	1	0.5	0.1	24.1	55.7	8.47E-06	0.8
1-5B	1.0	14.5	Saturated	34963.1	9230.3	3	0.5	0.1	24.1	55.7	8.47E-06	0.8
1-5C	1.0	14.5	Saturated	34964.0	9230.5	5	0.5	0.1	24.1	55.7	7.62E-06	0.8
1-5D	1.0	14.5	Saturated	34967.6	9231.4	10	0.7	0.2	24.1	55.7	1.22E-05	1.2
1-5E	1.0	14.5	Saturated	34969.0	9231.8	15	0.3	0.1	24.1	55.7	4.74E-06	0.5
Test Averages/Summary												
1-5	**1.0**	**14.5**	**Saturated**	**7.4**	**2.0**	**15**	**0.5**	**0.1**	**24.1**	**55.7**	**8.30E-06**	**0.8**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	11/09/19
WSP Personel	D. Mein/A. Hesse/K. Hanson
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	58.9
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-24A
Number of Tests	5
Lattitude	45.81814°N
Longitude	84.76479°W

Top of Rock, ft	223.00
Bottom of Boring, ft	316.30
Lake Depth, ft	225.00

Datum (Mudline) Elevation	356.70
Top of Rock Elevation, ft	133.70
Bottom of Hole Elevation, ft	40.40
Lake Level Elevation, ft	581.70

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.1	15.9	saturated	41.0	10.8	223.5	2.8	0.7	25.6	59.0	4.44E-05	4.4		
1-2	2.1	30.7	saturated	48.6	12.8	223.5	3.5	0.9	40.3	93.0	3.58E-05	3.5		
1-3	3.2	45.8	saturated	52.8	13.9	223.5	3.6	0.9	55.4	127.8	2.65E-05	2.6		
1-4	2.0	29.0	saturated	32.6	8.6	223.5	2.1	0.5	38.6	89.1	2.17E-05	2.1		
1-5	1.1	15.7	saturated	18.0	4.8	223.5	1.2	0.3	25.3	58.4	1.95E-05	1.9		
2-1	1.0	14.5	saturated	19.5	5.1	219.2	1.4	0.4	24.1	55.7	2.39E-05	2.4		
2-2	2.1	29.9	saturated	25.8	6.8	219.2	1.8	0.5	39.5	91.1	1.84E-05	1.8		
2-3	3.1	44.7	saturated	36.6	9.7	219.2	2.4	0.6	54.3	125.3	1.83E-05	1.8		
2-4	2.0	29.0	saturated	25.7	6.8	219.2	1.7	0.4	38.6	89.1	1.80E-05	1.8		
2-5	1.0	14.8	saturated	14.7	3.9	219.2	1.0	0.3	24.4	56.4	1.63E-05	1.6		
3-1	1.3	18.8	saturated	15.1	4.0	215.0	1.0	0.3	28.5	65.7	1.40E-05	1.4		
3-2	2.0	29.0	saturated	27.6	7.3	215.0	1.8	0.5	38.6	89.1	1.88E-05	1.9		
3-3	3.0	43.8	saturated	37.3	9.8	215.0	2.5	0.7	53.4	123.2	1.93E-05	1.9		
3-4	2.0	29.0	saturated	26.5	7.0	215.0	1.8	0.5	38.6	89.1	1.87E-05	1.8		
3-5	1.0	14.5	saturated	11.0	2.9	215.0	0.6	0.2	24.1	55.7	1.07E-05	1.1		
4-1	1.0	14.5	saturated	39.6	10.5	210.7	2.74	0.72	24.1	55.7	4.64E-05	4.6		
4-2	2.0	29.0	saturated	142.6	37.6	210.7	9.53	2.52	38.2	88.0	1.02E-04	10.1		
4-3	2.9	41.5	saturated	358.9	94.7	210.7	25.47	6.72	46.9	108.3	2.22E-04	21.9		
4-4	2.0	29.3	saturated	235.9	62.3	210.7	15.89	4.19	37.4	86.3	1.74E-04	17.1		
4-5	1.0	13.9	saturated	34.1	9.0	210.7	2.55	0.67	23.6	54.3	4.41E-05	4.4		
5-1	1.0	14.5	saturated	18.3	4.8	205.6	1.44	0.38	24.1	55.7	2.42E-05	2.4		
5-2	2.0	28.4	saturated	40.7	10.7	205.6	2.77	0.73	38.1	87.8	2.98E-05	2.9		
5-3	3.2	46.1	saturated	61.7	16.3	205.6	4.83	1.28	55.7	128.4	3.55E-05	3.5		
5-4	2.0	28.4	saturated	32.4	8.6	205.6	2.17	0.57	38.1	87.8	2.33E-05	2.3		
5-5	1.1	16.2	saturated	15.9	4.2	205.6	1.02	0.27	25.9	59.7	1.60E-05	1.6		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	284.8
Bottom of Test Interval Depth, ft	296.6

Estimated Hydrostatic Pressure, psi	223.5
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	290.7
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0
Datum (Mudline) Elevation, ft	356.7
Top of Test Interval Elevation, ft	71.9
Bottom of Test Interval Elevation, ft	60.1
Rubber Hose Length, ft	52.5
# of NQ Rods	56
# of HWY Rods	0

Note:

Start Time 03:26 | Stage/Packer Pressure, bar 25 | Friction Loss, *f*, ft 0.0 | Target Pressure, Bar 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		21059.7	5559.8	0							
1-1A	1.1	15.9	saturated	21062.6	5560.5	1	2.9	0.8	25.6	59.0	4.63E-05	4.6	
1-1B	1.1	15.9	saturated	21068.3	5562.0	3	2.9	0.8	25.6	59.0	4.55E-05	4.5	
1-1C	1.1	15.9	saturated	21073.8	5563.5	5	2.8	0.7	25.6	59.0	4.39E-05	4.3	
1-1D	1.1	15.9	saturated	21087.3	5567.0	10	2.7	0.7	25.6	59.0	4.31E-05	4.3	
1-1E	1.1	15.9	saturated	21100.7	5570.6	15	2.7	0.7	25.6	59.0	4.28E-05	4.2	
Test Averages/Summary													
1-1	**1.1**	**15.9**	**saturated**	**41.0**	**10.8**	**15**	**2.8**	**0.7**	**25.6**	**59.0**	**4.44E-05**	**4.4**	

Notes: Depth between 284.8 ft and 296.6 ft was retested. The initial test was stopped due to tank being empty. Transducers were not working consistantly. Flow readings were recorded from the analogue gauge.

Start Time 03:42 | Stage/Packer Pressure, bar 25 | Friction Loss, *f*, ft 0.1 | Target Pressure, Bar 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		21106.0	5572.0	0							
1-2A	2.3	33.3	saturated	21110.6	5573.2	1	4.6	1.2	42.9	99.1	4.38E-05	4.3	
1-2B	2.0	29.0	saturated	21118.1	5575.2	3	3.8	1.0	38.6	89.0	3.97E-05	3.9	
1-2C	2.0	29.0	saturated	21124.9	5577.0	5	3.4	0.9	38.6	89.0	3.60E-05	3.6	
1-2D	2.1	30.4	saturated	21140.1	5581.0	10	3.0	0.8	40.0	92.4	3.10E-05	3.1	
1-2E	2.2	31.9	saturated	21154.6	5584.8	15	2.9	0.8	41.5	95.7	2.86E-05	2.8	
Test Averages/Summary													
1-2	**2.1**	**30.7**	**saturated**	**48.6**	**12.8**	**15**	**3.5**	**0.9**	**40.3**	**93.0**	**3.58E-05**	**3.5**	

Notes: Depth between 284.8 ft and 296.6 ft was retested. The initial test was stopped due to tank being empty. Transducers were not working consistantly. Flow readings were recorded from the analogue gauge.

Start Time 03:59 | Stage/Packer Pressure, bar 25 | Friction Loss, *f*, ft 0.1 | Target Pressure, Bar 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.1	44.9		21162.8	5587.0	0							
1-3A	3.1	44.9	saturated	21166.6	5588.0	1	3.8	1.0	54.5	125.8	2.85E-05	2.8	
1-3B	3.2	46.4	saturated	21173.8	5589.9	3	3.6	1.0	56.0	129.2	2.63E-05	2.6	
1-3C	3.2	46.4	saturated	21181.0	5591.8	5	3.6	1.0	56.0	129.2	2.63E-05	2.6	
1-3D	3.3	47.8	saturated	21198.8	5596.5	10	3.6	0.9	57.4	132.5	2.53E-05	2.5	
1-3E	3.0	43.5	saturated	21215.6	5600.9	15	3.4	0.9	53.1	122.5	2.59E-05	2.6	
Test Averages/Summary													
1-3	**3.2**	**45.8**	**saturated**	**52.8**	**13.9**	**15**	**3.6**	**0.9**	**55.4**	**127.8**	**2.65E-05**	**2.6**	

Notes: Depth between 284.8 ft and 296.6 ft was retested. The initial test was stopped due to tank being empty. Transducers were not working consistantly. Flow readings were recorded from the analogue gauge.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	284.8
Bottom of Test Interval Depth, ft	296.6

Estimated Hydrostatic Pressure, psi	223.5
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	290.7
Test Interval Length (L), ft	11.8

Lake Depth, ft			225.0
Datum (Mudline) Elevation, ft			356.7
Top of Test Interval Elevation, ft			71.9
Bottom of Test Interval Elevation, ft			60.1
Rubber Hose Length, ft			52.5
# of NQ Rods	56	# of HWY Rods	0

Note:

Start Time: 04:17 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		21221.8	5602.6	0							
1-4A	2.0	29.0	saturated	21223.1	5602.9	1	1.3	0.3	38.6	89.1	1.38E-05	1.4	
1-4B	2.0	29.0	saturated	21227.7	5604.1	3	2.3	0.6	38.6	89.1	2.43E-05	2.4	
1-4C	2.0	29.0	saturated	21232.1	5605.3	5	2.2	0.6	38.6	89.1	2.33E-05	2.3	
1-4D	2.0	29.0	saturated	21243.1	5608.2	10	2.2	0.6	38.6	89.1	2.33E-05	2.3	
1-4E	2.0	29.0	saturated	21254.4	5611.2	15	2.3	0.6	38.6	89.1	2.39E-05	2.4	
Test Averages/Summary													
1-4	**2.0**	**29.0**	**saturated**	**32.6**	**8.6**	**15**	**2.1**	**0.5**	**38.6**	**89.1**	**2.17E-05**	**2.1**	

Notes: Depth between 284.8 ft and 296.6 ft was retested. The initial test was stopped due to tank being empty. Transducers were not working consistantly. Flow readings were recorded from the analogue gauge.

Start Time: 04:33 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		21256.0	5611.6	0							
1-5A	1.1	15.9	saturated	21257.2	5611.9	1	1.2	0.3	25.6	59.0	1.92E-05	1.9	
1-5B	1.1	15.9	saturated	21260.7	5612.8	3	1.8	0.5	25.6	59.0	2.80E-05	2.8	
1-5C	1.1	15.9	saturated	21262.1	5613.2	5	0.7	0.2	25.6	59.0	1.12E-05	1.1	
1-5D	1.1	15.9	saturated	21268.0	5614.8	10	1.2	0.3	25.6	59.0	1.89E-05	1.9	
1-5E	1.0	14.5	saturated	21274.0	5616.3	15	1.2	0.3	24.1	55.7	2.03E-05	2.0	
Test Averages/Summary													
1-5	**1.1**	**15.7**	**saturated**	**18.0**	**4.8**	**15**	**1.2**	**0.3**	**25.3**	**58.4**	**1.95E-05**	**1.9**	

Notes: Depth between 284.8 ft and 296.6 ft was retested. The initial test was stopped due to tank being empty. Transducers were not working consistantly. Flow readings were recorded from the analogue gauge.

FUG

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	275.0
Bottom of Test Interval Depth, ft	286.8

Estimated Hydrostatic Pressure, psi	219.2
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	280.9
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0		
Datum (Mudline) Elevation, ft	356.7		
Top of Test Interval Elevation, ft	81.7		
Bottom of Test Interval Elevation, ft	69.9		
Rubber Hose Length, ft	52.5		
# of NQ Rods	55	# of HWY Rods	0

Note:

Start Time: 05:54 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		21420.2	5654.9	0							
2-1A	1.0	14.5	saturated	21421.9	5655.4	1	1.7	0.4	24.1	55.7	2.88E-05	2.8	
2-1B	1.0	14.5	saturated	21424.6	5656.1	3	1.3	0.4	24.1	55.7	2.29E-05	2.3	
2-1C	1.0	14.5	saturated	21427.9	5657.0	5	1.7	0.4	24.1	55.7	2.79E-05	2.8	
2-1D	1.0	14.5	saturated	21433.4	5658.4	10	1.1	0.3	24.1	55.7	1.86E-05	1.8	
2-1E	1.0	14.5	saturated	21439.7	5660.1	15	1.3	0.3	24.1	55.7	2.13E-05	2.1	
Test Averages/Summary													
2-1	**1.0**	**14.5**	**saturated**	**19.5**	**5.1**	**15**	**1.4**	**0.4**	**24.1**	**55.7**	**2.39E-05**	**2.4**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 06:11 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		21443.8	5661.2	0							
2-2A	2.1	30.4	saturated	21445.7	5661.7	1	1.9	0.5	40.1	92.5	1.94E-05	1.9	
2-2B	2.1	30.4	saturated	21449.5	5662.7	3	1.9	0.5	40.1	92.5	1.94E-05	1.9	
2-2C	2.0	29.0	saturated	21453.1	5663.6	5	1.8	0.5	38.6	89.1	1.90E-05	1.9	
2-2D	2.1	30.4	saturated	21461.6	5665.9	10	1.7	0.4	40.1	92.5	1.73E-05	1.7	
2-2E	2.0	29.0	saturated	21469.6	5668.0	15	1.6	0.4	38.6	89.1	1.69E-05	1.7	
Test Averages/Summary													
2-2	**2.1**	**29.9**	**saturated**	**25.8**	**6.8**	**15**	**1.8**	**0.5**	**39.5**	**91.1**	**1.84E-05**	**1.8**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 06:29 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		21474.7	5669.3	0							
2-3A	3.1	44.9	saturated	21477.1	5670.0	1	2.4	0.6	54.6	125.9	1.80E-05	1.8	
2-3B	3.1	44.9	saturated	21481.9	5671.2	3	2.4	0.6	54.6	125.9	1.80E-05	1.8	
2-3C	3.1	44.9	saturated	21486.8	5672.5	5	2.4	0.6	54.6	125.9	1.84E-05	1.8	
2-3D	3.1	44.9	saturated	21499.1	5675.8	10	2.5	0.6	54.6	125.9	1.84E-05	1.8	
2-3E	3.0	43.5	saturated	21511.3	5679.0	15	2.4	0.6	53.1	122.6	1.88E-05	1.9	
Test Averages/Summary													
2-3	**3.1**	**44.7**	**saturated**	**36.6**	**9.7**	**15**	**2.4**	**0.6**	**54.3**	**125.3**	**1.83E-05**	**1.8**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

FUG

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	275.0
Bottom of Test Interval Depth, ft	286.8

Estimated Hydrostatic Pressure, psi	219.2
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	280.9
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0		
Datum (Mudline) Elevation, ft	356.7		
Top of Test Interval Elevation, ft	81.7		
Bottom of Test Interval Elevation, ft	69.9		
Rubber Hose Length, ft	52.5		
# of NQ Rods	55	# of HWY Rods	0

Note:

Start Time: 06:46 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		21514.1	5679.7	0							
2-4A	2.0	29.0	saturated	21515.7	5680.1	1	1.6	0.4	38.6	89.1	1.69E-05	1.7	
2-4B	2.0	29.0	saturated	21519.2	5681.1	3	1.8	0.5	38.6	89.1	1.85E-05	1.8	
2-4C	2.0	29.0	saturated	21522.7	5682.0	5	1.8	0.5	38.6	89.1	1.85E-05	1.8	
2-4D	2.0	29.0	saturated	21532.3	5684.5	10	1.9	0.5	38.6	89.1	2.03E-05	2.0	
2-4E	2.0	29.0	saturated	21539.8	5686.5	15	1.5	0.4	38.6	89.1	1.59E-05	1.6	
Test Averages/Summary													
2-4	**2.0**	**29.0**	**saturated**	**25.7**	**6.8**	**15**	**1.7**	**0.4**	**38.6**	**89.1**	**1.80E-05**	**1.8**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 07:04 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		21542.2	5687.1	0							
2-5A	1.1	15.9	saturated	21543.1	5687.4	1	0.9	0.2	25.6	59.0	1.44E-05	1.4	
2-5B	1.0	14.5	saturated	21545.1	5687.9	3	1.0	0.3	24.1	55.7	1.69E-05	1.7	
2-5C	1.0	14.5	saturated	21547.1	5688.4	5	1.0	0.3	24.1	55.7	1.69E-05	1.7	
2-5D	1.0	14.5	saturated	21552.0	5689.7	10	1.0	0.3	24.1	55.7	1.66E-05	1.6	
2-5E	1.0	14.5	saturated	21556.9	5691.0	15	1.0	0.3	24.1	55.7	1.66E-05	1.6	
Test Averages/Summary													
2-5	**1.0**	**14.8**	**saturated**	**14.7**	**3.9**	**15**	**1.0**	**0.3**	**24.4**	**56.4**	**1.63E-05**	**1.6**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	265.2
Bottom of Test Interval Depth, ft	276.9

Estimated Hydrostatic Pressure, psi	215.0
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	271.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0
Datum (Mudline) Elevation, ft	356.7
Top of Test Interval Elevation, ft	91.5
Bottom of Test Interval Elevation, ft	79.8
Rubber Hose Length, ft	52.5
# of NQ Rods: 55	# of HWY Rods: 0

Note:

Start Time: 08:25 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.3	18.8		22100.0	5834.4	0							
3-1A	1.3	18.8	saturated	22101.0	5834.7	1	1.0	0.3	28.5	65.7	1.44E-05	1.4	
3-1B	1.3	18.8	saturated	22103.0	5835.2	3	1.0	0.3	28.5	65.7	1.44E-05	1.4	
3-1C	1.3	18.8	saturated	22104.5	5835.6	5	0.8	0.2	28.5	65.7	1.08E-05	1.1	
3-1D	1.3	18.8	saturated	22110.1	5837.1	10	1.1	0.3	28.5	65.7	1.61E-05	1.6	
3-1E	1.3	18.8	saturated	22115.1	5838.4	15	1.0	0.3	28.5	65.7	1.44E-05	1.4	
Test Averages/Summary													
3-1	**1.3**	**18.8**	**saturated**	**15.1**	**4.0**	**15**	**1.0**	**0.3**	**28.5**	**65.7**	**1.40E-05**	**1.4**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge. Increaesd actual pressure to maintain flow. At 1.0 bar system was stopped or backflowing.

Start Time: 08:44 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		22124.8	5840.9	0							
3-2A	2.0	29.0	saturated	22126.4	5841.4	1	1.6	0.4	38.6	89.1	1.69E-05	1.7	
3-2B	2.0	29.0	saturated	22130.9	5842.6	3	2.3	0.6	38.6	89.1	2.38E-05	2.4	
3-2C	2.0	29.0	saturated	22133.4	5843.2	5	1.3	0.3	38.6	89.1	1.32E-05	1.3	
3-2D	2.0	29.0	saturated	22143.1	5845.8	10	1.9	0.5	38.6	89.1	2.05E-05	2.0	
3-2E	2.0	29.0	saturated	22152.4	5848.2	15	1.9	0.5	38.6	89.1	1.97E-05	1.9	
Test Averages/Summary													
3-2	**2.0**	**29.0**	**saturated**	**27.6**	**7.3**	**15**	**1.8**	**0.5**	**38.6**	**89.1**	**1.88E-05**	**1.9**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 09:03 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		22163.0	5851.0	0							
3-3A	3.1	44.9	saturated	22165.8	5851.8	1	2.8	0.7	54.6	125.9	2.10E-05	2.1	
3-3B	3.0	43.5	saturated	22170.7	5853.1	3	2.5	0.6	53.1	122.6	1.89E-05	1.9	
3-3C	3.0	43.5	saturated	22175.6	5854.4	5	2.4	0.6	53.1	122.6	1.89E-05	1.9	
3-3D	3.0	43.5	saturated	22188.0	5857.6	10	2.5	0.7	53.1	122.6	1.91E-05	1.9	
3-3E	3.0	43.5	saturated	22200.3	5860.9	15	2.5	0.6	53.1	122.6	1.89E-05	1.9	
Test Averages/Summary													
3-3	**3.0**	**43.8**	**saturated**	**37.3**	**9.8**	**15**	**2.5**	**0.7**	**53.4**	**123.2**	**1.93E-05**	**1.9**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	265.2
Bottom of Test Interval Depth, ft	276.9

Estimated Hydrostatic Pressure, psi	215.0
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	271.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0		
Datum (Mudline) Elevation, ft	356.7		
Top of Test Interval Elevation, ft	91.5		
Bottom of Test Interval Elevation, ft	79.8		
Rubber Hose Length, ft	52.5		
# of NQ Rods	55	# of HWY Rods	0

Note:

Start Time: 09:21 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		22204.6	5862.0	0							
3-4A	2.0	29.0	saturated	22206.4	5862.5	1	1.8	0.5	38.6	89.1	1.90E-05	1.9	
3-4B	2.0	29.0	saturated	22210.9	5863.7	3	2.3	0.6	38.6	89.1	2.38E-05	2.4	
3-4C	2.0	29.0	saturated	22213.4	5864.3	5	1.3	0.3	38.6	89.1	1.32E-05	1.3	
3-4D	2.0	29.0	saturated	22222.2	5866.7	10	1.8	0.5	38.6	89.1	1.86E-05	1.8	
3-4E	2.0	29.0	saturated	22231.1	5869.0	15	1.8	0.5	38.6	89.1	1.88E-05	1.9	
Test Averages/Summary													
3-4	**2.0**	**29.0**	**saturated**	**26.5**	**7.0**	**15**	**1.8**	**0.5**	**38.6**	**89.1**	**1.87E-05**	**1.8**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 09:44 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		22234.1	5869.8	0							
3-5A	1.0	14.5	saturated	22234.1	5869.8	1	0.0	0.0	24.1	55.7	0.00E+00	0.0	
3-5B	1.0	14.5	saturated	22234.2	5869.8	3	0.1	0.0	24.1	55.7	8.47E-07	0.1	
3-5C	1.0	14.5	saturated	22237.3	5870.6	5	1.5	0.4	24.1	55.7	2.63E-05	2.6	
3-5D	1.0	14.5	saturated	22241.0	5871.6	10	0.7	0.2	24.1	55.7	1.25E-05	1.2	
3-5E	1.0	14.5	saturated	22245.1	5872.7	15	0.8	0.2	24.1	55.7	1.39E-05	1.4	
Test Averages/Summary													
3-5	**1.0**	**14.5**	**saturated**	**11.0**	**2.9**	**15**	**0.6**	**0.2**	**24.1**	**55.7**	**1.07E-05**	**1.1**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	255.3
Bottom of Test Interval Depth, ft	267.1

Estimated Hydrostatic Pressure, psi	210.7
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	261.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0
Datum (Mudline) Elevation, ft	356.7
Top of Test Interval Elevation, ft	101.4
Bottom of Test Interval Elevation, ft	89.6
Rubber Hose Length, ft	52.5
# of NQ Rods: 55	# of HWY Rods: 0

Note:

Start Time: 11:00 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.0	14.5		22674.8	5986.1	0						
4-1A	1.0	14.5	saturated	22678.8	5987.2	1	4.0	1.1	24.1	55.7	6.78E-05	6.7
4-1B	1.0	14.5	saturated	22682.1	5988.1	3	1.6	0.4	24.1	55.7	2.79E-05	2.8
4-1C	1.0	14.5	saturated	22687.4	5989.5	5	2.7	0.7	24.1	55.7	4.49E-05	4.4
4-1D	1.0	14.5	saturated	22700.6	5993.0	10	2.6	0.7	24.1	55.7	4.47E-05	4.4
4-1E	1.0	14.5	saturated	22714.4	5996.6	15	2.8	0.7	24.1	55.7	4.67E-05	4.6
Test Averages/Summary												
4-1	**1.0**	**14.5**	**saturated**	**39.6**	**10.5**	**15**	**2.7**	**0.7**	**24.1**	**55.7**	**4.64E-05**	**4.6**

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 11:17 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 1.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		22733.7	6001.7	0						
4-2A	2.0	29.0	saturated	22743.8	6004.4	1	10.1	2.7	38.2	88.0	1.08E-04	10.7
4-2B	2.0	29.0	saturated	22761.2	6009.0	3	8.7	2.3	38.2	88.0	9.32E-05	9.2
4-2C	2.0	29.0	saturated	22780.7	6014.1	5	9.8	2.6	38.2	88.0	1.04E-04	10.3
4-2D	2.0	29.0	saturated	22827.4	6026.4	10	9.3	2.5	38.2	88.0	1.00E-04	9.9
4-2E	2.0	29.0	saturated	22876.3	6039.3	15	9.8	2.6	38.2	88.0	1.05E-04	10.3
Test Averages/Summary												
4-2	**2.0**	**29.0**	**saturated**	**142.6**	**37.6**	**15**	**9.5**	**2.5**	**38.2**	**88.0**	**1.02E-04**	**10.1**

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: 11:38 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 9.6 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.9	42.0		23063.0	6088.6	0						
4-3A	2.9	42.0	saturated	23094.6	6097.0	1	31.6	8.3	47.5	109.6	2.72E-04	26.8
4-3B	2.9	42.0	saturated	23155.5	6113.1	3	30.5	8.0	47.5	109.6	2.62E-04	25.9
4-3C	2.9	42.0	saturated	23195.6	6123.6	5	20.0	5.3	47.5	109.6	1.72E-04	17.0
4-3D	2.8	40.6	saturated	23268.8	6143.0	10	14.6	3.9	46.1	106.3	1.30E-04	12.8
4-3E	2.8	40.6	saturated	23421.9	6183.4	15	30.6	8.1	46.1	106.3	2.72E-04	26.8
Test Averages/Summary												
4-3	**2.9**	**41.5**	**saturated**	**358.9**	**94.7**	**15**	**25.5**	**6.7**	**46.9**	**108.3**	**2.22E-04**	**21.9**

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge. Valve open all way; not able to reach 3.0 bar.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	255.3
Bottom of Test Interval Depth, ft	267.1

Estimated Hydrostatic Pressure, psi	210.7
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	261.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0
Datum (Mudline) Elevation, ft	356.7
Top of Test Interval Elevation, ft	101.4
Bottom of Test Interval Elevation, ft	89.6
Rubber Hose Length, ft	52.5
# of NQ Rods	55
# of HWY Rods	0

Note:

Start Time: 11:53 | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 3.5 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		23453.0	6191.6	0							
4-4A	2.1	30.4	saturated	23470.0	6196.1	1	17.0	4.5	38.6	89.0	1.80E-04	17.8	
4-4B	2.0	29.0	saturated	23501.5	6204.4	3	15.8	4.2	37.1	85.6	1.73E-04	17.1	
4-4C	2.0	29.0	saturated	23532.2	6212.5	5	15.4	4.1	37.1	85.6	1.69E-04	16.7	
4-4D	2.0	29.0	saturated	23619.1	6235.4	10	17.4	4.6	37.1	85.6	1.91E-04	18.9	
4-4E	2.0	29.0	saturated	23688.9	6253.9	15	14.0	3.7	37.1	85.6	1.54E-04	15.2	
Test Averages/Summary													
4-4	**2.0**	**29.3**	**saturated**	**235.9**	**62.3**	**15**	**15.9**	**4.2**	**37.4**	**86.3**	**1.74E-04**	**17.1**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		23703.1	6257.6	0							
4-5A	1.0	14.5	saturated	23706.3	6258.5	1	3.2	0.8	24.1	55.7	5.42E-05	5.4	
4-5B	1.0	14.5	saturated	23710.7	6259.6	3	2.2	0.6	24.1	55.7	3.73E-05	3.7	
4-5C	1.0	14.5	saturated	23717.6	6261.4	5	3.4	0.9	24.1	55.7	5.84E-05	5.8	
4-5D	0.9	13.0	saturated	23727.2	6264.0	10	1.9	0.5	22.7	52.3	3.46E-05	3.4	
4-5E	0.9	13.0	saturated	23737.2	6266.6	15	2.0	0.5	22.7	52.3	3.60E-05	3.6	
Test Averages/Summary													
4-5	**1.0**	**13.9**	**saturated**	**34.1**	**9.0**	**15**	**2.6**	**0.7**	**23.6**	**54.3**	**4.41E-05**	**4.4**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	A. Hesse & K. Hanson
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	243.5
Bottom of Test Interval Depth, ft	255.3

Estimated Hydrostatic Pressure, psi	205.6
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	249.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0
Datum (Mudline) Elevation, ft	356.7
Top of Test Interval Elevation, ft	113.2
Bottom of Test Interval Elevation, ft	101.4
Rubber Hose Length, ft	52.5
# of NQ Rods: 55	# of HWY Rods: 0

Note:

Start Time: | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		24054.1	6350.3	0							
5-1A	1.0	14.5	saturated	24056.7	6351.0	1	2.6	0.7	24.1	55.7	4.40E-05	4.3	
5-1B	1.0	14.5	saturated	24058.6	6351.5	3	0.9	0.3	24.1	55.7	1.61E-05	1.6	
5-1C	1.1	15.9	saturated	24061.5	6352.2	5	1.5	0.4	25.6	59.0	2.32E-05	2.3	
5-1D	1.1	15.9	saturated	24068.3	6354.0	10	1.4	0.4	25.6	59.0	2.17E-05	2.1	
5-1E	0.8	11.6	saturated	24072.4	6355.1	15	0.8	0.2	21.2	49.0	1.58E-05	1.6	
Test Averages/Summary													
5-1	**1.0**	**14.5**	**saturated**	**18.3**	**4.8**	**15**	**1.4**	**0.4**	**24.1**	**55.7**	**2.42E-05**	**2.4**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		24077.2	6356.4	0							
5-2A	1.9	27.5	saturated	24080.2	6357.2	1	3.0	0.8	37.2	85.8	3.30E-05	3.3	
5-2B	2.0	29.0	saturated	24086.6	6358.9	3	3.2	0.8	38.6	89.1	3.39E-05	3.3	
5-2C	2.0	29.0	saturated	24091.3	6360.1	5	2.4	0.6	38.6	89.1	2.49E-05	2.5	
5-2D	2.0	29.0	saturated	24104.9	6363.7	10	2.7	0.7	38.6	89.1	2.88E-05	2.8	
5-2E	1.9	27.5	saturated	24117.9	6367.1	15	2.6	0.7	37.2	85.8	2.86E-05	2.8	
Test Averages/Summary													
5-2	**2.0**	**28.4**	**saturated**	**40.7**	**10.7**	**15**	**2.8**	**0.7**	**38.1**	**87.8**	**2.98E-05**	**2.9**	

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time: | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.4	49.3		24122.7	6368.4	0							
5-3A	3.2	46.4	saturated	24131.3	6370.7	1	8.6	2.3	55.9	129.1	6.28E-05	6.2	
5-3B	3.6	52.2	saturated	24139.7	6372.9	3	4.2	1.1	61.7	142.4	2.78E-05	2.7	
5-3C	3.0	43.5	saturated	24147.8	6375.0	5	4.0	1.1	53.0	122.4	3.12E-05	3.1	
5-3D	3.0	43.5	saturated	24166.2	6379.9	10	3.7	1.0	53.0	122.4	2.84E-05	2.8	
5-3E	3.1	44.9	saturated	24184.4	6384.7	15	3.6	1.0	54.5	125.7	2.73E-05	2.7	
Test Averages/Summary													
5-3	**3.2**	**46.1**	**saturated**	**61.7**	**16.3**	**15**	**4.8**	**1.3**	**55.7**	**128.4**	**3.55E-05**	**3.5**	

Notes: Pressure keeps creeping upl lowered manually multiple times towards end of test pressure droped - adjusted again. Sand pocket logged at depth of 74.76 - 75.4 meter (245.3 - 247.4 ft) below mudline. Took a long time to saturate thest interval with water, much longer than previous test zones. Possibly saturated/plugged up the sand zone.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/9/2019
WSP Personel	A. Hesse & K. Hanson
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-24A
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	243.5
Bottom of Test Interval Depth, ft	255.3

Estimated Hydrostatic Pressure, psi	205.6
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	249.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	225.0		
Datum (Mudline) Elevation, ft	356.7		
Top of Test Interval Elevation, ft	113.2		
Bottom of Test Interval Elevation, ft	101.4		
Rubber Hose Length, ft	52.5		
# of NQ Rods	55	# of HWY Rods	0

Note:

Start Time | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		24190.0	6386.2	0						
5-4A	1.9	27.5	saturated	24192.2	6386.7	1	2.2	0.6	37.2	85.8	2.42E-05	2.4
5-4B	1.9	27.5	saturated	24196.5	6387.9	3	2.1	0.6	37.2	85.8	2.36E-05	2.3
5-4C	2.0	29.0	saturated	24200.9	6389.0	5	2.2	0.6	38.6	89.1	2.33E-05	2.3
5-4D	2.0	29.0	saturated	24211.8	6391.9	10	2.2	0.6	38.6	89.1	2.31E-05	2.3
5-4E	2.0	29.0	saturated	24222.4	6394.7	15	2.1	0.6	38.6	89.1	2.24E-05	2.2
Test Averages/Summary												
5-4	**2.0**	**28.4**	**saturated**	**32.4**	**8.6**	**15**	**2.2**	**0.6**	**38.1**	**87.8**	**2.33E-05**	**2.3**

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Start Time | Stage/Packer Pressure, bar: 20 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.0	14.5		24224.3	6395.2	0						
5-5A	1.0	14.5	saturated	24225.1	6395.4	1	0.8	0.2	24.1	55.7	1.36E-05	1.3
5-5B	1.1	15.9	saturated	24227.2	6396.0	3	1.1	0.3	25.6	59.0	1.68E-05	1.7
5-5C	1.1	15.9	saturated	24229.3	6396.5	5	1.0	0.3	25.6	59.0	1.68E-05	1.7
5-5D	1.2	17.4	saturated	24235.7	6398.2	10	1.3	0.3	27.0	62.4	1.94E-05	1.9
5-5E	1.2	17.4	saturated	24240.2	6399.4	15	0.9	0.2	27.0	62.4	1.36E-05	1.3
Test Averages/Summary												
5-5	**1.1**	**16.2**	**saturated**	**15.9**	**4.2**	**15**	**1.0**	**0.3**	**25.9**	**59.7**	**1.60E-05**	**1.6**

Notes: Transducer cable not working consistently. Flow readings were recorded from analogue gauge.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	10/17/19
WSP Personel	C. Zhang
Driller	Fugro
Operator	T. Brindle
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	14.0
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-25
Number of Tests	1
Lattitude	45.81727°N
Longitude	84.76514°W

Top of Rock, ft	303.1
Bottom of Boring, ft	326.4
Lake Depth, ft	183.7

Datum (Mudline) Elevation	398.0
Top of Rock Elevation, ft	94.9
Bottom of Hole Elevation, ft	71.6
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.0	14.5	saturated	23.2	6.1	218.0	1.4	0.4	24.1	55.6	2.06E-05	1.9		
1-2	2.0	29.0	saturated	30.7	8.1	218.0	1.9	0.5	38.5	88.9	1.76E-05	1.7		
1-3	3.0	43.5	saturated	39.3	10.4	218.0	2.6	0.7	53.0	122.2	1.75E-05	1.7		
1-4	2.0	29.0	saturated	37.1	9.8	218.0	2.5	0.7	38.5	88.7	2.36E-05	2.2		
1-5	1.0	14.5	saturated	15.2	4.0	218.0	1.1	0.3	24.1	55.7	1.58E-05	1.5		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/17/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	T. Brindle

Boring ID	BH19-25
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	312.4
Bottom of Test Interval Depth, ft	326.4

Estimated Hydrostatic Pressure, psi	218.0
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	319.4
Test Interval Length (L), ft	14.0

Lake Depth, ft	183.7		
Datum (Mudline) Elevation, ft	398.0		
Top of Test Interval Elevation, ft	85.6		
Bottom of Test Interval Elevation, ft	71.6		
Rubber Hose Length, ft	52.5		
# of NQ Rods	14	# of HWY Rods	41

Note:

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				32164.6	8491.5	0							
1-1A	1.0	14.5	saturated	32165.0	8491.6	1	0.4	0.1	24.1	55.6	5.96E-06	0.6	
1-1B	1.0	14.5	saturated	32168.6	8492.5	3	1.8	0.5	24.1	55.6	2.68E-05	2.5	
1-1C	1.0	14.5	saturated	32171.5	8493.3	5	1.5	0.4	24.1	55.6	2.16E-05	2.0	
1-1D	1.0	14.5	saturated	32179.4	8495.4	10	1.6	0.4	24.1	55.6	2.35E-05	2.2	
1-1E	1.0	14.5	saturated	32187.8	8497.6	15	1.7	0.4	24.1	55.6	2.50E-05	2.4	
Test Averages/Summary													
1-1	**1.0**	**14.5**	**saturated**	**23.2**	**6.1**	**15**	**1.4**	**0.4**	**24.1**	**55.6**	**2.06E-05**	**1.9**	

Notes

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				32195.9	8499.7	0							
1-2A	2.0	29.0	saturated	32196.9	8500.0	1	1.0	0.3	38.5	88.9	9.31E-06	0.9	
1-2B	2.0	29.0	saturated	32201.9	8501.3	3	2.5	0.7	38.5	88.9	2.33E-05	2.2	
1-2C	2.0	29.0	saturated	32205.2	8502.2	5	1.6	0.4	38.5	88.9	1.54E-05	1.5	
1-2D	2.0	29.0	saturated	32215.8	8505.0	10	2.1	0.6	38.5	88.9	1.97E-05	1.9	
1-2E	2.0	29.0	saturated	32226.6	8507.8	15	2.2	0.6	38.5	88.9	2.01E-05	1.9	
Test Averages/Summary													
1-2	**2.0**	**29.0**	**saturated**	**30.7**	**8.1**	**15**	**1.9**	**0.5**	**38.5**	**88.9**	**1.76E-05**	**1.7**	

Notes

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				32231.7	8509.2	0							
1-3A	3.0	43.5	saturated	32234.2	8509.8	1	2.5	0.7	53.0	122.2	1.69E-05	1.6	
1-3B	3.0	43.5	saturated	32239.4	8511.2	3	2.6	0.7	53.0	122.2	1.76E-05	1.7	
1-3C	3.0	43.5	saturated	32244.4	8512.5	5	2.5	0.7	53.0	122.2	1.69E-05	1.6	
1-3D	3.0	43.5	saturated	32257.5	8516.0	10	2.6	0.7	53.0	122.2	1.78E-05	1.7	
1-3E	3.0	43.5	saturated	32271.0	8519.5	15	2.7	0.7	53.0	122.2	1.83E-05	1.7	
Test Averages/Summary													
1-3	**3.0**	**43.5**	**saturated**	**39.3**	**10.4**	**15**	**2.6**	**0.7**	**53.0**	**122.2**	**1.75E-05**	**1.7**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/17/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	T. Brindle

Boring ID	BH19-25
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	312.4
Bottom of Test Interval Depth, ft	326.4

Estimated Hydrostatic Pressure, psi	218.0
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	319.4
Test Interval Length (L), ft	14.0

Lake Depth, ft	183.7
Datum (Mudline) Elevation, ft	398.0
Top of Test Interval Elevation, ft	85.6
Bottom of Test Interval Elevation, ft	71.6
Rubber Hose Length, ft	52.5
# of NQ Rods: 14	# of HWY Rods: 41

Note:

Start Time: | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				32273.9	8520.3	0							
1-4A	2.0	29.0	saturated	32276.5	8521.0	1	2.6	0.7	38.5	88.7	2.43E-05	2.3	
1-4B	2.0	29.0	saturated	32282.9	8522.7	3	3.2	0.8	38.5	88.7	2.99E-05	2.8	
1-4C	2.0	29.0	saturated	32286.9	8523.7	5	2.0	0.5	38.5	88.7	1.87E-05	1.8	
1-4D	2.0	29.0	saturated	32308.9	8529.5	10	4.4	1.2	38.5	88.7	4.11E-05	3.9	
1-4E	2.0	29.0	saturated	32311.0	8530.1	15	0.4	0.1	38.5	88.7	3.92E-06	0.4	
Test Averages/Summary													
1-4	**2.0**	**29.0**	**saturated**	**37.1**	**9.8**	**15**	**2.5**	**0.7**	**38.5**	**88.7**	**2.36E-05**	**2.2**	

Notes:

Start Time: | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
				32314.5	8531.0	0							
1-5A	1.0	14.5	saturated	32315.7	8531.3	1	1.2	0.3	24.1	55.7	1.79E-05	1.7	
1-5B	1.0	14.5	saturated	32317.9	8531.9	3	1.1	0.3	24.1	55.7	1.64E-05	1.5	
1-5C	1.0	14.5	saturated	32320.1	8532.5	5	1.1	0.3	24.1	55.7	1.64E-05	1.5	
1-5D	1.0	14.5	saturated	32325.0	8533.8	10	1.0	0.3	24.1	55.7	1.46E-05	1.4	
1-5E	1.0	14.5	saturated	32329.7	8535.0	15	0.9	0.2	24.1	55.7	1.40E-05	1.3	
Test Averages/Summary													
1-5	**1.0**	**14.5**	**saturated**	**15.2**	**4.0**	**15**	**1.1**	**0.3**	**24.1**	**55.7**	**1.58E-05**	**1.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	11/02/19
WSP Personel	C. Zhang
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	23.6
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-27
Number of Tests	2
Lattitude	45.81551°N
Longitude	84.76579°W

Top of Rock, ft	282.5
Bottom of Boring, ft	328.4
Lake Depth, ft	163.4

Datum (Mudline) Elevation	418.3
Top of Rock Elevation, ft	135.8
Bottom of Hole Elevation, ft	89.9
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	0.9	13.3	saturated	29.9	7.9	207.1	1.9	0.5	23.0	53.0	3.40E-05	3.4		
1-2	2.0	29.0	saturated	30.5	8.1	207.1	2.0	0.5	38.5	88.8	2.14E-05	2.1		
1-3	2.7	39.1	saturated	47.4	12.5	207.1	2.8	0.7	49.2	113.6	2.36E-05	2.3		
1-4	1.6	22.6	saturated	32.3	8.5	207.1	2.2	0.6	34.5	79.6	2.80E-05	2.6		
1-5	0.8	11.9	saturated	20.2	5.3	207.1	1.3	0.3	21.5	49.6	2.49E-05	2.5		
2-1	1.0	14.5	saturated	78.4	20.7	202.9	6.2	1.6	22.8	52.5	1.39E-04	13.7		
2-2	2.1	30.2	saturated	164.5	43.4	202.9	10.5	2.8	35.5	82.0	1.20E-04	11.9		
2-3	3.0	44.1	saturated	233.9	61.7	202.9	13.7	3.6	46.3	106.7	1.22E-04	12.0		
2-4	2.0	29.6	saturated	186.3	49.2	202.9	12.2	3.2	33.1	76.5	1.51E-04	14.9		
2-5	0.9	12.8	saturated	84.1	22.2	202.9	5.0	1.3	21.5	49.6	9.60E-05	9.5		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/2/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-27
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	308.7
Bottom of Test Interval Depth, ft	320.5

Estimated Hydrostatic Pressure, psi	207.1
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	314.6
Test Interval Length (L), ft	11.8

Lake Depth, ft	163.4		
Datum (Mudline) Elevation, ft	418.3		
Top of Test Interval Elevation, ft	109.6		
Bottom of Test Interval Elevation, ft	97.8		
Rubber Hose Length, ft	52.5		
# of NQ Rods	12	# of HWY Rods	46

Note:

Start Time: 07:14 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		35242.9	9304.1	0							
1-1A	1.0	14.5	saturated	35244.9	9304.7	1	2.0	0.5	24.1	55.5	3.40E-05	3.4	
1-1B	0.9	13.0	saturated	35248.6	9305.6	3	1.8	0.5	22.6	52.1	3.35E-05	3.3	
1-1C	0.9	13.0		Missed		5							
1-1D	0.9	13.0	saturated	35266.9	9310.5	10	2.6	0.7	22.6	52.1	4.73E-05	4.7	
1-1E	0.9	13.0	saturated	35272.8	9312.0	15	1.2	0.3	22.6	52.1	2.13E-05	2.1	
Test Averages/Summary													
1-1	**0.9**	**13.3**	**saturated**	**29.9**	**7.9**	**15**	**1.9**	**0.5**	**23.0**	**53.0**	**3.40E-05**	**3.4**	

Notes: Flow unsteady, jumping back. Flow meter reading missed at at Test Step 1-1C.

Start Time: | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.3 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		35275.5	9312.7	0							
1-2A	2.0	29.0	saturated	35277.5	9313.3	1	2.0	0.5	38.5	88.8	2.12E-05	2.1	
1-2B	2.0	29.0	saturated	35281.5	9314.3	3	2.0	0.5	38.5	88.8	2.12E-05	2.1	
1-2C	2.0	29.0	saturated	35285.5	9315.4	5	2.0	0.5	38.5	88.8	2.12E-05	2.1	
1-2D	2.0	29.0	saturated	35296.0	9318.1	10	2.1	0.6	38.5	88.8	2.23E-05	2.2	
1-2E	2.0	29.0	saturated	35306.0	9320.8	15	2.0	0.5	38.5	88.8	2.12E-05	2.1	
Test Averages/Summary													
1-2	**2.0**	**29.0**	**saturated**	**30.5**	**8.1**	**15**	**2.0**	**0.5**	**38.5**	**88.8**	**2.14E-05**	**2.1**	

Notes: Flow unsteady, jumping around. Inflated packer to 30 bar. Transducer failed.

Start Time: | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.6 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.5	36.2		35321.6	9324.9	0							
1-3A	2.5	36.2		Missed		1							
1-3B	3.0	43.5	saturated	35329.1	9326.9	3	2.5	0.7	52.9	122.0	1.93E-05	1.9	
1-3C	2.5	36.2	saturated	35331.7	9327.6	5	1.3	0.3	45.6	105.3	1.16E-05	1.2	
1-3D	3.0	43.5	saturated	35346.0	9331.3	10	2.9	0.8	52.9	122.0	2.21E-05	2.2	
1-3E	2.5	36.2	saturated	35369.0	9337.4	15	4.6	1.2	45.6	105.3	4.12E-05	4.1	
Test Averages/Summary													
1-3	**2.7**	**39.1**	**saturated**	**47.4**	**12.5**	**15**	**2.8**	**0.7**	**49.2**	**113.6**	**2.36E-05**	**2.3**	

Notes: Flow and pressure not steady. Flow meter reading missed at Test Step 1-3A.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/2/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-27
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	308.7
Bottom of Test Interval Depth, ft	320.5

Estimated Hydrostatic Pressure, psi	207.1
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	314.6
Test Interval Length (L), ft	11.8

Lake Depth, ft			163.4
Datum (Mudline) Elevation, ft			418.3
Top of Test Interval Elevation, ft			109.6
Bottom of Test Interval Elevation, ft			97.8
Rubber Hose Length, ft			52.5
# of NQ Rods	12	# of HWY Rods	46

Note:

Start Time: 08:11 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.3 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		35362.3	9335.6	0							
1-4A	0.8	11.6	saturated	35364.6	9336.3	1	2.3	0.6	21.1	48.7	4.45E-05	4.4	
1-4B	0.9	13.0		Missed		3							
1-4C	2.1	30.4	saturated	35373.2	9338.5	5	2.1	0.6	40.0	92.2	2.20E-05	2.2	
1-4D	2.0	29.0	saturated	35384.0	9341.4	10	2.2	0.6	38.5	88.8	2.29E-05	2.3	
1-4E	2.0	29.0	saturated	35394.6	9344.2	15	2.1	0.6	38.5	88.8	2.25E-05	2.2	
Test Averages/Summary													
1-4	**1.6**	**22.6**	**saturated**	**32.3**	**8.5**	**15**	**2.2**	**0.6**	**34.5**	**79.6**	**2.80E-05**	**2.6**	

Notes: Flow and pressure not steady. Flow meter reading missed at Test Step 1-4B.

Start Time: 08:28 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		35395.4	9344.4	0							
1-5A	0.9	13.0	saturated	35396.6	9344.7	1	1.2	0.3	22.6	52.2	2.17E-05	2.1	
1-5B	0.8	11.6	saturated	35399.1	9345.4	3	1.3	0.3	21.2	48.9	2.41E-05	2.4	
1-5C	0.8	11.6	saturated	35401.7	9346.0	5	1.3	0.3	21.2	48.9	2.51E-05	2.5	
1-5D	0.8	11.6	saturated	35404.5	9346.8	10	0.6	0.1	21.2	48.9	1.08E-05	1.1	
1-5E	0.8	11.6	saturated	35415.6	9349.7	15	2.2	0.6	21.2	48.9	4.28E-05	4.2	
Test Averages/Summary													
1-5	**0.8**	**11.9**	**saturated**	**20.2**	**5.3**	**15**	**1.3**	**0.3**	**21.5**	**49.6**	**2.49E-05**	**2.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/2/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-27
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	298.9
Bottom of Test Interval Depth, ft	310.7

Estimated Hydrostatic Pressure, psi	202.9
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	304.8
Test Interval Length (L), ft	11.8

Lake Depth, ft	163.4
Datum (Mudline) Elevation, ft	418.3
Top of Test Interval Elevation, ft	119.4
Bottom of Test Interval Elevation, ft	107.6
Rubber Hose Length, ft	52.5
# of NQ Rods: 12	# of HWY Rods: 45

Note:

Start Time: 09:15 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 3.2 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.1	15.9		35583.4	9394.0	0						
2-1A	1.0	14.5	saturated	35598.8	9398.1	1	15.4	4.1	22.8	52.5	2.77E-04	27.3
2-1B	1.0	14.5	saturated	35598.4	9398.0	3	(0.2)	(0.1)				
2-1C	1.0	14.5	saturated	35608.1	9400.5	5	4.8	1.3	22.8	52.5	8.72E-05	8.6
2-1D	1.0	14.5	saturated	35635.5	9407.8	10	5.5	1.4	22.8	52.5	9.85E-05	9.7
2-1E	1.0	14.5	saturated	35661.8	9414.7	15	5.3	1.4	22.8	52.5	9.45E-05	9.3
Test Averages/Summary												
2-1	**1.0**	**14.5**	**saturated**	**78.4**	**20.7**	**15**	**6.2**	**1.6**	**22.8**	**52.5**	**1.39E-04**	**13.7**

Notes: Flow not steady, jumping back.
*Hydraulic conductivity calculation did not proceed with negative water take.

Start Time: 09:34 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 9.8 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.1	30.4		35684.0	9420.6	0						
2-2A	2.1	30.4	saturated	35693.2	9423.0	1	9.2	2.4	35.8	82.7	1.05E-04	10.4
2-2B	2.1	30.4	saturated	35713.0	9428.2	3	9.9	2.6	35.8	82.7	1.13E-04	11.2
2-2C	2.0	29.0	saturated	35733.3	9433.6	5	10.2	2.7	34.4	79.3	1.21E-04	11.9
2-2D	2.1	30.4	saturated	35785.0	9447.2	10	10.3	2.7	35.8	82.7	1.18E-04	11.6
2-2E	2.1	30.4	saturated	35848.5	9464.0	15	12.7	3.4	35.8	82.7	1.45E-04	14.3
Test Averages/Summary												
2-2	**2.1**	**30.2**	**saturated**	**164.5**	**43.4**	**15**	**10.5**	**2.8**	**35.5**	**82.0**	**1.20E-04**	**11.9**

Notes: Flow not steady, jumping back.

Start Time: 09:50 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 17.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		35878.6	9472.0	0						
2-3A	3.1	44.9	saturated	35882.8	9473.1	1	4.2	1.1	47.1	108.7	3.64E-05	3.6
2-3B	3.0	43.5	saturated	35912.9	9481.0	3	15.0	4.0	45.7	105.4	1.35E-04	13.3
2-3C	3.1	44.9	saturated	35944.8	9489.4	5	16.0	4.2	47.1	108.7	1.38E-04	13.7
2-3D	3.0	43.5	saturated	36026.7	9511.0	10	16.4	4.3	45.7	105.4	1.47E-04	14.5
2-3E	3.0	43.5	saturated	36112.5	9533.7	15	17.2	4.5	45.7	105.4	1.54E-04	15.2
Test Averages/Summary												
2-3	**3.0**	**44.1**	**saturated**	**233.9**	**61.7**	**15**	**13.7**	**3.6**	**46.3**	**106.7**	**1.22E-04**	**12.0**

Notes: Flow not steady, jumping back.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	11/2/2019
WSP Personel	C. Zhang
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-27
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	298.9
Bottom of Test Interval Depth, ft	310.7

Estimated Hydrostatic Pressure, psi	202.9
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	304.8
Test Interval Length (L), ft	11.8

Lake Depth, ft	163.4		
Datum (Mudline) Elevation, ft	418.3		
Top of Test Interval Elevation, ft	119.4		
Bottom of Test Interval Elevation, ft	107.6		
Rubber Hose Length, ft	52.5		
# of NQ Rods	12	# of HWY Rods	45

Note:

Start Time: 10:08 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 13.5 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		36146.5	9542.7	0							
2-4A	2.1	30.4		Missed		1							
2-4B	1.9	27.5	saturated	36175.0	9550.2	3	9.5	2.5	31.3	72.3	1.24E-04	12.2	
2-4C	2.0	29.0	saturated	36201.4	9557.2	5	13.2	3.5	32.8	75.6	1.65E-04	16.3	
2-4D	2.1	30.4	saturated	36267.0	9574.5	10	13.1	3.5	34.2	79.0	1.57E-04	15.5	
2-4E	2.1	30.4	saturated	36332.8	9591.9	15	13.2	3.5	34.2	79.0	1.57E-04	15.5	
Test Averages/Summary													
2-4	**2.0**	**29.6**	**saturated**	**186.3**	**49.2**	**15**	**12.2**	**3.2**	**33.1**	**76.5**	**1.51E-04**	**14.9**	

Notes: Flow not steady, jumping back. Flow meter reading missed at test step 2-4A.

Start Time: 10:24 | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 2.1 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		36338.4	9593.3	0							
2-5A	0.9	13.0	saturated	36341.4	9594.1	1	3.0	0.8	21.8	50.2	5.63E-05	5.6	
2-5B	0.8	11.6	saturated	36350.6	9596.6	3	4.6	1.2	20.3	46.9	9.25E-05	9.1	
2-5C	0.9	13.0	saturated	36361.5	9599.4	5	5.5	1.4	21.8	50.2	1.02E-04	10.1	
2-5D	0.9	13.0	saturated	36391.0	9607.2	10	5.9	1.6	21.8	50.2	1.11E-04	10.9	
2-5E	0.9	13.0	saturated	36422.5	9615.5	15	6.3	1.7	21.8	50.2	1.18E-04	11.7	
Test Averages/Summary													
2-5	**0.9**	**12.8**	**saturated**	**84.1**	**22.2**	**15**	**5.0**	**1.3**	**21.5**	**49.6**	**9.60E-05**	**9.5**	

Notes: Flow not steady, jumping back.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	10/21/19
WSP Personel	A. Moreland, C. Fischer
Driller	Fugro
Operator	T.Brindle
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	82.4
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-28
Number of Tests	7
Lattitude	45.81439°N
Longitude	84.76743°W

Top of Rock, ft	161.9
Bottom of Boring, ft	249.7
Lake Depth, ft	181.8

Datum (Mudline) Elevation	399.9
Top of Rock Elevation, ft	238.0
Bottom of Hole Elevation, ft	150.3
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	0.9	12.7	saturated	17.1	4.5	182.1	1.0	0.3	22.3	51.5	1.80E-05	1.7		
1-2	2.0	29.0	saturated	24.5	6.5	182.1	1.6	0.4	38.6	89.0	1.73E-05	1.7		
1-3	3.0	43.5	saturated	17.8	4.7	182.1	1.2	0.3	53.1	122.6	9.25E-06	0.9		
1-4	2.0	29.0	saturated	23.8	6.3	182.1	1.6	0.4	38.6	89.0	1.71E-05	1.7		
1-5	1.0	14.5	saturated	21.0	5.5	182.1	1.3	0.3	24.1	55.7	2.20E-05	2.2		
2-1	2.0	29.0	saturated	0.3	0.1	177.8	0.0	0.0	38.6	89.1	2.12E-07	0.0		
2-2	3.0	43.5	saturated	10.9	2.9	177.8	0.8	0.2	53.1	122.6	6.29E-06	0.6		
2-3	4.0	58.0	saturated	24.3	6.4	177.8	1.6	0.4	67.6	155.9	9.79E-06	1.0		
2-4	3.0	43.5	saturated	10.4	2.7	177.8	0.7	0.2	53.1	122.6	5.26E-06	0.5		
2-5	2.0	29.0	saturated	6.6	1.7	173.6	0.3	0.1	38.6	89.1	4.76E-06	0.3		
3-1	2.0	29.0	saturated	11.1	2.9	173.6	0.8	0.2	38.6	89.1	2.23E-05	0.8		
3-2	3.0	43.5	saturated	20.1	5.3	173.6	1.9	0.5	53.1	122.5	1.90E-05	1.5		
3-3	4.0	58.0	saturated	29.8	7.9	173.6	2.0	0.5	67.6	155.9	1.19E-05	1.2		
3-4	3.0	43.5	saturated	22.2	5.9	173.6	1.5	0.4	53.1	122.5	1.19E-05	1.2		
3-5	2.0	29.0	saturated	18.6	4.9	173.6	1.9	0.5	38.6	89.0	2.00E-05	2.0		
4-1	2.0	29.0	saturated	23.1	6.1	169.3	1.7	0.4	38.6	89.0	1.80E-05	1.8		
4-2	3.0	43.5	saturated	44.2	11.7	169.3	2.7	0.7	53.0	122.3	2.07E-05	2.0		
4-3	4.0	58.0	saturated	82.3	21.7	169.3	5.4	1.4	67.1	154.7	3.29E-05	3.3		
4-4	3.0	43.5	saturated	40.9	10.8	169.3	2.7	0.7	53.0	122.3	2.10E-05	2.1		
4-5	2.0	29.0	saturated	25.6	6.8	169.3	1.7	0.4	38.6	89.0	1.77E-05	1.7		
5-1	2.0	29.0	saturated	18.7	4.9	165.0	1.3	0.3	38.6	89.1	1.38E-05	1.4		
5-2	3.0	43.5	saturated	71.4	18.8	165.0	4.8	1.3	52.7	121.6	3.71E-05	3.7		
5-3	4.0	58.0	saturated	130.7	34.5	165.0	8.7	2.3	66.1	152.5	5.36E-05	5.3		
5-4	3.0	43.5	saturated	75.5	19.9	165.0	5.0	1.3	52.7	121.5	3.87E-05	3.8		
5-5	2.0	29.0	saturated	19.1	5.0	165.0	1.2	0.3	38.6	89.1	1.29E-05	1.3		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	10/21/19
WSP Personel	A. Moreland, C. Fischer
Driller	Fugro
Operator	T.Brindle
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	82.4
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-28
Number of Tests	7
Lattitude	45.81439°N
Longitude	84.76743°W

Top of Rock, ft	161.9
Bottom of Boring, ft	249.7
Lake Depth, ft	181.8

Datum (Mudline) Elevation	399.9
Top of Rock Elevation, ft	238.0
Bottom of Hole Elevation, ft	150.3
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
6-1	2.0	29.0	saturated	23.5	6.2	160.8	1.6	0.4	38.6	89.0	1.64E-05	1.6	|	
6-2	3.0	43.5	saturated	109.9	29.0	160.8	7.2	1.9	52.1	120.3	5.64E-05	5.6	|||||	
6-3	4.0	58.0	saturated	292.6	77.2	160.8	16.4	4.3	62.2	143.4	1.08E-04	10.7	|||||||||	
6-4	3.0	43.5	saturated	132.0	34.8	160.8	8.9	2.3	51.6	119.1	7.02E-05	6.9	||||||	
6-5	2.0	29.0	saturated	7.6	2.0	160.8	0.4	0.1	38.6	89.1	5.71E-06	0.4		
7-1	2.0	29.0	saturated	2.9	0.8	156.5	0.1	0.0	38.6	89.1	1.35E-06	0.1		
7-2	3.0	43.5	saturated	108.9	28.7	156.5	7.3	1.9	52.1	120.3	5.73E-05	5.7	|||||||||	
7-3	4.0	58.0	saturated	205.7	54.3	156.5	14.0	3.7	63.8	147.2	8.99E-05	8.9	||||||||||||||||	
7-4	3.0	43.5	saturated	126.7	33.4	156.5	8.3	2.2	51.8	119.6	6.56E-05	6.5	|||||||||||	
7-5	2.0	29.0	saturated	10.8	2.9	156.5	0.6	0.2	38.6	89.1	6.86E-06	0.7	|	

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	A. Moreland
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	232.5
Bottom of Test Interval Depth, ft	244.3

Estimated Hydrostatic Pressure, psi	182.1
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	238.4
Test Interval Length (L), ft	11.8

Lake Depth, ft			181.8
Datum (Mudline) Elevation, ft			399.9
Top of Test Interval Elevation, ft			167.4
Bottom of Test Interval Elevation, ft			155.6
Rubber Hose Length, ft			52.5
# of NQ Rods	20	# of HWY Rods	26

Note:

Start Time: 06:42 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		32532.9	8588.7	0							
1-1A	1.0	14.5	saturated	32533.1	8588.7	1	0.2	0.1	24.1	55.7	3.39E-06	0.3	
1-1B	0.9	13.0	saturated	32535.6	8589.4	3	1.3	0.3	22.7	52.3	2.25E-05	2.2	
1-1C	0.8	11.6	saturated	32544.0	8591.6	10	1.2	0.3	21.2	49.0	2.31E-05	2.3	
1-1D	0.8	11.6	saturated	32550.0	8593.2	15	1.2	0.3	21.2	49.0	2.31E-05	2.3	
-	-	-	saturated	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
1-1	**0.9**	**12.7**	**saturated**	**17.1**	**4.5**	**15**	**1.0**	**0.3**	**22.3**	**51.5**	**1.80E-05**	**1.7**	

Notes:

Start Time: 07:01 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		32563.0	8596.6	0							
1-2A	2.0	29.0	saturated	32564.6	8597.1	1	1.6	0.4	38.6	89.0	1.70E-05	1.7	
1-2B	2.0	29.0	saturated	32568.2	8598.0	3	1.8	0.5	38.6	89.0	1.91E-05	1.9	
1-2C	2.0	29.0	saturated	32571.2	8598.8	5	1.5	0.4	38.6	89.0	1.59E-05	1.6	
1-2D	2.0	29.0	saturated	32579.5	8601.0	10	1.7	0.4	38.6	89.0	1.76E-05	1.7	
1-2E	2.0	29.0	saturated	32587.5	8603.1	15	1.6	0.4	38.6	89.0	1.70E-05	1.7	
Test Averages/Summary													
1-2	**2.0**	**29.0**	**saturated**	**24.5**	**6.5**	**15**	**1.6**	**0.4**	**38.6**	**89.0**	**1.73E-05**	**1.7**	

Notes:

Start Time: 07:18 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		32594.2	8604.9	0							
1-3A	3.0	43.5	saturated	32595.5	8605.2	1	1.3	0.3	53.1	122.6	1.00E-05	1.0	
1-3B	3.0	43.5	saturated	32598.0	8605.9	3	1.3	0.3	53.1	122.6	9.62E-06	0.9	
1-3C	3.0	43.5	saturated	32600.2	8606.5	5	1.1	0.3	53.1	122.6	8.46E-06	0.8	
1-3D	3.0	43.5	saturated	32605.9	8608.0	10	1.1	0.3	53.1	122.6	8.77E-06	0.9	
1-3E	3.0	43.5	saturated	32612.0	8609.6	15	1.2	0.3	53.1	122.6	9.39E-06	0.9	
Test Averages/Summary													
1-3	**3.0**	**43.5**	**saturated**	**17.8**	**4.7**	**15**	**1.2**	**0.3**	**53.1**	**122.6**	**9.25E-06**	**0.9**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	A. Moreland
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	232.5
Bottom of Test Interval Depth, ft	244.3

Estimated Hydrostatic Pressure, psi	182.1
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	238.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	167.4		
Bottom of Test Interval Elevation, ft	155.6		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	26

Note:

Start Time: 07:34 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		32612.6	8609.7	0							
1-4A	2.0	29.0	saturated	32614.1	8610.1	1	1.5	0.4	38.6	89.0	1.59E-05	1.6	
1-4B	2.0	29.0	saturated	32617.5	8611.0	3	1.7	0.4	38.6	89.0	1.80E-05	1.8	
1-4C	2.0	29.0	saturated	32621.1	8612.0	5	1.8	0.5	38.6	89.0	1.91E-05	1.9	
1-4D	2.0	29.0	saturated	32628.7	8614.0	10	1.5	0.4	38.6	89.0	1.61E-05	1.6	
1-4E	2.0	29.0	saturated	32636.4	8616.0	15	1.5	0.4	38.6	89.0	1.63E-05	1.6	
Test Averages/Summary													
1-4	**2.0**	**29.0**	**saturated**	**23.8**	**6.3**	**15**	**1.6**	**0.4**	**38.6**	**89.0**	**1.71E-05**	**1.7**	

Notes:

Start Time: 07:53 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		32636.7	8616.1	0							
1-5A	1.0	14.5	saturated	32637.0	8616.2	1	0.3	0.1	24.1	55.7	5.08E-06	0.5	
1-5B	1.0	14.5	saturated	32640.7	8617.1	3	1.9	0.5	24.1	55.7	3.13E-05	3.1	
1-5C	1.0	14.5	saturated	32643.8	8618.0	5	1.5	0.4	24.1	55.7	2.63E-05	2.6	
1-5D	1.0	14.5	saturated	32650.3	8619.7	10	1.3	0.3	24.1	55.7	2.20E-05	2.2	
1-5E	1.0	14.5	saturated	32657.7	8621.6	15	1.5	0.4	24.1	55.7	2.51E-05	2.5	
Test Averages/Summary													
1-5	**1.0**	**14.5**	**saturated**	**21.0**	**5.5**	**15**	**1.3**	**0.3**	**24.1**	**55.7**	**2.20E-05**	**2.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	A. Moreland
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	222.7
Bottom of Test Interval Depth, ft	234.5

Estimated Hydrostatic Pressure, psi	177.8
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	228.6
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8
Datum (Mudline) Elevation, ft	399.9
Top of Test Interval Elevation, ft	177.2
Bottom of Test Interval Elevation, ft	165.4
Rubber Hose Length, ft	52.5
# of NQ Rods	20
# of HWY Rods	25

Note:

Start Time: 09:19 | Stage/Packer Pressure, bar: 27 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		32758.9	8648.3	0						
2-1A	2.0	29.0	saturated	32758.9	8648.3	1	0.0	0.0	38.6	89.1	0.00E+00	0.0
2-1B	2.0	29.0	saturated	32758.8	8648.3	3	(0.1)	(0.0)	38.6	89.1		
2-1C	2.0	29.0	saturated	32758.8	8648.3	5	0.0	0.0	38.6	89.1	0.00E+00	0.0
2-1D	2.0	29.0	saturated	32759.1	8648.4	10	0.1	0.0	38.6	89.1	6.35E-07	0.1
2-1E	2.0	29.0	saturated	32759.2	8648.4	15	0.0	0.0	38.6	89.1	2.12E-07	0.0
Test Averages/Summary												
2-1	**2.0**	**29.0**	**saturated**	**0.3**	**0.1**	**15**	**0.0**	**0.0**	**38.6**	**89.1**	**2.12E-07**	**0.0**

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Start Time: 09:37 | Stage/Packer Pressure, bar: 27 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		32764.9	8649.9	0						
2-2A	3.0	43.5	saturated	32765.9	8650.2	1	1.0	0.3	53.1	122.6	7.69E-06	0.8
2-2B	3.0	43.5	saturated	32767.8	8650.7	3	0.9	0.3	53.1	122.6	7.31E-06	0.7
2-2C	3.0	43.5	saturated	32769.6	8651.2	5	0.9	0.2	53.1	122.6	6.93E-06	0.7
2-2D	3.0	43.5	saturated	32772.8	8652.0	10	0.6	0.2	53.1	122.6	4.92E-06	0.5
2-2E	3.0	43.5	saturated	32775.8	8652.8	15	0.6	0.2	53.1	122.6	4.62E-06	0.5
Test Averages/Summary												
2-2	**3.0**	**43.5**	**saturated**	**10.9**	**2.9**	**15**	**0.8**	**0.2**	**53.1**	**122.6**	**6.29E-06**	**0.6**

Notes:

Start Time: 09:54 | Stage/Packer Pressure, bar: 27 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	4.0	58.0		32778.9	8653.6	0						
2-3A	4.0	58.0	saturated	32780.5	8654.1	1	1.6	0.4	67.6	155.9	9.68E-06	1.0
2-3B	4.0	58.0	saturated	32784.7	8655.2	3	2.1	0.6	67.6	155.9	1.27E-05	1.3
2-3C	4.0	58.0	saturated	32787.0	8655.8	5	1.2	0.3	67.6	155.9	6.96E-06	0.7
2-3D	4.0	58.0	saturated	32795.2	8657.9	10	1.6	0.4	67.6	155.9	9.92E-06	1.0
2-3E	4.0	58.0	saturated	32803.2	8660.0	15	1.6	0.4	67.6	155.9	9.68E-06	1.0
Test Averages/Summary												
2-3	**4.0**	**58.0**	**saturated**	**24.3**	**6.4**	**15**	**1.6**	**0.4**	**67.6**	**155.9**	**9.79E-06**	**1.0**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	A. Moreland
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	222.7
Bottom of Test Interval Depth, ft	234.5

Estimated Hydrostatic Pressure, psi	177.8
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	228.6
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8
Datum (Mudline) Elevation, ft	399.9
Top of Test Interval Elevation, ft	177.2
Bottom of Test Interval Elevation, ft	165.4
Rubber Hose Length, ft	52.5
# of NQ Rods	20
# of HWY Rods	25

Note:

Start Time: 10:10 | Stage/Packer Pressure, bar: 27 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		32804.3	8660.3	0							
2-4A	3.0	43.5	saturated	32805.0	8660.5	1	0.7	0.2	53.1	122.6	5.39E-06	0.5	
2-4B	3.0	43.5	saturated	32806.2	8660.8	3	0.6	0.2	53.1	122.6	4.62E-06	0.5	
2-4C	3.0	43.5	saturated	32807.6	8661.2	5	0.7	0.2	53.1	122.6	5.39E-06	0.5	
2-4D	3.0	43.5	saturated	32811.1	8662.1	10	0.7	0.2	53.1	122.6	5.39E-06	0.5	
2-4E	3.0	43.5	saturated	32814.7	8663.1	15	0.7	0.2	53.1	122.6	5.54E-06	0.5	
Test Averages/Summary													
2-4	**3.0**	**43.5**	**saturated**	**10.4**	**2.7**	**15**	**0.7**	**0.2**	**53.1**	**122.6**	**5.26E-06**	**0.5**	

Notes:

Start Time: 10:27 | Stage/Packer Pressure, bar: 27 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		32814.8	8663.1	0							
2-5A	2.0	29.0	saturated	32814.8	8663.1	1	0.0	0.0	38.6	89.1	0.00E+00	0.0	
2-5B	2.0	29.0	saturated	32814.2	8662.9	3	(0.3)	(0.1)	38.6	89.1			
2-5C	2.0	29.0	saturated	32815.4	8663.3	5	0.6	0.2	38.6	89.1	6.35E-06	0.6	
2-5D	2.0	29.0	saturated	32818.8	8664.2	10	0.7	0.2	38.6	89.1	7.20E-06	0.7	
2-5E	2.0	29.0	saturated	32821.4	8664.8	15	0.5	0.1	38.6	89.1	5.50E-06	0.5	
Test Averages/Summary													
2-5	**2.0**	**29.0**	**saturated**	**6.6**	**1.7**	**15**	**0.3**	**0.1**	**38.6**	**89.1**	**4.76E-06**	**0.3**	

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	A. Moreland
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	212.9
Bottom of Test Interval Depth, ft	224.6

Estimated Hydrostatic Pressure, psi	173.6
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	218.8
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	187.0		
Bottom of Test Interval Elevation, ft	175.3		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	24

Note:

Start Time: 11:20 | Stage/Packer Pressure, bar: 29 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		32866.3	8676.7	0							
3-1A	2.0	29.0	saturated	32867.2	8676.9	1	0.9	0.2	38.6	89.1	9.52E-06	0.9	|||
3-1B	2.0	29.0	saturated	32867.8	8677.1	3	0.3	0.1	38.6	89.1	3.17E-06	0.3		
3-1C	2.0	29.0	saturated	32870.4	8677.8	5	1.3	0.3	38.6	89.1	1.38E-05	1.4	||||
3-1D	2.0	29.0	saturated	32847.7	8671.8	10	(4.5)	(1.2)	38.6	89.1			
3-1E	2.0	29.0	saturated	32877.4	8679.6	15	5.9	1.6	38.6	89.1	6.29E-05	6.2	|||||||||||||||
Test Averages/Summary													
3-1	**2.0**	**29.0**	**saturated**	**11.1**	**2.9**	**15**	**0.8**	**0.2**	**38.6**	**89.1**	**2.23E-05**	**0.8**		

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Start Time: 11:37 | Stage/Packer Pressure, bar: 29 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		32883.6	8681.3	0							
3-2A	3.0	43.5	saturated	32885.7	8681.8	1	2.1	0.6	53.1	122.5	1.62E-05	1.6	|||||
3-2B	3.0	43.5	saturated	32896.2	8684.6	3	5.3	1.4	53.1	122.5	4.04E-05	4.0	|||||||||||
3-2C	3.0	43.5	saturated	32898.7	8685.3	5	1.3	0.3	53.1	122.5	9.63E-06	1.0	|||
3-2D	3.0	43.5	saturated	32897.3	8684.9	10	(0.3)	(0.1)	53.1	122.5			
3-2E	3.0	43.5	saturated	32903.7	8686.6	15	1.3	0.3	53.1	122.5	9.86E-06	1.0	|||
Test Averages/Summary													
3-2	**3.0**	**43.5**	**saturated**	**20.1**	**5.3**	**15**	**1.9**	**0.5**	**53.1**	**122.5**	**1.90E-05**	**1.5**	||||

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Start Time: 11:56 | Stage/Packer Pressure, bar: 29 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	4.0	58.0		32911.7	8688.7	0							
3-3A	4.0	58.0	saturated	32913.6	8689.2	1	1.9	0.5	67.6	155.9	1.15E-05	1.1	|||
3-3B	4.0	58.0	saturated	32917.5	8690.2	3	2.0	0.5	67.6	155.9	1.18E-05	1.2	|||
3-3C	4.0	58.0	saturated	32921.5	8691.3	5	2.0	0.5	67.6	155.9	1.21E-05	1.2	|||
3-3D	4.0	58.0	saturated	32931.1	8693.8	10	1.9	0.5	67.6	155.9	1.16E-05	1.1	|||
3-3E	4.0	58.0	saturated	32941.5	8696.6	15	2.1	0.5	67.6	155.9	1.26E-05	1.2	|||||
Test Averages/Summary													
3-3	**4.0**	**58.0**	**saturated**	**29.8**	**7.9**	**15**	**2.0**	**0.5**	**67.6**	**155.9**	**1.19E-05**	**1.2**	|||

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	A. Moreland
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	212.9
Bottom of Test Interval Depth, ft	224.6

Estimated Hydrostatic Pressure, psi	173.6
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	218.8
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	187.0		
Bottom of Test Interval Elevation, ft	175.3		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	24

Note:

Start Time: 12:17 | Stage/Packer Pressure, bar: 29 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		32947.0	8698.0	0							
3-4A	3.0	43.5	saturated	32948.5	8698.4	1	1.5	0.4	53.1	122.5	1.16E-05	1.1	|||
3-4B	3.0	43.5	saturated	32951.0	8699.1	3	1.3	0.3	53.1	122.5	9.63E-06	1.0	|||
3-4C	3.0	43.5	saturated	32955.4	8700.2	5	2.2	0.6	53.1	122.5	1.69E-05	1.7	|||||
3-4D	3.0	43.5	saturated	32961.7	8701.9	10	1.3	0.3	53.1	122.5	9.70E-06	1.0	|||
3-4E	3.0	43.5	saturated	32969.2	8703.9	15	1.5	0.4	53.1	122.5	1.16E-05	1.1	|||
Test Averages/Summary													
3-4	**3.0**	**43.5**	**saturated**	**22.2**	**5.9**	**15**	**1.5**	**0.4**	**53.1**	**122.5**	**1.19E-05**	**1.2**	|||

Notes:

Start Time: 12:34 | Stage/Packer Pressure, bar: 29 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		32965.4	8702.9	0							
3-5A	2.0	29.0	saturated	32971.2	8704.4	1	5.8	1.5	38.6	89.0	6.14E-05	6.1	||||||||||||||||
3-5B	2.0	29.0	saturated	32974.0	8705.1	3	1.4	0.4	38.6	89.0	1.48E-05	1.5	||||
3-5C	2.0	29.0	saturated	32974.8	8705.3	5	0.4	0.1	38.6	89.0	4.24E-06	0.4		
3-5D	2.0	29.0	saturated	32979.4	8706.6	10	0.9	0.2	38.6	89.0	9.75E-06	1.0	|||
3-5E	2.0	29.0	saturated	32984.0	8707.8	15	0.9	0.2	38.6	89.0	9.75E-06	1.0	|||
Test Averages/Summary													
3-5	**2.0**	**29.0**	**saturated**	**18.6**	**4.9**	**15**	**1.9**	**0.5**	**38.6**	**89.0**	**2.00E-05**	**2.0**	|||||

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	203.0
Bottom of Test Interval Depth, ft	214.8

Estimated Hydrostatic Pressure, psi	169.3
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	208.9
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	196.9		
Bottom of Test Interval Elevation, ft	185.1		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	23

Note:

Start Time: 13:38 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		33044.5	8723.7	0							
4-1A	2.0	29.0	saturated	33047.3	8724.5	1	2.8	0.7	38.6	89.0	2.97E-05	2.9	
4-1B	2.0	29.0	saturated	33048.4	8724.8	3	0.5	0.1	38.6	89.0	5.83E-06	0.6	
4-1C	2.0	29.0	saturated	33052.7	8725.9	5	2.1	0.6	38.6	89.0	2.28E-05	2.2	
4-1D	2.0	29.0	saturated	33059.7	8727.8	10	1.4	0.4	38.6	89.0	1.48E-05	1.5	
4-1E	2.0	29.0	saturated	33067.6	8729.8	15	1.6	0.4	38.6	89.0	1.67E-05	1.7	
Test Averages/Summary													
4-1	**2.0**	**29.0**	**saturated**	**23.1**	**6.1**	**15**	**1.7**	**0.4**	**38.6**	**89.0**	**1.80E-05**	**1.8**	

Notes:

Start Time: 14:12 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.3 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		33073.9	8731.5	0							
4-2A	3.0	43.5	saturated	33074.2	8731.6	1	0.3	0.1	53.0	122.3	2.31E-06	0.2	
4-2B	3.0	43.5	saturated	33082.4	8733.8	3	4.1	1.1	53.0	122.3	3.16E-05	3.1	
4-2C	3.0	43.5	saturated	33088.6	8735.4	5	3.1	0.8	53.0	122.3	2.39E-05	2.4	
4-2D	3.0	43.5	saturated	33103.6	8739.4	10	3.0	0.8	53.0	122.3	2.31E-05	2.3	
4-2E	3.0	43.5	saturated	33118.1	8743.2	15	2.9	0.8	53.0	122.3	2.24E-05	2.2	
Test Averages/Summary													
4-2	**3.0**	**43.5**	**saturated**	**44.2**	**11.7**	**15**	**2.7**	**0.7**	**53.0**	**122.3**	**2.07E-05**	**2.0**	

Notes:

Start Time: 14:22 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 1.3 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	4.0	58.0		33126.7	8745.4	0							
4-3A	4.0	58.0	saturated	33131.8	8746.8	1	5.1	1.3	67.1	154.7	3.11E-05	3.1	
4-3B	4.0	58.0	saturated	33144.6	8750.2	3	6.4	1.7	67.1	154.7	3.90E-05	3.9	
4-3C	4.0	58.0	saturated	33153.4	8752.5	5	4.4	1.2	67.1	154.7	2.68E-05	2.6	
4-3D	4.0	58.0	saturated	33181.2	8759.8	10	5.6	1.5	67.1	154.7	3.39E-05	3.3	
4-3E	4.0	58.0	saturated	33209.0	8767.2	15	5.6	1.5	67.1	154.7	3.39E-05	3.3	
Test Averages/Summary													
4-3	**4.0**	**58.0**	**saturated**	**82.3**	**21.7**	**15**	**5.4**	**1.4**	**67.1**	**154.7**	**3.29E-05**	**3.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	203.0
Bottom of Test Interval Depth, ft	214.8

Estimated Hydrostatic Pressure, psi	169.3
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	208.9
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	196.9		
Bottom of Test Interval Elevation, ft	185.1		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	23

Note:

Start Time: 14:47 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.3 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		33218.5	8769.7	0							
4-4A	3.0	43.5	saturated	33221.3	8770.4	1	2.8	0.7	53.0	122.3	2.16E-05	2.1	
4-4B	3.0	43.5	saturated	33226.7	8771.8	3	2.7	0.7	53.0	122.3	2.08E-05	2.1	
4-4C	3.0	43.5	saturated	33231.9	8773.2	5	2.6	0.7	53.0	122.3	2.01E-05	2.0	
4-4D	3.0	43.5	saturated	33245.5	8776.8	10	2.7	0.7	53.0	122.3	2.10E-05	2.1	
4-4E	3.0	43.5	saturated	33259.4	8780.5	15	2.8	0.7	53.0	122.3	2.14E-05	2.1	
Test Averages/Summary													
4-4	**3.0**	**43.5**	**saturated**	**40.9**	**10.8**	**15**	**2.7**	**0.7**	**53.0**	**122.3**	**2.10E-05**	**2.1**	

Notes:

Start Time: 3:02 PM | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		33264.7	8781.9	0							
4-5A	2.0	29.0	saturated	33265.7	8782.1	1	1.0	0.3	38.6	89.0	1.06E-05	1.0	
4-5B	2.0	29.0	saturated	33268.4	8782.9	3	1.4	0.4	38.6	89.0	1.43E-05	1.4	
4-5C	2.0	29.0	saturated	33273.8	8784.3	5	2.7	0.7	38.6	89.0	2.86E-05	2.8	
4-5D	2.0	29.0	saturated	33281.2	8786.2	10	1.5	0.4	38.6	89.0	1.57E-05	1.5	
4-5E	2.0	29.0	saturated	33290.3	8788.6	15	1.8	0.5	38.6	89.0	1.93E-05	1.9	
Test Averages/Summary													
4-5	**2.0**	**29.0**	**saturated**	**25.6**	**6.8**	**15**	**1.7**	**0.4**	**38.6**	**89.0**	**1.77E-05**	**1.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.2
Bottom of Test Interval Depth, ft	205.0

Estimated Hydrostatic Pressure, psi	165.0
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	199.1
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	206.7		
Bottom of Test Interval Elevation, ft	194.9		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	22

Note:

Start Time: 15:41 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		33328.1	8798.6	0							
5-1A	2.0	29.0	saturated	33329.8	8799.1	1	1.7	0.4	38.6	89.1	1.8E-05	1.8	
5-1B	2.0	29.0	saturated	33332.5	8799.8	3	1.3	0.4	38.6	89.1	1.4E-05	1.4	
5-1C	2.0	29.0	saturated	33334.6	8800.3	5	1.0	0.3	38.6	89.1	1.1E-05	1.1	
5-1D	2.0	29.0	saturated	33340.6	8801.9	10	1.2	0.3	38.6	89.1	1.3E-05	1.3	
5-1E	2.0	29.0	saturated	33346.8	8803.6	15	1.2	0.3	38.6	89.1	1.3E-05	1.3	
Test Averages/Summary													
5-1	**2.0**	**29.0**	**saturated**	**18.7**	**4.9**	**15**	**1.3**	**0.3**	**38.6**	**89.1**	**1.4E-05**	**1.4**	

Notes: At time = 1 min, slow packer pressure loss.

Start Time: 15:59 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 1.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		33356.2	8806.0	0							
5-2A	3.0	43.5	saturated	33361.5	8807.4	1	5.3	1.4	52.7	121.6	4.1E-05	4.1	
5-2B	3.0	43.5	saturated	33370.6	8809.8	3	4.5	1.2	52.7	121.6	3.5E-05	3.5	
5-2C	3.0	43.5	saturated	33379.4	8812.2	5	4.4	1.2	52.7	121.6	3.4E-05	3.4	
5-2D	3.0	43.5	saturated	33403.9	8818.6	10	4.9	1.3	52.7	121.6	3.8E-05	3.8	
5-2E	3.0	43.5	saturated	33427.6	8824.9	15	4.7	1.3	52.7	121.6	3.7E-05	3.6	
Test Averages/Summary													
5-2	**3.0**	**43.5**	**saturated**	**71.4**	**18.8**	**15**	**4.8**	**1.3**	**52.7**	**121.6**	**3.7E-05**	**3.7**	

Notes: At time = 3 min, water flow out of GEOBORE-S casing;
At time = 5 min, bubbles were noted in the casing.

Start Time: 16:15 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 3.5 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	4.0	58.0		33437.8	8827.6	0							
5-3A	4.0	58.0	saturated	33447.2	8830.1	1	9.4	2.5	66.1	152.5	5.8E-05	5.7	
5-3B	4.0	58.0	saturated	33463.2	8834.3	3	8.0	2.1	66.1	152.5	4.9E-05	4.9	
5-3C	4.0	58.0	saturated	33479.5	8838.6	5	8.2	2.2	66.1	152.5	5.0E-05	5.0	
5-3D	4.0	58.0	saturated	33524.5	8850.5	10	9.0	2.4	66.1	152.5	5.6E-05	5.5	
5-3E	4.0	58.0	saturated	33568.5	8862.1	15	8.8	2.3	66.1	152.5	5.4E-05	5.4	
Test Averages/Summary													
5-3	**4.0**	**58.0**	**saturated**	**130.7**	**34.5**	**15**	**8.7**	**2.3**	**66.1**	**152.5**	**5.4E-05**	**5.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.2
Bottom of Test Interval Depth, ft	205.0

Estimated Hydrostatic Pressure, psi	165.0
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	199.1
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	206.7		
Bottom of Test Interval Elevation, ft	194.9		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	22

Note:

Start Time: 16:32 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 1.1 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		33579.1	8864.9	0							
5-4A	3.0	43.5	saturated	33584.0	8866.2	1	4.9	1.3	52.7	121.5	3.8E-05	3.8	
5-4B	3.0	43.5	saturated	33593.8	8868.8	3	4.9	1.3	52.7	121.5	3.8E-05	3.8	
5-4C	3.0	43.5	saturated	33603.7	8871.4	5	4.9	1.3	52.7	121.5	3.8E-05	3.8	
5-4D	3.0	43.5	saturated	33628.5	8877.9	10	5.0	1.3	52.7	121.5	3.9E-05	3.8	
5-4E	3.0	43.5	saturated	33654.6	8884.8	15	5.2	1.4	52.7	121.5	4.1E-05	4.0	
Test Averages/Summary													
5-4	**3.0**	**43.5**	**saturated**	**75.5**	**19.9**	**15**	**5.0**	**1.3**	**52.7**	**121.5**	**3.9E-05**	**3.8**	

Notes:

Start Time: 16:49 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		33660.4	8886.3	0							
5-5A	2.0	29.0	saturated	33661.3	8886.6	1	0.9	0.2	38.6	89.1	9.5E-06	0.9	
5-5B	2.0	29.0	saturated	33664.9	8887.5	3	1.8	0.5	38.6	89.1	1.9E-05	1.9	
5-5C	2.0	29.0	saturated	33666.5	8888.0	5	0.8	0.2	38.6	89.1	8.5E-06	0.8	
5-5D	2.0	29.0	saturated	33673.4	8889.8	10	1.4	0.4	38.6	89.1	1.5E-05	1.4	
5-5E	2.0	29.0	saturated	33679.5	8891.4	15	1.2	0.3	38.6	89.1	1.3E-05	1.3	
Test Averages/Summary													
5-5	**2.0**	**29.0**	**saturated**	**19.1**	**5.0**	**15**	**1.2**	**0.3**	**38.6**	**89.1**	**1.3E-05**	**1.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.3
Bottom of Test Interval Depth, ft	195.1

Estimated Hydrostatic Pressure, psi	160.8
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	189.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8
Datum (Mudline) Elevation, ft	399.9
Top of Test Interval Elevation, ft	216.6
Bottom of Test Interval Elevation, ft	204.8
Rubber Hose Length, ft	52.5
# of NQ Rods	20
# of HWY Rods	21

Note:

Start Time: 17:48 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		33707.7	8898.8	0						
6-1A	2.0	29.0	saturated	33709.3	8899.3	1	1.6	0.4	38.6	89.0	1.7E-05	1.7
6-1B	2.0	29.0	saturated	33712.2	8900.0	3	1.4	0.4	38.6	89.0	1.5E-05	1.5
6-1C	2.0	29.0	saturated	33715.2	8900.8	5	1.5	0.4	38.6	89.0	1.6E-05	1.6
6-1D	2.0	29.0	saturated	33723.0	8902.9	10	1.6	0.4	38.6	89.0	1.7E-05	1.6
6-1E	2.0	29.0	saturated	33731.2	8905.0	15	1.6	0.4	38.6	89.0	1.7E-05	1.7
Test Averages/Summary												
6-1	**2.0**	**29.0**	**saturated**	**23.5**	**6.2**	**15**	**1.6**	**0.4**	**38.6**	**89.0**	**1.6E-05**	**1.6**

Notes:

Start Time: | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 2.3 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		33739.7	8907.3	0						
6-2A	3.0	43.5	saturated	33746.9	8909.2	1	7.2	1.9	52.1	120.3	5.6E-05	5.6
6-2B	3.0	43.5	saturated	33760.3	8912.7	3	6.7	1.8	52.1	120.3	5.3E-05	5.2
6-2C	3.0	43.5	saturated	33774.4	8916.4	5	7.0	1.9	52.1	120.3	5.5E-05	5.5
6-2D	3.0	43.5	saturated	33813.2	8926.7	10	7.8	2.0	52.1	120.3	6.1E-05	6.0
6-2E	3.0	43.5	saturated	33849.6	8936.3	15	7.3	1.9	52.1	120.3	5.7E-05	5.6
Test Averages/Summary												
6-2	**3.0**	**43.5**	**saturated**	**109.9**	**29.0**	**15**	**7.2**	**1.9**	**52.1**	**120.3**	**5.6E-05**	**5.6**

Notes:

Start Time: 18:21 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 12.6 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	4.0	58.0		33864.3	8940.2	0						
6-3A	4.0	58.0	saturated	33873.1	8942.5	1	8.8	2.3	62.2	143.4	5.8E-05	5.7
6-3B	4.0	58.0	saturated	33903.7	8950.6	3	15.3	4.0	62.2	143.4	1.0E-04	9.9
6-3C	4.0	58.0	saturated	33928.3	8957.1	5	12.3	3.2	62.2	143.4	8.1E-05	8.0
6-3D	4.0	58.0	saturated	34091.1	9000.1	10	32.6	8.6	62.2	143.4	2.1E-04	21.1
6-3E	4.0	58.0	saturated	34156.9	9017.4	15	13.2	3.5	62.2	143.4	8.7E-05	8.5
Test Averages/Summary												
6-3	**4.0**	**58.0**	**saturated**	**292.6**	**77.2**	**15**	**16.4**	**4.3**	**62.2**	**143.4**	**1.1E-04**	**10.7**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.3
Bottom of Test Interval Depth, ft	195.1

Estimated Hydrostatic Pressure, psi	160.8
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	189.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8
Datum (Mudline) Elevation, ft	399.9
Top of Test Interval Elevation, ft	216.6
Bottom of Test Interval Elevation, ft	204.8
Rubber Hose Length, ft	52.5
# of NQ Rods	20
# of HWY Rods	21

Note:

Start Time: 18:38 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 3.5 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		34177.9	9023.0	0						
6-4A	3.0	43.5	saturated	34187.2	9025.4	1	9.3	2.5	51.6	119.1	7.4E-05	7.3
6-4B	3.0	43.5	saturated	34206.6	9030.5	3	9.7	2.6	51.6	119.1	7.7E-05	7.6
6-4C	3.0	43.5	saturated	34222.1	9034.6	5	7.8	2.0	51.6	119.1	6.1E-05	6.1
6-4D	3.0	43.5	saturated	34266.2	9046.3	10	8.8	2.3	51.6	119.1	7.0E-05	6.9
6-4E	3.0	43.5	saturated	34309.9	9057.8	15	8.7	2.3	51.6	119.1	6.9E-05	6.8
Test Averages/Summary												
6-4	**3.0**	**43.5**	**saturated**	**132.0**	**34.8**	**15**	**8.9**	**2.3**	**51.6**	**119.1**	**7.0E-05**	**6.9**

Notes:

Start Time: 18:54 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		34318.1	9060.0	0						
6-5A	2.0	29.0	saturated	34318.8	9060.2	1	0.7	0.2	38.6	89.1	7.4E-06	0.7
6-5B	2.0	29.0	saturated	34319.0	9060.2	3	0.1	0.0	38.6	89.1	1.1E-06	0.1
6-5C	2.0	29.0	saturated	34318.9	9060.2	5	(0.0)	(0.0)				
6-5D	2.0	29.0	saturated	34322.9	9061.2	10	0.8	0.2	38.6	89.1	8.5E-06	0.8
6-5E	2.0	29.0	saturated	34325.7	9062.0	15	0.6	0.1	38.6	89.1	5.9E-06	0.6
Test Averages/Summary												
6-5	**2.0**	**29.0**	**saturated**	**7.6**	**2.0**	**15**	**0.4**	**0.1**	**38.6**	**89.1**	**5.7E-06**	**0.4**

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	7
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	173.5
Bottom of Test Interval Depth, ft	185.3

Estimated Hydrostatic Pressure, psi	156.5
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	179.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8
Datum (Mudline) Elevation, ft	399.9
Top of Test Interval Elevation, ft	226.4
Bottom of Test Interval Elevation, ft	214.6
Rubber Hose Length, ft	52.5
# of NQ Rods	20
# of HWY Rods	20

Note:

Start Time | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		34296.8	9054.4	0							
7-1A	2.0	29.0	saturated	34296.8	9054.4	1	0.0	0.0	38.6	89.1	0.00E+00	0.0	
7-1B	2.0	29.0	saturated	34296.8	9054.4	3	0.0	0.0	38.6	89.1	0.00E+00	0.0	
7-1C	2.0	29.0	saturated	34297.0	9054.4	5	0.1	0.0	38.6	89.1	1.06E-06	0.1	
7-1D	2.0	29.0	saturated	34298.5	9054.8	10	0.3	0.1	38.6	89.1	3.17E-06	0.3	
7-1E	2.0	29.0	saturated	34299.7	9055.1	15	0.2	0.1	38.6	89.1	2.54E-06	0.3	
Test Averages/Summary													
7-1	**2.0**	**29.0**	**saturated**	**2.9**	**0.8**	**15**	**0.1**	**0.0**	**38.6**	**89.1**	**1.35E-06**	**0.1**	

Notes

Start Time: 20:08 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 2.3 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		34312.2	9058.4	0							
7-2A	3.0	43.5	saturated	34320.4	9060.6	1	8.2	2.2	52.1	120.3	6.43E-05	6.3	
7-2B	3.0	43.5	saturated	34333.8	9064.1	3	6.7	1.8	52.1	120.3	5.25E-05	5.2	
7-2C	3.0	43.5	saturated	34347.8	9067.8	5	7.0	1.8	52.1	120.3	5.49E-05	5.4	
7-2D	3.0	43.5	saturated	34383.4	9077.2	10	7.1	1.9	52.1	120.3	5.58E-05	5.5	
7-2E	3.0	43.5	saturated	34421.1	9087.2	15	7.5	2.0	52.1	120.3	5.91E-05	5.8	
Test Averages/Summary													
7-2	**3.0**	**43.5**	**saturated**	**108.9**	**28.7**	**15**	**7.3**	**1.9**	**52.1**	**120.3**	**5.73E-05**	**5.7**	

Notes

Start Time: 20:25 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 8.8 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	4.0	58.0		34445.4	9093.6	0							
7-3A	4.0	58.0	saturated	34460.5	9097.6	1	15.1	4.0	63.8	147.2	9.67E-05	9.6	
7-3B	4.0	58.0	saturated	34488.6	9105.0	3	14.0	3.7	63.8	147.2	9.00E-05	8.9	
7-3C	4.0	58.0	saturated	34517.1	9112.5	5	14.3	3.8	63.8	147.2	9.13E-05	9.0	
7-3D	4.0	58.0	saturated	34587.8	9131.2	10	14.1	3.7	63.8	147.2	9.06E-05	8.9	
7-3E	4.0	58.0	saturated	34651.1	9147.9	15	12.7	3.3	63.8	147.2	8.11E-05	8.0	
Test Averages/Summary													
7-3	**4.0**	**58.0**	**saturated**	**205.7**	**54.3**	**15**	**14.0**	**3.7**	**63.8**	**147.2**	**8.99E-05**	**8.9**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	10/21/2019
WSP Personel	C. Fischer
Driller	Fugro
Operator	T.Brindle

Boring ID	BH19-28
Test Number	7
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	173.5
Bottom of Test Interval Depth, ft	185.3

Estimated Hydrostatic Pressure, psi	156.5
Pressure Gauge above Lake Level (h), ft	22.2
Vertical Center of Test Interval (D), ft	179.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	181.8		
Datum (Mudline) Elevation, ft	399.9		
Top of Test Interval Elevation, ft	226.4		
Bottom of Test Interval Elevation, ft	214.6		
Rubber Hose Length, ft	52.5		
# of NQ Rods	20	# of HWY Rods	20

Note:

Start Time: 20:41 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 3.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		34671.5	9153.3	0							
7-4A	3.0	43.5	saturated	34678.7	9155.2	1	7.2	1.9	51.8	119.6	5.68E-05	5.6	
7-4B	3.0	43.5	saturated	34695.8	9159.7	3	8.6	2.3	51.8	119.6	6.74E-05	6.7	
7-4C	3.0	43.5	saturated	34713.7	9164.4	5	8.9	2.4	51.8	119.6	7.06E-05	7.0	
7-4D	3.0	43.5	saturated	34755.6	9175.5	10	8.4	2.2	51.8	119.6	6.61E-05	6.5	
7-4E	3.0	43.5	saturated	34798.2	9186.7	15	8.5	2.2	51.8	119.6	6.72E-05	6.6	
Test Averages/Summary													
7-4	**3.0**	**43.5**	**saturated**	**126.7**	**33.4**	**15**	**8.3**	**2.2**	**51.8**	**119.6**	**6.56E-05**	**6.5**	

Notes:

Start Time: 20:02 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		34800.2	9187.3	0							
7-5A	2.0	29.0	saturated	34800.5	9187.3	1	0.3	0.1	38.6	89.1	3.17E-06	0.3	
7-5B	2.0	29.0	saturated	34801.7	9187.6	3	0.6	0.2	38.6	89.1	6.35E-06	0.6	
7-5C	2.0	29.0	saturated	34803.3	9188.1	5	0.8	0.2	38.6	89.1	8.47E-06	0.8	
7-5D	2.0	29.0	saturated	34807.2	9189.1	10	0.8	0.2	38.6	89.1	8.25E-06	0.8	
7-5E	2.0	29.0	saturated	34811.0	9190.1	15	0.8	0.2	38.6	89.1	8.04E-06	0.8	
Test Averages/Summary													
7-5	**2.0**	**29.0**	**saturated**	**10.8**	**2.9**	**15**	**0.6**	**0.2**	**38.6**	**89.1**	**6.86E-06**	**0.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	08/11/19
WSP Personnel	C. Zhang, K. Zeiger
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	13.5
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-31
Number of Tests	3
Lattitude	45.81090°N
Longitude	84.76751°W

Top of Rock, ft	132.2
Bottom of Boring, ft	265.7
Lake Depth, ft	119.3

Datum (Mudline) Elevation	462.4
Top of Rock Elevation, ft	330.2
Bottom of Hole Elevation, ft	196.7
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.0	14.5	saturated	781.9	206.4	140.8	49.63	13.10	0.0	0.0	Free Flow	Free Flow	Free Flow	Free flow may be due to fractured ground or unsealed packers.
1-2	2.2	31.9	saturated	1429.7	377.4	140.8	95.74	25.27	0.0	0.0	Free Flow	Free Flow	Free Flow	
1-3	2.6	38.0	saturated	1996.8	527.2	140.8	134.04	35.39	0.0	0.0	Free Flow	Free Flow	Free Flow	
1-4	2.0	29.6	saturated	1506.6	397.7	140.8	99.95	26.39	0.0	0.0	Free Flow	Free Flow	Free Flow	
1-5	1.0	14.5	saturated	771.2	203.6	140.8	48.43	12.79	0.0	0.0	Free Flow	Free Flow	Free Flow	
2-1	1.1	16.2	saturated	190.5	50.3	138.0	13.09	3.46	23.2	53.5	2.08E-04	18.1		
Test stopped														
2-R-1	1.4	19.6	saturated	286.2	75.6	138.0	33.99	8.97	1.3	3.0	Free Flow	Free Flow	Free Flow	Free flow may be due to fractured ground or unsealed packers.
2-R-2	2.0	29.0	saturated	199.1	52.6	138.0	11.07	2.92	37.2	85.9	1.04E-04	9.5		
2-R-3	3.8	55.6	saturated	10.1	2.7	138.0	2.83	0.75	66.8	154.0	1.55E-05	1.4		
2-R-4	2.3	33.3	saturated	4.9	1.3	138.0	2.17	0.57	44.6	103.0	1.68E-05	1.6		
Test stopped														
3-1	2.2	31.4	saturated	40.6	10.7	133.8	8.08	2.13	41.2	95.1	6.81E-05	6.3		
Test stopped														
3-R-1	3.4	48.9	saturated	249.0	65.7	133.8	22.17	5.85	47.7	110.1	1.64E-04	14.9		
3-R-2	3.7	52.9	saturated	256.7	67.8	133.8	27.71	7.32	44.5	102.7	2.30E-04	20.0		
3-R-3	4.9	70.3	saturated	358.0	94.5	133.8	39.15	10.34	41.9	96.7	3.25E-04	30.0		
Test stopped														

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	C. Zhang
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-31
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	198.3
Bottom of Test Interval Depth, ft	213.1

Estimated Hydrostatic Pressure, psi	140.8
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	205.7
Test Interval Length (L), ft	14.8

Lake Depth, ft	119.3		
Datum (Mudline) Elevation, ft	462.4		
Top of Test Interval Elevation, ft	264.1		
Bottom of Test Interval Elevation, ft	249.3		
Rubber Hose Length, ft	19.7		
# of NQ Rods	6	# of HWY Rods	31

Note:

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 158 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure* (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		48815.8	12887.4	0							
1-1A	1.0	14.5	saturated	48869.1	12901.4	1	53.3	14.1	0.0	0.0	Free Flow	Free Flow	Free Flow
1-1B	1.0	14.5	saturated	48943.6	12921.1	3	37.3	9.8	0.0	0.0	Free Flow	Free Flow	Free Flow
1-1C	0.9	13.0	saturated	49032.9	12944.7	5	44.7	11.8	0.0	0.0	Free Flow	Free Flow	Free Flow
1-1D	1.1	15.9	saturated	49268.5	13006.9	10	47.1	12.4	0.0	0.0	Free Flow	Free Flow	Free Flow
1-1E	1.0	14.5	saturated	49597.7	13093.8	15	65.8	17.4	0.0	0.0	Free Flow	Free Flow	Free Flow
Test Averages/Summary													
1-1	**1.0**	**14.5**	**saturated**	**781.9**	**206.4**	**15**	**49.6**	**13.1**	**0.0**	**0.0**	**Free Flow**	**Free Flow**	**Free Flow**

Notes: *The friction loss cannot generate negative test pressure, which is set at the lower bound of 0 psi indicating that free flow occurred. Free flow may be due to fractured ground or unsealed packers.

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 592.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure* (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		50291.2	13276.9	0							
1-2A	2.2	31.9	saturated	50459.6	13321.3	3	56.1	14.8	0.0	0.0	Free Flow	Free Flow	Free Flow
1-2B	2.2	31.9	saturated	50708.1	13386.9	5	124.3	32.8	0.0	0.0	Free Flow	Free Flow	Free Flow
1-2C	2.2	31.9	saturated	51207.1	13518.7	10	99.8	26.3	0.0	0.0	Free Flow	Free Flow	Free Flow
1-2D	2.2	31.9	saturated	51720.9	13654.3	15	102.8	27.1	0.0	0.0	Free Flow	Free Flow	Free Flow
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
1-2	**2.2**	**31.9**	**saturated**	**1429.7**	**377.4**	**15**	**95.7**	**25.3**	**0.0**	**0.0**	**Free Flow**	**Free Flow**	**Free Flow**

Notes: Missed flow meter reading at 1 minute time step. * The friction loss cannot generate negative test pressure, which is set at the lower bound of 0 psi indicating that free flow occurred. Free flow may be due to fractured ground or unsealed packers. At Test Steps 3-2C and 3-2D, the flow meter readings were mistakenly recorded as 50207.1 and 50720.9 Liter. Corrections were made.

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 1162.9 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure* (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.5	36.2		52106.2	13756.0	0							
1-3A	2.6	37.7	saturated	52249.0	13793.7	1	142.8	37.7	0.0	0.0	Free Flow	Free Flow	Free Flow
1-3B	2.6	37.7	saturated	52504.0	13861.1	3	127.5	33.7	0.0	0.0	Free Flow	Free Flow	Free Flow
1-3C	2.6	37.7	saturated	52771.0	13931.5	5	133.5	35.2	0.0	0.0	Free Flow	Free Flow	Free Flow
1-3D	2.6	37.7	saturated	53435.0	14106.8	10	132.8	35.1	0.0	0.0	Free Flow	Free Flow	Free Flow
1-3E	2.7	39.1	saturated	54103.0	14283.2	15	133.6	35.3	0.0	0.0	Free Flow	Free Flow	Free Flow
Test Averages/Summary													
1-3	**2.6**	**38.0**	**saturated**	**1996.8**	**527.2**	**15**	**134.0**	**35.4**	**0.0**	**0.0**	**Free Flow**	**Free Flow**	**Free Flow**

Notes: *The friction loss cannot generate negative test pressure, which is set at the lower bound of 0 psi indicating that free flow occurred. Free flow may be due to fractured ground or unsealed packers.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	C. Zhang
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-31
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	198.3
Bottom of Test Interval Depth, ft	213.1

Estimated Hydrostatic Pressure, psi	140.8
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	205.7
Test Interval Length (L), ft	14.8

Lake Depth, ft	119.3
Datum (Mudline) Elevation, ft	462.4
Top of Test Interval Elevation, ft	264.1
Bottom of Test Interval Elevation, ft	249.3
Rubber Hose Length, ft	19.7
# of NQ Rods	6
# of HWY Rods	31

Note:

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 645.4 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure* (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		54265.0	14326.0	0							
1-4A	2.1	30.4	saturated	54360.1	14351.1	1	95.1	25.1	0.0	0.0	Free Flow	Free Flow	Free Flow
1-4B	2.1	30.4	saturated	54568.0	14406.0	3	104.0	27.4	0.0	0.0	Free Flow	Free Flow	Free Flow
1-4C	2.0	29.0	saturated	54767.9	14458.7	5	100.0	26.4	0.0	0.0	Free Flow	Free Flow	Free Flow
1-4D	2.0	29.0	saturated	55265.0	14590.0	10	99.4	26.2	0.0	0.0	Free Flow	Free Flow	Free Flow
1-4E	2.0	29.0	saturated	55771.6	14723.7	15	101.3	26.7	0.0	0.0	Free Flow	Free Flow	Free Flow
Test Averages/Summary													
1-4	**2.0**	**29.6**	**saturated**	**1506.6**	**397.7**	**15**	**99.9**	**26.4**	**0.0**	**0.0**	**Free Flow**	**Free Flow**	**Free Flow**

Notes: *The friction loss cannot generate negative test pressure, which is set at the lower bound of 0 psi indicating that free flow occurred. Free flow may be due to fractured ground or unsealed packers.

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 150.4 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure* (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		55923.0	14763.7	0							
1-5A	1.0	14.5	saturated	55965.6	14774.9	1	42.6	11.2	0.0	0.0	Free Flow	Free Flow	Free Flow
1-5B	1.0	14.5	saturated	56055.1	14798.5	3	44.8	11.8	0.0	0.0	Free Flow	Free Flow	Free Flow
1-5C	1.0	14.5	saturated	56145.1	14822.3	5	45.0	11.9	0.0	0.0	Free Flow	Free Flow	Free Flow
1-5D	1.0	14.5	saturated	56370.5	14881.8	10	45.1	11.9	0.0	0.0	Free Flow	Free Flow	Free Flow
1-5E	1.0	14.5	saturated	56694.2	14967.3	15	64.7	17.1	0.0	0.0	Free Flow	Free Flow	Free Flow
Test Averages/Summary													
1-5	**1.0**	**14.5**	**saturated**	**771.2**	**203.6**	**15**	**48.4**	**12.8**	**0.0**	**0.0**	**Free Flow**	**Free Flow**	**Free Flow**

Notes: *The friction loss cannot generate negative test pressure, which is set at the lower bound of 0 psi indicating that free flow occurred. Free flow may be due to fractured ground or unsealed packers.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	K. Zeiger
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-31
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	191.8
Bottom of Test Interval Depth, ft	206.6

Estimated Hydrostatic Pressure, psi	138.0
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.2
Test Interval Length (L), ft	14.8

Lake Depth, ft	119.3
Datum (Mudline) Elevation, ft	462.4
Top of Test Interval Elevation, ft	270.6
Bottom of Test Interval Elevation, ft	255.8
Rubber Hose Length, ft	19.7
# of NQ Rods	6
# of HWY Rods	30

Note:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 10 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		57288.7	15124.2	0							
2-1A	1.0	14.5	saturated	57311.1	15130.1	1	22.4	5.9	21.5	49.5	3.60E-04	33.6	
2-1B	1.3	18.8	saturated	57341.0	15138.0	3	15.0	3.9	25.8	59.5	2.00E-04	18.6	
2-1C	1.5	21.7	saturated	57342.5	15138.4	5	0.8	0.2	28.7	66.2	9.00E-06	0.8	
2-1D	0.9	13.0	saturated	57396.7	15152.7	10	10.8	2.9	20.0	46.1	1.87E-04	17.4	
2-1E	0.9	13.0	saturated	57479.2	15174.5	15	16.5	4.4	20.0	46.1	2.84E-04	26.5	
Test Averages/Summary													
2-1	**1.1**	**16.2**	**saturated**	**190.5**	**50.3**	**15**	**13.1**	**3.5**	**23.2**	**53.5**	**2.08E-04**	**18.1**	

Notes: Unable to increase pressure due to possible lost seal. Test stopped.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	K. Zeiger
Driller	Fugro
Operator	C. Murphy
Lake Depth, ft	119.3
Datum (Mudline) Elevation, ft	462.4
Top of Test Interval Elevation, ft	270.6
Bottom of Test Interval Elevation, ft	255.8
Rubber Hose Length, ft	19.7
# of NQ Rods	6
# of HWY Rods	30

Boring ID	BH19-31
Test Number	2-R
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	191.8
Bottom of Test Interval Depth, ft	206.6

Estimated Hydrostatic Pressure, psi	138.0
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.2
Test Interval Length (L), ft	14.8

Note: The 'R' in the test name is for 'Reattempt'.

Start Time | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 71 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure* (P_t) $P_t = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.3	18.8		58274.4	15384.4	0							
2-R-1A	1.2	17.4	saturated	58314.7	15395.1	1	40.3	10.6	0.0	0.0	Free Flow	Free Flow	Free Flow
2-R-1B	1.2	17.4	saturated	58390.4	15415.1	3	37.9	10.0	0.0	0.0	Free Flow	Free Flow	Free Flow
2-R-1C	1.7	24.6	saturated	58469.7	15436.0	5	39.6	10.5	5.1	11.8	2.67E-03	248.8	
2-R-1D	1.3	18.8	saturated	58560.6	15460.0	10	18.2	4.8	0.0	0.0	Free Flow	Free Flow	Free Flow
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
2-R-1	**1.4**	**19.6**	**saturated**	**286.2**	**75.6**	**10**	**34.0**	**9.0**	**1.3**	**3.0**	**Free Flow**	**Free Flow**	**Free Flow**

Notes: Missed reading at 15 minute time step. *The friction loss cannot generate negative test pressure, which is set at the lower bound of 0 psi indicating that free flow occurred. Free flow may be due to fractured ground or unsealed packers.

Start Time | Stage/Packer Pressure, bar: 25 | Friction Loss, *f*, ft: 7.2 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_t) $P_t = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		58575.7	15464.0	0							
2-R-2A	2.0	29.0	saturated	58587.4	15467.1	1	11.7	3.1	37.2	85.9	1.08E-04	10.1	
2-R-2B	2.1	30.4	saturated	58590.5	15467.9	3	1.5	0.4	38.7	89.3	1.38E-05	1.3	
2-R-2C	2.2	31.9	saturated	58607.9	15472.5	5	8.7	2.3	40.1	92.6	7.47E-05	7.0	
2-R-2D	2.2	31.9	saturated	58712.4	15500.1	10	20.9	5.5	40.1	92.6	1.79E-04	16.7	
2-R-2E	1.5	21.7	saturated	58774.8	15516.5	15	12.5	3.3	30.0	69.2	1.43E-04	13.4	
Test Averages/Summary													
2-R-2	**2.0**	**29.0**	**saturated**	**199.1**	**52.6**	**15**	**11.1**	**2.9**	**37.2**	**85.9**	**1.04E-04**	**9.5**	

Notes:

Start Time | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_t) $P_t = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.9	42.0		60541.7	15983.0	0							
2-R-3A	3.5	50.7	saturated	60548.9	15984.9	1	7.2	1.9	61.9	142.9	4.00E-05	3.7	
2-R-3B	4.0	58.0	saturated	60550.9	15985.4	3	1.0	0.3	69.2	159.6	4.98E-06	0.5	
2-R-3C	4.0	58.0	saturated	60551.8	15985.7	6	0.3	0.1	69.2	159.6	1.49E-06	0.1	
2-R-3D	4.5	65.2	saturated	60513.5	15975.6	10	(9.6)	(2.5)					
2-R-3E	4.0	58.0	saturated	60524.7	15978.5	15	2.2	0.6	69.2	159.6	1.12E-05	1.0	
Test Averages/Summary													
2-R-3	**3.8**	**55.6**	**saturated**	**10.1**	**2.7**	**6**	**2.8**	**0.7**	**66.8**	**154.0**	**1.55E-05**	**1.4**	

Notes: Non-standard time steps. Packer lost pressure. Bottle Change. Reduce pressure and reverse flow at Test Steps 4-R-3D; Average hydraulic conductivity did not include the data from last two steps.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	K. Zeiger
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-31
Test Number	2-R
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	191.8
Bottom of Test Interval Depth, ft	206.6

Estimated Hydrostatic Pressure, psi	138.0
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.2
Test Interval Length (L), ft	14.8

Lake Depth, ft	119.3
Datum (Mudline) Elevation, ft	462.4
Top of Test Interval Elevation, ft	270.6
Bottom of Test Interval Elevation, ft	255.8
Rubber Hose Length, ft	19.7
# of NQ Rods	6
# of HWY Rods	30

Note: The 'R' in the test name is for 'Reattempt'.

Start Time | Stage/Packer Pressure, bar: 30 | Friction Loss, f, ft: 0.2 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.2	31.9		60438.8	15955.8	0							
2-R-4A	2.3	33.3	saturated	60442.6	15956.8	1	3.8	1.0	44.6	103.0	2.93E-05	2.7	
2-R-4B	2.3	33.3	saturated	60443.7	15957.1	3	0.5	0.1	44.6	103.0	4.25E-06	0.4	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
2-R-4	**2.3**	**33.3**	**saturated**	**4.9**	**1.3**	**3**	**2.2**	**0.6**	**44.6**	**103.0**	**1.68E-05**	**1.6**	

Notes: Missed reading at 5 minute time step. Unable to hold pressure at 10 minute time step.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	K. Zeiger
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-31
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	182.0
Bottom of Test Interval Depth, ft	196.8

Estimated Hydrostatic Pressure, psi	133.8
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	189.4
Test Interval Length (L), ft	14.8

Lake Depth, ft	119.3
Datum (Mudline) Elevation, ft	462.4
Top of Test Interval Elevation, ft	280.4
Bottom of Test Interval Elevation, ft	265.6
Rubber Hose Length, ft	19.7
# of NQ Rods	6
# of HWY Rods	29

Note:

Start Time: | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 4 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		60546.7	15984.3	0							
3-1A	2.1	30.4	saturated	60554.6	15986.4	1	7.9	2.1	40.3	92.9	6.76E-05	6.3	
3-1B	2.1	30.4	saturated	60576.1	15992.1	3	10.8	2.8	40.3	92.9	9.20E-05	8.6	
3-1C	2.3	33.3	saturated	60587.3	15995.0	5	5.6	1.5	43.2	99.6	4.47E-05	4.2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
3-1	**2.2**	**31.4**	**saturated**	**40.6**	**10.7**	**5**	**8.1**	**2.1**	**41.2**	**95.1**	**6.81E-05**	**6.3**	

Notes: At test step 5-1D, reverse flow to reduce pressure. Test stopped; unable to control the pressure without reverse flow.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	8/11/2019
WSP Personnel	K. Zeiger
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-31
Test Number	3-R
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	182.0
Bottom of Test Interval Depth, ft	196.8

Estimated Hydrostatic Pressure, psi	133.8
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	189.4
Test Interval Length (L), ft	14.8

Lake Depth, ft	119.3
Datum (Mudline) Elevation, ft	462.4
Top of Test Interval Elevation, ft	280.4
Bottom of Test Interval Elevation, ft	265.6
Rubber Hose Length, ft	19.7
# of NQ Rods	6
# of HWY Rods	29

Note: The 'R' in the test name is for 'Reattempt'.

Start Time: 15:36 | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 29 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.1	44.9		61014.1	16107.7	0							
3-R-1A	3.5	50.7	saturated	61042.0	16115.1	1	27.9	7.4	49.5	114.3	1.94E-04	18.1	
3-R-1B	3.5	50.7	saturated	61072.8	16123.2	3	15.4	4.1	49.5	114.3	1.07E-04	10.0	
3-R-1C	3.5	50.7	saturated	61097.2	16129.7	5	12.2	3.2	49.5	114.3	8.48E-05	7.9	
3-R-1D	3.0	43.5	saturated	61263.1	16173.5	10	33.2	8.8	42.3	97.6	2.70E-04	25.2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
3-R-1	**3.4**	**48.9**	**saturated**	**249.0**	**65.7**	**10**	**22.2**	**5.9**	**47.7**	**110.1**	**1.64E-04**	**14.9**	

Notes: Possible artesian flow at 3 bar. Reverse flow when pressure drops below 2 bar.

Start Time: | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 45.6 | Target Pressure, Bar: 4.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.9	56.5		61572.0	16255.0	0							
3-R-2A	4.0	58.0	saturated	61605.2	16263.8	1	33.2	8.8	49.6	114.4	2.31E-04	21.5	
3-R-2B	4.5	65.2	saturated	61675.7	16282.4	3	35.3	9.3	56.9	131.2	2.14E-04	19.9	
3-R-2C	3.9	56.5	saturated	61715.0	16292.8	5	19.7	5.2	48.2	111.1	1.41E-04	13.1	
3-R-2D	2.2	31.9	saturated	61828.7	16322.8	10	22.7	6.0	23.5	54.2	3.33E-04	31.1	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
3-R-2	**3.7**	**52.9**	**saturated**	**256.7**	**67.8**	**10**	**27.7**	**7.3**	**44.5**	**102.7**	**2.30E-04**	**20.0**	

Notes:

Start Time: | Stage/Packer Pressure, bar: 30 | Friction Loss, *f*, ft: 91.8 | Target Pressure, Bar: 5.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	5.1	73.9		62082.0	16389.6	0							
3-R-3A	5.4	78.3	saturated	62137.0	16404.2	1	55.0	14.5	49.9	115.1	3.80E-04	35.4	
3-R-3B	5.0	72.5	saturated	62202.0	16421.3	3	32.5	8.6	44.1	101.7	2.54E-04	23.7	
3-R-3C	5.0	72.5	saturated	62273.7	16440.3	5	35.8	9.5	44.1	101.7	2.80E-04	26.1	
3-R-3D	4.0	58.0	saturated	62440.0	16484.2	10	33.3	8.8	29.6	68.2	3.87E-04	36.1	
3-R-3E	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
3-R-3	**4.9**	**70.3**	**saturated**	**358.0**	**94.5**	**10**	**39.2**	**10.3**	**41.9**	**96.7**	**3.25E-04**	**30.0**	

Notes: Water kept pumping due to low temperature to prevent freezing. Leak in tool unable to keep seal due to gas running out before. Test stopped.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	09/22/19
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	25.1
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-32
Number of Tests	7
Lattitude	45.80755°N
Longitude	84.76880°W

Top of Rock, ft	92.4
Bottom of Boring, ft	197.2
Lake Depth, ft	130.2

Datum (Mudline) Elevation	451.4
Top of Rock Elevation, ft	359.0
Bottom of Hole Elevation, ft	254.2
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.3	19.1	saturated	0.0	0.0	135.4	0.00	0.00	30.5	70.4	0.00E+00	0.0		
1-2	2.2	31.6	saturated	6.9	1.8	135.4	0.44	0.12	43.0	99.1	4.18E-06	0.4		
1-3	3.3	47.3	saturated	16.9	4.5	135.4	1.16	0.31	58.6	135.3	8.07E-06	0.8		
1-4	2.0	29.0	saturated	7.3	1.9	135.4	0.50	0.13	40.4	93.1	5.10E-06	0.5		
1-5	1.0	14.5	saturated	0.0	0.0	135.4	0.00	0.00	25.9	59.7	0.00E+00	0.0		
2-1	1.2	17.4	saturated	8.4	2.2	131.2	0.64	0.17	28.8	66.4	9.07E-06	0.9		
2-2	2.0	29.0	saturated	19.6	5.2	131.2	1.30	0.34	40.4	93.1	1.31E-05	1.3		
2-3	3.0	43.8	saturated	23.8	6.3	131.2	1.83	0.48	55.2	127.2	1.35E-05	1.3		
2-4	2.0	29.0	saturated	19.1	5.0	131.2	1.26	0.33	40.4	93.1	1.27E-05	1.3		
2-5	1.0	14.5	saturated	0.9	0.2	131.2	0.04	0.01	25.9	59.7	6.64E-07	0.1		
3-1	1.0	14.5	saturated	0.4	0.1	126.9	0.05	0.01	25.9	59.7	7.90E-07	0.1		
3-2	2.1	30.4	saturated	3.1	0.8	126.9	0.23	0.06	41.2	95.1	2.29E-06	0.2		
3-3	3.0	44.1	saturated	2.8	0.7	126.9	0.28	0.07	55.4	127.9	2.11E-06	0.2		
3-4	2.0	29.0	saturated	4.0	1.1	126.9	0.18	0.05	40.4	93.1	1.78E-06	0.2		
3-5	1.0	14.5	saturated	0.1	0.0	126.9	0.00	0.00	25.9	59.7	6.32E-08	0.0		
4-1	1.0	14.5	saturated	18.8	5.0	122.7	1.27	0.33	25.9	59.7	2.00E-05	2.0		
4-2	2.2	31.2	saturated	38.7	10.2	122.7	2.58	0.68	42.5	98.1	2.48E-05	2.5		
4-3	3.0	43.5	saturated	55.3	14.6	122.7	3.68	0.97	54.8	126.5	2.75E-05	2.7		
4-4	2.0	29.0	saturated	40.2	10.6	122.7	2.52	0.67	40.4	93.1	2.56E-05	2.5		
4-5	1.0	14.8	saturated	27.7	7.3	122.7	1.79	0.47	26.2	60.4	2.81E-05	2.8		
5-1	1.0	14.2	saturated	44.9	11.9	118.4	3.16	0.83	25.6	59.0	5.12E-05	5.0		
5-2	2.0	29.6	saturated	112.5	29.7	118.4	7.14	1.88	40.8	94.1	7.18E-05	7.1		
5-3	2.8	40.3	saturated	187.9	49.6	118.4	12.46	3.29	51.1	117.8	1.00E-04	9.8		
5-4	2.1	30.2	saturated	189.5	50.0	118.4	12.77	3.37	40.9	94.3	1.28E-04	12.6		
5-5	0.9	13.4	saturated	118.3	31.2	118.4	7.67	2.02	24.6	56.7	1.29E-04	12.6		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	09/22/19
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	25.1
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-32
Number of Tests	7
Lattitude	45.80755°N
Longitude	84.76880°W

Top of Rock, ft	92.4
Bottom of Boring, ft	197.2
Lake Depth, ft	130.2

Datum (Mudline) Elevation	451.4
Top of Rock Elevation, ft	359.0
Bottom of Hole Elevation, ft	254.2
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
6-1	1.0	14.5	saturated	24.8	6.5	114.1	2.39	0.63	25.9	59.7	3.78E-05	3.7		
6-2	2.0	29.0	saturated	55.0	14.5	114.1	3.76	0.99	40.3	93.0	3.81E-05	3.8		
6-3	3.0	43.5	saturated	74.1	19.6	114.1	5.16	1.36	54.8	126.4	3.85E-05	3.8		
6-4	2.2	31.9	saturated	59.9	15.8	114.1	3.64	0.96	43.2	99.7	3.41E-05	3.4		
6-5	1.0	14.5	saturated	33.8	8.9	114.1	2.29	0.60	25.9	59.7	3.62E-05	3.6		
7-1	1.0	13.8	saturated	20.5	5.4	109.9	1.39	0.37	25.1	58.0	2.26E-05	2.2		
7-2	1.9	28.1	saturated	34.2	9.0	109.9	2.34	0.62	39.5	91.1	2.42E-05	2.4		
7-3	3.0	43.5	saturated	49.1	13.0	109.9	3.28	0.87	54.9	126.6	2.44E-05	2.4		
7-4	2.0	29.0	saturated	35.3	9.3	109.9	2.31	0.61	40.4	93.1	2.34E-05	2.3		
7-5	1.0	14.2	saturated	21.0	5.5	109.9	1.35	0.36	25.6	59.0	2.17E-05	2.1		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	09/22/19
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	25.1
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-32
Number of Tests	7
Lattitude	45.80755°N
Longitude	84.76880°W

Top of Rock, ft	92.4
Bottom of Boring, ft	197.2
Lake Depth, ft	130.2

Datum (Mudline) Elevation	451.4
Top of Rock Elevation, ft	359.0
Bottom of Hole Elevation, ft	254.2
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/20/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	176.4
Bottom of Test Interval Depth, ft	188.2

Estimated Hydrostatic Pressure, psi	135.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	182.3
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	275.0
Bottom of Test Interval Elevation, ft	263.2
Rubber Hose Length, ft	19.7
# of NQ Rods	35
# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r) Bar	Pressure Reading (P_r) psi	Analysis Type	Flow Meter Reading Liter	Flow Meter Reading gal	Elapsed Time in Minutes	Flowrate L/min	Flowrate gpm	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ psi	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ ft	Hydraulic Conductivity (K) cm/sec	Water Take Lugeons
	1.0	14.5		29267.5	7726.6	0						
1-1A	1.0	14.5	saturated	29267.5	7726.6	1	0.0	0.0	25.9	59.7	0.00E+00	0.0
1-1B	1.4	20.3	saturated	29267.5	7726.6	3	0.0	0.0	31.7	73.1	0.00E+00	0.0
1-1C	1.4	20.3	saturated	29267.5	7726.6	5	0.0	0.0	31.7	73.1	0.00E+00	0.0
1-1D	1.4	20.3	saturated	29267.5	7726.6	10	0.0	0.0	31.7	73.1	0.00E+00	0.0
1-1E	1.4	20.3	saturated	29267.5	7726.6	15	0.0	0.0	31.7	73.1	0.00E+00	0.0
Test Averages/Summary												
1-1	**1.3**	**19.1**	**saturated**	**0.0**	**0.0**	**15**	**0.0**	**0.0**	**30.5**	**70.4**	**0.00E+00**	**0.0**

Notes: No flow at 1 bar.

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r) Bar	Pressure Reading (P_r) psi	Analysis Type	Flow Meter Reading Liter	Flow Meter Reading gal	Elapsed Time in Minutes	Flowrate L/min	Flowrate gpm	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ psi	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ ft	Hydraulic Conductivity (K) cm/sec	Water Take Lugeons
	2.0	29.0		29267.8	7726.7	0						
1-2A	2.1	30.4	saturated	29267.9	7726.7	1	0.1	0.0	41.8	96.5	9.78E-07	0.1
1-2B	2.2	31.9	saturated	29268.8	7727.0	3	0.4	0.1	43.3	99.8	4.25E-06	0.4
1-2C	2.2	31.9	saturated	29270.4	7727.4	5	0.8	0.2	43.3	99.8	7.56E-06	0.7
1-2D	2.2	31.9	saturated	29274.7	7728.5	10	0.9	0.2	43.3	99.8	8.13E-06	0.8
1-2E	2.2	31.9	saturated	29274.7	7728.5	15	0.0	0.0	43.3	99.8	0.00E+00	0.0
Test Averages/Summary												
1-2	**2.2**	**31.6**	**saturated**	**6.9**	**1.8**	**15**	**0.4**	**0.1**	**43.0**	**99.1**	**4.18E-06**	**0.4**

Notes:

Start Time: 22:07 | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r) Bar	Pressure Reading (P_r) psi	Analysis Type	Flow Meter Reading Liter	Flow Meter Reading gal	Elapsed Time in Minutes	Flowrate L/min	Flowrate gpm	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ psi	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ ft	Hydraulic Conductivity (K) cm/sec	Water Take Lugeons
	3.1	44.9		29281.8	7730.4	0						
1-3A	3.2	46.4	saturated	29283.0	7730.7	1	1.2	0.3	57.8	133.3	8.49E-06	0.8
1-3B	3.2	46.4	saturated	29285.4	7731.3	3	1.2	0.3	57.8	133.3	8.49E-06	0.8
1-3C	3.2	46.4	saturated	29287.8	7732.0	5	1.2	0.3	57.8	133.3	8.49E-06	0.8
1-3D	3.3	47.8	saturated	29293.4	7733.5	10	1.1	0.3	59.2	136.6	7.73E-06	0.8
1-3E	3.4	49.3	saturated	29298.7	7734.9	15	1.1	0.3	60.7	140.0	7.14E-06	0.7
Test Averages/Summary												
1-3	**3.3**	**47.3**	**saturated**	**16.9**	**4.5**	**15**	**1.2**	**0.3**	**58.6**	**135.3**	**8.07E-06**	**0.8**

Notes: Pressure creeping up.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/20/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	176.4
Bottom of Test Interval Depth, ft	188.2

Estimated Hydrostatic Pressure, psi	135.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	182.3
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	275.0
Bottom of Test Interval Elevation, ft	263.2
Rubber Hose Length, ft	19.7
# of NQ Rods	35
# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		29299.3	7735.0	0							
1-4A	2.0	29.0	saturated	29299.8	7735.1	1	0.5	0.1	40.4	93.1	5.06E-06	0.5	
1-4B	2.0	29.0	saturated	29300.4	7735.3	3	0.3	0.1	40.4	93.1	3.04E-06	0.3	
1-4C	2.0	29.0	saturated	29302.0	7735.7	5	0.8	0.2	40.4	93.1	8.10E-06	0.8	
1-4D	2.0	29.0	saturated	29304.4	7736.4	10	0.5	0.1	40.4	93.1	4.86E-06	0.5	
1-4E	2.0	29.0	saturated	29306.6	7736.9	15	0.4	0.1	40.4	93.1	4.46E-06	0.4	
Test Averages/Summary													
1-4	**2.0**	**29.0**	**saturated**	**7.3**	**1.9**	**15**	**0.5**	**0.1**	**40.4**	**93.1**	**5.10E-06**	**0.5**	

Notes:

Start Time | Stage/Packer Pressure, bar | | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29306.8	7737.0	0							
1-5A	1.0	14.5	saturated	29306.8	7737.0	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5B	1.0	14.5	saturated	29306.8	7737.0	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5C	1.0	14.5	saturated	29306.8	7737.0	5	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5D	1.0	14.5	saturated	29306.8	7737.0	10	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5E	1.0	14.5	saturated	29306.8	7737.0	15	0.0	0.0	25.9	59.7	0.00E+00	0.0	
Test Averages/Summary													
1-5	**1.0**	**14.5**	**saturated**	**0.0**	**0.0**	**15**	**0.0**	**0.0**	**25.9**	**59.7**	**0.00E+00**	**0.0**	

Notes: No flow.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	166.5
Bottom of Test Interval Depth, ft	178.3

Estimated Hydrostatic Pressure, psi	131.2
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	172.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	284.9		
Bottom of Test Interval Elevation, ft	273.1		
Rubber Hose Length, ft	19.7		
# of NQ Rods	34	# of HWY Rods	1

Note:

Start Time: 23:11 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		29361.9	7751.5	0							
2-1A	1.2	17.4	saturated	29362.7	7751.8	1	0.8	0.2	28.8	66.4	1.14E-05	1.1	
2-1B	1.2	17.4	saturated	29364.2	7752.1	3	0.8	0.2	28.8	66.4	1.07E-05	1.1	
2-1C	1.2	17.4	saturated	29365.6	7752.5	5	0.7	0.2	28.8	66.4	9.95E-06	1.0	
2-1D	1.2	17.4	saturated	29368.3	7753.2	10	0.5	0.1	28.8	66.4	7.67E-06	0.8	
2-1E	1.2	17.4	saturated	29370.3	7753.8	15	0.4	0.1	28.8	66.4	5.68E-06	0.6	
Test Averages/Summary													
2-1	**1.2**	**17.4**	**saturated**	**8.4**	**2.2**	**15**	**0.6**	**0.2**	**28.8**	**66.4**	**9.07E-06**	**0.9**	

Notes:

Start Time: 23:27 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		29372.7	7754.4	0							
2-2A	2.0	29.0	saturated	29374.0	7754.7	1	1.3	0.3	40.4	93.1	1.32E-05	1.3	
2-2B	2.0	29.0	saturated	29376.6	7755.4	3	1.3	0.3	40.4	93.1	1.32E-05	1.3	
2-2C	2.0	29.0	saturated	29379.1	7756.1	5	1.3	0.3	40.4	93.1	1.27E-05	1.3	
2-2D	2.0	29.0	saturated	29385.6	7757.8	10	1.3	0.3	40.4	93.1	1.32E-05	1.3	
2-2E	2.0	29.0	saturated	29392.3	7759.6	15	1.3	0.4	40.4	93.1	1.36E-05	1.3	
Test Averages/Summary													
2-2	**2.0**	**29.0**	**saturated**	**19.6**	**5.2**	**15**	**1.3**	**0.3**	**40.4**	**93.1**	**1.31E-05**	**1.3**	

Notes:

Start Time: 23:44 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.9	42.0		29397.0	7760.8	0							
2-3A	3.1	44.9	saturated	29399.1	7761.4	1	2.1	0.6	56.3	129.9	1.52E-05	1.5	
2-3B	3.0	43.5	saturated	29403.7	7762.6	3	2.3	0.6	54.9	126.6	1.71E-05	1.7	
2-3C	3.0	43.5	saturated	29408.1	7763.7	5	2.2	0.6	54.9	126.6	1.64E-05	1.6	
2-3D	3.0	43.5	saturated	29419.0	7766.6	10	2.2	0.6	54.9	126.6	1.62E-05	1.6	
2-3E	3.0	43.5	saturated	29420.8	7767.1	15	0.4	0.1	54.9	126.6	2.68E-06	0.3	
Test Averages/Summary													
2-3	**3.0**	**43.8**	**saturated**	**23.8**	**6.3**	**15**	**1.8**	**0.5**	**55.2**	**127.2**	**1.35E-05**	**1.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	166.5
Bottom of Test Interval Depth, ft	178.3

Estimated Hydrostatic Pressure, psi	131.2
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	172.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	284.9		
Bottom of Test Interval Elevation, ft	273.1		
Rubber Hose Length, ft	19.7		
# of NQ Rods	34	# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		29433.2	7770.4	0							
2-4A	2.0	29.0	saturated	29434.4	7770.7	1	1.2	0.3	40.4	93.1	1.22E-05	1.2	
2-4B	2.0	29.0	saturated	29436.9	7771.3	3	1.3	0.3	40.4	93.1	1.27E-05	1.3	
2-4C	2.0	29.0	saturated	29439.4	7772.0	5	1.3	0.3	40.4	93.1	1.27E-05	1.3	
2-4D	2.0	29.0	saturated	29445.6	7773.6	10	1.2	0.3	40.4	93.1	1.26E-05	1.2	
2-4E	2.0	29.0	saturated	29452.3	7775.4	15	1.3	0.4	40.4	93.1	1.36E-05	1.3	
Test Averages/Summary													
2-4	**2.0**	**29.0**	**saturated**	**19.1**	**5.0**	**15**	**1.3**	**0.3**	**40.4**	**93.1**	**1.27E-05**	**1.3**	

Notes

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29452.5	7775.5	0							
2-5A	1.0	14.5	saturated	29452.5	7775.5	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
2-5B	1.0	14.5	saturated	29452.5	7775.5	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
2-5C	1.0	14.5	saturated	29452.6	7775.5	5	0.0	0.0	25.9	59.7	7.90E-07	0.1	
2-5D	1.0	14.5	saturated	29452.8	7775.5	10	0.0	0.0	25.9	59.7	6.32E-07	0.1	
2-5E	1.0	14.5	saturated	29453.4	7775.7	15	0.1	0.0	25.9	59.7	1.90E-06	0.2	
Test Averages/Summary													
2-5	**1.0**	**14.5**	**saturated**	**0.9**	**0.2**	**15**	**0.0**	**0.0**	**25.9**	**59.7**	**6.64E-07**	**0.1**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	156.7
Bottom of Test Interval Depth, ft	168.5

Estimated Hydrostatic Pressure, psi	126.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	162.6
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	294.7		
Bottom of Test Interval Elevation, ft	282.9		
Rubber Hose Length, ft	19.7		
# of NQ Rods	33	# of HWY Rods	1

Note:

Start Time: 15:16 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29594.1	7812.8	0							
3-1A	1.0	14.5	saturated	29594.2	7812.9	1	0.1	0.0	25.9	59.7	1.58E-06	0.2	
3-1B	1.0	14.5	saturated	29594.4	7812.9	3	0.1	0.0	25.9	59.7	1.58E-06	0.2	
3-1C	1.0	14.5	saturated	29594.5	7812.9	5	0.0	0.0	25.9	59.7	7.90E-07	0.1	
3-1D	1.0	14.5	saturated	29594.5	7812.9	10	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-1E	1.0	14.5	saturated	29594.5	7812.9	15	0.0	0.0	25.9	59.7	0.00E+00	0.0	
Test Averages/Summary													
3-1	**1.0**	**14.5**	**saturated**	**0.4**	**0.1**	**15**	**0.1**	**0.0**	**25.9**	**59.7**	**7.90E-07**	**0.1**	

Notes:

Start Time: 15:32 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		29595.2	7813.1	0							
3-2A	2.0	29.0	saturated	29595.6	7813.2	1	0.4	0.1	40.4	93.1	4.05E-06	0.4	
3-2B	2.0	29.0	saturated	29596.1	7813.4	3	0.3	0.1	40.4	93.1	2.53E-06	0.3	
3-2C	2.1	30.4	saturated	29596.3	7813.4	5	0.1	0.0	41.8	96.5	9.78E-07	0.1	
3-2D	2.1	30.4	saturated	29597.6	7813.8	10	0.3	0.1	41.8	96.5	2.54E-06	0.3	
3-2E	2.1	30.4	saturated	29598.3	7814.0	15	0.1	0.0	41.8	96.5	1.37E-06	0.1	
Test Averages/Summary													
3-2	**2.1**	**30.4**	**saturated**	**3.1**	**0.8**	**15**	**0.2**	**0.1**	**41.2**	**95.1**	**2.29E-06**	**0.2**	

Notes:

Start Time: 15:48 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		29598.7	7814.1	0							
3-3A	3.0	43.5	saturated	29599.1	7814.2	1	0.4	0.1	54.9	126.6	2.98E-06	0.3	
3-3B	3.0	43.5	saturated	29600.2	7814.5	3	0.6	0.1	54.9	126.6	4.10E-06	0.4	
3-3C	3.0	43.5	saturated	29600.9	7814.6	5	0.4	0.1	54.9	126.6	2.61E-06	0.3	
3-3D	3.1	44.9	saturated	29601.0	7814.7	10	0.0	0.0	56.3	129.9	1.45E-07	0.0	
3-3E	3.1	44.9	saturated	29601.5	7814.8	15	0.1	0.0	56.3	129.9	7.26E-07	0.1	
Test Averages/Summary													
3-3	**3.0**	**44.1**	**saturated**	**2.8**	**0.7**	**15**	**0.3**	**0.1**	**55.4**	**127.9**	**2.11E-06**	**0.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	156.7
Bottom of Test Interval Depth, ft	168.5

Estimated Hydrostatic Pressure, psi	126.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	162.6
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	294.7
Bottom of Test Interval Elevation, ft	282.9
Rubber Hose Length, ft	19.7
# of NQ Rods	33
# of HWY Rods	1

Note:

Start Time: 16:05 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		29601.5	7814.8	0							
3-4A	2.0	29.0	saturated	29601.6	7814.8	1	0.1	0.0	40.4	93.1	1.01E-06	0.1	
3-4B	2.0	29.0	saturated	29601.6	7814.8	3	0.0	0.0	40.4	93.1	0.00E+00	0.0	
3-4C	2.0	29.0	saturated	29601.6	7814.8	5	0.0	0.0	40.4	93.1	0.00E+00	0.0	
3-4D	2.0	29.0	saturated	29603.1	7815.2	10	0.3	0.1	40.4	93.1	3.04E-06	0.3	
3-4E	2.0	29.0	saturated	29605.5	7815.9	15	0.5	0.1	40.4	93.1	4.86E-06	0.5	
Test Averages/Summary													
3-4	**2.0**	**29.0**	**saturated**	**4.0**	**1.1**	**15**	**0.2**	**0.0**	**40.4**	**93.1**	**1.78E-06**	**0.2**	

Notes:

Start Time: 16:21 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29605.7	7815.9	0							
3-5A	1.0	14.5	saturated	29605.7	7815.9	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-5B	1.0	14.5	saturated	29605.7	7815.9	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-5C	1.0	14.5	saturated	29605.7	7815.9	5	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-5D	1.0	14.5	saturated	29605.7	7815.9	10	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-5E	1.0	14.5	saturated	29605.8	7815.9	15	0.0	0.0	25.9	59.7	3.16E-07	0.0	
Test Averages/Summary													
3-5	**1.0**	**14.5**	**saturated**	**0.1**	**0.0**	**15**	**0.0**	**0.0**	**25.9**	**59.7**	**6.32E-08**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	146.9
Bottom of Test Interval Depth, ft	158.6

Estimated Hydrostatic Pressure, psi	122.7
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	152.7
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	304.5
Bottom of Test Interval Elevation, ft	292.8
Rubber Hose Length, ft	19.7
# of NQ Rods	32
# of HWY Rods	1

Note:

Start Time: 17:05 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29694.2	7839.3	0							
4-1A	1.0	14.5	saturated	29695.5	7839.6	1	1.3	0.3	25.9	59.7	2.05E-05	2.0	
4-1B	1.0	14.5	saturated	29698.0	7840.3	3	1.3	0.3	25.9	59.7	1.98E-05	2.0	
4-1C	1.0	14.5	saturated	29700.6	7841.0	5	1.3	0.3	25.9	59.7	2.05E-05	2.0	
4-1D	1.0	14.5	saturated	29706.9	7842.6	10	1.3	0.3	25.9	59.7	1.99E-05	2.0	
4-1E	1.0	14.5	saturated	29713.0	7844.2	15	1.2	0.3	25.9	59.7	1.93E-05	1.9	
Test Averages/Summary													
4-1	**1.0**	**14.5**	**saturated**	**18.8**	**5.0**	**15**	**1.3**	**0.3**	**25.9**	**59.7**	**2.00E-05**	**2.0**	

Notes: Transducer level cut after 1 min. Possible delay due to data logger.

Start Time: 17:23 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		29717.8	7845.5	0							
4-2A	2.1	30.4	saturated	29720.4	7846.2	1	2.6	0.7	41.8	96.5	2.54E-05	2.5	
4-2B	2.1	30.4	saturated	29725.5	7847.5	3	2.5	0.7	41.8	96.5	2.49E-05	2.5	
4-2C	2.2	31.9	saturated	29743.2	7852.2	10	2.5	0.7	43.3	99.8	2.39E-05	2.4	
4-2D	2.2	31.9	saturated	29756.5	7855.7	15	2.7	0.7	43.3	99.8	2.51E-05	2.5	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
4-2	**2.2**	**31.2**	**saturated**	**38.7**	**10.2**	**15**	**2.6**	**0.7**	**42.5**	**98.1**	**2.48E-05**	**2.5**	

Notes: Missed reading at 5 minute time step.

Start Time: 17:40 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		29761.7	7857.1	0							
4-3A	3.0	43.5	saturated	29772.8	7860.0	3	3.7	1.0	54.8	126.5	2.76E-05	2.7	
4-3B	3.0	43.5	saturated	29780.1	7861.9	5	3.6	1.0	54.8	126.5	2.72E-05	2.7	
4-3C	3.0	43.5	saturated	29798.5	7866.8	10	3.7	1.0	54.8	126.5	2.74E-05	2.7	
4-3D	3.0	43.5	saturated	29817.0	7871.7	15	3.7	1.0	54.8	126.5	2.76E-05	2.7	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
4-3	**3.0**	**43.5**	**saturated**	**55.3**	**14.6**	**15**	**3.7**	**1.0**	**54.8**	**126.5**	**2.75E-05**	**2.7**	

Notes: Missed reading at 1 minute time step.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	146.9
Bottom of Test Interval Depth, ft	158.6

Estimated Hydrostatic Pressure, psi	122.7
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	152.7
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	304.5		
Bottom of Test Interval Elevation, ft	292.8		
Rubber Hose Length, ft	19.7		
# of NQ Rods	32	# of HWY Rods	1

Note:

Start Time: 5:57 PM | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		29824.7	7873.7	0							
4-4A	2.0	29.0	saturated	29832.7	7875.8	3	2.7	0.7	40.4	93.1	2.70E-05	2.7	
4-4B	2.0	29.0	saturated	29836.0	7876.7	5	1.6	0.4	40.4	93.1	1.67E-05	1.7	
4-4C	2.0	29.0	saturated	29851.4	7880.8	10	3.1	0.8	40.4	93.1	3.12E-05	3.1	
4-4D	2.0	29.0	saturated	29864.9	7884.3	15	2.7	0.7	40.4	93.1	2.73E-05	2.7	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
4-4	**2.0**	**29.0**	**saturated**	**40.2**	**10.6**	**15**	**2.5**	**0.7**	**40.4**	**93.1**	**2.56E-05**	**2.5**	

Notes: Missed reading at 1 minute time step.

Start Time: 18:14 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29867.5	7885.0	0							
4-5A	1.1	15.9	saturated	29868.9	7885.4	1	1.4	0.4	27.3	63.0	2.10E-05	2.1	
4-5B	1.0	14.5	saturated	29872.9	7886.4	3	2.0	0.5	25.9	59.7	3.16E-05	3.1	
4-5C	1.0	14.5	saturated	29876.6	7887.4	5	1.8	0.5	25.9	59.7	2.92E-05	2.9	
4-5D	1.0	14.5	saturated	29885.9	7889.9	10	1.9	0.5	25.9	59.7	2.94E-05	2.9	
4-5E	1.0	14.5	saturated	29895.2	7892.3	15	1.9	0.5	25.9	59.7	2.94E-05	2.9	
Test Averages/Summary													
4-5	**1.0**	**14.8**	**saturated**	**27.7**	**7.3**	**15**	**1.8**	**0.5**	**26.2**	**60.4**	**2.81E-05**	**2.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	137.0
Bottom of Test Interval Depth, ft	148.8

Estimated Hydrostatic Pressure, psi	118.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	142.9
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	314.4
Bottom of Test Interval Elevation, ft	302.6
Rubber Hose Length, ft	19.7
# of NQ Rods	31
# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		30098.7	7946.1	0							
5-1A	1.2	17.4	saturated	30101.2	7946.7	1	2.5	0.7	28.8	66.4	3.55E-05	3.5	
5-1B	0.9	13.0	saturated	30110.1	7949.1	3	4.4	1.2	24.4	56.3	7.45E-05	7.4	
5-1C	0.9	13.0	saturated	30117.2	7950.9	5	3.6	0.9	24.4	56.3	5.94E-05	5.9	
5-1D	0.9	13.0	saturated	30135.0	7955.6	10	3.6	0.9	24.4	56.3	5.96E-05	5.9	
5-1E	1.0	14.5	saturated	30143.6	7957.9	15	1.7	0.5	25.9	59.7	2.72E-05	2.7	
Test Averages/Summary													
5-1	**1.0**	**14.2**	**saturated**	**44.9**	**11.9**	**15**	**3.2**	**0.8**	**25.6**	**59.0**	**5.12E-05**	**5.0**	

Notes: Took long time (> 20 min) to fill the string and section.

Start Time: 19:25 | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.2	31.9		30165.9	7963.8	0							
5-2A	2.2	31.9	saturated	30171.5	7965.3	1	5.6	1.5	43.1	99.4	5.31E-05	5.2	
5-2B	1.9	27.5	saturated	30185.4	7968.9	3	7.0	1.8	38.7	89.4	7.33E-05	7.2	
5-2C	2.1	30.4	saturated	30200.5	7972.9	5	7.5	2.0	41.6	96.1	7.41E-05	7.3	
5-2D	2.0	29.0	saturated	30239.6	7983.3	10	7.8	2.1	40.2	92.7	7.95E-05	7.9	
5-2E	2.0	29.0	saturated	30278.4	7993.5	15	7.8	2.0	40.2	92.7	7.89E-05	7.8	
Test Averages/Summary													
5-2	**2.0**	**29.6**	**saturated**	**112.5**	**29.7**	**15**	**7.1**	**1.9**	**40.8**	**94.1**	**7.18E-05**	**7.1**	

Notes:

Start Time: 19:40 | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 1.4 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		30291.2	7996.9	0							
5-3A	3.0	43.5	saturated	30303.3	8000.1	1	12.1	3.2	54.3	125.2	9.12E-05	9.0	
5-3B	2.8	40.6	saturated	30328.4	8006.7	3	12.6	3.3	51.4	118.5	9.99E-05	9.9	
5-3C	3.0	43.5	saturated	30353.4	8013.3	5	12.5	3.3	54.3	125.2	9.42E-05	9.3	
5-3D	2.6	37.7	saturated	30416.2	8029.9	10	12.6	3.3	48.5	111.8	1.06E-04	10.5	
5-3E	2.5	36.2	saturated	30479.1	8046.5	15	12.6	3.3	47.0	108.5	1.09E-04	10.8	
Test Averages/Summary													
5-3	**2.8**	**40.3**	**saturated**	**187.9**	**49.6**	**15**	**12.5**	**3.3**	**51.1**	**117.8**	**1.00E-04**	**9.8**	

Notes: Difficult to keep pressure pump valve completely off. Pressure dropped to 2.4 bar at 6:33 minutes, then stayed between 2.4 and 2.8 bar.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	137.0
Bottom of Test Interval Depth, ft	148.8

Estimated Hydrostatic Pressure, psi	118.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	142.9
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	314.4		
Bottom of Test Interval Elevation, ft	302.6		
Rubber Hose Length, ft	19.7		
# of NQ Rods	31	# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, f, ft: 1.5 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		30492.5	8050.0	0							
5-4A	2.1	30.4	saturated	30506.1	8053.6	1	13.6	3.6	41.2	95.0	1.35E-04	13.3	
5-4B	2.3	33.3	saturated	30529.8	8059.9	3	11.9	3.1	44.1	101.7	1.10E-04	10.9	
5-4C	2.0	29.0	saturated	30556.4	8066.9	5	13.3	3.5	39.7	91.6	1.37E-04	13.5	
5-4D	2.0	29.0	saturated	30618.5	8083.3	10	12.4	3.3	39.7	91.6	1.28E-04	12.6	
5-4E	2.0	29.0	saturated	30682.0	8100.0	15	12.7	3.4	39.7	91.6	1.31E-04	12.9	
Test Averages/Summary													
5-4	**2.1**	**30.2**	**saturated**	**189.5**	**50.0**	**15**	**12.8**	**3.4**	**40.9**	**94.3**	**1.28E-04**	**12.6**	

Notes: Slowly jumps between 2.0 and 2.3 bar. 5-10 minutes stable at 2 bar.

Start Time: 19:13 | Stage/Packer Pressure, bar | Friction Loss, f, ft: 0.5 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		30707.9	8106.9	0							
5-5A	1.0	14.5	saturated	30723.1	8110.9	3	5.1	1.3	25.7	59.2	8.07E-05	8.0	
5-5B	1.0	14.5	saturated	30739.7	8115.3	5	8.3	2.2	25.7	59.2	1.32E-04	13.1	
5-5C	0.9	13.0	saturated	30782.3	8126.5	10	8.5	2.2	24.2	55.8	1.44E-04	14.2	
5-5D	0.8	11.6	saturated	30826.2	8138.1	15	8.8	2.3	22.8	52.5	1.58E-04	15.6	
-	-	-	saturated	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
5-5	**0.9**	**13.4**	**saturated**	**118.3**	**31.2**	**15**	**7.7**	**2.0**	**24.6**	**56.7**	**1.29E-04**	**12.6**	

Notes: Missed reading at 1 minute time step.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	127.2
Bottom of Test Interval Depth, ft	138.9

Estimated Hydrostatic Pressure, psi	114.1
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	133.1
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	324.2
Bottom of Test Interval Elevation, ft	312.5
Rubber Hose Length, ft	19.7
# of NQ Rods	30
# of HWY Rods	1

Note:

Start Time: 21:11 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		30921.1	8163.2	0							
6-1A	1.0	14.5	saturated	30923.3	8163.8	1	2.2	0.6	25.9	59.7	3.48E-05	3.4	
6-1B	1.0	14.5	saturated	30932.3	8166.1	5	2.3	0.6	25.9	59.7	3.56E-05	3.5	
6-1C	1.0	14.5	saturated	30945.9	8169.7	10	2.7	0.7	25.9	59.7	4.30E-05	4.2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
6-1	**1.0**	**14.5**	**saturated**	**24.8**	**6.5**	**10**	**2.4**	**0.6**	**25.9**	**59.7**	**3.78E-05**	**3.7**	

Notes: Missed reading at 3 and 15 minute time step.

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		30951.0	8171.1	0							
6-2A	2.0	29.0	saturated	30955.8	8172.3	1	4.8	1.3	40.3	93.0	4.87E-05	4.8	
6-2B	2.0	29.0	saturated	30962.0	8174.0	3	3.1	0.8	40.3	93.0	3.14E-05	3.1	
6-2C	2.0	29.0	saturated	30969.0	8175.8	5	3.5	0.9	40.3	93.0	3.55E-05	3.5	
6-2D	2.0	29.0	saturated	30986.8	8180.5	10	3.6	0.9	40.3	93.0	3.61E-05	3.6	
6-2E	2.0	29.0	saturated	31006.0	8185.6	15	3.8	1.0	40.3	93.0	3.89E-05	3.8	
Test Averages/Summary													
6-2	**2.0**	**29.0**	**saturated**	**55.0**	**14.5**	**15**	**3.8**	**1.0**	**40.3**	**93.0**	**3.81E-05**	**3.8**	

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		31024.9	8190.6	0							
6-3A	3.0	43.5	saturated	31031.5	8192.3	1	6.6	1.7	54.8	126.4	4.93E-05	4.9	
6-3B	3.0	43.5	saturated	31040.7	8194.7	3	4.6	1.2	54.8	126.4	3.43E-05	3.4	
6-3C	3.0	43.5	saturated	31050.5	8197.3	5	4.9	1.3	54.8	126.4	3.66E-05	3.6	
6-3D	3.0	43.5	saturated	31075.7	8204.0	10	5.0	1.3	54.8	126.4	3.76E-05	3.7	
6-3E	3.0	43.5	saturated	31099.0	8210.1	15	4.7	1.2	54.8	126.4	3.48E-05	3.4	
Test Averages/Summary													
6-3	**3.0**	**43.5**	**saturated**	**74.1**	**19.6**	**15**	**5.2**	**1.4**	**54.8**	**126.4**	**3.85E-05**	**3.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/21/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	127.2
Bottom of Test Interval Depth, ft	138.9

Estimated Hydrostatic Pressure, psi	114.1
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	133.1
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2
Datum (Mudline) Elevation, ft	451.4
Top of Test Interval Elevation, ft	324.2
Bottom of Test Interval Elevation, ft	312.5
Rubber Hose Length, ft	19.7
# of NQ Rods	30
# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, f, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		31104.9	8211.7	0							
6-4A	1.9	27.5	saturated	31107.1	8212.3	1	2.2	0.6	38.9	89.7	2.31E-05	2.3	
6-4B	2.3	33.3	saturated	31123.6	8216.6	5	4.1	1.1	44.7	103.1	3.78E-05	3.7	
6-4C	2.3	33.3	saturated	31144.1	8222.0	10	4.1	1.1	44.7	103.1	3.75E-05	3.7	
6-4D	2.3	33.3	saturated	31164.8	8227.5	15	4.1	1.1	44.7	103.1	3.79E-05	3.7	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
6-4	**2.2**	**31.9**	**saturated**	**59.9**	**15.8**	**15**	**3.6**	**1.0**	**43.2**	**99.7**	**3.41E-05**	**3.4**	

Notes: Missed reading at 3 minute time step.

Start Time | Stage/Packer Pressure, bar | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		31168.2	8228.4	0							
6-5A	1.0	14.5	saturated	31170.5	8229.0	1	2.3	0.6	25.9	59.7	3.63E-05	3.6	
6-5B	1.0	14.5	saturated	31175.3	8230.3	3	2.4	0.6	25.9	59.7	3.74E-05	3.7	
6-5C	1.0	14.5	saturated	31180.1	8231.5	5	2.4	0.6	25.9	59.7	3.79E-05	3.7	
6-5D	1.0	14.5	saturated	31192.0	8234.7	10	2.4	0.6	25.9	59.7	3.76E-05	3.7	
6-5E	1.0	14.5	saturated	31202.0	8237.3	15	2.0	0.5	25.9	59.7	3.16E-05	3.1	
Test Averages/Summary													
6-5	**1.0**	**14.5**	**saturated**	**33.8**	**8.9**	**15**	**2.3**	**0.6**	**25.9**	**59.7**	**3.62E-05**	**3.6**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/22/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	7
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	117.3
Bottom of Test Interval Depth, ft	129.1

Estimated Hydrostatic Pressure, psi	109.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	123.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	334.1		
Bottom of Test Interval Elevation, ft	322.3		
Rubber Hose Length, ft	19.7		
# of NQ Rods	29	# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		31321.5	8268.9	0							
7-1A	1.0	14.5	saturated	31322.8	8269.2	1	1.3	0.3	25.9	59.7	2.05E-05	2.0	
7-1B	1.0	14.5	saturated	31326.0	8270.1	3	1.6	0.4	25.9	59.7	2.53E-05	2.5	
7-1C	0.9	13.0	saturated	31335.5	8272.6	10	1.4	0.4	24.4	56.3	2.27E-05	2.2	
7-1D	0.9	13.0	saturated	31342.0	8274.3	15	1.3	0.3	24.4	56.3	2.18E-05	2.1	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
7-1	**1.0**	**13.8**	**saturated**	**20.5**	**5.4**	**15**	**1.4**	**0.4**	**25.1**	**58.0**	**2.26E-05**	**2.2**	

Notes: Missed reading at 5 minute time step.

Start Time: 23:28 | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.2	31.9		31348.4	8276.0	0							
7-2A	2.1	30.4	saturated	31351.0	8276.7	1	2.6	0.7	41.8	96.5	2.54E-05	2.5	
7-2B	1.9	27.5	saturated	31355.6	8277.9	3	2.3	0.6	38.9	89.8	2.42E-05	2.4	
7-2C	1.9	27.5	saturated	31360.2	8279.1	5	2.3	0.6	38.9	89.8	2.42E-05	2.4	
7-2D	1.9	27.5	saturated	31371.5	8282.1	10	2.3	0.6	38.9	89.8	2.37E-05	2.3	
7-2E	1.9	27.5	saturated	31382.6	8285.0	15	2.2	0.6	38.9	89.8	2.33E-05	2.3	
Test Averages/Summary													
7-2	**1.9**	**28.1**	**saturated**	**34.2**	**9.0**	**15**	**2.3**	**0.6**	**39.5**	**91.1**	**2.42E-05**	**2.4**	

Notes:

Start Time: 23:45 | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		31389.1	8286.7	0							
7-3A	3.0	43.5	saturated	31392.4	8287.6	1	3.3	0.9	54.9	126.6	2.46E-05	2.4	
7-3B	3.0	43.5	saturated	31405.6	8291.1	5	3.3	0.9	54.9	126.6	2.46E-05	2.4	
7-3C	3.0	43.5	saturated	31421.9	8295.4	10	3.3	0.9	54.9	126.6	2.43E-05	2.4	
7-3D	3.0	43.5	saturated	31438.2	8299.7	15	3.3	0.9	54.9	126.6	2.43E-05	2.4	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
7-3	**3.0**	**43.5**	**saturated**	**49.1**	**13.0**	**15**	**3.3**	**0.9**	**54.9**	**126.6**	**2.44E-05**	**2.4**	

Notes: Missed reading at 3 minute time step.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/22/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-32
Test Number	7
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	117.3
Bottom of Test Interval Depth, ft	129.1

Estimated Hydrostatic Pressure, psi	109.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	123.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	130.2		
Datum (Mudline) Elevation, ft	451.4		
Top of Test Interval Elevation, ft	334.1		
Bottom of Test Interval Elevation, ft	322.3		
Rubber Hose Length, ft	19.7		
# of NQ Rods	29	# of HWY Rods	1

Note:

Start Time: 00:00 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		31440.9	8300.4	0							
7-4A	2.0	29.0	saturated	31448.9	8302.5	3	2.7	0.7	40.4	93.1	2.70E-05	2.7	
7-4B	2.0	29.0	saturated	31452.6	8303.5	5	1.8	0.5	40.4	93.1	1.87E-05	1.9	
7-4C	2.0	29.0	saturated	31464.4	8306.6	10	2.4	0.6	40.4	93.1	2.39E-05	2.4	
7-4D	2.0	29.0	saturated	31476.2	8309.7	15	2.4	0.6	40.4	93.1	2.39E-05	2.4	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
7-4	**2.0**	**29.0**	**saturated**	**35.3**	**9.3**	**15**	**2.3**	**0.6**	**40.4**	**93.1**	**2.34E-05**	**2.3**	

Notes: Missed reading at 1 minute time step.

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		31477.8	8310.1	0							
7-5A	1.1	15.9	saturated	31478.9	8310.4	1	1.1	0.3	27.3	63.0	1.65E-05	1.6	
7-5B	1.0	14.5	saturated	31481.6	8311.1	3	1.3	0.4	25.9	59.7	2.13E-05	2.1	
7-5C	1.0	14.5	saturated	31484.5	8311.9	5	1.5	0.4	25.9	59.7	2.29E-05	2.3	
7-5D	0.9	13.0	saturated	31491.7	8313.8	10	1.4	0.4	24.4	56.3	2.41E-05	2.4	
7-5E	0.9	13.0	saturated	31498.8	8315.7	15	1.4	0.4	24.4	56.3	2.38E-05	2.3	
Test Averages/Summary													
7-5	**1.0**	**14.2**	**saturated**	**21.0**	**5.5**	**15**	**1.4**	**0.4**	**25.6**	**59.0**	**2.17E-05**	**2.1**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	07/22/19
WSP Personnel	L. Avila
Driller	Fugro
Operator	T. Brindle
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	10.8
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-33
Number of Tests	2
Lattitude	45.80489°N
Longitude	84.76979°W

Top of Rock, ft	112.8
Bottom of Boring, ft	217.6
Lake Depth, ft	95.1

Datum (Mudline) Elevation	486.5
Top of Rock Elevation, ft	373.7
Bottom of Hole Elevation, ft	268.9
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.0	14.5	saturated	7.3	1.9	130.2	0.9	0.2	25.9	59.7	1.49E-05	1.5	|||||	
1-2	1.6	22.6	saturated	6.7	1.8	130.2	0.4	0.1	34.0	78.4	5.09E-06	0.5	||	
1-3	2.4	34.1	saturated	26.7	7.0	130.2	2.4	0.6	45.4	104.8	2.32E-05	2.3	||||||||	
1-4	1.9	27.5	saturated	15.3	4.0	130.2	0.9	0.2	38.9	89.8	1.05E-05	1.1	||||	
1-5	1.1	15.9	saturated	3.6	1.0	130.2	0.3	0.1	27.3	63.0	5.29E-06	0.5	||	
2-1	1.3	18.6	saturated	113.0	29.8	125.9	9.62	2.54	29.8	68.6	1.43E-04	14.2	||	
2-2	1.8	26.1	saturated	217.0	57.3	125.9	26.46	6.99	35.9	82.7	3.21E-04	32.4	|||||	
2-3	3.1	44.7	saturated	227.6	60.1	125.9	15.63	4.13	55.5	128.0	1.23E-04	12.4	||	
2-4	1.3	18.8	saturated	150.1	39.6	125.9	10.14	2.68	30.0	69.2	1.47E-04	14.8	||	
2-5	1.0	14.5	saturated	117.2	30.9	125.9	7.96	2.10	25.7	59.4	1.35E-04	13.6	||	

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/22/2019
WSP Personnel	L. Avila
Driller	Fugro
Operator	T. Brindle

Boring ID	BH19-33
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	199.7
Bottom of Test Interval Depth, ft	210.6

Estimated Hydrostatic Pressure, psi	130.2
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	205.2
Test Interval Length (L), ft	10.8

Lake Depth, ft	95.1
Datum (Mudline) Elevation, ft	486.5
Top of Test Interval Elevation, ft	286.8
Bottom of Test Interval Elevation, ft	275.9
Rubber Hose Length, ft	19.7
# of NQ Rods	20
# of HWY Rods	0

Note:

Start Time: 04:30 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		912.4	240.9	0							
1-1A	1.0	14.5	saturated	915.2	241.6	1	2.8	0.7	25.9	59.7	4.71E-05	4.8	
1-1B	1.0	14.5	saturated	916.6	242.0	3	0.7	0.2	25.9	59.7	1.18E-05	1.2	
1-1C	1.0	14.5	saturated	917.6	242.2	5	0.5	0.1	25.9	59.7	8.41E-06	0.8	
1-1D	1.0	14.5	saturated	919.6	242.8	10	0.4	0.1	25.9	59.7	6.73E-06	0.7	
1-1E	1.0	14.5	saturated	919.7	242.8	15	0.0	0.0	25.9	59.7	3.36E-07	0.0	
Test Averages/Summary													
1-1	**1.0**	**14.5**	**saturated**	**7.3**	**1.9**	**15**	**0.9**	**0.2**	**25.9**	**59.7**	**1.49E-05**	**1.5**	

Notes:

Start Time: 04:50 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.8	26.1		920.6	243.0	0							
1-2A	1.8	26.1	saturated	920.9	243.1	1	0.3	0.1	37.5	86.4	3.48E-06	0.4	
1-2B	1.5	21.7	saturated	921.5	243.3	3	0.3	0.1	33.1	76.4	3.94E-06	0.4	
1-2C	1.5	21.7	saturated	922.2	243.5	5	0.4	0.1	33.1	76.4	4.60E-06	0.5	
1-2D	1.5	21.7	saturated	924.6	244.1	10	0.5	0.1	33.1	76.4	6.31E-06	0.6	
1-2E	1.5	21.7	saturated	927.3	244.8	15	0.5	0.1	33.1	76.4	7.09E-06	0.7	
Test Averages/Summary													
1-2	**1.6**	**22.6**	**saturated**	**6.7**	**1.8**	**15**	**0.4**	**0.1**	**34.0**	**78.4**	**5.09E-06**	**0.5**	

Notes:

Start Time: 05:08 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.4	34.1		931.2	245.8	0							
1-3A	2.4	34.1	saturated	935.3	246.9	1	4.1	1.1	45.4	104.8	3.93E-05	4.0	
1-3B	2.4	34.1	saturated	942.7	248.9	3	3.7	1.0	45.4	104.8	3.54E-05	3.6	
1-3C	2.4	34.1	saturated	946.9	250.0	5	2.1	0.6	45.4	104.8	2.01E-05	2.0	
1-3D	2.4	34.1	saturated	951.3	251.1	10	0.9	0.2	45.4	104.8	8.43E-06	0.9	
1-3E	2.4	34.1	saturated	957.9	252.9	15	1.3	0.3	45.4	104.8	1.26E-05	1.3	
Test Averages/Summary													
1-3	**2.4**	**34.1**	**saturated**	**26.7**	**7.0**	**15**	**2.4**	**0.6**	**45.4**	**104.8**	**2.32E-05**	**2.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/22/2019
WSP Personnel	L. Avila
Driller	Fugro
Operator	T. Brindle

Boring ID	BH19-33
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	199.7
Bottom of Test Interval Depth, ft	210.6

Estimated Hydrostatic Pressure, psi	130.2
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	205.2
Test Interval Length (L), ft	10.8

Lake Depth, ft	95.1
Datum (Mudline) Elevation, ft	486.5
Top of Test Interval Elevation, ft	286.8
Bottom of Test Interval Elevation, ft	275.9
Rubber Hose Length, ft	19.7
# of NQ Rods	20
# of HWY Rods	0

Note:

Start Time: 05:25 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.9	27.5		958.1	252.9	0							
1-4A	1.9	27.5	saturated	959.0	253.2	1	0.9	0.2	38.9	89.8	1.01E-05	1.0	||||
1-4B	1.9	27.5	saturated	960.3	253.5	3	0.6	0.2	38.9	89.8	7.27E-06	0.7	|||
1-4C	1.9	27.5	saturated	962.0	254.0	5	0.9	0.2	38.9	89.8	9.50E-06	1.0	||||
1-4D	1.9	27.5	saturated	966.0	255.0	10	0.8	0.2	38.9	89.8	8.94E-06	0.9	|||
1-4E	1.9	27.5	saturated	973.4	257.0	15	1.5	0.4	38.9	89.8	1.65E-05	1.7	|||||||
Test Averages/Summary													
1-4	**1.9**	**27.5**	**saturated**	**15.3**	**4.0**	**15**	**0.9**	**0.2**	**38.9**	**89.8**	**1.05E-05**	**1.1**	||||

Notes:

Start Time: 05:42 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		973.6	257.0	0							
1-5A	1.1	15.9	saturated	974.4	257.2	1	0.8	0.2	27.3	63.0	1.27E-05	1.3	|||||
1-5B	1.1	15.9	saturated	975.0	257.4	3	0.3	0.1	27.3	63.0	4.78E-06	0.5	||
1-5C	1.1	15.9	saturated	975.4	257.5	5	0.2	0.1	27.3	63.0	3.19E-06	0.3		
1-5D	1.1	15.9	saturated	976.4	257.8	10	0.2	0.1	27.3	63.0	3.19E-06	0.3		
1-5E	1.1	15.9	saturated	977.2	258.0	15	0.2	0.0	27.3	63.0	2.55E-06	0.3		
Test Averages/Summary													
1-5	**1.1**	**15.9**	**saturated**	**3.6**	**1.0**	**15**	**0.3**	**0.1**	**27.3**	**63.0**	**5.29E-06**	**0.5**	||

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/22/2019
WSP Personnel	L. Avila
Driller	Fugro
Operator	T. Brindle

Boring ID	BH19-33
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	189.9
Bottom of Test Interval Depth, ft	200.7

Estimated Hydrostatic Pressure, psi	125.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	195.3
Test Interval Length (L), ft	10.8

Lake Depth, ft	95.1
Datum (Mudline) Elevation, ft	486.5
Top of Test Interval Elevation, ft	296.6
Bottom of Test Interval Elevation, ft	285.8
Rubber Hose Length, ft	19.7
# of NQ Rods: 19	# of HWY Rods: 0

Note:

Start Time: 09:18 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.2	17.4		812.7	214.6	0						
2-1A	1.2	17.4	saturated	834.7	220.4	1	22.0	5.8	28.6	66.0	3.35E-04	33.8
2-1B	1.3	18.8	saturated	859.5	226.9	3	12.4	3.3	30.0	69.3	1.80E-04	18.1
2-1C	1.3	18.8	saturated	861.1	227.3	5	0.8	0.2	30.0	69.3	1.16E-05	1.2
2-1D	1.3	18.8	saturated	894.9	236.3	10	6.8	1.8	30.0	69.3	9.79E-05	9.9
2-1E	1.3	18.8	saturated	925.7	244.4	15	6.2	1.6	30.0	69.3	8.92E-05	9.0
Test Averages/Summary												
2-1	**1.3**	**18.6**	**saturated**	**113.0**	**29.8**	**15**	**9.6**	**2.5**	**29.8**	**68.6**	**1.43E-04**	**14.2**

Notes:

Start Time: 09:44 | Stage/Packer Pressure, bar: 16 | Friction Loss, *f*, ft: 3.7 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.8	26.1		919.8	242.8	0						
2-2A	1.8	26.1	saturated	1018.8	269.0	1	99.0	26.1	35.9	82.7	1.20E-03	121.2
2-2B	1.8	26.1	saturated	1034.7	273.2	3	8.0	2.1	35.9	82.7	9.65E-05	9.7
2-2C	1.8	26.1	saturated	1051.2	277.5	5	8.3	2.2	35.9	82.7	1.00E-04	10.1
2-2D	1.8	26.1	saturated	1093.4	288.7	10	8.4	2.2	35.9	82.7	1.02E-04	10.3
2-2E	1.8	26.1	saturated	1136.8	300.1	15	8.7	2.3	35.9	82.7	1.05E-04	10.6
Test Averages/Summary												
2-2	**1.8**	**26.1**	**saturated**	**217.0**	**57.3**	**15**	**26.5**	**7.0**	**35.9**	**82.7**	**3.21E-04**	**32.4**

Notes:

Start Time: 10:03 | Stage/Packer Pressure, bar: 17 | Friction Loss, *f*, ft: 1.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.2	45.7		1174.6	310.1	0						
2-3A	3.1	44.9	saturated	1191.7	314.6	1	17.1	4.5	55.8	128.7	1.33E-04	13.5
2-3B	3.1	44.9	saturated	1221.0	322.3	3	14.7	3.9	55.8	128.7	1.14E-04	11.5
2-3C	3.1	44.9	saturated	1254.8	331.3	5	16.9	4.5	55.8	128.7	1.32E-04	13.3
2-3D	3.1	44.9	saturated	1323.1	349.3	10	13.7	3.6	55.8	128.7	1.07E-04	10.8
2-3E	3.0	43.5	saturated	1402.2	370.2	15	15.8	4.2	54.3	125.4	1.27E-04	12.8
Test Averages/Summary												
2-3	**3.1**	**44.7**	**saturated**	**227.6**	**60.1**	**15**	**15.6**	**4.1**	**55.5**	**128.0**	**1.23E-04**	**12.4**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/22/2019
WSP Personnel	L. Avila
Driller	Fugro
Operator	T. Brindle

Boring ID	BH19-33
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	189.9
Bottom of Test Interval Depth, ft	200.7

Estimated Hydrostatic Pressure, psi	125.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	195.3
Test Interval Length (L), ft	10.8

Lake Depth, ft	95.1		
Datum (Mudline) Elevation, ft	486.5		
Top of Test Interval Elevation, ft	296.6		
Bottom of Test Interval Elevation, ft	285.8		
Rubber Hose Length, ft	19.7		
# of NQ Rods	19	# of HWY Rods	0

Note:

Start Time: 10:20 | Stage/Packer Pressure, bar: 17 | Friction Loss, f, ft: 0.5 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.4	20.3		1415.7	373.7	0						
2-4A	1.3	18.8	saturated	1426.5	376.6	1	10.8	2.9	30.0	69.2	1.57E-04	15.8
2-4B	1.3	18.8	saturated	1446.5	381.9	3	10.0	2.6	30.0	69.2	1.45E-04	14.6
2-4C	1.3	18.8	saturated	1466.6	387.2	5	10.1	2.7	30.0	69.2	1.46E-04	14.7
2-4D	1.3	18.8	saturated	1527.1	403.2	10	12.1	3.2	30.0	69.2	1.75E-04	17.7
2-4E	1.3	18.8	saturated	1565.8	413.4	15	7.7	2.0	30.0	69.2	1.12E-04	11.3
Test Averages/Summary												
2-4	**1.3**	**18.8**	**saturated**	**150.1**	**39.6**	**15**	**10.1**	**2.7**	**30.0**	**69.2**	**1.47E-04**	**14.8**

Notes:

Start Time: 10:38 | Stage/Packer Pressure, bar: 17 | Friction Loss, f, ft: 0.3 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.0	14.5		1586.4	418.8	0						
2-5A	1.0	14.5	saturated	1595.2	421.1	1	8.8	2.3	25.7	59.4	1.49E-04	15.0
2-5B	1.0	14.5	saturated	1611.0	425.3	3	7.9	2.1	25.7	59.4	1.34E-04	13.5
2-5C	1.0	14.5	saturated	1626.3	429.3	5	7.6	2.0	25.7	59.4	1.29E-04	13.1
2-5D	1.0	14.5	saturated	1664.2	439.3	10	7.6	2.0	25.7	59.4	1.28E-04	12.9
2-5E	1.0	14.5	saturated	1703.6	449.8	15	7.9	2.1	25.7	59.4	1.33E-04	13.4
Test Averages/Summary												
2-5	**1.0**	**14.5**	**saturated**	**117.2**	**30.9**	**15**	**8.0**	**2.1**	**25.7**	**59.4**	**1.35E-04**	**13.6**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	07/28/19
WSP Personel	L. Avila, C. Fischer
Driller	Fugro
Operator	T. Brindle
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	64.1
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-35
Number of Tests	6
Lattitude	45.79960°N
Longitude	84.77182°W

Top of Rock, ft	155.8
Bottom of Boring, ft	231.3
Lake Depth, ft	82.5

Datum (Mudline) Elevation	499.2
Top of Rock Elevation, ft	343.4
Bottom of Hole Elevation, ft	267.9
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.0	14.5	saturated	0.0	0.0	130.7	0.0	0.0	25.9	59.7	0.00E+00	0.0		
1-2	2.0	29.0	saturated	3.0	0.8	130.7	0.3	0.1	40.4	93.1	2.63E-06	0.3	|||	
1-3	2.6	37.7	saturated	15.4	4.1	130.7	1.2	0.3	49.1	113.2	9.77E-06	1.0	||||||	
1-4	2.0	29.0	saturated	0.2	0.1	130.7	0.0	0.0	40.4	93.1	1.42E-07	0.0		
1-5	1.0	14.5	saturated	0.0	0.0	130.7	0.0	0.0	25.9	59.7	0.00E+00	0.0		
2-1	1.0	14.5	saturated	0.1	0.0	126.4	0.0	0.0	25.9	59.7	1.58E-07	0.0		
2-2	2.0	28.3	saturated	18.5	4.9	126.4	1.5	0.4	39.6	91.5	1.50E-05	1.5	||||||||	
2-3	2.9	42.3	saturated	3.9	1.0	126.4	0.2	0.1	53.7	123.9	1.89E-06	0.2	||	
2-4	2.0	29.0	saturated	1.2	0.3	126.4	0.1	0.0	40.4	93.1	8.30E-07	0.1		
2-5	1.1	15.8	saturated	0.6	0.2	126.4	0.0	0.0	27.2	62.7	6.97E-07	0.1		
3-1	1.0	14.5	saturated	1.2	0.3	122.1	0.1	0.0	25.9	59.7	8.53E-07	0.1		
3-2	2.0	29.0	saturated	45.4	12.0	122.1	3.1	0.8	40.4	93.1	3.16E-05	3.1	||||||||	
3-3	2.8	40.6	saturated	93.4	24.7	122.1	6.4	1.7	51.9	119.7	5.08E-05	5.0	||||||||||||	
3-4	2.0	29.0	saturated	58.7	15.5	122.1	4.0	1.1	40.3	93.0	4.08E-05	4.0	||||||||||	
3-5	1.0	14.5	saturated	30.9	8.2	122.1	2.1	0.5	25.9	59.7	3.27E-05	3.2	||||||||	
4-1	1.0	14.5	saturated	15.9	4.2	117.9	1.0	0.3	25.9	59.7	1.55E-05	1.5	||||||||	
4-2	2.0	29.0	saturated	41.0	10.8	117.9	2.8	0.7	40.4	93.1	2.86E-05	2.8	||||||||||||||	
4-3	3.0	43.5	saturated	56.6	14.9	117.9	3.8	1.0	54.9	126.6	2.82E-05	2.8	||||||||||||||	
4-4	2.0	29.0	saturated	36.7	9.7	117.9	2.5	0.7	40.4	93.1	2.50E-05	2.5	||||||||||||	
4-5	1.0	14.5	saturated	20.5	5.4	117.9	1.4	0.4	25.9	59.7	2.19E-05	2.2	||||||||||	
5-1	1.0	14.5	saturated	12.3	3.2	114.3	0.2	0.0	25.9	59.7	2.27E-05	0.4		
5-2	2.0	29.0	saturated	44.6	11.8	114.3	2.9	0.8	40.4	93.1	3.71E-05	4.0	||||||||	
5-3	3.0	43.5	saturated	108.2	28.6	114.3	7.1	1.9	54.8	126.4	6.70E-05	7.2	||||||||||||||	
5-4	2.0	29.0	saturated	74.9	19.8	114.3	5.1	1.3	40.3	93.0	6.50E-05	7.0	||||||||||||||	
5-5	1.0	14.5	saturated	48.0	12.7	114.3	3.2	0.8	25.9	59.7	6.41E-05	6.9	||||||||||||||	

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	07/28/19
WSP Personel	L. Avila, C. Fischer
Driller	Fugro
Operator	T. Brindle
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	64.1
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-35
Number of Tests	6
Lattitude	45.79960°N
Longitude	84.77182°W

Top of Rock, ft	155.8
Bottom of Boring, ft	231.3
Lake Depth, ft	82.5

Datum (Mudline) Elevation	499.2
Top of Rock Elevation, ft	343.4
Bottom of Hole Elevation, ft	267.9
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
6-1	1.0	14.5	saturated	40.4	10.7	110.1	2.8	0.7	25.9	59.7	5.55E-05	6.0		
6-2	2.0	29.0	saturated	79.8	21.1	110.1	4.8	1.3	40.3	93.0	6.22E-05	6.7		
6-3	3.0	43.5	saturated	133.7	35.3	110.1	8.6	2.3	54.7	126.3	8.12E-05	8.8		
6-4	2.0	29.0	saturated	153.5	40.5	110.1	6.6	2.1	40.3	92.9	1.01E-04	10.9		
6-5	1.0	14.5	saturated	88.1	23.3	110.1	5.9	1.6	25.8	59.5	1.19E-04	12.8		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	L. Avila
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	213.2
Bottom of Test Interval Depth, ft	224.9

Estimated Hydrostatic Pressure, psi	130.7
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	219.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	286.0		
Bottom of Test Interval Elevation, ft	274.3		
Rubber Hose Length, ft	19.7		
# of NQ Rods	22	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 09:15 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		745.6	196.8	0							
1-1A	1.0	14.5	saturated	745.6	196.8	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-1B	1.0	14.5	saturated	745.6	196.8	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-1C	1.0	14.5	saturated	745.6	196.8	5	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-1D	1.0	14.5	saturated	745.6	196.8	10	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-1E	1.0	14.5	saturated	745.6	196.8	15	0.0	0.0	25.9	59.7	0.00E+00	0.0	
Test Averages/Summary													
1-1	**1.0**	**14.5**	**saturated**	**0.0**	**0.0**	**15**	**0.0**	**0.0**	**25.9**	**59.7**	**0.00E+00**	**0.0**	

Notes: Gauge below test zone indicated twice amount of pressure.

Start Time: 09:36 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		746.7	197.1	0							
1-2A	2.0	29.0	saturated	747.2	197.3	1	0.5	0.1	40.4	93.1	5.06E-06	0.5	
1-2B	2.0	29.0	saturated	747.7	197.4	3	0.3	0.1	40.4	93.1	2.53E-06	0.3	
1-2C	2.0	29.0	saturated	748.2	197.5	5	0.3	0.1	40.4	93.1	2.53E-06	0.3	
1-2D	2.0	29.0	saturated	749.1	197.8	10	0.2	0.0	40.4	93.1	1.82E-06	0.2	
1-2E	2.0	29.0	saturated	749.7	197.9	15	0.1	0.0	40.4	93.1	1.22E-06	0.1	
Test Averages/Summary													
1-2	**2.0**	**29.0**	**saturated**	**3.0**	**0.8**	**15**	**0.3**	**0.1**	**40.4**	**93.1**	**2.63E-06**	**0.3**	

Notes:

Start Time: 10:02 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		762.7	201.4	0							
1-3A	3.0	43.5	saturated	764.6	201.9	1	1.9	0.5	54.9	126.6	1.42E-05	1.4	
1-3B	3.0	43.5	saturated	766.8	202.4	3	1.1	0.3	54.9	126.6	8.20E-06	0.8	
1-3C	3.0	43.5	saturated	769.4	203.1	5	1.3	0.3	54.9	126.6	9.69E-06	1.0	
1-3D	3.0	43.5	saturated	775.8	204.8	10	1.3	0.3	54.9	126.6	9.54E-06	0.9	
1-3E	1.0	14.5	saturated	778.1	205.4	15	0.5	0.1	25.9	59.7	7.27E-06	0.7	
Test Averages/Summary													
1-3	**2.6**	**37.7**	**saturated**	**15.4**	**4.1**	**15**	**1.2**	**0.3**	**49.1**	**113.2**	**9.77E-06**	**1.0**	

Notes: Dropped to 1.0 bar at 1-3E.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	L. Avila
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	213.2
Bottom of Test Interval Depth, ft	224.9

Estimated Hydrostatic Pressure, psi	130.7
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	219.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	286.0		
Bottom of Test Interval Elevation, ft	274.3		
Rubber Hose Length, ft	19.7		
# of NQ Rods	22	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 10:20 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		778.2	205.4	0							
1-4A	2.0	29.0	saturated	778.2	205.4	1	0.0	0.0	40.4	93.1	0.00E+00	0.0	
1-4B	2.0	29.0	saturated	778.3	205.5	3	0.0	0.0	40.4	93.1	5.06E-07	0.1	
1-4C	2.0	29.0	saturated	778.3	205.5	5	0.0	0.0	40.4	93.1	0.00E+00	0.0	
1-4D	2.0	29.0	saturated	778.3	205.5	10	0.0	0.0	40.4	93.1	0.00E+00	0.0	
1-4E	2.0	29.0	saturated	778.4	205.5	15	0.0	0.0	40.4	93.1	2.03E-07	0.0	
Test Averages/Summary													
1-4	**2.0**	**29.0**	**saturated**	**0.2**	**0.1**	**15**	**0.0**	**0.0**	**40.4**	**93.1**	**1.42E-07**	**0.0**	

Notes:

Start Time: 10:39 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		778.4	205.5	0							
1-5A	1.0	14.5	saturated	778.4	205.5	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5B	1.0	14.5	saturated	778.4	205.5	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5C	1.0	14.5	saturated	778.4	205.5	5	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5D	1.0	14.5	saturated	778.4	205.5	10	0.0	0.0	25.9	59.7	0.00E+00	0.0	
1-5E	1.0	14.5	saturated	778.4	205.5	15	0.0	0.0	25.9	59.7	0.00E+00	0.0	
Test Averages/Summary													
1-5	**1.0**	**14.5**	**saturated**	**0.0**	**0.0**	**15**	**0.0**	**0.0**	**25.9**	**59.7**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	L. Avila
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	203.3
Bottom of Test Interval Depth, ft	215.1

Estimated Hydrostatic Pressure, psi	126.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	209.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5
Datum (Mudline) Elevation, ft	499.2
Top of Test Interval Elevation, ft	295.9
Bottom of Test Interval Elevation, ft	284.1
Rubber Hose Length, ft	19.7
# of NQ Rods	21
# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 11:34 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		797.7	210.6	0							
2-1A	1.0	14.5	saturated	797.7	210.6	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
2-1B	1.0	14.5	saturated	797.7	210.6	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
2-1C	1.0	14.5	saturated	797.8	210.6	5	0.0	0.0	25.9	59.7	7.90E-07	0.1	
2-1D	1.0	14.5	saturated	797.8	210.6	10	0.0	0.0	25.9	59.7	0.00E+00	0.0	
2-1E	1.0	14.5	saturated	797.8	210.6	15	0.0	0.0	25.9	59.7	0.00E+00	0.0	
Test Averages/Summary													
2-1	**1.0**	**14.5**	**saturated**	**0.1**	**0.0**	**15**	**0.0**	**0.0**	**25.9**	**59.7**	**1.58E-07**	**0.0**	

Notes:

Start Time: 11:53 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		813.8	214.8	0							
2-2A	2.0	29.0	saturated	816.1	215.5	1	2.3	0.6	40.4	93.1	2.33E-05	2.3	
2-2B	1.9	27.5	saturated	818.2	216.0	3	1.1	0.3	38.9	89.8	1.10E-05	1.1	
2-2C	2.0	28.3	saturated	821.9	217.0	5	1.8	0.5	39.6	91.5	1.91E-05	1.9	
2-2D	1.9	27.5	saturated	826.9	218.3	10	1.0	0.3	38.9	89.8	1.05E-05	1.0	
2-2E	2.0	29.0	saturated	832.3	219.7	15	1.1	0.3	40.4	93.1	1.09E-05	1.1	
Test Averages/Summary													
2-2	**2.0**	**28.3**	**saturated**	**18.5**	**4.9**	**15**	**1.5**	**0.4**	**39.6**	**91.5**	**1.50E-05**	**1.5**	

Notes:

Start Time: 12:14 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.9	42.0		840.6	221.9	0							
2-3A	2.9	42.0	saturated	840.8	222.0	1	0.2	0.1	53.4	123.2	1.53E-06	0.2	
2-3B	2.9	42.0	saturated	841.2	222.1	3	0.2	0.1	53.4	123.2	1.53E-06	0.2	
2-3C	3.0	42.8	saturated	841.8	222.2	5	0.3	0.1	54.1	124.9	2.27E-06	0.2	
2-3D	2.9	42.0	saturated	843.1	222.6	10	0.3	0.1	53.4	123.2	1.99E-06	0.2	
2-3E	3.0	42.8	saturated	844.5	222.9	15	0.3	0.1	54.1	124.9	2.11E-06	0.2	
Test Averages/Summary													
2-3	**2.9**	**42.3**	**saturated**	**3.9**	**1.0**	**15**	**0.2**	**0.1**	**53.7**	**123.9**	**1.89E-06**	**0.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	L. Avila
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	203.3
Bottom of Test Interval Depth, ft	215.1

Estimated Hydrostatic Pressure, psi	126.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	209.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	295.9		
Bottom of Test Interval Elevation, ft	284.1		
Rubber Hose Length, ft	19.7		
# of NQ Rods	21	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 12:36 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		845.4	223.2	0							
2-4A	2.0	29.0	saturated	845.5	223.2	1	0.1	0.0	40.4	93.1	1.01E-06	0.1	
2-4B	2.0	29.0	saturated	845.6	223.2	3	0.1	0.0	40.4	93.1	5.06E-07	0.1	
2-4C	2.0	29.0	saturated	845.8	223.3	5	0.1	0.0	40.4	93.1	1.01E-06	0.1	
2-4D	2.0	29.0	saturated	846.2	223.4	10	0.1	0.0	40.4	93.1	8.10E-07	0.1	
2-4E	2.0	29.0	saturated	846.6	223.5	15	0.1	0.0	40.4	93.1	8.10E-07	0.1	
Test Averages/Summary													
2-4	**2.0**	**29.0**	**saturated**	**1.2**	**0.3**	**15**	**0.1**	**0.0**	**40.4**	**93.1**	**8.30E-07**	**0.1**	

Notes:

Start Time: 12:54 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.2		846.6	223.5	0							
2-5A	1.1	15.2	saturated	846.7	223.5	1	0.1	0.0	26.6	61.4	1.54E-06	0.2	
2-5B	1.1	15.9	saturated	846.7	223.5	3	0.0	0.0	27.3	63.0	0.00E+00	0.0	
2-5C	1.1	15.9	saturated	846.8	223.6	5	0.0	0.0	27.3	63.0	7.48E-07	0.1	
2-5D	1.1	15.9	saturated	847.0	223.6	10	0.0	0.0	27.3	63.0	5.99E-07	0.1	
2-5E	1.1	15.9	saturated	847.2	223.7	15	0.0	0.0	27.3	63.0	5.99E-07	0.1	
Test Averages/Summary													
2-5	**1.1**	**15.8**	**saturated**	**0.6**	**0.2**	**15**	**0.0**	**0.0**	**27.2**	**62.7**	**6.97E-07**	**0.1**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	L. Avila, C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.5
Bottom of Test Interval Depth, ft	205.2

Estimated Hydrostatic Pressure, psi	122.1
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	305.7		
Bottom of Test Interval Elevation, ft	294.0		
Rubber Hose Length, ft	19.7		
# of NQ Rods	20	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 14:10 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		18961.8	5005.9	0							
3-1A	1.0	14.5	saturated	18961.8	5005.9	1	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-1B	1.0	14.5	saturated	18961.8	5005.9	3	0.0	0.0	25.9	59.7	0.00E+00	0.0	
3-1C	1.0	14.5	saturated	18961.9	5005.9	5	0.1	0.0	25.9	59.7	7.90E-07	0.1	
3-1D	1.0	14.5	saturated	18962.4	5006.1	10	0.1	0.0	25.9	59.7	1.58E-06	0.2	
3-1E	1.0	14.5	saturated	18963.0	5006.2	15	0.1	0.0	25.9	59.7	1.90E-06	0.2	
Test Averages/Summary													
3-1	**1.0**	**14.5**	**saturated**	**1.2**	**0.3**	**15**	**0.1**	**0.0**	**25.9**	**59.7**	**8.53E-07**	**0.1**	

Notes:

Start Time: 14:29 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		18968.0	5007.6	0							
3-2A	2.0	29.0	saturated	18971.9	5008.6	1	3.9	1.0	40.4	93.1	3.95E-05	3.9	
3-2B	2.0	29.0	saturated	18978.2	5010.2	3	3.1	0.8	40.4	93.1	3.19E-05	3.2	
3-2C	2.0	29.0	saturated	18983.3	5011.6	5	2.5	0.7	40.4	93.1	2.58E-05	2.6	
3-2D	2.0	29.0	saturated	18998.4	5015.6	10	3.0	0.8	40.4	93.1	3.06E-05	3.0	
3-2E	2.0	29.0	saturated	19013.4	5019.5	15	3.0	0.8	40.4	93.1	3.04E-05	3.0	
Test Averages/Summary													
3-2	**2.0**	**29.0**	**saturated**	**45.4**	**12.0**	**15**	**3.1**	**0.8**	**40.4**	**93.1**	**3.16E-05**	**3.1**	

Notes:

Start Time: 14:47 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		19028.0	5023.4	0							
3-3A	3.0	43.5	saturated	19035.5	5025.4	1	7.5	2.0	54.8	126.4	5.60E-05	5.5	
3-3B	3.0	43.5	saturated	19047.0	5028.4	3	5.8	1.5	54.8	126.4	4.29E-05	4.2	
3-3C	3.0	43.5	saturated	19059.5	5031.7	5	6.3	1.7	54.8	126.4	4.66E-05	4.6	
3-3D	3.0	43.5	saturated	19091.4	5040.1	10	6.4	1.7	54.8	126.4	4.76E-05	4.7	
3-3E	2.0	29.0	saturated	19121.4	5048.0	15	6.0	1.6	40.3	92.9	6.09E-05	6.0	
Test Averages/Summary													
3-3	**2.8**	**40.6**	**saturated**	**93.4**	**24.7**	**15**	**6.4**	**1.7**	**51.9**	**119.7**	**5.08E-05**	**5.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	L. Avila, C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.5
Bottom of Test Interval Depth, ft	205.2

Estimated Hydrostatic Pressure, psi	122.1
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5
Datum (Mudline) Elevation, ft	499.2
Top of Test Interval Elevation, ft	305.7
Bottom of Test Interval Elevation, ft	294.0
Rubber Hose Length, ft	19.7
# of NQ Rods	20
# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 15:05 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		19135.0	5051.6	0							
3-4A	2.0	29.0	saturated	19139.3	5052.8	1	4.3	1.1	40.3	93.0	4.36E-05	4.3	
3-4B	2.0	29.0	saturated	19147.7	5055.0	3	4.2	1.1	40.3	93.0	4.26E-05	4.2	
3-4C	2.0	29.0	saturated	19155.7	5057.1	5	4.0	1.1	40.3	93.0	4.06E-05	4.0	
3-4D	2.0	29.0	saturated	19175.1	5062.2	10	3.9	1.0	40.3	93.0	3.93E-05	3.9	
3-4E	2.0	29.0	saturated	19193.7	5067.1	15	3.7	1.0	40.3	93.0	3.77E-05	3.7	
Test Averages/Summary													
3-4	**2.0**	**29.0**	**saturated**	**58.7**	**15.5**	**15**	**4.0**	**1.1**	**40.3**	**93.0**	**4.08E-05**	**4.0**	

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		19199.0	5068.5	0							
3-5A	1.0	14.5	saturated	19201.0	5069.1	1	2.0	0.5	25.9	59.7	3.16E-05	3.1	
3-5B	1.0	14.5	saturated	19205.5	5070.3	3	2.3	0.6	25.9	59.7	3.56E-05	3.5	
3-5C	1.0	14.5	saturated	19209.6	5071.3	5	2.0	0.5	25.9	59.7	3.24E-05	3.2	
3-5D	1.0	14.5	saturated	19219.8	5074.0	10	2.0	0.5	25.9	59.7	3.22E-05	3.2	
3-5E	1.0	14.5	saturated	19229.9	5076.7	15	2.0	0.5	25.9	59.7	3.19E-05	3.2	
Test Averages/Summary													
3-5	**1.0**	**14.5**	**saturated**	**30.9**	**8.2**	**15**	**2.1**	**0.5**	**25.9**	**59.7**	**3.27E-05**	**3.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.6
Bottom of Test Interval Depth, ft	195.4

Estimated Hydrostatic Pressure, psi	117.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	189.5
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	315.6		
Bottom of Test Interval Elevation, ft	303.8		
Rubber Hose Length, ft	19.7		
# of NQ Rods	19	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 16:16 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		19306.7	5097.0	0							
4-1A	1.0	14.5	saturated	19307.7	5097.2	1	1.0	0.3	25.9	59.7	1.58E-05	1.6	
4-1B	1.0	14.5	saturated	19309.7	5097.8	3	1.0	0.3	25.9	59.7	1.58E-05	1.6	
4-1C	1.0	14.5	saturated	19310.8	5098.1	5	0.5	0.1	25.9	59.7	8.69E-06	0.9	
4-1D	1.0	14.5	saturated	19317.3	5099.8	10	1.3	0.3	25.9	59.7	2.05E-05	2.0	
4-1E	1.0	14.5	saturated	19322.6	5101.2	15	1.1	0.3	25.9	59.7	1.68E-05	1.7	
Test Averages/Summary													
4-1	**1.0**	**14.5**	**saturated**	**15.9**	**4.2**	**15**	**1.0**	**0.3**	**25.9**	**59.7**	**1.55E-05**	**1.5**	

Notes:

Start Time: 16:34 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		19330.3	5103.2	0							
4-2A	2.0	29.0	saturated	19333.4	5104.0	1	3.1	0.8	40.4	93.1	3.14E-05	3.1	
4-2B	2.0	29.0	saturated	19339.0	5105.5	3	2.8	0.7	40.4	93.1	2.84E-05	2.8	
4-2C	2.0	29.0	saturated	19344.9	5107.1	5	3.0	0.8	40.4	93.1	2.99E-05	3.0	
4-2D	2.0	29.0	saturated	19358.2	5110.6	10	2.7	0.7	40.4	93.1	2.69E-05	2.7	
4-2E	2.0	29.0	saturated	19371.3	5114.0	15	2.6	0.7	40.4	93.1	2.65E-05	2.6	
Test Averages/Summary													
4-2	**2.0**	**29.0**	**saturated**	**41.0**	**10.8**	**15**	**2.8**	**0.7**	**40.4**	**93.1**	**2.86E-05**	**2.8**	

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		19380.0	5116.3	0							
4-3A	3.0	43.5	saturated	19384.0	5117.4	1	4.0	1.1	54.9	126.6	2.98E-05	2.9	
4-3B	3.0	43.5	saturated	19391.9	5119.5	3	4.0	1.0	54.9	126.6	2.94E-05	2.9	
4-3C	3.0	43.5	saturated	19398.7	5121.3	5	3.4	0.9	54.9	126.6	2.53E-05	2.5	
4-3D	3.0	43.5	saturated	19417.3	5126.2	10	3.7	1.0	54.9	126.6	2.77E-05	2.7	
4-3E	3.0	43.5	saturated	19436.6	5131.3	15	3.9	1.0	54.9	126.6	2.88E-05	2.8	
Test Averages/Summary													
4-3	**3.0**	**43.5**	**saturated**	**56.6**	**14.9**	**15**	**3.8**	**1.0**	**54.9**	**126.6**	**2.82E-05**	**2.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.6
Bottom of Test Interval Depth, ft	195.4

Estimated Hydrostatic Pressure, psi	117.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	189.5
Test Interval Length (L), ft	11.8

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	315.6		
Bottom of Test Interval Elevation, ft	303.8		
Rubber Hose Length, ft	19.7		
# of NQ Rods	19	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 17:11 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		19448.0	5134.3	0							
4-4A	2.0	29.0	saturated	19450.6	5135.0	1	2.6	0.7	40.4	93.1	2.63E-05	2.6	
4-4B	2.0	29.0	saturated	19455.7	5136.3	3	2.6	0.7	40.4	93.1	2.58E-05	2.6	
4-4C	2.0	29.0	saturated	19460.4	5137.5	5	2.4	0.6	40.4	93.1	2.38E-05	2.4	
4-4D	2.0	29.0	saturated	19472.7	5140.8	10	2.5	0.6	40.4	93.1	2.49E-05	2.5	
4-4E	2.0	29.0	saturated	19484.7	5144.0	15	2.4	0.6	40.4	93.1	2.43E-05	2.4	
Test Averages/Summary													
4-4	**2.0**	**29.0**	**saturated**	**36.7**	**9.7**	**15**	**2.5**	**0.7**	**40.4**	**93.1**	**2.50E-05**	**2.5**	

Notes:

Start Time: 17:30 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		19491.0	5145.6	0							
4-5A	1.0	14.5	saturated	19492.4	5146.0	1	1.4	0.4	25.9	59.7	2.21E-05	2.2	
4-5B	1.0	14.5	saturated	19495.3	5146.8	3	1.4	0.4	25.9	59.7	2.29E-05	2.3	
4-5C	1.0	14.5	saturated	19498.1	5147.5	5	1.4	0.4	25.9	59.7	2.21E-05	2.2	
4-5D	1.0	14.5	saturated	19504.6	5149.2	10	1.3	0.3	25.9	59.7	2.05E-05	2.0	
4-5E	1.0	14.5	saturated	19511.5	5151.0	15	1.4	0.4	25.9	59.7	2.18E-05	2.2	
Test Averages/Summary													
4-5	**1.0**	**14.5**	**saturated**	**20.5**	**5.4**	**15**	**1.4**	**0.4**	**25.9**	**59.7**	**2.19E-05**	**2.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	177.1
Bottom of Test Interval Depth, ft	185.6

Estimated Hydrostatic Pressure, psi	114.3
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	181.3
Test Interval Length (L), ft	8.5

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	322.1		
Bottom of Test Interval Elevation, ft	313.6		
Rubber Hose Length, ft	19.7		
# of NQ Rods	18	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 18:33 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		19559.0	5163.6	0							
5-1A	1.0	14.5	saturated	19555.3	5162.6	1	(3.7)	(1.0)					
5-1B	1.0	14.5	saturated	19557.5	5163.2	3	1.1	0.3	25.9	59.7	2.21E-05	2.4	
5-1C	1.0	14.5	saturated	19559.7	5163.8	5	1.1	0.3	25.9	59.7	2.21E-05	2.4	
5-1D	1.0	14.5	saturated	19565.3	5165.2	10	1.1	0.3	25.9	59.7	2.25E-05	2.4	
5-1E	1.0	14.5	saturated	19571.3	5166.8	15	1.2	0.3	25.9	59.7	2.41E-05	2.6	
Test Averages/Summary													
5-1	**1.0**	**14.5**	**saturated**	**12.3**	**3.2**	**15**	**0.2**	**0.0**	**25.9**	**59.7**	**2.27E-05**	**0.4**	

Notes: Hydraulic conductivity was not calculated when the flowrate was negative.

Start Time: 18:50 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		19576.1	5168.1	0							
5-2A	2.0	29.0	saturated	19578.8	5168.8	1	2.7	0.7	40.4	93.1	3.47E-05	3.7	
5-2B	2.0	29.0	saturated	19584.3	5170.3	3	2.8	0.7	40.4	93.1	3.54E-05	3.8	
5-2C	2.0	29.0	saturated	19589.9	5171.7	5	2.8	0.7	40.4	93.1	3.60E-05	3.9	
5-2D	2.0	29.0	saturated	19604.5	5175.6	10	2.9	0.8	40.4	93.1	3.76E-05	4.0	
5-2E	2.0	29.0	saturated	19620.7	5179.9	15	3.2	0.9	40.4	93.1	4.17E-05	4.5	
Test Averages/Summary													
5-2	**2.0**	**29.0**	**saturated**	**44.6**	**11.8**	**15**	**2.9**	**0.8**	**40.4**	**93.1**	**3.71E-05**	**4.0**	

Notes:

Start Time: 19:08 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		19635.0	5183.6	0							
5-3A	3.0	43.5	saturated	19641.8	5185.4	1	6.8	1.8	54.8	126.4	6.44E-05	6.9	
5-3B	3.0	43.5	saturated	19655.4	5189.0	3	6.8	1.8	54.8	126.4	6.44E-05	6.9	
5-3C	3.0	43.5	saturated	19669.3	5192.7	5	6.9	1.8	54.8	126.4	6.59E-05	7.1	
5-3D	3.0	43.5	saturated	19704.3	5201.9	10	7.0	1.8	54.8	126.4	6.63E-05	7.2	
5-3E	3.0	43.5	saturated	19743.2	5212.2	15	7.8	2.1	54.8	126.4	7.37E-05	7.9	
Test Averages/Summary													
5-3	**3.0**	**43.5**	**saturated**	**108.2**	**28.6**	**15**	**7.1**	**1.9**	**54.8**	**126.4**	**6.70E-05**	**7.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	177.1
Bottom of Test Interval Depth, ft	185.6

Estimated Hydrostatic Pressure, psi	114.3
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	181.3
Test Interval Length (L), ft	8.5

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	322.1		
Bottom of Test Interval Elevation, ft	313.6		
Rubber Hose Length, ft	19.7		
# of NQ Rods	18	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 19:25 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		19752.0	5214.5	0							
5-4A	2.0	29.0	saturated	19757.3	5215.9	1	5.3	1.4	40.3	93.0	6.82E-05	7.4	
5-4B	2.0	29.0	saturated	19767.4	5218.6	3	5.1	1.3	40.3	93.0	6.50E-05	7.0	
5-4C	2.0	29.0	saturated	19777.4	5221.2	5	5.0	1.3	40.3	93.0	6.44E-05	6.9	
5-4D	2.0	29.0	saturated	19802.6	5227.9	10	5.0	1.3	40.3	93.0	6.49E-05	7.0	
5-4E	2.0	29.0	saturated	19826.9	5234.3	15	4.9	1.3	40.3	93.0	6.26E-05	6.7	
Test Averages/Summary													
5-4	**2.0**	**29.0**	**saturated**	**74.9**	**19.8**	**15**	**5.1**	**1.3**	**40.3**	**93.0**	**6.50E-05**	**7.0**	

Notes:

Start Time: 19:42 | Stage/Packer Pressure, bar: | Friction Loss, f, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		19835.0	5236.4	0							
5-5A	1.0	14.5	saturated	19838.3	5237.3	1	3.3	0.9	25.9	59.7	6.62E-05	7.1	
5-5B	1.0	14.5	saturated	19844.5	5238.9	3	3.1	0.8	25.9	59.7	6.22E-05	6.7	
5-5C	1.0	14.5	saturated	19850.7	5240.6	5	3.1	0.8	25.9	59.7	6.22E-05	6.7	
5-5D	1.0	14.5	saturated	19866.8	5244.8	10	3.2	0.9	25.9	59.7	6.46E-05	7.0	
5-5E	1.0	14.5	saturated	19883.0	5249.1	15	3.2	0.9	25.9	59.7	6.50E-05	7.0	
Test Averages/Summary													
5-5	**1.0**	**14.5**	**saturated**	**48.0**	**12.7**	**15**	**3.2**	**0.8**	**25.9**	**59.7**	**6.41E-05**	**6.9**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	167.2
Bottom of Test Interval Depth, ft	175.7

Estimated Hydrostatic Pressure, psi	110.1
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	171.5
Test Interval Length (L), ft	8.5

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	332.0		
Bottom of Test Interval Elevation, ft	323.5		
Rubber Hose Length, ft	19.7		
# of NQ Rods	17	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time: 20:47 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		19940.2	5264.2	0							
6-1A	1.0	14.5	saturated	19942.9	5264.9	1	2.7	0.7	25.9	59.7	5.42E-05	5.8	
6-1B	1.0	14.5	saturated	19948.2	5266.3	3	2.6	0.7	25.9	59.7	5.32E-05	5.7	
6-1C	1.0	14.5	saturated	19954.9	5268.1	5	3.4	0.9	25.9	59.7	6.72E-05	7.2	
6-1D	1.0	14.5	saturated	19967.5	5271.4	10	2.5	0.7	25.9	59.7	5.06E-05	5.5	
6-1E	1.0	14.5	saturated	19980.6	5274.9	15	2.6	0.7	25.9	59.7	5.26E-05	5.7	
Test Averages/Summary													
6-1	**1.0**	**14.5**	**saturated**	**40.4**	**10.7**	**15**	**2.8**	**0.7**	**25.9**	**59.7**	**5.55E-05**	**6.0**	

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		19985.0	5276.0	0							
6-2A	2.0	29.0	saturated	19993.8	5278.4	2	4.4	1.2	40.3	93.0	5.66E-05	6.1	
6-2B	2.0	29.0	saturated	19996.8	5279.2	3	3.0	0.8	40.3	93.0	3.86E-05	4.2	
6-2C	2.0	29.0	saturated	20007.3	5281.9	5	5.3	1.4	40.3	93.0	6.76E-05	7.3	
6-2D	2.0	29.0	saturated	20035.3	5289.3	10	5.6	1.5	40.3	93.0	7.21E-05	7.8	
6-2E	2.0	29.0	saturated	20064.8	5297.1	15	5.9	1.6	40.3	93.0	7.60E-05	8.2	
Test Averages/Summary													
6-2	**2.0**	**29.0**	**saturated**	**79.8**	**21.1**	**15**	**4.8**	**1.3**	**40.3**	**93.0**	**6.22E-05**	**6.7**	

Notes: Non-standard time steps.

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.3 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		20072.0	5299.0	0							
6-3A	3.0	43.5	saturated	20080.6	5301.3	1	8.6	2.3	54.7	126.3	8.16E-05	8.8	
6-3B	3.0	43.5	saturated	20104.6	5307.6	4	8.0	2.1	54.7	126.3	7.59E-05	8.2	
6-3C	3.0	43.5	saturated	20112.1	5309.6	5	7.5	2.0	54.7	126.3	7.11E-05	7.7	
6-3D	3.0	43.5	saturated	20158.6	5321.9	10	9.3	2.5	54.7	126.3	8.82E-05	9.5	
6-3E	3.0	43.5	saturated	20205.7	5334.3	15	9.4	2.5	54.7	126.3	8.94E-05	9.6	
Test Averages/Summary													
6-3	**3.0**	**43.5**	**saturated**	**133.7**	**35.3**	**15**	**8.6**	**2.3**	**54.7**	**126.3**	**8.12E-05**	**8.8**	

Notes: Non-standard time steps.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	7/28/2019
WSP Personnel:	C. Fischer
Driller:	Fugro
Operator:	T. Brindle

Boring ID	BH19-35
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	167.2
Bottom of Test Interval Depth, ft	175.7

Estimated Hydrostatic Pressure, psi	110.1
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	171.5
Test Interval Length (L), ft	8.5

Lake Depth, ft	82.5		
Datum (Mudline) Elevation, ft	499.2		
Top of Test Interval Elevation, ft	332.0		
Bottom of Test Interval Elevation, ft	323.5		
Rubber Hose Length, ft	19.7		
# of NQ Rods	17	# of HWY Rods	0

Note: Number of NQ rods were not noted in field logs and thus were back-calculated.

Start Time | Stage/Packer Pressure, bar | | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		20215.7	5336.9	0							
6-4A	2.0	29.0	saturated	20223.5	5339.0	1	7.8	2.1	40.3	92.9	1.01E-04	10.8	
6-4B	2.0	29.0	saturated	20236.6	5342.5	3	6.5	1.7	40.3	92.9	8.44E-05	9.1	
6-4C	2.0	29.0	saturated	20255.3	5347.4	6	6.2	1.6	40.3	92.9	8.03E-05	8.7	
6-4D	2.0	29.0	saturated	20294.9	5357.9	10	9.9	2.6	40.3	92.9	1.28E-04	13.8	
6-4E	2.0	29.0	saturated	20336.9	5368.9	15	4.0	2.2	40.3	92.9	1.08E-04	11.7	
6-4F	2.0	29.0	saturated	20377.0	5379.5	20	5.0	2.1	40.3	92.9	1.03E-04	11.1	
Test Averages/Summary													
6-4	**2.0**	**29.0**	**saturated**	**153.5**	**40.5**	**20**	**6.6**	**2.1**	**40.3**	**92.9**	**1.01E-04**	**10.9**	

Notes: Non-standard time steps. In test step 6-4C, pressure suddenly increased to 6 bar.

Start Time | Stage/Packer Pressure, bar | | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_i) $P_i = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		20387.2	5382.2	0							
6-5A	1.0	14.5	saturated	20400.0	5385.6	2	6.4	1.7	25.8	59.5	1.29E-04	13.9	
6-5B	1.0	14.5	saturated	20405.8	5387.1	3	5.8	1.5	25.8	59.5	1.17E-04	12.6	
6-5C	1.0	14.5	saturated	20417.3	5390.2	5	5.8	1.5	25.8	59.5	1.16E-04	12.5	
6-5D	1.0	14.5	saturated	20445.7	5397.7	10	5.7	1.5	25.8	59.5	1.14E-04	12.3	
6-5E	1.0	14.5	saturated	20475.3	5405.5	15	5.9	1.6	25.8	59.5	1.19E-04	12.8	
Test Averages/Summary													
6-5	**1.0**	**14.5**	**saturated**	**88.1**	**23.3**	**15**	**5.9**	**1.6**	**25.8**	**59.5**	**1.19E-04**	**12.8**	

Notes: Non-standard time steps.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	09/17/19
WSP Personnel	C. Fischer
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	82.4
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-36
Number of Tests	7
Lattitude	45.79716°N
Longitude	84.77391°W

Top of Rock, ft	123.7
Bottom of Boring, ft	221.5
Lake Depth, ft	79.3

Datum (Mudline) Elevation	502.4
Top of Rock Elevation, ft	378.7
Bottom of Hole Elevation, ft	280.9
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_i)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
1-1	1.1	15.9	saturated	20.3	5.4	124.9	1.4	0.4	27.3	63.0	2.05E-05	2.0		
1-2	2.1	30.2	saturated	55.5	14.7	124.9	3.4	0.9	41.5	95.7	3.34E-05	3.3		
1-3	3.1	45.5	saturated	79.0	20.9	124.9	5.6	1.5	56.8	131.1	4.03E-05	4.0		
1-4	2.1	30.7	saturated	73.4	19.4	124.9	4.9	1.3	42.0	96.9	4.72E-05	4.7		
1-5	1.0	14.5	saturated	46.7	12.3	124.9	3.1	0.8	25.9	59.7	4.88E-05	4.8		
2-1	1.0	14.1	saturated	13.6	3.6	120.7	0.9	0.2	25.5	58.8	1.47E-05	1.4		
2-2	2.1	29.9	saturated	22.8	6.0	120.7	1.6	0.4	41.2	95.1	1.56E-05	1.5		
2-3	3.0	43.5	saturated	30.4	8.0	120.7	2.0	0.5	54.9	126.6	1.50E-05	1.5		
2-4	2.1	30.4	saturated	23.0	6.1	120.7	1.6	0.4	41.8	96.5	1.52E-05	1.5		
2-5	1.1	15.4	saturated	15.3	4.0	120.7	1.6	0.4	27.0	62.2	3.33E-05	2.4		
3-1	1.1	15.9	saturated	36.6	9.7	116.4	2.7	0.7	27.3	63.0	4.09E-05	4.0		
3-2	2.0	29.0	saturated	27.5	7.3	116.4	1.9	0.5	40.4	93.1	1.89E-05	1.9		
3-3	3.2	46.4	saturated	38.9	10.3	116.4	2.6	0.7	57.8	133.3	1.85E-05	1.8		
3-4	2.1	30.4	saturated	29.5	7.8	116.4	2.0	0.5	41.8	96.5	1.92E-05	1.9		
3-5	1.0	14.5	saturated	21.4	5.6	116.4	1.4	0.4	25.9	59.7	2.23E-05	2.2		
4-1	1.1	15.4	saturated	30.2	8.0	112.2	2.0	0.5	26.7	61.7	3.02E-05	3.0		
4-2	2.0	29.0	saturated	42.4	11.2	112.2	2.8	0.7	40.4	93.1	2.86E-05	2.8		
4-3	3.0	44.1	saturated	52.6	13.9	112.2	3.6	0.9	55.4	127.8	2.64E-05	2.6		
4-4	2.0	29.0	saturated	37.4	9.9	112.2	2.5	0.7	40.4	93.1	2.52E-05	2.5		
4-5	1.1	15.9	saturated	34.8	9.2	112.2	2.0	0.5	27.3	63.0	3.04E-05	3.0		
5-1	1.0	14.5	saturated	105.1	27.7	107.9	7.2	1.9	25.7	59.3	1.14E-04	11.2		
5-2	2.2	31.5	saturated	138.1	36.5	107.9	9.3	2.4	42.6	98.3	8.91E-05	8.8		
5-3	3.0	43.5	saturated	155.6	41.1	107.9	10.4	2.7	54.5	125.7	7.77E-05	7.7		
5-4	2.0	29.0	saturated	120.2	31.7	107.9	9.4	2.5	40.1	92.4	9.55E-05	9.4		
5-5	1.0	14.5	saturated	73.6	19.4	107.9	4.7	1.2	25.8	59.6	7.38E-05	7.3		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Completion (All Tests)	09/17/19
WSP Personnel	C. Fischer
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	82.4
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-36
Number of Tests	7
Lattitude	45.79716°N
Longitude	84.77391°W

Top of Rock, ft	123.7
Bottom of Boring, ft	221.5
Lake Depth, ft	79.3

Datum (Mudline) Elevation	502.4
Top of Rock Elevation, ft	378.7
Bottom of Hole Elevation, ft	280.9
Lake Level Elevation, ft	581.7

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
6-1	1.0	14.8	saturated	177.3	46.8	103.6	12.0	3.2	25.6	59.2	1.91E-04	18.9		
6-2	2.0	29.0	saturated	205.6	54.3	103.6	14.2	3.7	39.6	91.4	1.46E-04	14.5		
6-3	3.0	43.5	saturated	266.2	70.3	103.6	17.8	4.7	53.7	123.8	1.36E-04	13.4		
6-4	2.0	28.7	saturated	203.6	53.8	103.6	13.9	3.7	39.3	90.8	1.45E-04	14.3		
6-5	1.0	14.5	saturated	155.1	40.9	103.6	10.5	2.8	25.5	58.8	1.68E-04	16.6		
7-1	1.0	14.5	saturated	141.8	37.4	99.4	10.0	2.6	25.5	58.9	1.60E-04	15.8		
7-2	2.0	29.3	saturated	183.2	48.4	99.4	12.3	3.3	40.1	92.6	1.26E-04	12.4		
7-3	3.0	43.8	saturated	226.0	59.7	99.4	15.2	4.0	54.3	125.2	1.15E-04	11.3		
7-4	2.0	29.0	saturated	176.9	46.7	99.4	11.7	3.1	39.9	92.0	1.20E-04	11.8		
7-5	1.0	15.1	saturated	118.2	31.2	99.4	7.8	2.1	26.3	60.6	1.21E-04	12.0		

Line 5 Replacement and Tunnel Project - Packer Testing
Transducer Data

Project ID	31402024.00
Date of Completion (All Tests)	09/17/19
WSP Personnel	C. Fischer
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	82.4
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-36
Number of Tests	7
Lattitude	45.79716°N
Longitude	84.77391°W

Top of Rock, ft	123.7
Bottom of Boring, ft	221.5
Lake Depth, ft	79.3
Test Interval, ft	11.8

Datum (Mudline) Elevation	502.4
Top of Rock Elevation, ft	378.7
Bottom of Hole Elevation, ft	280.9
Lake Level Elevation, ft	581.7

Test Step ID	Transducer Zone Pressure		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take		Notes
	m	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
	90.0	128.0												
1-1	102.9	146.3	saturated	20.3	5.4	124.9	1.4	0.4	18.3	42.3	3.06E-05	3.0	||||
1-2	113.5	161.4	saturated	55.5	14.7	124.9	3.4	0.9	33.4	77.1	4.14E-05	4.1	||||||
1-3	124.0	176.3	saturated	79.0	20.9	124.9	5.6	1.5	48.3	111.5	4.73E-05	4.7	|||||||
1-4	113.8	161.8	saturated	73.4	19.4	124.9	4.9	1.3	33.8	78.1	5.87E-05	5.8	|||||||
1-5	100.6	143.0	saturated	46.7	12.3	124.9	3.1	0.8	15.1	34.8	8.37E-05	8.3	||||||||||
	83.6	118.9												
2-1	98.3	139.8	saturated	13.6	3.6	120.7	0.9	0.2	20.9	48.2	1.79E-05	1.8	||
2-2	110.3	156.8	saturated	22.8	6.0	120.7	1.6	0.4	38.0	87.6	1.69E-05	1.7	||
2-3	120.0	170.6	saturated	30.4	8.0	120.7	2.0	0.5	51.7	119.4	1.59E-05	1.6	||
2-4	110.4	157.0	saturated	23.0	6.1	120.7	1.6	0.4	38.1	87.9	1.67E-05	1.6	||
2-5	100.0	142.2	saturated	15.3	4.0	120.7	1.6	0.4	23.3	53.8	2.81E-05	2.8	||||
	80.7	114.7												
3-1	101.8	144.7	saturated	36.6	9.7	116.4	2.7	0.7	30.0	69.2	3.72E-05	3.7	|||||
3-2	110.0	156.4	saturated	27.5	7.3	116.4	1.9	0.5	41.7	96.1	1.83E-05	1.8	||
3-3	123.9	176.1	saturated	38.9	10.3	116.4	2.6	0.7	61.4	141.7	1.74E-05	1.7	||
3-4	111.9	159.1	saturated	29.5	7.8	116.4	2.0	0.5	44.4	102.3	1.81E-05	1.8	||
3-5	100.2	142.5	saturated	21.4	5.6	116.4	1.4	0.4	27.7	64.0	2.08E-05	2.1	|||
	77.3	109.9												
4-1	95.0	135.1	saturated	30.2	8.0	112.2	2.0	0.5	25.2	58.1	3.21E-05	3.2	||||
4-2	104.5	148.6	saturated	42.4	11.2	112.2	2.8	0.7	38.7	89.2	2.99E-05	3.0	||||
4-3	118.0	167.8	saturated	52.6	13.9	112.2	3.6	0.9	57.9	133.5	2.53E-05	2.5	|||
4-4	105.5	150.0	saturated	37.4	9.9	112.2	2.5	0.7	40.1	92.5	2.53E-05	2.5	|||
4-5	94.1	133.8	saturated	34.8	9.2	112.2	2.0	0.5	23.9	55.1	3.48E-05	3.4	|||||

Line 5 Replacement and Tunnel Project - Packer Testing
Transducer Data

Project ID	31402024.00
Date of Completion (All Tests)	09/17/19
WSP Personnel	C. Fischer
Driller	Fugro
Operator	C. Murphy
Riser Type and ID, inch	NQ (2.36) - HWY (1.62)
Total Length of Testing, ft	82.4
Boring Angle from Vertical, °	0.0
Borehole Diameter, inch	5.76

Boring ID	BH19-36
Number of Tests	7
Lattitude	45.79716°N
Longitude	84.77391°W

Top of Rock, ft	123.7
Bottom of Boring, ft	221.5
Lake Depth, ft	79.3
Test Interval, ft	11.8

Datum (Mudline) Elevation	502.4
Top of Rock Elevation, ft	378.7
Bottom of Hole Elevation, ft	280.9
Lake Level Elevation, ft	581.7

Test Step ID	Transducer Zone Pressure		Analysis Type	Flow Meter Reading		Estimated Hydrostatic Pressure (psi)	Flowrate		Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take		Notes
	m	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons		
	74.7	106.2												
5-1	94.8	134.8	saturated	105.1	27.7	107.9	7.2	1.9	28.6	65.9	1.02E-04	10.1		
5-2	108.7	154.5	saturated	138.1	36.5	107.9	9.3	2.4	48.3	111.5	7.84E-05	7.7		
5-3	116.7	165.9	saturated	155.6	41.1	107.9	10.4	2.7	59.7	137.8	7.09E-05	7.0		
5-4	105.6	150.1	saturated	120.2	31.7	107.9	9.4	2.5	43.9	101.3	8.71E-05	8.6		
5-5	93.3	132.6	saturated	73.6	19.4	107.9	4.7	1.2	26.4	61.0	7.21E-05	7.1		
	71.2	101.2												
6-1	93.0	132.2	saturated	177.3	46.8	103.6	12.0	3.2	31.0	71.5	1.58E-04	15.6		
6-2	102.5	145.7	saturated	205.6	54.3	103.6	14.2	3.7	44.5	102.7	1.30E-04	12.9		
6-3	112.5	159.9	saturated	266.2	70.3	103.6	17.8	4.7	58.7	135.5	1.24E-04	12.2		
6-4	102.3	145.4	saturated	203.6	53.8	103.6	13.9	3.7	44.2	102.0	1.29E-04	12.7		
6-5	92.6	131.6	saturated	155.1	40.9	103.6	10.5	2.8	30.4	70.2	1.41E-04	13.9		
	68.1	96.8												
7-1	86.7	123.3	saturated	141.8	37.4	99.4	10.0	2.6	26.4	61.0	1.55E-04	15.3		
7-2	97.5	138.6	saturated	183.2	48.4	99.4	12.3	3.3	41.8	96.4	1.20E-04	11.9		
7-3	106.8	151.8	saturated	226.0	59.7	99.4	15.2	4.0	55.0	126.9	1.13E-04	11.2		
7-4	96.3	136.9	saturated	176.9	46.7	99.4	11.7	3.1	40.1	92.5	1.19E-04	11.8		
7-5	84.9	120.7	saturated	118.2	31.2	99.4	7.8	2.1	23.9	55.1	1.33E-04	13.2		

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/16/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	203.1
Bottom of Test Interval Depth, ft	214.9

Estimated Hydrostatic Pressure, psi	124.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	209.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	299.3
Bottom of Test Interval Elevation, ft	287.5
Rubber Hose Length, ft	19.7
# of NQ Rods	32
# of HWY Rods	1

Note:

Start Time: 09:44 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.1	15.9		24696.1	6519.8	0						
1-1A	1.1	15.9	saturated	24697.5	6520.1	1	1.4	0.4	27.3	63.0	2.10E-05	2.1
1-1B	1.1	15.9	saturated	24700.3	6520.9	3	1.4	0.4	27.3	63.0	2.10E-05	2.1
1-1C	1.1	15.9	saturated	24703.1	6521.6	5	1.4	0.4	27.3	63.0	2.10E-05	2.1
1-1D	1.1	15.9	saturated	24710.2	6523.5	10	1.4	0.4	27.3	63.0	2.12E-05	2.1
1-1E	1.1	15.9	saturated	24716.4	6525.1	15	1.2	0.3	27.3	63.0	1.86E-05	1.8
Test Averages/Summary												
1-1	**1.1**	**15.9**	**saturated**	**20.3**	**5.4**	**15**	**1.4**	**0.4**	**27.3**	**63.0**	**2.05E-05**	**2.0**

Notes:

Start Time: 22:00 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		24721.6	6526.5	0						
1-2A	2.1	30.4	saturated	24724.2	6527.2	1	2.6	0.7	41.8	96.4	2.54E-05	2.5
1-2B	2.1	30.4	saturated	24729.9	6528.7	3	2.9	0.8	41.8	96.4	2.79E-05	2.8
1-2C	2.0	29.0	saturated	24736.7	6530.5	5	3.4	0.9	40.3	93.0	3.45E-05	3.4
1-2D	2.1	30.4	saturated	24752.1	6534.6	10	3.1	0.8	41.8	96.4	3.01E-05	3.0
1-2E	2.1	30.4	saturated	24777.1	6541.2	15	5.0	1.3	41.8	96.4	4.89E-05	4.8
Test Averages/Summary												
1-2	**2.1**	**30.2**	**saturated**	**55.5**	**14.7**	**15**	**3.4**	**0.9**	**41.5**	**95.7**	**3.34E-05**	**3.3**

Notes:

Start Time: 22:18 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.1	44.9		24777.9	6541.4	0						
1-3A	3.2	46.4	saturated	24787.7	6544.0	1	9.8	2.6	57.7	133.1	6.95E-05	6.9
1-3B	3.2	46.4	saturated	24792.8	6545.3	3	2.5	0.7	57.7	133.1	1.81E-05	1.8
1-3C	3.3	47.8	saturated	24802.2	6547.8	5	4.7	1.2	59.1	136.4	3.25E-05	3.2
1-3D	3.0	43.5	saturated	24837.4	6557.1	10	7.0	1.9	54.8	126.4	5.25E-05	5.2
1-3E	3.0	43.5	saturated	24856.9	6562.2	15	3.9	1.0	54.8	126.4	2.91E-05	2.9
Test Averages/Summary												
1-3	**3.1**	**45.5**	**saturated**	**79.0**	**20.9**	**15**	**5.6**	**1.5**	**56.8**	**131.1**	**4.03E-05**	**4.0**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/16/2019
WSP Personnel	A. Hesse
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	1
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	203.1
Bottom of Test Interval Depth, ft	214.9

Estimated Hydrostatic Pressure, psi	124.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	209.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3		
Datum (Mudline) Elevation, ft	502.4		
Top of Test Interval Elevation, ft	299.3		
Bottom of Test Interval Elevation, ft	287.5		
Rubber Hose Length, ft	19.7		
# of NQ Rods	32	# of HWY Rods	1

Note:

Start Time: 22:34 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.2 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		24865.7	6564.5	0							
1-4A	2.1	30.4	saturated	24870.5	6565.8	1	4.8	1.3	41.7	96.3	4.70E-05	4.6	
1-4B	2.1	30.4	saturated	24880.2	6568.4	3	4.9	1.3	41.7	96.3	4.75E-05	4.7	
1-4C	2.1	30.4	saturated	24889.7	6570.9	5	4.8	1.3	41.7	96.3	4.65E-05	4.6	
1-4D	2.1	30.4	saturated	24914.2	6577.3	10	4.9	1.3	41.7	96.3	4.80E-05	4.7	
1-4E	2.2	31.9	saturated	24939.1	6583.9	15	5.0	1.3	43.2	99.6	4.72E-05	4.7	
Test Averages/Summary													
1-4	**2.1**	**30.7**	**saturated**	**73.4**	**19.4**	**15**	**4.9**	**1.3**	**42.0**	**96.9**	**4.72E-05**	**4.7**	

Notes:

Start Time: 22:52 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		24946.6	6585.9	0							
1-5A	1.0	14.5	saturated	24949.6	6586.7	1	3.0	0.8	25.9	59.7	4.74E-05	4.7	
1-5B	1.0	14.5	saturated	24955.7	6588.3	3	3.1	0.8	25.9	59.7	4.82E-05	4.8	
1-5C	1.0	14.5	saturated	24961.9	6589.9	5	3.1	0.8	25.9	59.7	4.90E-05	4.8	
1-5D	1.0	14.5	saturated	24977.6	6594.1	10	3.1	0.8	25.9	59.7	4.96E-05	4.9	
1-5E	1.0	14.5	saturated	24993.3	6598.2	15	3.1	0.8	25.9	59.7	4.96E-05	4.9	
Test Averages/Summary													
1-5	**1.0**	**14.5**	**saturated**	**46.7**	**12.3**	**15**	**3.1**	**0.8**	**25.9**	**59.7**	**4.88E-05**	**4.8**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.3
Bottom of Test Interval Depth, ft	205.1

Estimated Hydrostatic Pressure, psi	120.7
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	309.1
Bottom of Test Interval Elevation, ft	297.3
Rubber Hose Length, ft	19.7
# of NQ Rods	31
# of HWY Rods	1

Note:

Start Time: 23:37 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r) Bar	Pressure Reading (P_r) psi	Analysis Type	Flow Meter Reading Liter	Flow Meter Reading gal	Elapsed Time in Minutes	Flowrate L/min	Flowrate gpm	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ psi	Corrected Test Pressure (P_I) ft	Hydraulic Conductivity* (K) cm/sec	Water Take Lugeons	
	1.0	14.5		25067.4	6617.8	0							
2-1A	1.0	14.5	saturated	25070.2	6618.5	3	0.9	0.2	25.9	59.7	1.47E-05	1.5	III
2-1B	0.9	13.0	saturated	25072.1	6619.0	5	0.9	0.3	24.4	56.3	1.59E-05	1.6	III
2-1C	1.0	14.5	saturated	25076.6	6620.2	10	0.9	0.2	25.9	59.7	1.42E-05	1.4	III
2-1D	1.0	14.5	saturated	25081.0	6621.4	15	0.9	0.2	25.9	59.7	1.39E-05	1.4	III
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
2-1	**1.0**	**14.1**	**saturated**	**13.6**	**3.6**	**15**	**0.9**	**0.2**	**25.5**	**58.8**	**1.47E-05**	**1.4**	**III**

Notes: Missed reading at 1 minute time step.

Start Time: 23:55 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r) Bar	Pressure Reading (P_r) psi	Analysis Type	Flow Meter Reading Liter	Flow Meter Reading gal	Elapsed Time in Minutes	Flowrate L/min	Flowrate gpm	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ psi	Corrected Test Pressure (P_I) ft	Hydraulic Conductivity (K) cm/sec	Water Take Lugeons	
	2.0	29.0		25087.9	6623.2	0							
2-2A	2.0	29.0	saturated	25089.6	6623.7	1	1.7	0.4	40.4	93.1	1.72E-05	1.7	III
2-2B	2.0	29.0	saturated	25092.8	6624.5	3	1.6	0.4	40.4	93.1	1.62E-05	1.6	III
2-2C	2.1	30.4	saturated	25096.0	6625.3	5	1.6	0.4	41.8	96.5	1.56E-05	1.5	III
2-2D	2.1	30.4	saturated	25103.6	6627.4	10	1.5	0.4	41.8	96.5	1.49E-05	1.5	III
2-2E	2.1	30.4	saturated	25110.7	6629.2	15	1.4	0.4	41.8	96.5	1.39E-05	1.4	III
Test Averages/Summary													
2-2	**2.1**	**29.9**	**saturated**	**22.8**	**6.0**	**15**	**1.6**	**0.4**	**41.2**	**95.1**	**1.56E-05**	**1.5**	**III**

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r) Bar	Pressure Reading (P_r) psi	Analysis Type	Flow Meter Reading Liter	Flow Meter Reading gal	Elapsed Time in Minutes	Flowrate L/min	Flowrate gpm	Corrected Test Pressure (P_I) $P_I = P_r + h - f$ psi	Corrected Test Pressure (P_I) ft	Hydraulic Conductivity (K) cm/sec	Water Take Lugeons	
	3.0	43.5		25114.6	6630.3	0							
2-3A	3.0	43.5	saturated	25116.6	6630.8	1	2.0	0.5	54.9	126.6	1.49E-05	1.5	III
2-3B	3.0	43.5	saturated	25120.6	6631.8	3	2.0	0.5	54.9	126.6	1.49E-05	1.5	III
2-3C	3.0	43.5	saturated	25124.6	6632.9	5	2.0	0.5	54.9	126.6	1.49E-05	1.5	III
2-3D	3.0	43.5	saturated	25134.8	6635.6	10	2.0	0.5	54.9	126.6	1.52E-05	1.5	III
2-3E	3.0	43.5	saturated	25145.0	6638.3	15	2.0	0.5	54.9	126.6	1.52E-05	1.5	III
Test Averages/Summary													
2-3	**3.0**	**43.5**	**saturated**	**30.4**	**8.0**	**15**	**2.0**	**0.5**	**54.9**	**126.6**	**1.50E-05**	**1.5**	**III**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	A. Hesse, D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	2
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	193.3
Bottom of Test Interval Depth, ft	205.1

Estimated Hydrostatic Pressure, psi	120.7
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	199.2
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	309.1
Bottom of Test Interval Elevation, ft	297.3
Rubber Hose Length, ft	19.7
# of NQ Rods	31
# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		25149.4	6639.4	0							
2-4A	2.1	30.4	saturated	25151.0	6639.9	1	1.6	0.4	41.8	96.5	1.56E-05	1.5	|||
2-4B	2.1	30.4	saturated	25154.1	6640.7	3	1.5	0.4	41.8	96.5	1.52E-05	1.5	|||
2-4C	2.1	30.4	saturated	25157.3	6641.5	5	1.6	0.4	41.8	96.5	1.56E-05	1.5	|||
2-4D	2.1	30.4	saturated	25165.0	6643.6	10	1.5	0.4	41.8	96.5	1.51E-05	1.5	|||
2-4E	2.1	30.4	saturated	25172.4	6645.5	15	1.5	0.4	41.8	96.5	1.45E-05	1.4	|||
Test Averages/Summary													
2-4	**2.1**	**30.4**	**saturated**	**23.0**	**6.1**	**15**	**1.6**	**0.4**	**41.8**	**96.5**	**1.52E-05**	**1.5**	|||

Notes

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.1	15.9		25174.2	6646.0	0							
2-5A	1.1	15.9	saturated	25175.4	6646.3	1	1.2	0.3	27.3	63.0	1.80E-05	1.8	||||
2-5B	1.0	14.5	saturated	25176.8	6646.7	3	0.7	0.2	25.9	59.7	1.11E-05	1.1	||
2-5C	1.1	15.9	saturated	25188.7	6649.8	5	6.0	1.6	27.3	63.0	8.90E-05	8.8	||||||||||||||||
2-5D	1.0	14.5	saturated	25184.5	6648.7	10	(0.8)	(0.2)					
2-5E	1.1	15.9	saturated	25189.5	6650.0	15	1.0	0.3	27.3	63.0	1.50E-05	1.5	|||
Test Averages/Summary													
2-5	**1.1**	**15.4**	**saturated**	**15.3**	**4.0**	**15**	**1.6**	**0.4**	**27.0**	**62.2**	**3.33E-05**	**2.4**	|||||

Notes: *Hydraulic conductivity calculation did not proceed with negative water take.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.5
Bottom of Test Interval Depth, ft	195.2

Estimated Hydrostatic Pressure, psi	116.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	189.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3		
Datum (Mudline) Elevation, ft	502.4		
Top of Test Interval Elevation, ft	318.9		
Bottom of Test Interval Elevation, ft	307.2		
Rubber Hose Length, ft	19.7		
# of NQ Rods	30	# of HWY Rods	1

Note:

Start Time: 01:35 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.1	15.9		25392.8	6703.7	0						
3-1A	1.1	15.9	saturated	25396.4	6704.6	1	3.6	1.0	27.3	63.0	5.39E-05	5.3
3-1B	1.1	15.9	saturated	25402.5	6706.3	3	3.0	0.8	27.3	63.0	4.56E-05	4.5
3-1C	1.1	15.9	saturated	25407.9	6707.7	5	2.7	0.7	27.3	63.0	4.04E-05	4.0
3-1D	1.1	15.9	saturated	25419.8	6710.8	10	2.4	0.6	27.3	63.0	3.56E-05	3.5
3-1E	1.1	15.9	saturated	25429.4	6713.4	15	1.9	0.5	27.3	63.0	2.87E-05	2.8
Test Averages/Summary												
3-1	**1.1**	**15.9**	**saturated**	**36.6**	**9.7**	**15**	**2.7**	**0.7**	**27.3**	**63.0**	**4.09E-05**	**4.0**

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		25434.9	6714.8	0						
3-2A	2.0	29.0	saturated	25438.9	6715.9	2	2.0	0.5	40.4	93.1	2.03E-05	2.0
3-2B	2.0	29.0	saturated	25440.8	6716.4	3	1.9	0.5	40.4	93.1	1.92E-05	1.9
3-2C	2.0	29.0	saturated	25444.5	6717.3	5	1.9	0.5	40.4	93.1	1.87E-05	1.9
3-2D	2.0	29.0	saturated	25453.5	6719.7	10	1.8	0.5	40.4	93.1	1.82E-05	1.8
3-2E	2.0	29.0	saturated	25462.4	6722.1	15	1.8	0.5	40.4	93.1	1.80E-05	1.8
Test Averages/Summary												
3-2	**2.0**	**29.0**	**saturated**	**27.5**	**7.3**	**15**	**1.9**	**0.5**	**40.4**	**93.1**	**1.89E-05**	**1.9**

Notes: Non-standard time steps.

Start Time: 02:09 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		25466.3	6723.1	0						
3-3A	3.2	46.4	saturated	25469.0	6723.8	1	2.7	0.7	57.8	133.3	1.91E-05	1.9
3-3B	3.1	44.9	saturated	25474.0	6725.1	3	2.5	0.7	56.3	129.9	1.81E-05	1.8
3-3C	3.1	44.9	saturated	25479.4	6726.6	5	2.7	0.7	56.3	129.9	1.96E-05	1.9
3-3D	3.3	47.8	saturated	25492.3	6730.0	10	2.6	0.7	59.2	136.6	1.78E-05	1.8
3-3E	3.3	47.8	saturated	25505.2	6733.4	15	2.6	0.7	59.2	136.6	1.78E-05	1.8
Test Averages/Summary												
3-3	**3.2**	**46.4**	**saturated**	**38.9**	**10.3**	**15**	**2.6**	**0.7**	**57.8**	**133.3**	**1.85E-05**	**1.8**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	3
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	183.5
Bottom of Test Interval Depth, ft	195.2

Estimated Hydrostatic Pressure, psi	116.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	189.4
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3		
Datum (Mudline) Elevation, ft	502.4		
Top of Test Interval Elevation, ft	318.9		
Bottom of Test Interval Elevation, ft	307.2		
Rubber Hose Length, ft	19.7		
# of NQ Rods	30	# of HWY Rods	1

Note:

Start Time: 02:29 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.1	30.4		25510.9	6734.9	0							
3-4A	2.1	30.4	saturated	25512.9	6735.4	1	2.0	0.5	41.8	96.5	1.96E-05	1.9	
3-4B	2.1	30.4	saturated	25516.8	6736.4	3	1.9	0.5	41.8	96.5	1.91E-05	1.9	
3-4C	2.1	30.4	saturated	25520.7	6737.5	5	2.0	0.5	41.8	96.5	1.91E-05	1.9	
3-4D	2.1	30.4	saturated	25530.6	6740.1	10	2.0	0.5	41.8	96.5	1.94E-05	1.9	
3-4E	2.1	30.4	saturated	25540.4	6742.7	15	2.0	0.5	41.8	96.5	1.92E-05	1.9	
Test Averages/Summary													
3-4	**2.1**	**30.4**	**saturated**	**29.5**	**7.8**	**15**	**2.0**	**0.5**	**41.8**	**96.5**	**1.92E-05**	**1.9**	

Notes:

Start Time: | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		25543.5	6743.5	0							
3-5A	1.0	14.5	saturated	25546.3	6744.2	2	1.4	0.4	25.9	59.7	2.21E-05	2.2	
3-5B	1.0	14.5	saturated	25547.7	6744.6	3	1.4	0.4	25.9	59.7	2.21E-05	2.2	
3-5C	1.0	14.5	saturated	25550.4	6745.3	5	1.4	0.4	25.9	59.7	2.13E-05	2.1	
3-5D	1.0	14.5	saturated	25557.2	6747.1	10	1.4	0.4	25.9	59.7	2.15E-05	2.1	
3-5E	1.0	14.5	saturated	25564.9	6749.1	15	1.5	0.4	25.9	59.7	2.43E-05	2.4	
Test Averages/Summary													
3-5	**1.0**	**14.5**	**saturated**	**21.4**	**5.6**	**15**	**1.4**	**0.4**	**25.9**	**59.7**	**2.23E-05**	**2.2**	

Notes: Non-standard time steps.

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	173.6
Bottom of Test Interval Depth, ft	185.4

Estimated Hydrostatic Pressure, psi	112.2
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	179.5
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	328.8
Bottom of Test Interval Elevation, ft	317.0
Rubber Hose Length, ft	19.7
# of NQ Rods	29
# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.1	15.9		25735.8	6794.3	0						
4-1A	1.0	14.5	saturated	25737.8	6794.8	1	2.0	0.5	25.9	59.7	3.16E-05	3.1
4-1B	1.0	14.5	saturated	25741.1	6795.7	3	1.6	0.4	25.9	59.7	2.61E-05	2.6
4-1C	1.1	15.9	saturated	25745.3	6796.8	5	2.1	0.6	27.3	63.0	3.14E-05	3.1
4-1D	1.1	15.9	saturated	25755.8	6799.5	10	2.1	0.6	27.3	63.0	3.14E-05	3.1
4-1E	1.1	15.9	saturated	25766.0	6802.2	15	2.0	0.5	27.3	63.0	3.05E-05	3.0
Test Averages/Summary												
4-1	**1.1**	**15.4**	**saturated**	**30.2**	**8.0**	**15**	**2.0**	**0.5**	**26.7**	**61.7**	**3.02E-05**	**3.0**

Notes

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		25770.2	6803.3	0						
4-2A	2.0	29.0	saturated	25773.0	6804.1	1	2.8	0.7	40.4	93.1	2.84E-05	2.8
4-2B	2.0	29.0	saturated	25778.7	6805.6	3	2.9	0.8	40.4	93.1	2.89E-05	2.9
4-2C	2.0	29.0	saturated	25784.4	6807.1	5	2.9	0.8	40.4	93.1	2.89E-05	2.9
4-2D	2.0	29.0	saturated	25798.7	6810.9	10	2.9	0.8	40.4	93.1	2.90E-05	2.9
4-2E	2.0	29.0	saturated	25812.6	6814.5	15	2.8	0.7	40.4	93.1	2.82E-05	2.8
Test Averages/Summary												
4-2	**2.0**	**29.0**	**saturated**	**42.4**	**11.2**	**15**	**2.8**	**0.7**	**40.4**	**93.1**	**2.86E-05**	**2.8**

Notes

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		25817.1	6815.7	0						
4-3A	3.0	43.5	saturated	25820.9	6816.7	1	3.8	1.0	54.8	126.5	2.83E-05	2.8
4-3B	3.0	43.5	saturated	25828.2	6818.6	3	3.6	1.0	54.8	126.5	2.72E-05	2.7
4-3C	3.0	43.5	saturated	25835.4	6820.5	5	3.6	1.0	54.8	126.5	2.68E-05	2.7
4-3D	3.1	44.9	saturated	25852.7	6825.1	10	3.5	0.9	56.3	129.8	2.51E-05	2.5
4-3E	3.1	44.9	saturated	25869.7	6829.6	15	3.4	0.9	56.3	129.8	2.47E-05	2.4
Test Averages/Summary												
4-3	**3.0**	**44.1**	**saturated**	**52.6**	**13.9**	**15**	**3.6**	**0.9**	**55.4**	**127.8**	**2.64E-05**	**2.6**

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	4
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	173.6
Bottom of Test Interval Depth, ft	185.4

Estimated Hydrostatic Pressure, psi	112.2
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	179.5
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3		
Datum (Mudline) Elevation, ft	502.4		
Top of Test Interval Elevation, ft	328.8		
Bottom of Test Interval Elevation, ft	317.0		
Rubber Hose Length, ft	19.7		
# of NQ Rods	29	# of HWY Rods	1

Note:

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		25873.2	6830.5	0							
4-4A	2.0	29.0	saturated	25875.7	6831.2	1	2.5	0.7	40.4	93.1	2.53E-05	2.5	
4-4B	2.0	29.0	saturated	25880.6	6832.5	3	2.4	0.6	40.4	93.1	2.48E-05	2.5	
4-4C	2.0	29.0	saturated	25885.5	6833.8	5	2.5	0.6	40.4	93.1	2.48E-05	2.5	
4-4D	2.0	29.0	saturated	25898.0	6837.1	10	2.5	0.7	40.4	93.1	2.53E-05	2.5	
4-4E	2.0	29.0	saturated	25910.6	6840.4	15	2.5	0.7	40.4	93.1	2.55E-05	2.5	
Test Averages/Summary													
4-4	**2.0**	**29.0**	**saturated**	**37.4**	**9.9**	**15**	**2.5**	**0.7**	**40.4**	**93.1**	**2.52E-05**	**2.5**	

Notes

Start Time | Stage/Packer Pressure, bar | Friction Loss, *f*, ft: 0.0 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.2	17.4		25914.3	6841.4	0							
4-5A	1.1	15.9	saturated	25915.8	6841.8	1	1.5	0.4	27.3	63.0	2.24E-05	2.2	
4-5B	1.1	15.9	saturated	25919.2	6842.7	3	1.7	0.4	27.3	63.0	2.54E-05	2.5	
4-5C	1.1	15.9	saturated	25922.5	6843.5	5	1.6	0.4	27.3	63.0	2.47E-05	2.4	
4-5D	1.1	15.9	saturated	25930.8	6845.7	10	1.7	0.4	27.3	63.0	2.48E-05	2.5	
4-5E	1.1	15.9	saturated	25949.1	6850.6	15	3.7	1.0	27.3	63.0	5.48E-05	5.4	
Test Averages/Summary													
4-5	**1.1**	**15.9**	**saturated**	**34.8**	**9.2**	**15**	**2.0**	**0.5**	**27.3**	**63.0**	**3.04E-05**	**3.0**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	163.8
Bottom of Test Interval Depth, ft	175.6

Estimated Hydrostatic Pressure, psi	107.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	169.7
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3		
Datum (Mudline) Elevation, ft	502.4		
Top of Test Interval Elevation, ft	338.6		
Bottom of Test Interval Elevation, ft	326.8		
Rubber Hose Length, ft	19.7		
# of NQ Rods	28	# of HWY Rods	1

Note:

Start Time: 05:30 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		26117.0	6894.9	0							
5-1A	1.0	14.5	saturated	26124.6	6896.9	1	7.6	2.0	25.7	59.3	1.21E-04	11.9	
5-1B	1.0	14.5	saturated	26139.2	6900.7	3	7.3	1.9	25.7	59.3	1.16E-04	11.5	
5-1C	1.0	14.5	saturated	26153.5	6904.5	5	7.1	1.9	25.7	59.3	1.14E-04	11.2	
5-1D	1.0	14.5	saturated	26188.1	6913.7	10	6.9	1.8	25.7	59.3	1.10E-04	10.9	
5-1E	1.0	14.5	saturated	26222.1	6922.6	15	6.8	1.8	25.7	59.3	1.08E-04	10.7	
Test Averages/Summary													
5-1	**1.0**	**14.5**	**saturated**	**105.1**	**27.7**	**15**	**7.2**	**1.9**	**25.7**	**59.3**	**1.14E-04**	**11.2**	

Notes:

Start Time: 05:54 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.7 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		26235.7	6926.2	0							
5-2A	2.1	30.4	saturated	26264.5	6933.8	3	9.6	2.5	41.5	95.8	9.45E-05	9.3	
5-2B	2.1	30.4	saturated	26283.3	6938.8	5	9.4	2.5	41.5	95.8	9.26E-05	9.1	
5-2C	2.2	31.9	saturated	26329.1	6950.9	10	9.2	2.4	43.0	99.1	8.72E-05	8.6	
5-2D	2.3	33.3	saturated	26373.8	6962.7	15	8.9	2.4	44.4	102.5	8.23E-05	8.1	
-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Averages/Summary													
5-2	**2.2**	**31.5**	**saturated**	**138.1**	**36.5**	**15**	**9.3**	**2.4**	**42.6**	**98.3**	**8.91E-05**	**8.8**	

Notes: Missing reading at time = 1 min.

Start Time: 06:04 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.9 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		26387.7	6966.4	0							
5-3A	3.0	43.5	saturated	26398.0	6969.1	1	10.3	2.7	54.5	125.7	7.73E-05	7.6	
5-3B	3.0	43.5	saturated	26418.8	6974.6	3	10.4	2.7	54.5	125.7	7.81E-05	7.7	
5-3C	3.0	43.5	saturated	26439.4	6980.0	5	10.3	2.7	54.5	125.7	7.73E-05	7.6	
5-3D	3.0	43.5	saturated	26491.2	6993.7	10	10.4	2.7	54.5	125.7	7.78E-05	7.7	
5-3E	3.0	43.5	saturated	26543.3	7007.4	15	10.4	2.8	54.5	125.7	7.82E-05	7.7	
Test Averages/Summary													
5-3	**3.0**	**43.5**	**saturated**	**155.6**	**41.1**	**15**	**10.4**	**2.7**	**54.5**	**125.7**	**7.77E-05**	**7.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	5
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	163.8
Bottom of Test Interval Depth, ft	175.6

Estimated Hydrostatic Pressure, psi	107.9
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	169.7
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	338.6
Bottom of Test Interval Elevation, ft	326.8
Rubber Hose Length, ft	19.7
# of NQ Rods	28
# of HWY Rods	1

Note:

Start Time: 06:22 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.7 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		26550.9	7009.4	0							
5-4A	2.0	29.0	saturated	26567.8	7013.9	1	16.9	4.5	40.1	92.4	1.72E-04	17.0	
5-4B	2.0	29.0	saturated	26583.4	7018.0	3	7.8	2.1	40.1	92.4	7.96E-05	7.9	
5-4C	2.0	29.0	saturated	26598.5	7022.0	5	7.5	2.0	40.1	92.4	7.70E-05	7.6	
5-4D	2.0	29.0	saturated	26635.2	7031.7	10	7.3	1.9	40.1	92.4	7.49E-05	7.4	
5-4E	2.0	29.0	saturated	26671.1	7041.2	15	7.2	1.9	40.1	92.4	7.33E-05	7.2	
Test Averages/Summary													
5-4	**2.0**	**29.0**	**saturated**	**120.2**	**31.7**	**15**	**9.4**	**2.5**	**40.1**	**92.4**	**9.55E-05**	**9.4**	

Notes:

Start Time: 06:39 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.1 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		26681.2	7043.8	0							
5-5A	1.0	14.5	saturated	26686.1	7045.1	1	4.9	1.3	25.8	59.6	7.76E-05	7.7	
5-5B	1.0	14.5	saturated	26695.9	7047.7	3	4.9	1.3	25.8	59.6	7.76E-05	7.7	
5-5C	1.0	14.5	saturated	26701.7	7049.2	5	2.9	0.8	25.8	59.6	4.59E-05	4.5	
5-5D	1.0	14.5	saturated	26729.6	7056.6	10	5.6	1.5	25.8	59.6	8.83E-05	8.7	
5-5E	1.0	14.5	saturated	26754.8	7063.3	15	5.0	1.3	25.8	59.6	7.98E-05	7.9	
Test Averages/Summary													
5-5	**1.0**	**14.5**	**saturated**	**73.6**	**19.4**	**15**	**4.7**	**1.2**	**25.8**	**59.6**	**7.38E-05**	**7.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	153.9
Bottom of Test Interval Depth, ft	165.7

Estimated Hydrostatic Pressure, psi	103.6
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	159.8
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	348.5
Bottom of Test Interval Elevation, ft	336.7
Rubber Hose Length, ft	19.7
# of NQ Rods	27
# of HWY Rods	1

Note:

Start Time: 07:27 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 1.2 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.0	14.5		26914.6	7105.5	0						
6-1A	1.0	14.5	saturated	26926.8	7108.7	1	12.2	3.2	25.4	58.5	1.97E-04	19.4
6-1B	1.0	14.5	saturated	26950.9	7115.0	3	12.1	3.2	25.4	58.5	1.94E-04	19.2
6-1C	1.0	14.5	saturated	26976.0	7121.7	5	12.5	3.3	25.4	58.5	2.02E-04	20.0
6-1D	1.0	14.5	saturated	27034.5	7137.1	10	11.7	3.1	25.4	58.5	1.89E-04	18.6
6-1E	1.1	15.9	saturated	27091.9	7152.3	15	11.5	3.0	26.8	61.8	1.75E-04	17.3
Test Averages/Summary												
6-1	**1.0**	**14.8**	**saturated**	**177.3**	**46.8**	**15**	**12.0**	**3.2**	**25.6**	**59.2**	**1.91E-04**	**18.9**

Notes:

Start Time: 07:45 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 1.7 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		27117.1	7158.9	0						
6-2A	2.0	29.0	saturated	27132.4	7163.0	1	15.3	4.0	39.6	91.4	1.58E-04	15.6
6-2B	2.0	29.0	saturated	27161.4	7170.6	3	14.5	3.8	39.6	91.4	1.50E-04	14.8
6-2C	2.0	29.0	saturated	27191.0	7178.4	5	14.8	3.9	39.6	91.4	1.53E-04	15.1
6-2D	2.0	29.0	saturated	27264.7	7197.9	10	14.7	3.9	39.6	91.4	1.52E-04	15.0
6-2E	2.0	29.0	saturated	27322.7	7213.2	15	11.6	3.1	39.6	91.4	1.20E-04	11.8
Test Averages/Summary												
6-2	**2.0**	**29.0**	**saturated**	**205.6**	**54.3**	**15**	**14.2**	**3.7**	**39.6**	**91.4**	**1.46E-04**	**14.5**

Notes:

Start Time: 08:01 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 2.8 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	3.0	43.5		27345.0	7219.1	0						
6-3A	3.0	43.5	saturated	27362.9	7223.8	1	17.9	4.7	53.7	123.8	1.36E-04	13.5
6-3B	3.0	43.5	saturated	27399.9	7233.6	3	18.5	4.9	53.7	123.8	1.41E-04	13.9
6-3C	3.0	43.5	saturated	27434.4	7242.7	5	17.3	4.6	53.7	123.8	1.31E-04	13.0
6-3D	3.0	43.5	saturated	27523.9	7266.3	10	17.9	4.7	53.7	123.8	1.36E-04	13.5
6-3E	3.0	43.5	saturated	27611.2	7289.4	15	17.5	4.6	53.7	123.8	1.33E-04	13.1
Test Averages/Summary												
6-3	**3.0**	**43.5**	**saturated**	**266.2**	**70.3**	**15**	**17.8**	**4.7**	**53.7**	**123.8**	**1.36E-04**	**13.4**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	6
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	153.9
Bottom of Test Interval Depth, ft	165.7

Estimated Hydrostatic Pressure, psi	103.6
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	159.8
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3		
Datum (Mudline) Elevation, ft	502.4		
Top of Test Interval Elevation, ft	348.5		
Bottom of Test Interval Elevation, ft	336.7		
Rubber Hose Length, ft	19.7		
# of NQ Rods	27	# of HWY Rods	1

Note:

Start Time: 08:17 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 1.7 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	2.0	29.0		27637.0	7296.2	0						
6-4A	1.9	27.5	saturated	27651.2	7299.9	1	14.2	3.7	38.2	88.1	1.52E-04	15.0
6-4B	2.0	29.0	saturated	27680.2	7307.6	3	14.5	3.8	39.6	91.4	1.50E-04	14.8
6-4C	2.0	29.0	saturated	27709.8	7315.4	5	14.8	3.9	39.6	91.4	1.53E-04	15.1
6-4D	2.0	29.0	saturated	27779.5	7333.8	10	13.9	3.7	39.6	91.4	1.44E-04	14.2
6-4E	2.0	29.0	saturated	27840.6	7349.9	15	12.2	3.2	39.6	91.4	1.26E-04	12.4
Test Averages/Summary												
6-4	**2.0**	**28.7**	**saturated**	**203.6**	**53.8**	**15**	**13.9**	**3.7**	**39.3**	**90.8**	**1.45E-04**	**14.3**

Notes:

Start Time: 08:32 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.9 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity* (K)	Water Take
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons
	1.0	14.5		27867.3	7357.0	0						
6-5A	1.0	14.5	saturated	27878.7	7360.0	1	11.4	3.0	25.5	58.8	1.83E-04	18.1
6-5B	1.0	14.5	saturated	27909.6	7368.1	3	15.4	4.1	25.5	58.8	2.48E-04	24.5
6-5C	1.0	14.5	saturated	27919.4	7370.7	5	4.9	1.3	25.5	58.8	7.86E-05	7.8
6-5D	1.0	14.5	saturated	27971.3	7384.4	10	10.4	2.7	25.5	58.8	1.67E-04	16.4
6-5E	1.0	14.5	saturated	28022.4	7397.9	15	10.2	2.7	25.5	58.8	1.64E-04	16.2
Test Averages/Summary												
6-5	**1.0**	**14.5**	**saturated**	**155.1**	**40.9**	**15**	**10.5**	**2.8**	**25.5**	**58.8**	**1.68E-04**	**16.6**

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	7
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	144.1
Bottom of Test Interval Depth, ft	155.9

Estimated Hydrostatic Pressure, psi	99.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	150.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	358.3
Bottom of Test Interval Elevation, ft	346.5
Rubber Hose Length, ft	19.7
# of NQ Rods	26
# of HWY Rods	1

Note:

Start Time: 09:40 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.8 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_t) $P_t = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		28214.0	7448.5	0							
7-1A	1.0	14.5	saturated	28225.0	7451.4	1	11.0	2.9	25.5	58.9	1.76E-04	17.4	
7-1B	1.0	14.5	saturated	28246.5	7457.1	3	10.8	2.8	25.5	58.9	1.72E-04	17.0	
7-1C	1.0	14.5	saturated	28267.9	7462.7	5	10.7	2.8	25.5	58.9	1.71E-04	16.9	
7-1D	1.0	14.5	saturated	28313.1	7474.7	10	9.0	2.4	25.5	58.9	1.45E-04	14.3	
7-1E	1.0	14.5	saturated	28355.8	7485.9	15	8.5	2.3	25.5	58.9	1.37E-04	13.5	
Test Averages/Summary													
7-1	**1.0**	**14.5**	**saturated**	**141.8**	**37.4**	**15**	**10.0**	**2.6**	**25.5**	**58.9**	**1.60E-04**	**15.8**	

Notes:

Start Time: 09:56 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 1.2 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_t) $P_t = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		28371.8	7490.2	0							
7-2A	2.0	29.0	saturated	28385.4	7493.7	1	13.6	3.6	39.8	91.9	1.40E-04	13.8	
7-2B	2.0	29.0	saturated	28408.7	7499.9	3	11.6	3.1	39.8	91.9	1.20E-04	11.8	
7-2C	2.0	29.0	saturated	28432.3	7506.1	5	11.8	3.1	39.8	91.9	1.21E-04	12.0	
7-2D	2.0	29.0	saturated	28493.7	7522.3	10	12.3	3.2	39.8	91.9	1.26E-04	12.4	
7-2E	2.1	30.4	saturated	28555.0	7538.5	15	12.3	3.2	41.3	95.3	1.21E-04	12.0	
Test Averages/Summary													
7-2	**2.0**	**29.3**	**saturated**	**183.2**	**48.4**	**15**	**12.3**	**3.3**	**40.1**	**92.6**	**1.26E-04**	**12.4**	

Notes:

Start Time: 10:14 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 2.0 | Target Pressure, Bar: 3.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_t) $P_t = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	3.0	43.5		28581.2	7545.4	0							
7-3A	3.0	43.5	saturated	28596.4	7549.4	1	15.2	4.0	54.0	124.6	1.15E-04	11.4	
7-3B	3.0	43.5	saturated	28627.2	7557.6	3	15.4	4.1	54.0	124.6	1.17E-04	11.5	
7-3C	3.1	44.9	saturated	28658.8	7565.9	5	15.8	4.2	55.4	127.9	1.16E-04	11.5	
7-3D	3.0	43.5	saturated	28731.7	7585.2	10	14.6	3.8	54.0	124.6	1.10E-04	10.9	
7-3E	3.0	43.5	saturated	28807.2	7605.1	15	15.1	4.0	54.0	124.6	1.14E-04	11.3	
Test Averages/Summary													
7-3	**3.0**	**43.8**	**saturated**	**226.0**	**59.7**	**15**	**15.2**	**4.0**	**54.3**	**125.2**	**1.15E-04**	**11.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

Project ID	31402024.00
Date of Test Completion	9/17/2019
WSP Personnel	D. Mein
Driller	Fugro
Operator	C. Murphy

Boring ID	BH19-36
Test Number	7
Borehole Diameter, ft	0.5
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	144.1
Bottom of Test Interval Depth, ft	155.9

Estimated Hydrostatic Pressure, psi	99.4
Pressure Gauge above Lake Level (h), ft	26.2
Vertical Center of Test Interval (D), ft	150.0
Test Interval Length (L), ft	11.8

Lake Depth, ft	79.3
Datum (Mudline) Elevation, ft	502.4
Top of Test Interval Elevation, ft	358.3
Bottom of Test Interval Elevation, ft	346.5
Rubber Hose Length, ft	19.7
# of NQ Rods	26
# of HWY Rods	1

Note:

Start Time: 10:30 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 1.1 | Target Pressure, Bar: 2.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	2.0	29.0		28833.5	7612.0	0							
7-4A	2.0	29.0	saturated	28845.1	7615.1	1	11.6	3.1	39.9	92.0	1.19E-04	11.7	
7-4B	2.0	29.0	saturated	28868.1	7621.2	3	11.5	3.0	39.9	92.0	1.18E-04	11.6	
7-4C	2.0	29.0	saturated	28891.3	7627.3	5	11.6	3.1	39.9	92.0	1.19E-04	11.7	
7-4D	2.0	29.0	saturated	28950.3	7642.9	10	11.8	3.1	39.9	92.0	1.21E-04	11.9	
7-4E	2.0	29.0	saturated	29010.4	7658.7	15	12.0	3.2	39.9	92.0	1.23E-04	12.2	
Test Averages/Summary													
7-4	**2.0**	**29.0**	**saturated**	**176.9**	**46.7**	**15**	**11.7**	**3.1**	**39.9**	**92.0**	**1.20E-04**	**11.8**	

Notes:

Start Time: 10:47 | Stage/Packer Pressure, bar: | Friction Loss, *f*, ft: 0.4 | Target Pressure, Bar: 1.0

Test Step ID	Pressure Reading (P_r)		Analysis Type	Flow Meter Reading		Elapsed Time in Minutes	Flowrate		Corrected Test Pressure (P_I) $P_I = P_r + h - f$		Hydraulic Conductivity (K)	Water Take	
	Bar	psi		Liter	gal		L/min	gpm	psi	ft	cm/sec	Lugeons	
	1.0	14.5		29027.8	7663.3	0							
7-5A	1.0	14.5	saturated	29034.5	7665.1	1	6.7	1.8	25.7	59.3	1.07E-04	10.5	
7-5B	1.1	15.9	saturated	29051.4	7669.6	3	8.5	2.2	27.1	62.6	1.27E-04	12.6	
7-5C	1.0	14.5	saturated	29067.5	7673.8	5	8.0	2.1	25.7	59.3	1.28E-04	12.6	
7-5D	1.1	15.9	saturated	29108.0	7684.5	10	8.1	2.1	27.1	62.6	1.22E-04	12.0	
7-5E	1.0	14.5	saturated	29146.0	7694.5	15	7.6	2.0	25.7	59.3	1.21E-04	11.9	
Test Averages/Summary													
7-5	**1.0**	**15.1**	**saturated**	**118.2**	**31.2**	**15**	**7.8**	**2.1**	**26.3**	**60.6**	**1.21E-04**	**12.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/18/19
WSP Personnel	VARIES
Subcontractor	Cascade Drilling
Driller	VARIES

Boring ID	BH19-37
Number of Tests	8
Lattitude	45.79428°N
Longitude	84.77377°W

Top of Rock, ft	148.00
Bottom of Boring, ft	248.40
Depth to Groundwater (D_{WL}), ft	18.95

Datum Elevation	600.7
Top of Rock Elevation, ft	452.7
Bottom of Hole Elevation, ft	352.3
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	90.30
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	97.0	112.0	saturated	111.7	111.6	15	0.00	0.00	14.7	33.8	0.00E+00	0.0		
1-2	97.0	127.0	saturated	126.7	126.7	15	0.00	0.00	29.7	68.5	0.00E+00	0.0		
1-3	97.0	142.0	saturated	143.9	143.9	15	0.00	0.00	47.0	108.4	0.00E+00	0.0		No Flow
1-4	97.0	127.0	saturated	127.3	127.3	15	0.00	0.00	30.3	70.0	0.00E+00	0.0		
1-5	97.0	112.0	saturated	113.2	113.2	15	0.00	0.00	16.1	37.2	0.00E+00	0.0		
2-1	92.1	107.1	saturated	106.7	106.7	15	0.00	0.00	14.6	33.8	0.00E+00	0.0		
2-2	92.1	122.1	saturated	123.6	123.6	15	0.00	0.00	31.5	72.7	0.00E+00	0.0		
2-3	92.1	137.1	saturated	138.9	138.9	15	0.00	0.00	46.8	108.0	0.00E+00	0.0		No Flow
2-4	92.1	122.1	saturated	122.8	122.8	15	0.00	0.00	30.7	70.9	0.00E+00	0.0		
2-5	92.1	107.1	saturated	106.4	106.4	15	0.00	0.00	14.3	32.9	0.00E+00	0.0		
3-1	87.4	102.4	saturated	102.9	102.9	15	0.00	0.00	15.5	35.9	0.00E+00	0.0		
3-2	87.4	117.4	saturated	117.4	117.4	15	1.59	0.13	30.1	69.4	8.18E-06	0.7		
3-3	87.4	132.4	saturated	131.9	131.9	15	10.21	0.69	44.6	102.9	2.90E-05	2.7		
3-4	87.4	117.4	saturated	117.9	117.9	15	0.08	0.01	30.5	70.4	3.44E-07	0.0		
3-5	87.4	102.4	saturated	103.9	103.9	15	0.00	0.00	16.5	38.1	0.00E+00	0.0		
4-1	83.2	98.2	saturated	100.5	100.5	15	39.53	2.78	17.5	40.3	2.98E-04	27.3		
4-2	83.2	113.2	saturated	114.7	114.7	15	56.95	3.90	31.5	72.8	2.31E-04	21.2		
4-3	83.2	128.2	saturated	130.2	130.2	15	69.40	4.70	47.0	108.4	1.87E-04	17.2		
4-4	83.2	113.2	saturated	113.9	113.9	15	44.29	2.95	30.6	70.6	1.80E-04	16.6		
4-5	83.2	98.2	saturated	99.5	99.5	15	24.58	1.60	16.2	37.5	1.85E-04	17.0		
5-1	75.9	90.9	saturated	92.5	92.5	15	22.27	1.51	16.6	38.4	1.70E-04	15.6		
5-2	75.9	105.9	saturated	106.7	106.7	15	31.00	2.09	30.9	71.4	1.26E-04	11.6		
5-3	75.9	120.9	saturated	121.6	121.6	15	44.54	3.05	45.8	105.6	1.25E-04	11.4		
5-4	75.9	105.9	saturated	106.4	106.4	15	30.28	2.06	30.6	70.6	1.25E-04	11.5		
5-5	75.9	90.9	saturated	91.6	91.6	15	17.74	1.19	15.7	36.3	1.41E-04	12.9		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/18/19
WSP Personnel	VARIES
Subcontractor	Cascade Drilling
Driller	VARIES

Boring ID	BH19-37
Number of Tests	8
Lattitude	45.79428°N
Longitude	84.77377°W

Top of Rock, ft	148.00
Bottom of Boring, ft	248.40
Depth to Groundwater (D_{WL}), ft	18.95

Datum Elevation	600.7
Top of Rock Elevation, ft	452.7
Bottom of Hole Elevation, ft	352.3
Groundwater Elevation, ft	581.8

Total Length of Testing, ft	90.30
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
6-1	70.5	85.5	saturated	89.3	89.3	15	31.98	2.08	19.2	44.3	2.03E-04	18.6		
6-2	70.5	100.5	saturated	103.4	103.4	15	40.86	2.76	33.2	76.7	1.55E-04	14.3		
6-3	70.5	115.5	saturated	119.0	119.0	15	54.80	3.71	48.7	112.3	1.42E-04	13.1		
6-4	70.5	100.5	saturated	100.0	100.0	15	39.12	2.64	29.7	68.4	1.66E-04	15.2		
6-5	70.5	85.5	saturated	84.9	84.9	15	22.90	1.54	14.4	33.3	2.00E-04	18.3		
7-1	65.7	80.7	saturated	82.2	82.2	15	46.68	3.14	16.8	38.7	3.52E-04	32.1		
7-2	65.7	95.7	saturated	95.5	95.5	15	70.48	4.75	29.9	69.1	2.96E-04	27.2		
7-3	65.7	110.7	saturated	112.3	112.3	15	106.74	7.16	47.3	109.2	2.83E-04	25.9		
7-4	65.7	95.7	saturated	96.5	96.5	15	74.22	5.01	31.0	71.4	3.02E-04	27.7		
7-5	65.7	80.7	saturated	81.0	81.0	15	44.95	3.02	15.4	35.5	3.66E-04	33.7		
8-1	62.7	77.7	saturated	79.8	79.8	15	17.97	1.25	17.3	40.0	1.35E-04	12.3		
8-2	62.7	92.7	saturated	93.2	93.2	15	28.20	1.92	30.6	70.5	1.17E-04	10.8		
8-3	62.7	107.7	saturated	109.4	109.4	15	43.99	2.93	47.0	108.3	1.17E-04	10.7		
8-4	62.7	92.7	saturated	93.2	93.2	15	29.58	2.01	30.5	70.4	1.23E-04	11.3		
8-5	62.7	77.7	saturated	77.6	77.6	15	15.71	1.07	14.9	34.3	1.34E-04	12.3		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	232.80
Bottom of Test Interval Depth, ft	243.30

Hydrostatic Pressure (P_0), psi	97.04
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	237.30
Vertical Center of Test Interval (D), ft	238.05
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	367.9
Bottom of Test Interval Elevation, ft	357.4

Start Time: 11:20 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				111.4		0	573.3						
1-1A	97.0	112.0	saturated	111.4	111.4	1	573.3	0.00	14.40	33.2	0.00E+00	0.0	
1-1B	97.0	112.0	saturated	111.5	111.5	3	573.3	0.00	14.50	33.5	0.00E+00	0.0	
1-1C	97.0	112.0	saturated	111.7	111.7	5	573.3	0.00	14.66	33.8	0.00E+00	0.0	
1-1D	97.0	112.0	saturated	111.8	111.8	10	573.3	0.00	14.77	34.1	0.00E+00	0.0	
1-1E	97.0	112.0	saturated	112.0	112.0	15	573.3	0.00	14.95	34.5	0.00E+00	0.0	
Test Averages/Summary													
1-1	**97.0**	**112.0**	**saturated**	**111.7**	**111.6**	**15**	**0.0**	**0.00**	**14.65**	**33.81**	**0.00E+00**	**0.0**	

Notes:

Start Time: 11:38 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				126.7		0	573.5						
1-2A	97.0	127.0	saturated	126.3	126.3	1	573.5	0.00	29.28	67.5	0.00E+00	0.0	
1-2B	97.0	127.0	saturated	126.6	126.6	3	573.5	0.00	29.51	68.1	0.00E+00	0.0	
1-2C	97.0	127.0	saturated	126.6	126.6	5	573.5	0.00	29.60	68.3	0.00E+00	0.0	
1-2D	97.0	127.0	saturated	127.1	127.1	10	573.5	0.00	30.07	69.4	0.00E+00	0.0	
1-2E	97.0	127.0	saturated	127.1	127.1	15	573.5	0.00	30.02	69.3	0.00E+00	0.0	
Test Averages/Summary													
1-2	**97.0**	**127.0**	**saturated**	**126.7**	**126.7**	**15**	**0.0**	**0.00**	**29.70**	**68.51**	**0.00E+00**	**0.0**	

Notes:

Start Time: 11:56 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				143.4		0	573.7						
1-3A	97.0	142.0	saturated	143.9	143.9	1	573.7	0.00	46.84	108.1	0.00E+00	0.0	
1-3B	97.0	142.0	saturated	143.8	143.8	3	573.7	0.00	46.79	107.9	0.00E+00	0.0	
1-3C	97.0	142.0	saturated	143.8	143.7	5	573.7	0.00	46.70	107.7	0.00E+00	0.0	
1-3D	97.0	142.0	saturated	144.1	144.1	10	573.7	0.00	47.09	108.6	0.00E+00	0.0	
1-3E	97.0	142.0	saturated	144.6	144.6	15	573.7	0.00	47.60	109.8	0.00E+00	0.0	
Test Averages/Summary													
1-3	**97.0**	**142.0**	**saturated**	**143.9**	**143.9**	**15**	**0.0**	**0.00**	**47.00**	**108.44**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	232.80
Bottom of Test Interval Depth, ft	243.30

Hydrostatic Pressure (P_0), psi	97.04
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	237.30
Vertical Center of Test Interval (D), ft	238.05
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	367.9
Bottom of Test Interval Elevation, ft	357.4

Start Time: 12:12 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				127.2		0	573.7						
1-4A	97.0	127.0	saturated	127.1	127.1	1	573.7	0.00	30.09	69.4	0.00E+00	0.0	
1-4B	97.0	127.0	saturated	127.1	127.1	3	573.7	0.00	30.08	69.4	0.00E+00	0.0	
1-4C	97.0	127.0	saturated	127.3	127.3	5	573.7	0.00	30.25	69.8	0.00E+00	0.0	
1-4D	97.0	127.0	saturated	127.4	127.4	10	573.7	0.00	30.33	70.0	0.00E+00	0.0	
1-4E	97.0	127.0	saturated	128.0	128.0	15	573.7	0.00	30.96	71.4	0.00E+00	0.0	
Test Averages/Summary													
1-4	**97.0**	**127.0**	**saturated**	**127.3**	**127.3**	**15**	**0.0**	**0.00**	**30.34**	**69.99**	**0.00E+00**	**0.0**	

Notes:

Start Time: 12:29 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_t)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				113.2		0	573.7						
1-5A	97.0	112.0	saturated	113.1	113.1	1	573.7	0.00	16.08	37.1	0.00E+00	0.0	
1-5B	97.0	112.0	saturated	113.0	113.0	3	573.7	0.00	15.98	36.9	0.00E+00	0.0	
1-5C	97.0	112.0	saturated	113.1	113.1	5	573.7	0.00	16.03	37.0	0.00E+00	0.0	
1-5D	97.0	112.0	saturated	113.3	113.3	10	573.7	0.00	16.22	37.4	0.00E+00	0.0	
1-5E	97.0	112.0	saturated	113.4	113.4	15	573.7	0.00	16.32	37.7	0.00E+00	0.0	
Test Averages/Summary													
1-5	**97.0**	**112.0**	**saturated**	**113.2**	**113.2**	**15**	**0.0**	**0.00**	**16.13**	**37.20**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	222.30
Bottom of Test Interval Depth, ft	232.80

Hydrostatic Pressure (P_0), psi	92.10
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	226.80
Vertical Center of Test Interval (D), ft	227.55
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	378.4
Bottom of Test Interval Elevation, ft	367.9

Start Time: 13:00 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				106.5		0	574.1						
2-1A	92.1	107.1	saturated	106.5	106.5	1	574.1	0.00	14.42	33.3	0.00E+00	0.0	
2-1B	92.1	107.1	saturated	106.7	106.7	3	574.1	0.00	14.60	33.7	0.00E+00	0.0	
2-1C	92.1	107.1	saturated	106.7	106.7	5	574.1	0.00	14.63	33.7	0.00E+00	0.0	
2-1D	92.1	107.1	saturated	106.8	106.8	10	574.1	0.00	14.66	33.8	0.00E+00	0.0	
2-1E	92.1	107.1	saturated	107.0	107.0	15	574.1	0.00	14.88	34.3	0.00E+00	0.0	
Test Averages/Summary													
2-1	**92.1**	**107.1**	**saturated**	**106.7**	**106.7**	**15**	**0.0**	**0.00**	**14.64**	**33.77**	**0.00E+00**	**0.0**	

Notes:

Start Time: 13:17 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				123.2		0	574.5						
2-2A	92.1	122.1	saturated	123.4	123.4	1	574.5	0.00	31.29	72.2	0.00E+00	0.0	
2-2B	92.1	122.1	saturated	123.4	123.4	3	574.5	0.00	31.32	72.3	0.00E+00	0.0	
2-2C	92.1	122.1	saturated	123.6	123.6	5	574.5	0.00	31.52	72.7	0.00E+00	0.0	
2-2D	92.1	122.1	saturated	123.7	123.7	10	574.5	0.00	31.64	73.0	0.00E+00	0.0	
2-2E	92.1	122.1	saturated	123.9	123.9	15	574.5	0.00	31.82	73.4	0.00E+00	0.0	
Test Averages/Summary													
2-2	**92.1**	**122.1**	**saturated**	**123.6**	**123.6**	**15**	**0.0**	**0.00**	**31.52**	**72.71**	**0.00E+00**	**0.0**	

Notes:

Start Time: 13:33 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				138.7		0	574.7						
2-3A	92.1	137.1	saturated	138.4	138.4	1	574.7	0.00	46.31	106.8	0.00E+00	0.0	
2-3B	92.1	137.1	saturated	138.9	138.9	3	574.7	0.00	46.81	108.0	0.00E+00	0.0	
2-3C	92.1	137.1	saturated	139.1	139.1	5	574.7	0.00	46.97	108.4	0.00E+00	0.0	
2-3D	92.1	137.1	saturated	139.4	139.4	10	574.7	0.00	47.28	109.1	0.00E+00	0.0	
2-3E	92.1	137.1	saturated	138.8	138.8	15	574.7	0.00	46.69	107.7	0.00E+00	0.0	
Test Averages/Summary													
2-3	**92.1**	**137.1**	**saturated**	**138.9**	**138.9**	**15**	**0.0**	**0.00**	**46.81**	**108.00**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	222.30
Bottom of Test Interval Depth, ft	232.80

Hydrostatic Pressure (P_0), psi	92.10
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	226.80
Vertical Center of Test Interval (D), ft	227.55
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	378.4
Bottom of Test Interval Elevation, ft	367.9

Start Time: 13:50 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				122.5		0	574.7						
2-4A	92.1	122.1	saturated	122.5	122.5	1	574.7	0.00	30.40	70.1	0.00E+00	0.0	
2-4B	92.1	122.1	saturated	122.6	122.6	3	574.7	0.00	30.54	70.5	0.00E+00	0.0	
2-4C	92.1	122.1	saturated	122.7	122.7	5	574.7	0.00	30.57	70.5	0.00E+00	0.0	
2-4D	92.1	122.1	saturated	122.8	122.8	10	574.7	0.00	30.67	70.8	0.00E+00	0.0	
2-4E	92.1	122.1	saturated	123.6	123.5	15	574.7	0.00	31.44	72.5	0.00E+00	0.0	
Test Averages/Summary													
2-4	**92.1**	**122.1**	**saturated**	**122.8**	**122.8**	**15**	**0.0**	**0.00**	**30.72**	**70.88**	**0.00E+00**	**0.0**	

Notes:

Start Time: 14:08 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				106.3		0	574.7						
2-5A	92.1	107.1	saturated	106.3	106.3	1	574.7	0.00	14.17	32.7	0.00E+00	0.0	
2-5B	92.1	107.1	saturated	106.3	106.3	3	574.7	0.00	14.22	32.8	0.00E+00	0.0	
2-5C	92.1	107.1	saturated	106.4	106.4	5	574.7	0.00	14.30	33.0	0.00E+00	0.0	
2-5D	92.1	107.1	saturated	106.4	106.4	10	574.7	0.00	14.25	32.9	0.00E+00	0.0	
2-5E	92.1	107.1	saturated	106.5	106.5	15	574.7	0.00	14.41	33.3	0.00E+00	0.0	
Test Averages/Summary													
2-5	**92.1**	**107.1**	**saturated**	**106.4**	**106.4**	**15**	**0.0**	**0.00**	**14.27**	**32.92**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	211.80
Bottom of Test Interval Depth, ft	222.30

Hydrostatic Pressure (P_0), psi	87.40
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	216.30
Vertical Center of Test Interval (D), ft	217.05
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	388.9
Bottom of Test Interval Elevation, ft	378.4

Start Time: 14:35 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				102.6		0	575.6						
3-1A	87.4	102.4	saturated	102.7	102.7	1	575.6	0.00	15.31	35.3	0.00E+00	0.0	
3-1B	87.4	102.4	saturated	102.9	102.9	3	575.6	0.00	15.46	35.7	0.00E+00	0.0	
3-1C	87.4	102.4	saturated	102.9	102.9	5	575.6	0.00	15.53	35.8	0.00E+00	0.0	
3-1D	87.4	102.4	saturated	103.1	103.1	10	575.6	0.00	15.66	36.1	0.00E+00	0.0	
3-1E	87.4	102.4	saturated	103.2	103.2	15	575.6	0.00	15.79	36.4	0.00E+00	0.0	
Test Averages/Summary													
3-1	**87.4**	**102.4**	**saturated**	**102.9**	**102.9**	**15**	**0.0**	**0.00**	**15.55**	**35.87**	**0.00E+00**	**0.0**	

Notes:

Start Time: 14:53 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				117.1		0	576.5						
3-2A	87.4	117.4	saturated	117.2	117.2	1	576.7	0.18	29.76	68.7	1.13E-05	1.0	
3-2B	87.4	117.4	saturated	117.3	117.3	3	577.0	0.17	29.93	69.0	1.06E-05	1.0	
3-2C	87.4	117.4	saturated	117.5	117.4	5	577.3	0.15	30.04	69.3	9.63E-06	0.9	
3-2D	87.4	117.4	saturated	117.7	117.7	10	577.8	0.09	30.30	69.9	5.79E-06	0.5	
3-2E	87.4	117.4	saturated	117.8	117.8	15	578.1	0.06	30.35	70.0	3.57E-06	0.3	
Test Averages/Summary													
3-2	**87.4**	**117.4**	**saturated**	**117.4**	**117.4**	**15**	**1.6**	**0.13**	**30.08**	**69.39**	**8.18E-06**	**0.7**	

Notes:

Start Time: 13:10 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				131.7		0	578.8						
3-3A	87.4	132.4	saturated	131.8	131.8	1	579.6	0.71	44.40	102.4	2.99E-05	2.7	
3-3B	87.4	132.4	saturated	131.7	131.7	3	581.0	0.70	44.29	102.2	2.95E-05	2.7	
3-3C	87.4	132.4	saturated	131.9	131.9	5	582.4	0.72	44.45	102.5	3.02E-05	2.8	
3-3D	87.4	132.4	saturated	132.1	132.1	10	586.0	0.71	44.71	103.2	2.97E-05	2.7	
3-3E	87.4	132.4	saturated	132.5	132.5	15	589.1	0.62	45.08	104.0	2.57E-05	2.4	
Test Averages/Summary													
3-3	**87.4**	**132.4**	**saturated**	**131.9**	**131.9**	**15**	**10.2**	**0.69**	**44.59**	**102.86**	**2.90E-05**	**2.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	211.80
Bottom of Test Interval Depth, ft	222.30

Hydrostatic Pressure (P_0), psi	87.40
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	216.30
Vertical Center of Test Interval (D), ft	217.05
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	388.9
Bottom of Test Interval Elevation, ft	378.4

Start Time: 13:27 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				117.8		0	589.3						
3-4A	87.4	117.4	saturated	117.9	117.9	1	589.3	0.00	30.49	70.3	0.00E+00	0.0	
3-4B	87.4	117.4	saturated	117.6	117.6	3	589.3	0.01	30.20	69.7	6.18E-07	0.1	
3-4C	87.4	117.4	saturated	117.8	117.8	5	589.3	0.01	30.39	70.1	6.14E-07	0.1	
3-4D	87.4	117.4	saturated	117.9	117.9	10	589.4	0.00	30.52	70.4	2.45E-07	0.0	
3-4E	87.4	117.4	saturated	118.3	118.3	15	589.4	0.00	30.89	71.3	2.42E-07	0.0	
Test Averages/Summary													
3-4	**87.4**	**117.4**	**saturated**	**117.9**	**117.9**	**15**	**0.1**	**0.01**	**30.50**	**70.36**	**3.44E-07**	**0.0**	

Notes:

Start Time: 13:43 — Packer Pressure, psi: 240

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				103.9		0	589.4						
3-5A	87.4	102.4	saturated	103.9	103.9	1	589.4	0.00	16.47	38.0	0.00E+00	0.0	
3-5B	87.4	102.4	saturated	103.8	103.8	3	589.4	0.00	16.39	37.8	0.00E+00	0.0	
3-5C	87.4	102.4	saturated	103.9	103.8	5	589.4	0.00	16.45	37.9	0.00E+00	0.0	
3-5D	87.4	102.4	saturated	103.9	103.9	10	589.4	0.00	16.53	38.1	0.00E+00	0.0	
3-5E	87.4	102.4	saturated	104.1	104.1	15	589.4	0.00	16.66	38.4	0.00E+00	0.0	
Test Averages/Summary													
3-5	**87.4**	**102.4**	**saturated**	**103.9**	**103.9**	**15**	**0.0**	**0.00**	**16.50**	**38.06**	**0.00E+00**	**0.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	201.30
Bottom of Test Interval Depth, ft	211.80

Hydrostatic Pressure (P_0), psi	83.20
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	205.80
Vertical Center of Test Interval (D), ft	206.55
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	399.4
Bottom of Test Interval Elevation, ft	388.9

Start Time: 16:14 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				99.6		0	600.0						
4-1A	83.2	98.2	saturated	100.3	100.3	1	603.2	3.22	17.06	39.4	3.52E-04	32.4	
4-1B	83.2	98.2	saturated	100.4	100.4	3	609.1	2.96	17.23	39.8	3.21E-04	29.5	
4-1C	83.2	98.2	saturated	101.0	101.0	5	614.6	2.75	17.75	41.0	2.89E-04	26.5	
4-1D	83.2	98.2	saturated	100.9	100.8	10	627.4	2.56	17.64	40.7	2.70E-04	24.9	
4-1E	83.2	98.2	saturated	100.9	100.9	15	639.5	2.42	17.67	40.8	2.56E-04	23.5	
Test Averages/Summary													
4-1	**83.2**	**98.2**	**saturated**	**100.5**	**100.5**	**15**	**39.5**	**2.78**	**17.47**	**40.31**	**2.98E-04**	**27.3**	

Notes: During this test the pressure kept climbing even with adjusting the bypass valve (lowering flow).

Start Time: 16:31 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				114.6		0	645.9						
4-2A	83.2	113.2	saturated	114.8	114.8	1	650.1	4.21	31.55	72.8	2.49E-04	22.9	
4-2B	83.2	113.2	saturated	114.5	114.5	3	658.1	4.00	31.33	72.3	2.38E-04	21.9	
4-2C	83.2	113.2	saturated	115.0	115.0	5	666.0	3.94	31.75	73.3	2.32E-04	21.3	
4-2D	83.2	113.2	saturated	114.6	114.6	10	684.7	3.75	31.35	72.3	2.23E-04	20.5	
4-2E	83.2	113.2	saturated	115.0	114.9	15	702.8	3.62	31.75	73.2	2.13E-04	19.6	
Test Averages/Summary													
4-2	**83.2**	**113.2**	**saturated**	**114.7**	**114.7**	**15**	**57.0**	**3.90**	**31.55**	**72.78**	**2.31E-04**	**21.2**	

Notes:

Start Time: 16:49 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				130.4		0	713.4						
4-3A	83.2	128.2	saturated	130.7	130.7	1	718.3	4.91	47.49	109.6	1.93E-04	17.7	
4-3B	83.2	128.2	saturated	129.8	129.8	3	728.0	4.86	46.64	107.6	1.94E-04	17.9	
4-3C	83.2	128.2	saturated	129.4	129.4	5	737.3	4.64	46.24	106.7	1.87E-04	17.2	
4-3D	83.2	128.2	saturated	130.3	130.3	10	760.3	4.59	47.14	108.7	1.82E-04	16.7	
4-3E	83.2	128.2	saturated	130.7	130.7	15	782.8	4.51	47.51	109.6	1.77E-04	16.3	
Test Averages/Summary													
4-3	**83.2**	**128.2**	**saturated**	**130.2**	**130.2**	**15**	**69.4**	**4.70**	**47.00**	**108.43**	**1.87E-04**	**17.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger
Subcontractor	Cascade Drilling
Driller	C. Barden

Boring ID	BH19-37
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	201.30
Bottom of Test Interval Depth, ft	211.80

Hydrostatic Pressure (P_0), psi	83.20
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	205.80
Vertical Center of Test Interval (D), ft	206.55
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	399.4
Bottom of Test Interval Elevation, ft	388.9

Start Time: 17:05 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				114.2		0	785.1						
4-4A	83.2	113.2	saturated	114.0	114.0	1	788.1	3.02	30.84	71.1	1.83E-04	16.8	
4-4B	83.2	113.2	saturated	113.8	113.7	3	793.9	2.89	30.55	70.5	1.77E-04	16.2	
4-4C	83.2	113.2	saturated	113.6	113.6	5	799.7	2.94	30.35	70.0	1.81E-04	16.6	
4-4D	83.2	113.2	saturated	113.7	113.7	10	814.5	2.96	30.52	70.4	1.81E-04	16.6	
4-4E	83.2	113.2	saturated	113.9	113.9	15	829.4	2.97	30.71	70.8	1.80E-04	16.6	
Test Averages/Summary													
4-4	**83.2**	**113.2**	**saturated**	**113.9**	**113.9**	**15**	**44.3**	**2.95**	**30.59**	**70.58**	**1.80E-04**	**16.6**	

Notes:

Start Time: 17:22 — Packer Pressure, psi: 230

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				99.7		0	832.0						
4-5A	83.2	98.2	saturated	99.6	99.6	1	833.5	1.50	16.37	37.8	1.71E-04	15.7	
4-5B	83.2	98.2	saturated	99.5	99.4	3	836.6	1.56	16.24	37.5	1.79E-04	16.5	
4-5C	83.2	98.2	saturated	99.4	99.4	5	839.8	1.62	16.22	37.4	1.86E-04	17.1	
4-5D	83.2	98.2	saturated	99.4	99.4	10	847.9	1.62	16.19	37.4	1.87E-04	17.2	
4-5E	83.2	98.2	saturated	99.4	99.4	15	856.6	1.72	16.17	37.3	1.99E-04	18.3	
Test Averages/Summary													
4-5	**83.2**	**98.2**	**saturated**	**99.5**	**99.5**	**15**	**24.6**	**1.60**	**16.24**	**37.46**	**1.85E-04**	**17.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger/O. El-Quqa
Subcontractor	Cascade Drilling
Driller	C. Barden/S. Parks

Boring ID	BH19-37
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	184.50
Bottom of Test Interval Depth, ft	195.00

Hydrostatic Pressure (P_0), psi	75.90
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	189.00
Vertical Center of Test Interval (D), ft	189.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	416.2
Bottom of Test Interval Elevation, ft	405.7

Start Time: 18:09 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				92.0		0	858.8						
5-1A	75.9	90.9	saturated	92.2	92.2	1	860.5	1.67	16.33	37.7	1.91E-04	17.5	
5-1B	75.9	90.9	saturated	92.4	92.4	3	863.5	1.50	16.46	38.0	1.70E-04	15.6	
5-1C	75.9	90.9	saturated	92.4	92.4	5	866.4	1.47	16.51	38.1	1.66E-04	15.3	
5-1D	75.9	90.9	saturated	92.7	92.7	10	873.7	1.46	16.84	38.9	1.62E-04	14.9	
5-1E	75.9	90.9	saturated	93.0	93.0	15	881.1	1.47	17.10	39.5	1.61E-04	14.8	
Test Averages/Summary													
5-1	**75.9**	**90.9**	**saturated**	**92.5**	**92.5**	**15**	**22.3**	**1.51**	**16.65**	**38.41**	**1.70E-04**	**15.6**	

Notes: Crew change at end of test

Start Time: 20:23 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				106.0		0	886.0						
5-2A	75.9	105.9	saturated	105.9	105.9	1	888.2	2.20	29.98	69.2	1.37E-04	12.6	
5-2B	75.9	105.9	saturated	106.4	106.4	3	892.3	2.07	30.45	70.3	1.27E-04	11.7	
5-2C	75.9	105.9	saturated	106.7	106.7	5	896.5	2.06	30.79	71.0	1.25E-04	11.5	
5-2D	75.9	105.9	saturated	107.6	107.5	10	906.7	2.06	31.65	73.0	1.21E-04	11.1	
5-2E	75.9	105.9	saturated	107.7	107.7	15	917.0	2.05	31.80	73.4	1.20E-04	11.1	
Test Averages/Summary													
5-2	**75.9**	**105.9**	**saturated**	**106.7**	**106.7**	**15**	**31.0**	**2.09**	**30.93**	**71.36**	**1.26E-04**	**11.6**	

Notes:

Start Time: 20:39 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				121.1		0	920.0						
5-3A	75.9	120.9	saturated	120.2	120.2	1	923.5	3.52	44.33	102.3	1.48E-04	13.6	
5-3B	75.9	120.9	saturated	120.6	120.5	3	929.4	2.93	44.65	103.0	1.23E-04	11.3	
5-3C	75.9	120.9	saturated	121.3	121.3	5	935.3	2.94	45.39	104.7	1.21E-04	11.1	
5-3D	75.9	120.9	saturated	122.9	122.8	10	950.0	2.94	46.95	108.3	1.17E-04	10.7	
5-3E	75.9	120.9	saturated	123.5	123.5	15	964.5	2.92	47.64	109.9	1.14E-04	10.5	
Test Averages/Summary													
5-3	**75.9**	**120.9**	**saturated**	**121.6**	**121.6**	**15**	**44.5**	**3.05**	**45.79**	**105.64**	**1.25E-04**	**11.4**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	K. Zeiger/O. El-Quqa
Subcontractor	Cascade Drilling
Driller	C. Barden/S. Parks

Boring ID	BH19-37
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	184.50
Bottom of Test Interval Depth, ft	195.00

Hydrostatic Pressure (P_0), psi	75.90
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	189.00
Vertical Center of Test Interval (D), ft	189.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	416.2
Bottom of Test Interval Elevation, ft	405.7

Start Time: 20:55 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				106.2		0	967.0						
5-4A	75.9	105.9	saturated	106.3	106.3	1	969.1	2.14	30.40	70.1	1.31E-04	12.1	
5-4B	75.9	105.9	saturated	106.4	106.4	3	973.3	2.07	30.53	70.4	1.26E-04	11.6	
5-4C	75.9	105.9	saturated	106.6	106.6	5	977.5	2.12	30.67	70.7	1.29E-04	11.8	
5-4D	75.9	105.9	saturated	106.8	106.8	10	987.7	2.05	30.88	71.2	1.24E-04	11.4	
5-4E	75.9	105.9	saturated	106.4	106.4	15	997.3	1.91	30.45	70.3	1.17E-04	10.8	
Test Averages/Summary													
5-4	**75.9**	**105.9**	**saturated**	**106.4**	**106.4**	**15**	**30.3**	**2.06**	**30.59**	**70.56**	**1.25E-04**	**11.5**	

Notes:

Start Time: 21:11 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				91.6		0	1,000.0						
5-5A	75.9	90.9	saturated	91.7	91.7	1	1,001.2	1.21	15.75	36.3	1.43E-04	13.2	
5-5B	75.9	90.9	saturated	91.5	91.5	3	1,003.6	1.19	15.61	36.0	1.42E-04	13.0	
5-5C	75.9	90.9	saturated	91.7	91.6	5	1,005.9	1.17	15.74	36.3	1.39E-04	12.7	
5-5D	75.9	90.9	saturated	91.7	91.7	10	1,011.9	1.19	15.80	36.4	1.40E-04	12.9	
5-5E	75.9	90.9	saturated	91.7	91.7	15	1,017.7	1.18	15.77	36.4	1.39E-04	12.8	
Test Averages/Summary													
5-5	**75.9**	**90.9**	**saturated**	**91.6**	**91.6**	**15**	**17.7**	**1.19**	**15.73**	**36.30**	**1.41E-04**	**12.9**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-37
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	171.00
Bottom of Test Interval Depth, ft	181.50

Hydrostatic Pressure (P_0), psi	70.48
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	175.50
Vertical Center of Test Interval (D), ft	176.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	429.7
Bottom of Test Interval Elevation, ft	419.2

Start Time: 21:41 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				87.6		0	1,023.0						
6-1A	70.5	85.5	saturated	88.4	88.4	1	1,025.4	2.42	17.89	41.3	2.53E-04	23.2	
6-1B	70.5	85.5	saturated	89.1	89.1	3	1,030.0	2.26	18.62	43.0	2.27E-04	20.9	
6-1C	70.5	85.5	saturated	89.6	89.6	5	1,032.3	1.17	19.15	44.2	1.14E-04	10.5	
6-1D	70.5	85.5	saturated	90.4	90.4	10	1,044.7	2.47	19.94	46.0	2.32E-04	21.3	
6-1E	70.5	85.5	saturated	90.9	90.9	15	1,055.0	2.06	20.39	47.0	1.89E-04	17.4	
Test Averages/Summary													
6-1	**70.5**	**85.5**	**saturated**	**89.3**	**89.3**	**15**	**32.0**	**2.08**	**19.20**	**44.29**	**2.03E-04**	**18.6**	

Notes:

Start Time: 21:58 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				101.7		0	1,058.0						
6-2A	70.5	100.5	saturated	102.3	102.3	1	1,060.9	2.86	31.83	73.4	1.68E-04	15.4	
6-2B	70.5	100.5	saturated	103.1	103.1	3	1,066.5	2.83	32.63	75.3	1.62E-04	14.9	
6-2C	70.5	100.5	saturated	103.8	103.7	5	1,072.0	2.76	33.26	76.7	1.55E-04	14.2	
6-2D	70.5	100.5	saturated	104.5	104.5	10	1,085.6	2.70	34.03	78.5	1.48E-04	13.6	
6-2E	70.5	100.5	saturated	105.0	105.0	15	1,098.9	2.66	34.48	79.5	1.44E-04	13.2	
Test Averages/Summary													
6-2	**70.5**	**100.5**	**saturated**	**103.4**	**103.4**	**15**	**40.9**	**2.76**	**33.25**	**76.70**	**1.55E-04**	**14.3**	

Notes:

Start Time: 22:14 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				118.0		0	1,102.0						
6-3A	70.5	115.5	saturated	118.5	118.5	1	1,105.8	3.80	48.05	110.8	1.48E-04	13.6	
6-3B	70.5	115.5	saturated	118.9	118.9	3	1,113.1	3.64	48.42	111.7	1.40E-04	12.9	
6-3C	70.5	115.5	saturated	119.5	119.5	5	1,121.0	3.94	48.98	113.0	1.50E-04	13.8	
6-3D	70.5	115.5	saturated	120.2	120.2	10	1,138.7	3.54	49.69	114.6	1.33E-04	12.2	
6-3E	70.5	115.5	saturated	118.8	118.8	15	1,156.8	3.63	48.34	111.5	1.40E-04	12.9	
Test Averages/Summary													
6-3	**70.5**	**115.5**	**saturated**	**119.0**	**119.0**	**15**	**54.8**	**3.71**	**48.69**	**112.34**	**1.42E-04**	**13.1**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-37
Test Number	6
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	171.00
Bottom of Test Interval Depth, ft	181.50

Hydrostatic Pressure (P_0), psi	70.48
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	175.50
Vertical Center of Test Interval (D), ft	176.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	429.7
Bottom of Test Interval Elevation, ft	419.2

Start Time: 22:30 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				99.5		0	1,161.0						
6-4A	70.5	100.5	saturated	99.8	99.8	1	1,163.7	2.74	29.35	67.7	1.74E-04	16.0	
6-4B	70.5	100.5	saturated	99.9	99.9	3	1,169.1	2.65	29.41	67.8	1.69E-04	15.5	
6-4C	70.5	100.5	saturated	99.7	99.6	5	1,174.3	2.62	29.17	67.3	1.67E-04	15.4	
6-4D	70.5	100.5	saturated	100.5	100.4	10	1,187.3	2.60	29.96	69.1	1.62E-04	14.9	
6-4E	70.5	100.5	saturated	100.9	100.9	15	1,200.1	2.57	30.42	70.2	1.58E-04	14.5	
Test Averages/Summary													
6-4	**70.5**	**100.5**	**saturated**	**100.0**	**100.0**	**15**	**39.1**	**2.64**	**29.66**	**68.43**	**1.66E-04**	**15.2**	

Notes:

Start Time: 22:47 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				84.9		0	1,203.0						
6-5A	70.5	85.5	saturated	84.8	84.8	1.5	1,205.5	1.65	14.35	33.1	2.15E-04	19.8	
6-5B	70.5	85.5	saturated	84.9	84.9	3	1,207.7	1.48	14.41	33.2	1.92E-04	17.6	
6-5C	70.5	85.5	saturated	84.8	84.8	5	1,210.8	1.57	14.35	33.1	2.04E-04	18.8	
6-5D	70.5	85.5	saturated	84.9	84.9	10	1,218.5	1.53	14.44	33.3	1.98E-04	18.2	
6-5E	70.5	85.5	saturated	85.1	85.1	15	1,225.9	1.48	14.65	33.8	1.89E-04	17.4	
Test Averages/Summary													
6-5	**70.5**	**85.5**	**saturated**	**84.9**	**84.9**	**15**	**22.9**	**1.54**	**14.44**	**33.31**	**2.00E-04**	**18.3**	

Notes: Time step 6-5B taken at 1.5 minutes instead of 1 minute.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17-18/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-37
Test Number	7
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	160.50
Bottom of Test Interval Depth, ft	171.00

Hydrostatic Pressure (P_0), psi	65.71
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	165.00
Vertical Center of Test Interval (D), ft	165.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	440.2
Bottom of Test Interval Elevation, ft	429.7

Start Time: 23:14 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.8		0	1,231.0						
7-1A	65.7	80.7	saturated	80.9	80.9	1	1,234.2	3.24	15.21	35.1	3.98E-04	36.5	
7-1B	65.7	80.7	saturated	81.6	81.6	3	1,240.6	3.17	15.89	36.6	3.73E-04	34.2	
7-1C	65.7	80.7	saturated	82.3	82.3	5	1,246.8	3.11	16.61	38.3	3.49E-04	32.1	
7-1D	65.7	80.7	saturated	83.3	83.3	10	1,262.4	3.12	17.59	40.6	3.31E-04	30.4	
7-1E	65.7	80.7	saturated	84.3	84.3	15	1,277.7	3.06	18.54	42.8	3.08E-04	28.3	
Test Averages/Summary													
7-1	**65.7**	**80.7**	**saturated**	**82.2**	**82.2**	**15**	**46.7**	**3.14**	**16.77**	**38.68**	**3.52E-04**	**32.1**	

Notes:

Start Time: 23:30 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				94.6		0	1,281.0						
7-2A	65.7	95.7	saturated	95.1	95.1	1	1,286.2	5.20	29.43	67.9	3.30E-04	30.3	
7-2B	65.7	95.7	saturated	95.4	95.4	3	1,295.4	4.57	29.69	68.5	2.88E-04	26.4	
7-2C	65.7	95.7	saturated	95.4	95.4	5	1,304.5	4.56	29.69	68.5	2.86E-04	26.3	
7-2D	65.7	95.7	saturated	96.1	96.1	10	1,328.1	4.73	30.38	70.1	2.91E-04	26.7	
7-2E	65.7	95.7	saturated	96.2	96.2	15	1,351.5	4.67	30.48	70.3	2.86E-04	26.3	
Test Averages/Summary													
7-2	**65.7**	**95.7**	**saturated**	**95.5**	**95.5**	**15**	**70.5**	**4.75**	**29.93**	**69.06**	**2.96E-04**	**27.2**	

Notes:

Start Time: 23:46 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer: Pressure Reading (P_r)	Transducer: Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				108.5		0	1,356.0						
7-3A	65.7	110.7	saturated	109.8	109.8	1	1,363.6	7.62	44.05	101.6	3.23E-04	29.7	
7-3B	65.7	110.7	saturated	112.1	112.1	3	1,377.3	6.85	46.38	107.0	2.76E-04	25.3	
7-3C	65.7	110.7	saturated	113.0	112.9	5	1,391.4	7.04	47.23	109.0	2.78E-04	25.6	
7-3D	65.7	110.7	saturated	114.6	114.6	10	1,426.8	7.08	48.88	112.8	2.71E-04	24.9	
7-3E	65.7	110.7	saturated	115.9	115.9	15	1,462.7	7.18	50.15	115.7	2.67E-04	24.6	
Test Averages/Summary													
7-3	**65.7**	**110.7**	**saturated**	**112.3**	**112.3**	**15**	**106.7**	**7.16**	**47.34**	**109.21**	**2.83E-04**	**25.9**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/17-18/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-37
Test Number	7
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	160.50
Bottom of Test Interval Depth, ft	171.00

Hydrostatic Pressure (P_0), psi	65.71
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	165.00
Vertical Center of Test Interval (D), ft	165.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	440.2
Bottom of Test Interval Elevation, ft	429.7

Start Time: 00:02 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				95.6		0	1,470.0						
7-4A	65.7	95.7	saturated	95.7	95.7	1	1,475.3	5.25	30.03	69.3	3.26E-04	30.0	
7-4B	65.7	95.7	saturated	96.6	96.6	3	1,485.2	4.97	30.91	71.3	3.00E-04	27.6	
7-4C	65.7	95.7	saturated	96.5	96.5	5	1,495.2	5.01	30.80	71.1	3.04E-04	27.9	
7-4D	65.7	95.7	saturated	97.1	97.0	10	1,519.4	4.83	31.33	72.3	2.88E-04	26.5	
7-4E	65.7	95.7	saturated	97.4	97.4	15	1,544.2	4.97	31.71	73.1	2.93E-04	26.9	
Test Averages/Summary													
7-4	**65.7**	**95.7**	**saturated**	**96.5**	**96.5**	**15**	**74.2**	**5.01**	**30.96**	**71.42**	**3.02E-04**	**27.7**	

Notes:

Start Time: 00:18 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.8		0	1,549.0						
7-5A	65.7	80.7	saturated	80.9	80.9	1	1,552.2	3.22	15.22	35.1	3.95E-04	36.3	
7-5B	65.7	80.7	saturated	81.0	81.0	4	1,561.4	3.07	15.25	35.2	3.76E-04	34.5	
7-5C	65.7	80.7	saturated	81.1	81.1	5	1,564.3	2.86	15.35	35.4	3.48E-04	32.0	
7-5D	65.7	80.7	saturated	81.2	81.2	10	1,579.2	2.99	15.46	35.7	3.61E-04	33.2	
7-5E	65.7	80.7	saturated	81.3	81.3	15	1,594.0	2.95	15.57	35.9	3.53E-04	32.5	
Test Averages/Summary													
7-5	**65.7**	**80.7**	**saturated**	**81.0**	**81.0**	**15**	**45.0**	**3.02**	**15.37**	**35.45**	**3.66E-04**	**33.7**	

Notes: Time step 7-5C taken at 4 minutes instead of 3 minutes.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/18/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-37
Test Number	8
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	153.00
Bottom of Test Interval Depth, ft	163.50

Hydrostatic Pressure (P_0), psi	62.70
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	157.50
Vertical Center of Test Interval (D), ft	158.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	447.7
Bottom of Test Interval Elevation, ft	437.2

Start Time: 00:46 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				78.8		0	1,596.0						
8-1A	62.7	77.7	saturated	79.2	79.2	1	1,597.5	1.46	16.54	38.2	1.65E-04	15.1	
8-1B	62.7	77.7	saturated	79.7	79.7	3	1,600.2	1.35	16.99	39.2	1.48E-04	13.6	
8-1C	62.7	77.7	saturated	79.9	79.9	5	1,602.4	1.12	17.17	39.6	1.22E-04	11.2	
8-1D	62.7	77.7	saturated	80.6	80.6	10	1,608.4	1.20	17.89	41.3	1.25E-04	11.5	
8-1E	62.7	77.7	saturated	80.9	80.9	15	1,614.0	1.11	18.15	41.9	1.14E-04	10.5	
Test Averages/Summary													
8-1	**62.7**	**77.7**	**saturated**	**79.8**	**79.8**	**15**	**18.0**	**1.25**	**17.35**	**40.02**	**1.35E-04**	**12.3**	

Notes:

Start Time: 01:02 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				92.8		0	1,616.0						
8-2A	62.7	92.7	saturated	92.7	92.6	1	1,618.1	2.10	29.95	69.1	1.31E-04	12.0	
8-2B	62.7	92.7	saturated	93.1	93.1	3	1,621.8	1.87	30.42	70.2	1.15E-04	10.5	
8-2C	62.7	92.7	saturated	93.5	93.5	5	1,625.6	1.90	30.77	71.0	1.15E-04	10.6	
8-2D	62.7	92.7	saturated	93.6	93.6	10	1,635.0	1.87	30.93	71.4	1.13E-04	10.4	
8-2E	62.7	92.7	saturated	93.5	93.5	15	1,644.2	1.84	30.82	71.1	1.12E-04	10.3	
Test Averages/Summary													
8-2	**62.7**	**92.7**	**saturated**	**93.2**	**93.2**	**15**	**28.2**	**1.92**	**30.58**	**70.54**	**1.17E-04**	**10.8**	

Notes:

Start Time: 01:18 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer Pressure Reading (P_r)	Transducer Corrected Pressure (P_a)	Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				108.2		0	1,647.0						
8-3A	62.7	107.7	saturated	108.8	108.8	1	1,650.3	3.32	46.09	106.3	1.34E-04	12.4	
8-3B	62.7	107.7	saturated	109.4	109.4	3	1,656.2	2.93	46.65	107.6	1.17E-04	10.8	
8-3C	62.7	107.7	saturated	109.7	109.7	5	1,661.0	2.42	46.99	108.4	9.63E-05	8.9	
8-3D	62.7	107.7	saturated	110.1	110.1	10	1,676.6	3.11	47.36	109.3	1.23E-04	11.3	
8-3E	62.7	107.7	saturated	110.4	110.4	15	1,691.0	2.88	47.68	110.0	1.13E-04	10.4	
Test Averages/Summary													
8-3	**62.7**	**107.7**	**saturated**	**109.4**	**109.4**	**15**	**44.0**	**2.93**	**46.95**	**108.32**	**1.17E-04**	**10.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/18/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-37
Test Number	8
Borehole Diameter, ft	0.3
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	153.00
Bottom of Test Interval Depth, ft	163.50

Hydrostatic Pressure (P_0), psi	62.70
Transducer Zero Reading (R_0)	0.008
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	157.50
Vertical Center of Test Interval (D), ft	158.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	18.95
Groundwater Elevation, ft	581.8
Top of Test Interval Elevation, ft	447.7
Bottom of Test Interval Elevation, ft	437.2

Start Time: 01:35 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				92.7		0	1,694.0						
8-4A	62.7	92.7	saturated	92.8	92.8	1	1,696.2	2.16	30.10	69.4	1.34E-04	12.3	
8-4B	62.7	92.7	saturated	92.8	92.8	3	1,700.0	1.92	30.10	69.4	1.19E-04	10.9	
8-4C	62.7	92.7	saturated	93.1	93.0	5	1,704.2	2.10	30.34	70.0	1.29E-04	11.9	
8-4D	62.7	92.7	saturated	93.6	93.6	10	1,713.8	1.92	30.87	71.2	1.16E-04	10.6	
8-4E	62.7	92.7	saturated	94.0	93.9	15	1,723.6	1.96	31.24	72.1	1.17E-04	10.8	
Test Averages/Summary													
8-4	**62.7**	**92.7**	**saturated**	**93.2**	**93.2**	**15**	**29.6**	**2.01**	**30.53**	**70.43**	**1.23E-04**	**11.3**	

Notes:

Start Time: 01:51 — Packer Pressure, psi: 210

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				77.5		0	1,726.0						
8-5A	62.7	77.7	saturated	77.5	77.5	1	1,727.1	1.13	14.81	34.2	1.42E-04	13.1	
8-5B	62.7	77.7	saturated	77.6	77.6	3	1,729.3	1.06	14.86	34.3	1.34E-04	12.3	
8-5C	62.7	77.7	saturated	77.6	77.6	5	1,731.4	1.08	14.89	34.3	1.35E-04	12.4	
8-5D	62.7	77.7	saturated	77.6	77.6	10	1,736.6	1.04	14.89	34.3	1.31E-04	12.0	
8-5E	62.7	77.7	saturated	77.6	77.6	15	1,741.7	1.01	14.88	34.3	1.27E-04	11.7	
Test Averages/Summary													
8-5	**62.7**	**77.7**	**saturated**	**77.6**	**77.6**	**15**	**15.7**	**1.07**	**14.86**	**34.29**	**1.34E-04**	**12.3**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/21/19
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Number of Tests	5
Lattitude	45.79162°N
Longitude	84.77478°W

Top of Rock, ft	120.00
Bottom of Boring, ft	203.00
Depth to Groundwater (D_{WL}), ft	16.31

Datum Elevation	598.2
Top of Rock Elevation, ft	478.2
Bottom of Hole Elevation, ft	395.2
Groundwater Elevation, ft	581.9

Total Length of Testing, ft	46.50
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_t)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
1-1	64.0	79.0	saturated	83.0	82.9	15	386.84	26.06	19.4	44.8	2.52E-03	230.3		
1-2	64.0	94.0	saturated	95.2	95.2	15	494.28	33.16	31.6	73.0	1.96E-03	179.8		
1-3	64.0	79.0	saturated	80.5	80.5	15	298.48	19.99	16.6	38.3	2.25E-03	206.6		
2-1	59.0	74.0	saturated	75.9	75.8	15	98.36	6.62	17.0	39.3	7.27E-04	66.7		
2-2	59.0	89.0	saturated	92.4	92.4	15	155.64	10.48	33.9	78.2	5.81E-04	53.0		
2-3	59.0	104.0	saturated	102.5	102.5	15	219.22	14.57	43.1	99.5	6.32E-04	58.0		
2-4	59.0	89.0	saturated	90.7	90.7	15	179.66	11.96	31.9	73.6	7.00E-04	64.3		
2-5	59.0	74.0	saturated	75.0	75.0	15	114.82	7.66	16.0	36.9	8.95E-04	82.2		
3-1	54.3	69.3	saturated	71.1	71.0	15	68.56	4.59	17.2	39.6	5.01E-04	45.8		
3-2	54.3	84.3	saturated	84.3	84.3	15	100.74	6.85	30.2	69.7	4.24E-04	38.9		
3-3	54.3	99.3	saturated	101.9	101.9	15	137.54	9.18	48.2	111.2	3.56E-04	32.7		
3-4	54.3	84.3	saturated	85.3	85.3	15	96.74	6.55	31.1	71.8	3.93E-04	36.1		
3-5	54.3	69.3	saturated	69.2	69.2	15	56.52	3.69	15.0	34.5	4.60E-04	42.3		
4-1	49.7	64.7	saturated	67.1	67.0	15	74.44	5.02	17.6	40.6	5.34E-04	48.9		
4-2	49.7	79.7	saturated	80.8	80.8	15	118.11	7.90	31.0	71.6	4.75E-04	43.7		
4-3	49.7	94.7	saturated	94.2	94.2	15	166.20	11.16	44.0	101.6	4.73E-04	43.5		
4-4	49.7	79.7	saturated	81.6	81.6	15	126.22	8.55	32.1	74.0	4.98E-04	45.7		
4-5	49.7	64.7	saturated	65.1	65.1	15	69.88	4.61	15.4	35.5	5.61E-04	51.5		

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Completion (All Tests)	07/21/19
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Number of Tests	5
Lattitude	45.79162°N
Longitude	84.77478°W

Top of Rock, ft	120.00
Bottom of Boring, ft	203.00
Depth to Groundwater (D_{WL}), ft	16.31

Datum Elevation	598.2
Top of Rock Elevation, ft	478.2
Bottom of Hole Elevation, ft	395.2
Groundwater Elevation, ft	581.9

Total Length of Testing, ft	46.50
Boring Angle from Vertical, °	0.0
Borehole Diameter, ft	0.32

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Total Time	Total Flow	Average Flowrate	Average Test Pressure (P_I)		Average Hydraulic Conductivity (K)	Average Water Take		Notes
				Average Pressure Reading (P_r)	Corrected Average Pressure (P_a)									
	psi	psi		psi	psi	min	gal	gpm	psi	ft	cm/sec	Lugeons		
5-1	48.2	63.2	saturated	63.3	63.3	15	98.96	6.62	15.4	35.6	8.05E-04	73.7				
5-2	48.2	78.2	saturated	82.4	82.4	15	151.06	10.19	34.9	80.4	5.46E-04	50.1				
5-3	48.2	93.2	saturated	94.5	94.5	15	192.32	12.88	46.0	106.1	5.26E-04	48.0				
5-4	48.2	78.2	saturated	80.3	80.3	15	146.48	9.90	32.7	75.4	5.67E-04	52.0				
5-5	48.2	63.2	saturated	62.9	62.9	15	95.50	6.43	14.7	33.9	8.17E-04	75.0				

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/20/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	1
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	160.00
Bottom of Test Interval Depth, ft	170.50

Hydrostatic Pressure (P_0), psi	63.99
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	164.50
Vertical Center of Test Interval (D), ft	165.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	438.2
Bottom of Test Interval Elevation, ft	427.7

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.5		0	1,787.0						
1-1A	64.0	79.0	saturated	82.1	82.0	1	1,815.4	28.42	18.03	41.6	2.94E-03	270.4	
1-1B	64.0	79.0	saturated	82.8	82.7	3	1,866.4	25.50	18.73	43.2	2.54E-03	233.5	
1-1C	64.0	79.0	saturated	83.1	83.1	5	1,916.0	24.81	19.10	44.1	2.42E-03	222.8	
1-1D	64.0	79.0	saturated	84.6	84.6	10	2,044.1	25.62	20.58	47.5	2.32E-03	213.5	
1-1E	64.0	79.0	saturated	84.6	84.6	15	2,173.8	25.94	20.59	47.5	2.35E-03	216.2	
Test Averages/Summary													
1-1	**64.0**	**79.0**	**saturated**	**83.0**	**82.9**	**15**	**386.8**	**26.06**	**19.41**	**44.77**	**2.52E-03**	**230.3**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				92.6		0	2,218.0						
1-2A	64.0	94.0	saturated	93.6	93.6	1	2,253.1	35.09	29.59	68.3	2.21E-03	203.5	
1-2B	64.0	94.0	saturated	94.7	94.7	3	2,316.4	31.68	30.70	70.8	1.93E-03	177.0	
1-2C	64.0	94.0	saturated	95.5	95.4	5	2,382.7	33.11	31.45	72.5	1.97E-03	180.6	
1-2D	64.0	94.0	saturated	96.9	96.8	10	2,547.1	32.89	32.85	75.8	1.87E-03	171.7	
1-2E	64.0	94.0	saturated	97.7	97.6	15	2,712.3	33.04	33.62	77.6	1.83E-03	168.5	
Test Averages/Summary													
1-2	**64.0**	**94.0**	**saturated**	**95.2**	**95.2**	**15**	**494.3**	**33.16**	**31.64**	**73.00**	**1.96E-03**	**179.8**	

Notes: Pump Maxed in 1 min interval.

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				79.8		0	2,747.0						
1-3A	64.0	79.0	saturated	80.0	80.0	1	2,767.9	20.88	15.97	36.8	2.44E-03	224.3	
1-3B	64.0	79.0	saturated	80.4	80.3	3	2,807.7	19.93	16.34	37.7	2.28E-03	209.2	
1-3C	64.0	79.0	saturated	80.7	80.6	5	2,846.4	19.33	16.63	38.4	2.17E-03	199.4	
1-3D	64.0	79.0	saturated	80.9	80.9	10	2,946.9	20.11	16.90	39.0	2.22E-03	204.1	
1-3E	64.0	79.0	saturated	81.2	81.2	15	3,045.5	19.71	17.16	39.6	2.14E-03	197.0	
Test Averages/Summary													
1-3	**64.0**	**79.0**	**saturated**	**80.5**	**80.5**	**15**	**298.5**	**19.99**	**16.60**	**38.30**	**2.25E-03**	**206.6**	

Notes: 45 and 30 test pressures skipped due to pump maxing out.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	149.50
Bottom of Test Interval Depth, ft	160.00

Hydrostatic Pressure (P_0), psi	58.98
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	154.00
Vertical Center of Test Interval (D), ft	154.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	448.7
Bottom of Test Interval Elevation, ft	438.2

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				75.1		0	3,062.0						
2-1A	59.0	74.0	saturated	75.4	75.4	1	3,069.0	6.98	16.40	37.8	7.95E-04	73.0	
2-1B	59.0	74.0	saturated	76.2	76.1	3	3,081.8	6.41	17.17	39.6	6.98E-04	64.1	
2-1C	59.0	74.0	saturated	76.5	76.5	5	3,095.1	6.66	17.51	40.4	7.11E-04	65.3	
2-1D	59.0	74.0	saturated	76.0	75.9	10	3,127.9	6.54	16.95	39.1	7.20E-04	66.2	
2-1E	59.0	74.0	saturated	76.1	76.0	15	3,160.4	6.50	17.06	39.4	7.12E-04	65.4	
Test Averages/Summary													
2-1	**59.0**	**74.0**	**saturated**	**75.9**	**75.8**	**15**	**98.4**	**6.62**	**17.02**	**39.26**	**7.27E-04**	**66.7**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				89.7		0	3,166.0						
2-2A	59.0	89.0	saturated	94.0	93.9	1	3,177.3	11.27	34.95	80.6	6.02E-04	55.3	
2-2B	59.0	89.0	saturated	95.1	95.1	3	3,197.9	10.31	36.09	83.3	5.33E-04	49.0	
2-2C	59.0	89.0	saturated	95.1	95.1	5	3,218.2	10.15	36.09	83.3	5.25E-04	48.2	
2-2D	59.0	89.0	saturated	92.6	92.5	10	3,269.5	10.26	33.55	77.4	5.71E-04	52.5	
2-2E	59.0	89.0	saturated	87.8	87.8	15	3,321.6	10.43	28.82	66.5	6.76E-04	62.1	
Test Averages/Summary													
2-2	**59.0**	**89.0**	**saturated**	**92.4**	**92.4**	**15**	**155.6**	**10.48**	**33.90**	**78.21**	**5.81E-04**	**53.0**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				104.6		0	3,337.0						
2-3A	59.0	104.0	saturated	105.8	105.8	1	3,351.8	14.81	46.79	107.9	5.91E-04	54.3	
2-3B	59.0	104.0	saturated	100.5	100.5	3.5	3,390.5	15.47	41.49	95.7	6.96E-04	64.0	
2-3C	59.0	104.0	saturated	100.9	100.8	5	3,410.7	13.45	41.84	96.5	6.00E-04	55.1	
2-3D	59.0	104.0	saturated	101.3	101.3	10	3,483.6	14.59	42.30	97.6	6.44E-04	59.2	
2-3E	59.0	104.0	saturated	102.1	102.1	15	3,556.2	14.52	43.13	99.5	6.29E-04	57.8	
Test Averages/Summary													
2-3	**59.0**	**104.0**	**saturated**	**102.5**	**102.5**	**15**	**219.2**	**14.57**	**43.11**	**99.45**	**6.32E-04**	**58.0**	

Notes: Time step 2-3B taken at 3.5 minutes instead of 3 minutes.

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	2
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	149.50
Bottom of Test Interval Depth, ft	160.00

Hydrostatic Pressure (P_0), psi	58.98
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	154.00
Vertical Center of Test Interval (D), ft	154.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	448.7
Bottom of Test Interval Elevation, ft	438.2

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				89.7		0	3,567.0						
2-4A	59.0	89.0	saturated	90.1	90.0	1	3,579.4	12.36	31.05	71.6	7.43E-04	68.3	
2-4B	59.0	89.0	saturated	90.4	90.4	3	3,602.2	11.43	31.39	72.4	6.80E-04	62.5	
2-4C	59.0	89.0	saturated	90.9	90.8	5	3,626.0	11.89	31.84	73.5	6.97E-04	64.0	
2-4D	59.0	89.0	saturated	91.5	91.5	10	3,685.9	11.98	32.48	74.9	6.89E-04	63.3	
2-4E	59.0	89.0	saturated	91.7	91.7	15	3,746.7	12.15	32.72	75.5	6.93E-04	63.7	
Test Averages/Summary													
2-4	**59.0**	**89.0**	**saturated**	**90.7**	**90.7**	**15**	**179.7**	**11.96**	**31.90**	**73.59**	**7.00E-04**	**64.3**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				74.7		0	3,757.0						
2-5A	59.0	74.0	saturated	74.8	74.7	1	3,764.8	7.79	15.76	36.3	9.23E-04	84.8	
2-5B	59.0	74.0	saturated	74.8	74.8	3	3,779.9	7.55	15.81	36.5	8.92E-04	81.9	
2-5C	59.0	74.0	saturated	75.1	75.0	5	3,795.2	7.66	16.05	37.0	8.92E-04	81.9	
2-5D	59.0	74.0	saturated	75.1	75.1	10	3,833.4	7.63	16.07	37.1	8.86E-04	81.4	
2-5E	59.0	74.0	saturated	75.3	75.3	15	3,871.8	7.69	16.29	37.6	8.81E-04	81.0	
Test Averages/Summary													
2-5	**59.0**	**74.0**	**saturated**	**75.0**	**75.0**	**15**	**114.8**	**7.66**	**15.99**	**36.90**	**8.95E-04**	**82.2**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	139.00
Bottom of Test Interval Depth, ft	149.50

Hydrostatic Pressure (P_0), psi	54.26
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	143.50
Vertical Center of Test Interval (D), ft	144.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	459.2
Bottom of Test Interval Elevation, ft	448.7

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				69.0		0	3,879.0						
3-1A	54.3	69.3	saturated	69.9	69.8	1	3,883.7	4.67	15.58	35.9	5.60E-04	51.4	
3-1B	54.3	69.3	saturated	70.7	70.7	3	3,892.7	4.53	16.42	37.9	5.15E-04	47.4	
3-1C	54.3	69.3	saturated	71.5	71.4	5	3,901.9	4.60	17.17	39.6	5.00E-04	46.0	
3-1D	54.3	69.3	saturated	72.6	72.6	10	3,924.8	4.58	18.34	42.3	4.66E-04	42.8	
3-1E	54.3	69.3	saturated	72.7	72.7	15	3,947.6	4.55	18.41	42.5	4.61E-04	42.4	
Test Averages/Summary													
3-1	**54.3**	**69.3**	**saturated**	**71.1**	**71.0**	**15**	**68.6**	**4.59**	**17.18**	**39.64**	**5.01E-04**	**45.8**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				83.3		0	3,951.0						
3-2A	54.3	84.3	saturated	84.0	84.0	1	3,958.3	7.32	29.72	68.6	4.60E-04	42.2	
3-2B	54.3	84.3	saturated	84.1	84.0	3	3,971.4	6.53	29.78	68.7	4.10E-04	37.6	
3-2C	54.3	84.3	saturated	84.5	84.5	5	3,985.8	7.23	30.25	69.8	4.46E-04	41.0	
3-2D	54.3	84.3	saturated	84.9	84.8	10	4,018.3	6.49	30.57	70.5	3.96E-04	36.4	
3-2E	54.3	84.3	saturated	85.0	85.0	15	4,051.7	6.69	30.73	70.9	4.07E-04	37.4	
Test Averages/Summary													
3-2	**54.3**	**84.3**	**saturated**	**84.3**	**84.3**	**15**	**100.7**	**6.85**	**30.21**	**69.70**	**4.24E-04**	**38.9**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_i)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				98.8		0	4,059.0						
3-3A	54.3	99.3	saturated	101.1	101.0	1	4,068.7	9.67	46.77	107.9	3.86E-04	35.5	
3-3B	54.3	99.3	saturated	102.0	102.0	3	4,086.7	9.02	47.73	110.1	3.53E-04	32.4	
3-3C	54.3	99.3	saturated	102.7	102.7	5	4,104.2	8.75	48.44	111.7	3.37E-04	31.0	
3-3D	54.3	99.3	saturated	102.9	102.9	10	4,151.2	9.40	48.62	112.2	3.61E-04	33.2	
3-3E	54.3	99.3	saturated	103.7	103.6	15	4,196.5	9.06	49.39	114.0	3.42E-04	31.5	
Test Averages/Summary													
3-3	**54.3**	**99.3**	**saturated**	**101.9**	**101.9**	**15**	**137.5**	**9.18**	**48.19**	**111.17**	**3.56E-04**	**32.7**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	3
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	139.00
Bottom of Test Interval Depth, ft	149.50

Hydrostatic Pressure (P_0), psi	54.26
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	143.50
Vertical Center of Test Interval (D), ft	144.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	459.2
Bottom of Test Interval Elevation, ft	448.7

Start Time | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				84.6		0	4,203.0						
3-4A	54.3	84.3	saturated	84.7	84.7	1	4,210.1	7.12	30.41	70.2	4.37E-04	40.2	
3-4B	54.3	84.3	saturated	85.0	84.9	3	4,223.1	6.51	30.68	70.8	3.96E-04	36.4	
3-4C	54.3	84.3	saturated	85.2	85.1	5	4,235.8	6.34	30.89	71.3	3.83E-04	35.2	
3-4D	54.3	84.3	saturated	86.0	85.9	10	4,268.4	6.52	31.69	73.1	3.84E-04	35.3	
3-4E	54.3	84.3	saturated	86.4	86.3	15	4,299.7	6.26	32.06	74.0	3.65E-04	33.5	
Test Averages/Summary													
3-4	**54.3**	**84.3**	**saturated**	**85.3**	**85.3**	**15**	**96.7**	**6.55**	**31.14**	**71.85**	**3.93E-04**	**36.1**	

Notes

Start Time | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				69.1		0	4,305.0						
3-5A	54.3	69.3	saturated	69.1	69.1	1	4,308.0	3.02	14.83	34.2	3.80E-04	34.9	
3-5B	54.3	69.3	saturated	69.2	69.2	3	4,316.6	4.27	14.91	34.4	5.35E-04	49.1	
3-5C	54.3	69.3	saturated	69.3	69.2	5	4,323.8	3.61	14.96	34.5	4.51E-04	41.4	
3-5D	54.3	69.3	saturated	69.3	69.3	10	4,343.0	3.84	15.01	34.6	4.77E-04	43.8	
3-5E	54.3	69.3	saturated	69.4	69.3	15	4,361.5	3.71	15.07	34.8	4.60E-04	42.3	
Test Averages/Summary													
3-5	**54.3**	**69.3**	**saturated**	**69.2**	**69.2**	**15**	**56.5**	**3.69**	**14.95**	**34.50**	**4.60E-04**	**42.3**	

Notes

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	128.50
Bottom of Test Interval Depth, ft	139.00

Hydrostatic Pressure (P_0), psi	49.74
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	133.00
Vertical Center of Test Interval (D), ft	133.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	469.7
Bottom of Test Interval Elevation, ft	459.2

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				65.4		0	4,370.0						
4-1A	49.7	64.7	saturated	66.1	66.0	1	4,375.3	5.28	16.29	37.6	6.05E-04	55.6	
4-1B	49.7	64.7	saturated	66.8	66.8	3	4,385.2	4.97	17.06	39.3	5.44E-04	50.0	
4-1C	49.7	64.7	saturated	67.8	67.7	5	4,395.2	4.98	17.99	41.5	5.17E-04	47.5	
4-1D	49.7	64.7	saturated	68.0	68.0	10	4,420.2	5.00	18.25	42.1	5.11E-04	47.0	
4-1E	49.7	64.7	saturated	68.2	68.2	15	4,444.4	4.85	18.41	42.5	4.92E-04	45.2	
Test Averages/Summary													
4-1	**49.7**	**64.7**	**saturated**	**67.1**	**67.0**	**15**	**74.4**	**5.02**	**17.60**	**40.60**	**5.34E-04**	**48.9**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.8		0	4,451.0						
4-2A	49.7	79.7	saturated	80.7	80.7	1	4,459.2	8.23	30.91	71.3	4.97E-04	45.7	
4-2B	49.7	79.7	saturated	81.1	81.0	3	4,475.4	8.09	31.28	72.2	4.82E-04	44.3	
4-2C	49.7	79.7	saturated	80.8	80.8	5	4,490.2	7.38	31.02	71.6	4.44E-04	40.8	
4-2D	49.7	79.7	saturated	80.5	80.4	10	4,529.7	7.90	30.70	70.8	4.81E-04	44.2	
4-2E	49.7	79.7	saturated	81.0	81.0	15	4,569.1	7.89	31.26	72.1	4.71E-04	43.3	
Test Averages/Summary													
4-2	**49.7**	**79.7**	**saturated**	**80.8**	**80.8**	**15**	**118.1**	**7.90**	**31.03**	**71.59**	**4.75E-04**	**43.7**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				96.0		0	4,579.0						
4-3A	49.7	94.7	saturated	94.6	94.6	1	4,590.8	11.76	44.82	103.4	4.90E-04	45.0	
4-3B	49.7	94.7	saturated	93.4	93.4	3	4,612.5	10.85	43.66	100.7	4.64E-04	42.6	
4-3C	49.7	94.7	saturated	93.2	93.2	5	4,634.6	11.06	43.44	100.2	4.75E-04	43.7	
4-3D	49.7	94.7	saturated	93.4	93.3	10	4,690.0	11.08	43.58	100.5	4.75E-04	43.6	
4-3E	49.7	94.7	saturated	94.5	94.5	15	4,745.2	11.05	44.74	103.2	4.61E-04	42.3	
Test Averages/Summary													
4-3	**49.7**	**94.7**	**saturated**	**94.2**	**94.2**	**15**	**166.2**	**11.16**	**44.05**	**101.62**	**4.73E-04**	**43.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	4
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	128.50
Bottom of Test Interval Depth, ft	139.00

Hydrostatic Pressure (P_0), psi	49.74
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	133.00
Vertical Center of Test Interval (D), ft	133.75
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	469.7
Bottom of Test Interval Elevation, ft	459.2

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				80.6		0	4,755.0						
4-4A	49.7	79.7	saturated	81.0	80.9	1	4,764.4	9.43	31.20	72.0	5.64E-04	51.8	
4-4B	49.7	79.7	saturated	81.3	81.3	3	4,780.8	8.19	31.52	72.7	4.85E-04	44.6	
4-4C	49.7	79.7	saturated	81.8	81.7	5	4,797.6	8.39	31.97	73.8	4.90E-04	45.0	
4-4D	49.7	79.7	saturated	82.3	82.3	10	4,839.5	8.37	32.56	75.1	4.80E-04	44.1	
4-4E	49.7	79.7	saturated	82.9	82.8	15	4,881.2	8.35	33.09	76.3	4.71E-04	43.3	
Test Averages/Summary													
4-4	**49.7**	**79.7**	**saturated**	**81.6**	**81.6**	**15**	**126.2**	**8.55**	**32.07**	**73.98**	**4.98E-04**	**45.7**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				64.7		0	4,887.0						
4-5A	49.7	64.7	saturated	64.8	64.8	1	4,891.6	4.56	15.03	34.7	5.66E-04	52.0	
4-5B	49.7	64.7	saturated	64.9	64.9	3	4,900.1	4.25	15.14	34.9	5.25E-04	48.2	
4-5C	49.7	64.7	saturated	65.0	64.9	5	4,909.7	4.83	15.17	35.0	5.94E-04	54.6	
4-5D	49.7	64.7	saturated	65.4	65.4	10	4,933.3	4.72	15.65	36.1	5.64E-04	51.8	
4-5E	49.7	64.7	saturated	65.6	65.6	15	4,956.9	4.71	15.86	36.6	5.54E-04	50.9	
Test Averages/Summary													
4-5	**49.7**	**64.7**	**saturated**	**65.1**	**65.1**	**15**	**69.9**	**4.61**	**15.37**	**35.46**	**5.61E-04**	**51.5**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	124.00
Bottom of Test Interval Depth, ft	134.50

Hydrostatic Pressure (P_0), psi	48.17
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	128.50
Vertical Center of Test Interval (D), ft	129.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	474.2
Bottom of Test Interval Elevation, ft	463.7

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				61.7		0	5,003.0						
5-1A	48.2	63.2	saturated	62.1	62.1	1	5,009.8	6.84	13.90	32.1	9.19E-04	84.4	
5-1B	48.2	63.2	saturated	63.4	63.4	3	5,023.2	6.69	15.20	35.1	8.22E-04	75.5	
5-1C	48.2	63.2	saturated	63.9	63.8	5	5,036.0	6.40	15.65	36.1	7.63E-04	70.1	
5-1D	48.2	63.2	saturated	64.5	64.4	10	5,069.4	6.68	16.26	37.5	7.67E-04	70.5	
5-1E	48.2	63.2	saturated	64.3	64.3	15	5,102.0	6.51	16.10	37.1	7.55E-04	69.3	
Test Averages/Summary													
5-1	**48.2**	**63.2**	**saturated**	**63.3**	**63.3**	**15**	**99.0**	**6.62**	**15.42**	**35.58**	**8.05E-04**	**73.7**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				79.0		0	5,108.0						
5-2A	48.2	78.2	saturated	83.3	83.3	1	5,118.9	10.94	35.08	80.9	5.82E-04	53.5	
5-2B	48.2	78.2	saturated	82.0	81.9	3	5,138.5	9.78	33.76	77.9	5.41E-04	49.7	
5-2C	48.2	78.2	saturated	84.3	84.2	5	5,158.9	10.19	36.07	83.2	5.27E-04	48.5	
5-2D	48.2	78.2	saturated	82.9	82.8	10	5,208.8	9.99	34.66	80.0	5.38E-04	49.5	
5-2E	48.2	78.2	saturated	83.0	83.0	15	5,259.1	10.04	34.79	80.3	5.39E-04	49.5	
Test Averages/Summary													
5-2	**48.2**	**78.2**	**saturated**	**82.4**	**82.4**	**15**	**151.1**	**10.19**	**34.87**	**80.45**	**5.46E-04**	**50.1**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				96.1		0	5,269.0						
5-3A	48.2	93.2	saturated	97.5	97.5	1	5,282.4	13.38	49.31	113.8	5.07E-04	46.5	
5-3B	48.2	93.2	saturated	87.5	87.5	3	5,307.9	12.78	39.33	90.7	6.06E-04	55.7	
5-3C	48.2	93.2	saturated	95.5	95.5	5	5,333.2	12.61	47.32	109.2	4.98E-04	45.7	
5-3D	48.2	93.2	saturated	94.6	94.5	10	5,396.1	12.58	46.34	106.9	5.07E-04	46.6	
5-3E	48.2	93.2	saturated	95.9	95.8	15	5,461.3	13.05	47.64	109.9	5.11E-04	47.0	
Test Averages/Summary													
5-3	**48.2**	**93.2**	**saturated**	**94.5**	**94.5**	**15**	**192.3**	**12.88**	**45.99**	**106.10**	**5.26E-04**	**48.0**	

Notes:

Line 5 Replacement and Tunnel Project - Packer Testing

WSP Project ID	31402024.00
Date of Test Completion	7/21/2019
WSP Personnel	O. El-Quqa
Subcontractor	Cascade Drilling
Driller	S. Parkes

Boring ID	BH19-38
Test Number	5
Borehole Diameter, ft	0.32
Boring Angle from Vertical, °	0
Top of Test Interval Depth, ft	124.00
Bottom of Test Interval Depth, ft	134.50

Hydrostatic Pressure (P_0), psi	48.17
Transducer Zero Reading (R_0)	0.039
Dist from Top Packer to Transducer, ft	4.5
Transducer Depth, ft	128.50
Vertical Center of Test Interval (D), ft	129.25
Test Interval Length (L), ft	10.50

Depth to Groundwater (D_{WL}), ft	16.31
Groundwater Elevation, ft	581.9
Top of Test Interval Elevation, ft	474.2
Bottom of Test Interval Elevation, ft	463.7

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				77.7		0	5,475.0						
5-4A	48.2	78.2	saturated	78.8	78.7	1	5,485.4	10.35	30.54	70.5	6.33E-04	58.1	
5-4B	48.2	78.2	saturated	80.0	80.0	3	5,505.2	9.91	31.82	73.4	5.82E-04	53.5	
5-4C	48.2	78.2	saturated	80.7	80.7	5	5,525.1	9.94	32.48	74.9	5.72E-04	52.5	
5-4D	48.2	78.2	saturated	82.3	82.3	10	5,573.6	9.71	34.10	78.7	5.31E-04	48.8	
5-4E	48.2	78.2	saturated	82.6	82.5	15	5,621.5	9.57	34.37	79.3	5.20E-04	47.8	
Test Averages/Summary													
5-4	**48.2**	**78.2**	**saturated**	**80.3**	**80.3**	**15**	**146.5**	**9.90**	**32.66**	**75.35**	**5.67E-04**	**52.0**	

Notes:

Start Time: | Packer Pressure, psi: 160

Test Step ID	Hydrostatic Pressure (P_0)	Target Pressure (P_T)	Analysis Type	Transducer		Time from Start	Flow Meter Reading	Flowrate	Test Pressure (P_I)		Hydraulic Conductivity (K)	Water Take	
				Pressure Reading (P_r)	Corrected Pressure (P_a)								
	psi	psi		psi	psi		gal	gpm	psi	ft	cm/sec	Lugeons	
				63.1		0	5,628.0						
5-5A	48.2	63.2	saturated	62.5	62.5	1	5,634.2	6.21	14.32	33.0	8.09E-04	74.4	
5-5B	48.2	63.2	saturated	62.6	62.5	3	5,648.2	6.97	14.38	33.2	9.06E-04	83.2	
5-5C	48.2	63.2	saturated	62.8	62.8	5	5,661.1	6.47	14.61	33.7	8.26E-04	75.9	
5-5D	48.2	63.2	saturated	63.1	63.1	10	5,692.3	6.24	14.91	34.4	7.82E-04	71.9	
5-5E	48.2	63.2	saturated	63.5	63.5	15	5,723.5	6.24	15.28	35.2	7.62E-04	70.0	
Test Averages/Summary													
5-5	**48.2**	**63.2**	**saturated**	**62.9**	**62.9**	**15**	**95.5**	**6.43**	**14.70**	**33.91**	**8.17E-04**	**75.0**	

Notes:

APPENDIX

F-2 *SLUG TESTING DATA*

Date:	6/26/2019

Line 5 Replacement and Tunnel Project - Slug Testing

Borehole	BH19-09/PZ19-09	**WSP Personnel**	K. Hanson/A. Heft
Borehole Inclination/Azimuth	Vertical	**Depth to Top of Screen, ft**	85
Slug Diameter, in	1.625	**Screen Length, ft**	10
Slug Length, ft	4.00	**Piezometer Diameter, in**	2.047 I.D./2.375 O.D.
Slug Volume, ft^3	0.0576	**Boring Diameter, in**	6
Static Depth to Groundwater, ft	32.85	**Depth to Water at Time Zero, ft**	N/A

Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)
5	-	125	32.81	245	32.83	365	
10	31.42	130	32.81	250		370	
15	31.80	135	32.81	255		375	
20	31.96	140	32.81	260		380	
25	32.13	145	32.82	265		385	
30	32.28	150	32.82	270		390	
35	32.34	155	32.82	275		395	
40	32.54	160	32.82	280		400	
45	32.59	165	32.82	285		405	
50	32.64	170	32.82	290		410	
55	32.67	175	32.82	295		415	
60	32.71	**180**	32.82	**300**		**420**	
65	32.73	185	32.82	305		425	
70	32.74	190	32.82	310		430	
75	32.76	195	32.82	315		435	
80	32.77	200	32.83	320		440	
85	32.78	205	32.83	325		445	
90	32.78	210	32.83	330		450	
95	32.79	215	32.83	335		455	
100	32.79	220	32.83	340		460	
105	32.80	225	32.83	345		465	
110	32.80	230	32.83	350		470	
115	32.80	235	32.83	355		475	
120	32.80	**240**	32.83	**360**		**480**	

Notes: Test performed inside the piezometer at 16:30. It was not possible to get a water depth reading at T=0 or 5 sec. Test was ended at 245 seconds

Date:	6/26/2019

Line 5 Replacement and Tunnel Project - Slug Testing

Borehole	BH19-10	**WSP Personnel**	K. Hanson/A. Heft
Borehole Inclination/Azimuth	Vertical	**Depth to Top of Screen, ft**	N/A
Slug Diameter, in	1.625	**Screen Length, ft**	N/A
Slug Length, ft	7.00	**Piezometer Diameter, in**	N/A
Slug Volume, ft^3	0.1008	**Boring Diameter, in**	3.375
Static Depth to Groundwater, ft	74.27	**Depth to Water at Time Zero, ft**	N/A

Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)
5	73.08	125	74.27	245		365	
10	73.48	130	74.27	250		370	
15	73.70	135		255		375	
20	73.85	140		260		380	
25	73.91	145		265		385	
30	73.99	150		270		390	
35	74.06	155		275		395	
40	74.11	160		280		400	
45	74.14	165		285		405	
50	74.17	170		290		410	
55	74.19	175		295		415	
60	74.20	**180**		**300**		**420**	
65	74.22	185		305		425	
70	74.23	190		310		430	
75	74.23	195		315		435	
80	74.24	200		320		440	
85	74.25	205		325		445	
90	74.25	210		330		450	
95	74.25	215		335		455	
100	74.26	220		340		460	
105	74.26	225		345		465	
110	74.26	230		350		470	
115	74.26	235		355		475	
120	74.26	**240**		**360**		**480**	

Notes:

Test performed in open boring at 12:45. It was not possible to get a water depth reading at T = 0 sec. No well casing or screen was installed in the boring. Test was ended at 130 seconds.

Date:	6/27/2019

Line 5 Replacement and Tunnel Project - Slug Testing

Borehole	BH19-12	**WSP Personnel**	K. Hanson/A. Heft
Borehole Inclination/Azimuth	Vertical	**Depth to Top of Screen, ft**	N/A
Slug Diameter, in	4.500	**Screen Length, ft**	N/A
Slug Length, ft	3.00	**Piezometer Diameter, in**	N/A
Slug Volume, ft^3	0.3313	**Boring Diameter, in**	6
Static Depth to Groundwater, ft	65.83	**Depth to Water at Time Zero, ft**	N/A

Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)
7	64.81	125	65.66	245	65.83	365	
10	-	130	65.68	250		370	
15	64.86	135	65.69	255		375	
20	64.93	140	65.70	260		380	
25	65.00	145	65.72	265		385	
30	65.05	150	65.73	270		390	
35	65.12	155	65.74	275		395	
40	65.19	160	65.75	280		400	
45	65.23	165	65.76	285		405	
50	65.27	170	65.77	290		410	
55	65.33	175	65.77	295		415	
60	65.37	**180**	65.78	**300**		**420**	
65	65.42	185	65.79	305		425	
70	65.44	190	65.79	310		430	
75	65.47	195	65.80	315		435	
80	65.50	200	65.81	320		440	
85	65.52	205	65.81	325		445	
90	65.54	210	65.81	330		450	
95	65.56	215	65.81	335		455	
100	65.59	220	65.82	340		460	
105	65.60	225	65.82	345		465	
110	65.62	230	65.83	350		470	
115	65.63	235	65.83	355		475	
120	65.64	**240**	65.83	**360**		**480**	

Notes:

Test performed in open boring at 13:10. It was not possible to get a water depth reading at T = 0 sec.
No casing or screen was installed, boring left open for pumping test. Test ended at 245 seconds

Date:	6/27/2019

Line 5 Replacement and Tunnel Project - Slug Testing

Borehole	PZ19-40	**WSP Personnel**	K. Hanson/A. Heft
Borehole Inclination/Azimuth	Vertical	**Depth to Top of Screen, ft**	85
Slug Diameter, in	1.625	**Screen Length, ft**	10
Slug Length, ft	4.00	**Piezometer Diameter, in**	2.047 I.D./2.375 O.D.
Slug Volume, ft^3	0.0576	**Boring Diameter, in**	6
Static Depth to Groundwater, ft	65.33	**Depth to Water at Time Zero, ft**	N/A

Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)
7	64.30	125	65.30	245		365	
10	64.66	130	65.30	250		370	
15	64.81	135	65.30	255		375	
20	64.94	140	65.30	260		380	
25	65.07	145	65.30	265		385	
30	65.12	150	65.30	270		390	
35	65.16	155	65.30	275		395	
40	65.20	160	65.30	280		400	
45	65.22	165	65.30	285		405	
50	65.23	170	65.30	290		410	
55	65.25	175		295		415	
60	65.26	**180**		**300**		**420**	
65	65.27	185		305		425	
70	65.28	190		310		430	
75	65.28	195		315		435	
80	65.29	200		320		440	
85	65.30	205		325		445	
90	65.30	210		330		450	
95	65.30	215		335		455	
100	65.30	220		340		460	
105	65.30	225		345		465	
110	65.30	230		350		470	
115	65.30	235		355		475	
120	65.30	**240**		**360**		**480**	

Notes: Test performed inside constructed piezometer at 16:00. It was not possible to get a water depth reading at T = 0 sec. Test was ended at 170 seconds.

Date:	6/27/2019

Line 5 Replacement and Tunnel Project - Slug Testing

Borehole	PZ19-41	**WSP Personnel**	K. Hanson/A. Heft
Borehole Inclination/Azimuth	Vertical	**Depth to Top of Screen, ft**	85
Slug Diameter, in	1.625	**Screen Length, ft**	10
Slug Length, ft	4.00	**Piezometer Diameter, in**	2.047 I.D./2.375 O.D.
Slug Volume, ft^3	0.0576	**Boring Diameter, in**	6
Static Depth to Groundwater, ft	65.24	**Depth to Water at Time Zero, ft**	N/A

Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)
5	64.53	125	65.24	245		365	
10	64.79	130	65.24	250		370	
15	64.93	135	65.24	255		375	
20	65.03	140	65.24	260		380	
25	65.09	145	65.24	265		385	
30	65.11	150	65.24	270		390	
35	65.14	155		275		395	
40	65.16	160		280		400	
45	65.18	165		285		405	
50	65.19	170		290		410	
55	65.20	175		295		415	
60	65.20	**180**		**300**		**420**	
65	65.20	185		305		425	
70	65.21	190		310		430	
75	65.21	195		315		435	
80	65.21	200		320		440	
85	65.22	205		325		445	
90	65.22	210		330		450	
95	65.22	215		335		455	
100	65.23	220		340		460	
105	65.23	225		345		465	
110	65.23	230		350		470	
115	65.23	235		355		475	
120	65.23	**240**		**360**		**480**	

Notes: Test performed in constructed piezometer at 15:00. It was not possible to get a water depth reading at T = 0 sec. Test was ended at 150 seconds.

Date:	6/27/2019

Line 5 Replacement and Tunnel Project - Slug Testing

Borehole	PZ19-42	**WSP Personnel**	K. Hanson/A. Heft
Borehole Inclination/Azimuth	Vertical	**Depth to Top of Screen, ft**	40
Slug Diameter, in	1.625	**Screen Length, ft**	10
Slug Length, ft	4.00	**Piezometer Diameter, in**	2.047 I.D./2.375 O.D.
Slug Volume, ft^3	0.0576	**Boring Diameter, in**	6
Static Depth to Groundwater, ft	34.36	**Depth to Water at Time Zero, ft**	N/A

Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)	Time (s)	Depth to Water (ft)
5	34.08	125		245		365	
10	34.22	130		250		370	
15	34.29	135		255		375	
20	34.33	140		260		380	
25	34.35	145		265		385	
30	34.35	150		270		390	
35	34.36	155		275		395	
40	34.36	160		280		400	
45	34.36	165		285		405	
50	34.36	170		290		410	
55		175		295		415	
60		**180**		**300**		**420**	
65		185		305		425	
70		190		310		430	
75		195		315		435	
80		200		320		440	
85		205		325		445	
90		210		330		450	
95		215		335		455	
100		220		340		460	
105		225		345		465	
110		230		350		470	
115		235		355		475	
120		**240**		**360**		**480**	

Notes: Test performed in constructed piezometer at 11:30. It was not possible to get a water depth reading at T = 0 sec. Test was ended at 50 seconds.

APPENDIX

F-3 *GROUNDWATER SAMPLING*

Table F-3.1- YSI 556 MPS Meter Reading Summary
Geotechnical Data Report
Line 5 Replacement and Tunnel Project

Boring ID	Date	Time	Atmospheric Pressure (mm HG)	Temperature (°C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH	Redox Potential (mV)	DTGW (ft)
BH19-12	6/3/2019	13:36	746.8	10.94	0.554	0.25	9.64	-256.6	63.99
BH19-08	6/26/2019	15:54	744.6	10.83	0.578	2.78	7.73	204.2	> 2
BH19-09	6/26/2019	17:32	743.6	12.33	0.615	0.40	7.65	-222.4	32.82
BH19-10	6/26/2019	13:56	740.9	13.01	0.556	8.71	7.39	320.2	74.28
BH19-15	6/26/2019	14:06	740.3	12.94	0.825	N/A	7.68	N/A	N/A
BH19-12	6/27/2019	14:33	745.2	10.61	0.615	1.47	9.28	-174.4	65.91
PZ19-40	6/27/2019	16:40	746.1	12.18	0.573	8.39	7.31	75.5	65.30
PZ19-41	6/27/2019	15:36	745.9	13.51	0.580	7.51	7.27	83.7	65.25
PZ19-42	6/27/2019	12:12	747.4	9.40	0.601	7.35	6.56	178.3	34.38
BH19-16	7/3/2019	14:50	741.9	18.42	0.337	3.98	7.20	41.7	N/A
BH19-17	7/9/2019	22:33	741.2	18.81	0.406	2.26	9.17	-108.6	N/A
BH19-37	7/17/2019	03:36	759.8	17.97	0.472	1.40	7.91	1.2	N/A
BH19-38	7/20/2019	22:01	756.1	19.25	0.474	0.13	9.58	-216.6	N/A
BH19-07	7/23/2019	23:22	763.6	16.70	1.878	0.52	7.87	-21.3	N/A
PW19-12	7/24/2019	08:19	740.0	10.14	0.610	3.27	7.03	-7.0	N/A
PW19-12	7/26/2019	14:24	749.6	9.31	0.571	1.85	7.36	51.9	24.59
BH19-24A	9/11/2019	21:52	765.1	13.80	0.599	5.20	9.01	585.9	N/A
BH19-36	9/17/2019	02:40	766.6	19.33	0.337	7.32	8.70	536.8	N/A
BH19-32	9/22/2019	04:47	759.1	20.85	0.394	4.42	7.86	497.3	N/A
BH19-25	10/17/2019	10:27	759.8	9.49	1.950	5.92	8.86	282.0	N/A
BH19-28	10/22/2019	03:27	731.2	12.32	0.243	11.10	7.29	326.1	N/A
BH19-19	10/27/2019	16:05	753.8	14.00	0.239	12.93	7.20	223.2	N/A
BH19-35	7/29/2019	01:07	760.6	22.33	0.320	2.48	8.40	576.8	N/A

Notes:
1) N/A - Not Available
2) BH19-12 was enlarged to become the pumping well for the Aquifer Test (PW19-12).
3) Depth to groundwater was not recorded for Nearshore and Deepwater borings.

Table F-3.2 - Groundwater Testing Summary
Geotechnical Data Report
Line 5 Replacement and Tunnel Project

Sample Name ----->	BH19-07	BH19-08	BH19-09	BH19-10	BH19-12	BH19-15	BH19-16	BH19-17	BH19-19	BH19-24A	BH19-25	BH19-28	BH19-32	BH19-33	BH19-35	BH19-36	BH19-37	BH19-38
Sampled Depth ---->	120'	NM	98'	105'	98'	212'	250'	317'	181'	257'	312'	210'	--	174'	207'	163'	180'	155'
Collection Date ---->	7/23/2019	6/26/2019	6/26/2019	6/26/2019	6/3/2019	6/26/2019	7/3/2019	7/10/2019	10/27/2019	9/11/2019	10/17/2019	10/22/2019	9/22/2019	7/22/2019	7/29/2019	9/17/2019	7/17/2019	7/20/2019
Collection Time ---->	23:35	16:03	17:42	14:06	13:48	06:46	14:50	10:33	16:15	23:00	10:30	03:30	05:15	17:50	01:00	14:50	NA	NA
Analytical Laboratory >	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC
Dissolved Gasses																		
Methane (µg/L)	**11**	U	U	U	U	U	U	**5.5**	U	U	--	U	U	U	U	U	U	**7.1**
Hydrogen Sulfide (mg/L)	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Cations/Anions																		
Calcium (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron, Ferric (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sodium (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloride (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fluoride (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ortho-Phosphate (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfate (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfide (µg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron, Ferrous (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other																		
pH	--	--	--	--	9.64	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Dissolved Solids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bicarbonate Alkalinity (µg $CaCO_3$/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Specific Conductance (µmho/cm)	--	--	--	--	U	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:
1) -- = Not analyzed.
2) U = Analyte not detected at or above the laboratory reporting limit.
3) Analyte concentrations detected above the method detection limits are shown in BOLD.
4) See laboratory analytical reports for specific detailed data notes and qualifications

Table F-3.2 - Groundwater Testing Summary
Geotechnical Data Report
Line 5 Replacement and Tunnel Project

Sample Name ----->	PW19-12	PW19-12 (Initial)	PW19-12 (Final)	PZ19-40	PZ19-41	PZ19-42												
Sampled Depth ----->	98'	137'	137'	93'	98'	48'	--	--	--	--	--	--	--	--	--	--	--	--
Collection Date ----->	6/27/2019	7/24/2019	7/26/2019	6/27/2019	6/27/2019	6/27/2019	--	--	--	--	--	--	--	--	--	--	--	--
Collection Time ----->	14:42	08:05	08:07	16:49	15:45	12:20	--	--	--	--	--	--	--	--	--	--	--	--
Analytical Laboratory >	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	FIBERTEC	--	--	--	--	--	--	--	--	--	--	--	--
Dissolved Gasses																		
Methane (µg/L)	**5.3**	--	--	U	U	U	--	--	--	--	--	--	--	--	--	--	--	--
Hydrogen Sulfide (mg/L)	U	--	--	U	U	U	--	--	--	--	--	--	--	--	--	--	--	--
Cations/Anions																		
Calcium (µg/L)	--	**94,000**	**83,000**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron, Ferric (µg/L)	--	**690**	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium (µg/L)	--	**34,000**	**28,000**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium (µg/L)	--	U	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sodium (µg/L)	--	**1,200**	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloride (µg/L)	--	U	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fluoride (µg/L)	--	U	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ortho-Phosphate (µg/L)	--	U	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfate (µg/L)	--	**13,000**	**12,000**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfide (µg/L)	--	U	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron, Ferrous (mg/L)	--	U	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other																		
pH	--	7.34	7.37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Dissolved Solids	--	**350,000**	**350,000**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bicarbonate Alkalinity (µg $CaCO_3$/L)	--	**320,000**	**310,000**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Specific Conductance (µmho/cm)	--	**580**	**580**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:
1) -- = Not analyzed.
2) U = Analyte not detected at or above the laboratory reporting limit.
3) Analyte concentrations detected above the method detection limits are shown in BOLD.
4) See laboratory analytical reports for specific detailed data notes and qualifications.

Fibertec
environmental
services

Wednesday, June 12, 2019

Fibertec Project Number:	90853
Project Identification:	31402024 /31402024
Submittal Date:	06/04/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

By Rikki Lott at 3:00 PM, Jun 12, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH-19-12**	Chain of Custody:	**178151**
Client Project Name:	**31402024**	Sample No:	**1**	Collect Date:	**06/03/19**
Client Project No:	**31402024**	Sample Matrix:	**Ground Water**	Collect Time:	**13:48**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Temperature, Field Measured **Aliquot ID: 90853-001B** **Matrix: Ground Water**
Method: EPA 0170.1 (Field) **Description: BH-19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Temperature	**10.9**		°C	0.0	1.0	NA	NA	06/03/19 00:00	NA	F-T

Specific Conductance at 25°C, Field Measured **Aliquot ID: 90853-001B** **Matrix: Ground Water**
Method: EPA 9050A **Description: BH-19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Specific Conductance	U		µmho/cm	1.0	1.0	NA	NA	06/03/19	NA	F-T

Methane by GC/FID **Aliquot ID: 90853-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH-19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	06/11/19	PS19F11G	06/11/19	S419F11A	RDK

pH, Electrometric (Field Measured) **Aliquot ID: 90853-001B** **Matrix: Ground Water**
Method: SM 4500-H+ B-2011 (Field) **Description: BH-19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. pH	**9.64**		pH Units	-1.00	1.0	NA	NA	06/03/19 00:00	NA	F-T

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 90853-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH-19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	06/05/19	W219F05A	CMB

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

Fibertec environmental services

Quality Control Report
Preparation Batch QC Summary
Gas Chromatography - Flame Ionization Detector
Aqueous

Batch ID: PS19F11G
Page: 1 of 1
Date: 06/12/19

Preparation Batch: PS19F11G **Preparation Date: 06/11/19**

		Method Blank (MB)			Laboratory Control Sample (LCS)					LCS Duplicate (LCD)				Run Code		
	Parameter	Result µg/L	RL µg/L	Q	Result µg/L	Spike µg/L	Rec. %	LCL - UCL %	Q	Rec. %	RPD %	UCL %	Q	MB	LCS	LCD
1.	Methane	U	2.6		18.9	17.5	108	80 - 120		106	2	20		MB-1	LCS-1	LCD-1

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Run Code (Analysis Sequence/Run Time):

MB-1	S419F11A	06/11/19 11:38
LCS-1	S419F11A	06/11/19 11:47
LCD-1	S419F11A	06/11/19 11:55

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Rikki Lott at 3:04 PM, Jun 12, 2019

1914 Holloway Drive *Holt, MI 48842* *T: (517) 699-0345* *F: (517) 699-0388*
11766 E. Grand River *Brighton, MI 48116* *T: (810) 220-3300* *F: (810) 220-3311*
8660 S. Mackinaw Trail *Cadillac, MI 49601* *T: (231) 775-8368* *F: (231) 775-8584*

lab@fibertec.us

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 178151
PAGE 1 of 1

Client Name: WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024
Email distribution list: adam.heft@wsp.com
~~[illegible]~~ conrad.fischer@wsp.com
Quote#
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	PARAMETERS: Methane	PARAMETERS: Hydrogen sulfide	HOLD SAMPLE
6/3/19	13:45	1	BH-19-12	GW	3	X	X	

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

Deliverables: X Level 2; Level 3; Level 4; EDD

Remarks: Temp = 10.94 cond = 0.554 pH = 9.64

RCVD BY LAB
JUN 04 2019
Initial: DG

Comments:

Sampled/Relinquished By: Adam Heft — Date/ Time: 6/4/19 16:26 — Received By:
Relinquished By: — Date/ Time: — Received By:
Relinquished By: — Date/ Time: — Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day ____2 bus. days _____3 bus. days _____4 bus. days
X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY
Fibertec project number: 90853
Temperature upon receipt at Lab: 4.4°C
RCVD ON ICE

Please see back for terms and conditions

Fibertec
environmental
services

Tuesday, July 09, 2019

Fibertec Project Number:	91338
Project Identification:	31402024.00A /31402024.00A
Submittal Date:	07/01/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

Samples were received at lab at 13.0° Celsius, which exceeds the maximum criteria of 6° Celsius.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 3:54 PM, Jul 09, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-08**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**1**	Collect Date:	**06/26/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**16:03**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-001B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-08**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-001A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-08**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-09**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**2**	Collect Date:	**06/26/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**17:42**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-002B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-09**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-002A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-09**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-10**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**3**	Collect Date:	**06/26/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**14:06**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-003B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-10**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-003A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-10**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-15**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**4**	Collect Date:	**06/26/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**06:46**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-004B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-15**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U	J	µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-004A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-15**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-PZ-40**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**5**	Collect Date:	**06/27/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**16:49**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-005B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-PZ-40**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-005A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-PZ-40**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-PZ-41**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**6**	Collect Date:	**06/27/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**15:45**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-006B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-PZ-41**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-006A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-PZ-41**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**PW19-12**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**7**	Collect Date:	**06/27/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**14:42**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-007B** **Matrix: Ground Water**
Method: RSK-175 **Description: PW19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	**5.3**	J	µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-007A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: PW19-12**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-PZ-42 (PZ-42)**	Chain of Custody:	**163350**
Client Project Name:	**31402024.00A**	Sample No:	**8**	Collect Date:	**06/27/19**
Client Project No:	**31402024.00A**	Sample Matrix:	**Ground Water**	Collect Time:	**12:20**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91338-008B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-PZ-42 (PZ-42)**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U	J	µg/L	2.6	1.0	07/08/19	PS19G08F	07/08/19	S419G08A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91338-008A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-PZ-42 (PZ-42)**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/03/19	W219G03A	AMW

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

J : The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

Analysis Locations:

All analyses performed in Holt.

Accreditation Number(s):

T104704518-19-8 (TX)

Fibertec environmental services

Quality Control Report
Preparation Batch QC Summary
Gas Chromatography - Flame Ionization Detector
Aqueous

Batch ID: PS19G08F
Page: 1 of 1
Date: 07/09/19

Preparation Batch: PS19G08F **Preparation Date: 07/08/19**

		Method Blank (MB)			Laboratory Control Sample (LCS)					LCS Duplicate (LCD)				Run Code		
	Parameter	Result µg/L	RL µg/L	Q	Result µg/L	Spike µg/L	Rec. %	LCL - UCL %	Q	Rec. %	RPD %	UCL %	Q	MB	LCS	LCD
1.	Methane	U	2.6		21.0	17.6	120	80 - 120		113	6	20		MB-1	LCS-1	LCD-1

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Run Code (Analysis Sequence/Run Time):

MB-1	S419G08A	07/08/19 11:40
LCS-1	S419G08A	07/08/19 11:50
LCD-1	S419G08A	07/08/19 12:00

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Stephannie Wallace at 3:55 PM, Jul 09, 2019

1914 Holloway Drive, Holt, MI 48842, T: (517) 699-0345, F: (517) 699-0388
11766 E. Grand River, Brighton, MI 48116, T: (810) 220-3300, F: (810) 220-3311
8660 S. Mackinaw Trail, Cadillac, MI 49601, T: (231) 775-8368, F: (231) 775-8584

lab@fibertec.us

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # **163350**
PAGE 1 of 1

Client Name: WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024.00A
Email distribution list: adam.heft@wsp.com
Quote# Up North / 31402024
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	Methane	Hydrogen Sulfide	HOLD SAMPLE	Remarks:
6/26/19	16:03	1	BH19-08	GW	3	X	X		Temp = 10.83 Cond = 0.578 pH = 7.73
	17:42	2	BH19-09	GW	3	X	X		Temp = 12.33 Cond = 0.615 pH = 7.65
	14:06	3	BH19-10	GW	3	X	X		Temp = 13.01 Cond = 0.556 pH = 7.39
	06:46	4	BH19-15	GW	3	X	X		Temp = 12.94 Cond = 0.825 pH = 7.68
6/27/19	16:49	5	BH19-PZ-40	GW	3	X	X		Temp = 12.18 Cond = 0.573 pH = 7.31
	15:45	6	BH19-PZ-41	GW	3	X	X		Temp = 13.51 Cond = 0.580 pH = 7.27
	14:42	7	PW19-12	GW	3	X	X		Temp = 10.61 Cond = 0.615 pH = 9.28
	12:20	8	BH19-PZ-42 (PZ-42)	GW	3	X	X		Temp = 9.40 Cond = 0.601 pH = 6.56

PARAMETERS

Matrix Code

S	Soil	GW	Ground Water
A	Air	SW	Surface Water
O	Oil	WW	Waste Water
P	Wipe	X	Other: Specify

Deliverables

X	Level 2
	Level 3
	Level 4
	EDD

RCVD BY LAB
JUL 01 2019

Comments:

Sampled/Relinquished By: Adam M. Heft	Date/ Time 7/1/19 16:30	Received By: Initial: NE
Relinquished By:	Date/ Time	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 91338 RCVD ON ICE

Temperature upon receipt at Lab: 13.0°C

Please see back for terms and conditions

Fibertec
environmental
services

Monday, July 22, 2019

Fibertec Project Number:	91471
Project Identification:	31402024.00B /31402024.00B
Submittal Date:	07/11/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 12:39 PM, Jul 22, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-16**	Chain of Custody:	**178153**
Client Project Name:	**31402024.00B**	Sample No:	**1**	Collect Date:	**07/03/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**14:50**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91471-001B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-16**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U	H	µg/L	2.6	1.0	07/18/19	PS19G18F	07/18/19	S419G18D	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91471-001A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-16**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U	H	mg/L	0.020	1.0	07/11/19	W219G11B	07/11/19	W219G11B	SEM

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-17**	Chain of Custody:	**178153**
Client Project Name:	**31402024.00B**	Sample No:	**2**	Collect Date:	**07/10/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**10:33**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91471-002B** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-17**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	**5.5**	H	µg/L	2.6	1.0	07/18/19	PS19G18F	07/18/19	S419G18D	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91471-002A** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-17**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	07/11/19	W219G11B	07/11/19	W219G11B	SEM

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

H : Hold time exceeded.

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19G18F: Method Blank (MB) — RSK-175

Run Time: PS19G18F.MB 07/18/2019 14:04 [S419G18D]

Analyte	MB Result µg/L	MB Qualifier	MB RDL µg/L
Methane	U		2.6

PS19G18F: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19G18F.LCS: 07/18/2019 14:12 [S419G18D] PS19G18F.LCSD: 07/18/2019 14:19 [S419G18D]

Analyte	LCS Spike Amount µg/L	LCS Result µg/L	LCS Rec. %	Rec. Limits %	LCS Qualifier	LCSD Spike Amount µg/L	LCSD Result µg/L	LCSD Rec. %	LCSD Qualifier	RPD %	RPD Limits %	RPD Qualifier
Methane	17.6	17.1	97	80-120		17.6	17.1	97		0	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Anthony Donnelly at 5:54 PM, Jul 22, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # **178153**

Client Name: WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024.003
Email distribution list: adam.heft@wsp.com
Quote# In Mail
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	Methane	Hydrogen Sulfide	HOLD SAMPLE	Remarks
7/3/19	1450	1	BH19-16	GW	3	X	X		Temp = 18.4 Cond = 0.337 pH=7.20
7/10/19	1033	2	BH19-17	GW	3	X	X		Temp = 18.81 cond = 0.406 pH= 9.17

PARAMETERS

Matrix Code

S	Soil	GW	Ground Water
A	Air	SW	Surface Water
O	Oil	WW	Waste Water
P	Wipe	X	Other: Specify

Deliverables

- [X] Level 2
- [ ] Level 3
- [ ] Level 4
- [ ] EDD

RCVD BY LAB
JUL 11 2019
Initial: JS

Comments:

Sampled/Relinquished By: Adam W. Heft	Date/ Time 7/11/19 0948	Received By:
Relinquished By:	Date/ Time	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

[X] 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 91471

Temperature upon receipt at Lab: 3.4°C

RCVD ON ICE

Please see back for terms and conditions

Fibertec
environmental
services

Monday, July 29, 2019

Fibertec Project Number:	91684
Project Identification:	31402024.00B /31402024.00B
Submittal Date:	07/22/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 1:06 PM, Jul 29, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-37**	Chain of Custody:	**177118**
Client Project Name:	**31402024.00B**	Sample No:	**1**	Collect Date:	**07/17/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**NA**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91684-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-37**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U	J-	µg/L	2.6	1.0	07/24/19	PS19G24G	07/24/19	S419G24A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91684-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-37**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/23/19	W219G23B	AMW

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-38**	Chain of Custody:	**177118**
Client Project Name:	**31402024.00B**	Sample No:	**2**	Collect Date:	**07/20/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**NA**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91684-002A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-38**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	**7.1**	J-	µg/L	2.6	1.0	07/24/19	PS19G24G	07/24/19	S419G24A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91684-002** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-38**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/23/19	W219G23B	AMW

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

J- : The result is an estimated quantity, but the result may be biased low.

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19G24G: Method Blank (MB) — RSK-175

Run Time: PS19G24G.MB 07/24/2019 11:39 [S419G24A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19G24G: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19G24G.LCS: 07/24/2019 11:49 [S419G24A] PS19G24G.LCSD: 07/24/2019 11:57 [S419G24A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	18.8	17.5	93	80-120		18.8	17.3	92		1	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Tracy Tipton at 11:25 AM, Jul 25, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # **177118**
PAGE 1 of 1

Client Name: WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024.003
Email distribution list: adam.heft@wsp.com
Quote# UP North / 31402024
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	PARAMETERS: Methane	PARAMETERS: Hydrogen Sulfide	HOLD SAMPLE
7/17/19		1	BH19-37	GW	3	X	X	
7/20/19		2	BH19-38	GW	3	X	X	

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

Deliverables: X Level 2; Level 3; Level 4; EDD

Remarks:
Temp = 17.97 Cond = 0.472 pH = 7.91
Temp = 19.25 Cond = 0.474 pH = 9.58

RCVD BY LAB
JUL 23 2019
Initial: JS

Comments:

Sampled/Relinquished By: Osama El-Rayes	Date/ Time 7/22/19 2:00PM	Received By: Adam W. Heft
Relinquished By: Adam W. Heft	Date/ Time 7/22/19 4:10	Received By: UPS
Relinquished By: UPS	Date/ Time 7/23/19 9:45AM	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 91684

RCV'D ON ICE

Temperature upon receipt at Lab: 3.6°C

Please see back for terms and conditions

Fibertec
environmental
services

Tuesday, August 06, 2019

Fibertec Project Number:	91802
Project Identification:	31402024.00B /31402024.00B
Submittal Date:	07/29/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

Samples were received at lab at 9.5° Celsius, which exceeds the maximum criteria of 6° Celsius.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 8:49 AM, Aug 06, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-07**	Chain of Custody:	**143569**
Client Project Name:	**31402024.00B**	Sample No:	**1**	Collect Date:	**07/22/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**11:25**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91802-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-07**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	**11**		µg/L	2.6	1.0	07/31/19	PS19G31J	07/31/19	S419G31B	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91802-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-07**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/29/19	W219G29B	CMB

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-33**	Chain of Custody:	**143569**
Client Project Name:	**31402024.00B**	Sample No:	**2**	Collect Date:	**07/22/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**17:50**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91802-002A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-33**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	07/31/19	PS19G31J	07/31/19	S419G31B	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91802-002** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-33**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	NA	NA	07/29/19	W219G29B	CMB

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19G31J: Method Blank (MB)

RSK-175

Run Time: PS19G31J.MB 07/31/2019 13:00 [S419G31B]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19G31J: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD)

RSK-175

Run Time: PS19G31J.LCS: 07/31/2019 13:08 [S419G31B] PS19G31J.LCSD: 07/31/2019 13:15 [S419G31B]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	18.8	20.2	107	80-120		18.8	20.4	108		1	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Tracy Tipton at 4:31 PM, Aug 01, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertec.us

Geoprobe
11766 E. Grand River
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 143569
PAGE 1 of 1

Client Name: WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024.00B
adam.heft@wsp.com
QUOTE# Up North/31402024
Purchase Order#

Lab Sample #	Date	Time	Client Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	PRESERVED (Y/N)	PARAMETERS: Methan	Hydrogen Sulfide
	7/23/19	11:25PM	1	BH19-07	GW	3	Y	X	X
	7/22/19	17:50	2	BH19-33	GW	3	Y	X	X

Turnaround
- [ ] 24 hour RUSH (surcharge applies)
- [ ] 48 hour RUSH (surcharge applies)
- [ ] 72 hour RUSH (surcharge applies)
- [X] Standard (5-7 bus. days)
- [ ] Other: Specify

Matrix Code
S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

- [ ] FES Drilling Services

Deliverables
- [X] Level 2
- [ ] Level 3
- [ ] Level 4
- [ ] EDD

Remarks:
Temp=16.70 Cond=1.878 pH=7.87
Temp=22.25 Cond=0.410 pH=7.77

RCVD BY LAB
JUL 29 2019
Initial: NE

Comments:

	Date/ Time	
Relinquished By: Adam W. Heft	7/29/19 10:50	Received By:
Relinquished By:	Date/ Time	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

LAB USE ONLY:
Fibertec project number: 91802
Laboratory Tracking:
Temperature at Receipt: 9.5°C

COC Revision: February, 2013

TERMS & CONDITIONS ON BACK

Fibertec
environmental
services

Wednesday, August 07, 2019

Fibertec Project Number:	91803
Project Identification:	31402024.00B /31402024.00B
Submittal Date:	07/29/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

Samples received at lab at 9.3° Celsius, which exceeds the maximum critieria of 6 ° Celsius.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

By Rikki Lott at 10:35 AM, Aug 07, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**PW19-12 Initial**	Chain of Custody:	**177119**
Client Project Name:	**31402024.00B**	Sample No:		Collect Date:	**07/24/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**08:05**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Trace Elements by ICP/MS, Total Recoverable **Aliquot ID: 91803-001C** **Matrix: Ground Water**
Method: EPA 3005A (Total Recoverable)/EPA 6020A **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Calcium	**94000**		µg/L	1000	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM
2. Iron	**690**		µg/L	100	10	08/01/19	PT19H01D	08/05/19	T419H05A	SEM
3. Magnesium	**34000**		µg/L	300	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM
4. Potassium	U		µg/L	1000	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM
5. Sodium	**1200**	LLV+	µg/L	1000	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM

pH, Electrometric **Aliquot ID: 91803-001** **Matrix: Ground Water**
Method: EPA 9040C **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. pH	**7.34**	H	pH Units	-1.00	1.0	NA	NA	07/30/19 10:13	WD19G30A	CMB

Specific Conductance at 25°C **Aliquot ID: 91803-001** **Matrix: Ground Water**
Method: EPA 9050A **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Specific Conductance	**580**		µmho/cm	1.0	1.0	NA	NA	07/31/19	WR19G31A	CMB

Inorganic Anions by IC **Aliquot ID: 91803-001** **Matrix: Ground Water**
Method: EPA 9056A **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Chloride	U		µg/L	10000	1.0	07/30/19	PW19G30E	07/30/19	WT19G30A	VO
2. Fluoride	U		µg/L	100	1.0	07/30/19	PW19G30E	07/30/19	WT19G30A	VO
3. Ortho-Phosphate-P	U	H	µg/L	50	1.0	07/30/19 20:57	PW19G30E	07/30/19 20:57	WT19G30A	VO
4. Sulfate	**13000**		µg/L	1000	1.0	07/30/19	PW19G30E	07/30/19	WT19G30A	VO

Sulfide **Aliquot ID: 91803-001A** **Matrix: Ground Water**
Method: HACH 8131 **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Sulfide	U		µg/L	200	1.0	NA	NA	07/31/19	W219G31C	CMB

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**PW19-12 Initial**	Chain of Custody:	**177119**
Client Project Name:	**31402024.00B**	Sample No:		Collect Date:	**07/24/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**08:05**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Iron, Ferrous (Fe2+) **Aliquot ID: 91803-001D** **Matrix: Ground Water**
Method: HACH 8146 **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Iron, Ferrous	U	H	mg/L	0.25	5.0	08/05/19 13:03	PW19H05B	08/05/19 13:34	WF19H05A	AMW

Alkalinity by Titrimetry **Aliquot ID: 91803-001** **Matrix: Ground Water**
Method: SM 2320 B-2011 **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Bicarbonate Alkalinity	**320000**		µg CaCO3/L	20000	1.0	07/30/19	W119G30A	07/30/19	W119G30A	CMB

Residue, Filterable (TDS) **Aliquot ID: 91803-001** **Matrix: Ground Water**
Method: SM 2540 C-2011 **Description: PW19-12 Initial**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Total Dissolved Solids	**350000**		µg/L	50000	1.3	07/31/19	WH19G31A	08/02/19	WH19G31A	CMB

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**PW19-12 Final**	Chain of Custody:	**177119**
Client Project Name:	**31402024.00B**	Sample No:		Collect Date:	**07/26/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**08:07**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Trace Elements by ICP/MS, Total Recoverable **Aliquot ID: 91803-002C** **Matrix: Ground Water**
Method: EPA 3005A (Total Recoverable)/EPA 6020A **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Calcium	**83000**		µg/L	1000	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM
2. Iron	U		µg/L	100	10	08/01/19	PT19H01D	08/05/19	T419H05A	SEM
3. Magnesium	**28000**		µg/L	300	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM
4. Potassium	U		µg/L	1000	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM
5. Sodium	U		µg/L	1000	10	08/01/19	PT19H01D	08/06/19	T419H06A	SEM

pH, Electrometric **Aliquot ID: 91803-002** **Matrix: Ground Water**
Method: EPA 9040C **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. pH	**7.37**	H	pH Units	-1.00	1.0	NA	NA	07/30/19 10:15	WD19G30A	CMB

Specific Conductance at 25°C **Aliquot ID: 91803-002** **Matrix: Ground Water**
Method: EPA 9050A **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Specific Conductance	**580**		µmho/cm	1.0	1.0	NA	NA	07/31/19	WR19G31A	CMB

Inorganic Anions by IC **Aliquot ID: 91803-002** **Matrix: Ground Water**
Method: EPA 9056A **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Chloride	U		µg/L	10000	1.0	07/30/19	PW19G30E	07/30/19	WT19G30A	VO
2. Fluoride	U		µg/L	100	1.0	07/30/19	PW19G30E	07/30/19	WT19G30A	VO
3. Ortho-Phosphate-P	U	H	µg/L	50	1.0	07/30/19 21:17	PW19G30E	07/30/19 21:17	WT19G30A	VO
4. Sulfate	**12000**		µg/L	1000	1.0	07/30/19	PW19G30E	07/30/19	WT19G30A	VO

Sulfide **Aliquot ID: 91803-002A** **Matrix: Ground Water**
Method: HACH 8131 **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Sulfide	U	F-	µg/L	200	1.0	NA	NA	07/31/19	W219G31C	CMB

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**PW19-12 Final**	Chain of Custody:	**177119**
Client Project Name:	**31402024.00B**	Sample No:		Collect Date:	**07/26/19**
Client Project No:	**31402024.00B**	Sample Matrix:	**Ground Water**	Collect Time:	**08:07**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Iron, Ferrous (Fe2+) **Aliquot ID: 91803-002D** **Matrix: Ground Water**
Method: HACH 8146 **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Iron, Ferrous	U	H	mg/L	0.25	5.0	08/05/19 13:03	PW19H05B	08/05/19 13:35	WF19H05A	AMW

Alkalinity by Titrimetry **Aliquot ID: 91803-002** **Matrix: Ground Water**
Method: SM 2320 B-2011 **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Bicarbonate Alkalinity	**310000**		µg CaCO3/L	20000	1.0	07/30/19	W119G30A	07/30/19	W119G30A	CMB

Residue, Filterable (TDS) **Aliquot ID: 91803-002** **Matrix: Ground Water**
Method: SM 2540 C-2011 **Description: PW19-12 Final**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
1. Total Dissolved Solids	**350000**		µg/L	51000	1.3	07/31/19	WH19G31A	08/02/19	WH19G31A	CMB

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

F- : Recovery from the spiked aliquot exceeds the lower control limit (matrix spike or matrix spike duplicate).
H : Hold time exceeded.
LLV : Recovery in the associated low-level continuing calibration verification sample (LLCCV) exceeds the upper control limit. Results may be biased high.

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PT19H01D: Method Blank (MB) — EPA 6020A

Run Time: PT19H01D.MB 08/02/2019 15:56 [T419H02B]

Analyte	MB Result µg/L	MB Qualifier	MB RDL µg/L
Calcium	U		1000
Iron	U		100
Magnesium	U		300
Potassium	U		1000
Sodium	U		1000

PT19H01D: Laboratory Control Sample (LCS) — EPA 6020A

Run Time: PT19H01D.LCS: 08/02/2019 15:58 [T419H02B]

Analyte	LCS Spike Amount µg/L	LCS Result µg/L	LCS Rec. %	Rec. Limits %	LCS Qualifier
Calcium	15000	15600	104	85-115	
Iron	2500	2600	104	85-115	
Magnesium	5000	4940	99	85-115	
Potassium	5000	5070	101	85-115	
Sodium	15000	14100	94	85-115	

PW19G30E: Method Blank (MB)

EPA 9056A

Run Time: PW19G30E.MB 07/30/2019 15:29 [WT19G30A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Chloride	U		10000
Fluoride	U		100
Ortho-Phosphate-P	U		25
Sulfate	U		1000

PW19G30E: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD)

EPA 9056A

Run Time: PW19G30E.LCS: 07/30/2019 19:18 [WT19G30A] PW19G30E.LCSD: 07/30/2019 19:38 [WT19G30A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Chloride	50000	46700	93	90-110		50000	46700	93		0	20	
Fluoride	2500	2630	105	90-110		2500	2740	110		5	20	
Ortho-Phosphate-P	2500	2750	110	90-110		2500	2770	111	*	1	20	
Sulfate	25000	24200	97	90-110		25000	24300	97		0	20	

PW19H05B: Method Blank (MB)

HACH 8146

Run Time: PW19H05B.MB 08/05/2019 13:32 [WF19H05A]

Analyte	MB Result	MB Qualifier	MB RDL
	mg/L		mg/L
Iron, Ferrous	U		0.050

PW19H05B: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD)

HACH 8146

Run Time: PW19H05B.LCS: 08/05/2019 13:33 [WF19H05A] PW19H05B.LCSD: 08/05/2019 13:33 [WF19H05A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	mg/L	mg/L	%	%		mg/L	mg/L	%		%	%	
Iron, Ferrous	1.00	0.920	92	90-110		1.00	0.940	94		2	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Veronica Hutchins at 2:46 PM, Aug 06, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # **177119**
PAGE 1 of 1

Client Name: WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024.003
Email distribution list: adam.heft@wsp.com
Quote# Up North / 31402024
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	pH ✓, TDS ✓	Specific Conductance ✓	Sulfate ✓, Sulfide ✓	Phosphate ✓	Chloride ✓, Fluoride ✓	Bicarbonate ✓	Ca ✓	Fe^{2+}, Fe^{3+},	Mg ✓	Na ✓, K ✓	HOLD SAMPLE
7/24/19	8:05	1	PW19-12 Initial	GW	6	X	X	X	X	X	X	X	X	X	X	
7/26/19	8:07	2	PW19-12 Final	GW	6	X	X	X	X	X	X	X	X	X	X	

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

Deliverables: X Level 2; Level 3; Level 4; EDD

Remarks:

RCVD BY LAB
JUL 29 2019
Initial: NE

Comments:

Sampled/Relinquished By: Adam W. Heft	Date/ Time 7/29/19 10:50	Received By:
Relinquished By:	Date/ Time	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number:

Temperature upon receipt at Lab: 9.3°C 91803

Please see back for terms and conditions

Fibertec
environmental
services

Wednesday, August 14, 2019

Fibertec Project Number:	91962
Project Identification:	31402024.003 /31402024.003
Submittal Date:	08/06/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

By Sharon Rakow at 2:14 PM, Aug 14, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-35**	Chain of Custody:	**175630**
Client Project Name:	**31402024.003**	Sample No:	**1**	Collect Date:	**07/29/19**
Client Project No:	**31402024.003**	Sample Matrix:	**Ground Water**	Collect Time:	**01:00**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 91962-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-35**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	08/12/19	PS19H12G	08/12/19	S419H12A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 91962-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-35**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U	H	mg/L	0.020	1.0	08/07/19	W219H07C	08/07/19	W219H07C	VO

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

H : Hold time exceeded.

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19H12G: Method Blank (MB) — RSK-175

Run Time: PS19H12G.MB 08/12/2019 14:16 [S419H12A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19H12G: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19H12G.LCS: 08/12/2019 14:23 [S419H12A] PS19H12G.LCSD: 08/12/2019 14:39 [S419H12A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	17.5	15.4	88	80-120		17.5	15.4	88		0	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Anthony Donnelly at 4:23 PM, Aug 13, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 175630
PAGE 1 of 1

Client Name: WSP USA
Contact Person: Adam Heft
Project Name/ Number: 31402024.003
Email distribution list: adam.heft@wsp.com
Quote# Up North / 31402024
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	Methane	Hydrogen Sulfide	HOLD SAMPLE
7/29/19	0100	1	BH19-35	GW	3	X	X	

PARAMETERS

Matrix Code

S	Soil	GW	Ground Water
A	Air	SW	Surface Water
O	Oil	WW	Waste Water
P	Wipe	X	Other: Specify

Deliverables
- X Level 2
- Level 3
- Level 4
- EDD

Remarks: Temp = 24.32 Cond = 0.452 pH = 8.04

RCVD BY LAB
AUG 06 2019
Initial: JS

Comments:

	Date/ Time	Received By:
Sampled/Relinquished By:	8.6.19 15:26	Adam W. Heft
Relinquished By: Adam W. Heft	8/6/19 16:50	
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 91962 RCVD ON ICE

Temperature upon receipt at Lab: 3.6°C

Please see back for terms and conditions

Fibertec
environmental
services

Wednesday, September 25, 2019

Fibertec Project Number:	92696
Project Identification:	31401952 /31401952
Submittal Date:	09/18/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 3:24 PM, Sep 25, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-36**	Chain of Custody:	**178483**
Client Project Name:	**31401952**	Sample No:	**1**	Collect Date:	**09/17/19**
Client Project No:	**31401952**	Sample Matrix:	**Ground Water**	Collect Time:	**14:50**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 92696-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-36**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	09/18/19	PS19I18K	09/18/19	S419I18A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 92696-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-36**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	09/18/19	W219I18B	09/18/19	W219I18B	VO

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19I18K: Method Blank (MB) — RSK-175

Run Time: PS19I18K.MB 09/18/2019 14:07 [S419I18A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19I18K: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19I18K.LCS: 09/18/2019 14:15 [S419I18A] PS19I18K.LCSD: 09/18/2019 14:26 [S419I18A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	17.5	15.7	89	80-120		17.5	15.8	90		1	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Tracy Tipton at 3:31 PM, Sep 25, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # **178483**
PAGE 1 of 1

Client Name: WSP
Contact Person: ADAM HEFT, DUNCAN MEIN
Project Name/ Number: 31401952
Email distribution list: adam.heft@wsp.com
duncan.mein@wsp.com
Quote#
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	METHANE (CH_4)	HYD. SULFIDE (H_2S)	HOLD SAMPLE
9/17/19	14:50	1	BH19-36	GW	2	X		
9/17/19	14:50	1	BH19-36	GW	1		X	

Matrix Code			
S	Soil	GW	Ground Water
A	Air	SW	Surface Water
O	Oil	WW	Waste Water
P	Wipe	X	Other: Specify

Deliverables	
	Level 2
	Level 3
	Level 4
	EDD

Remarks:
PARAMETERS AT TIME OF COLLECTION
TEMP = 19.33°C
COND = 0.337
pH = 8.70

RCVD BY LAB
SEP 18 2019
Initial: DG

Comments:

	Date/ Time	
Sampled/Relinquished By: KENNETH HANSON	9/18/19 11:24	Received By:
Relinquished By:	9/18/19 15:23	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY
Fibertec project number: 92696
Temperature upon receipt at Lab: 4.3° RCV'D ON ICE

Please see back for terms and conditions

Fibertec
environmental
services

Wednesday, September 25, 2019

Fibertec Project Number:	92699
Project Identification:	31401952 /31401952
Submittal Date:	09/18/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 2:59 PM, Sep 25, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-24A**	Chain of Custody:	**173644**
Client Project Name:	**31401952**	Sample No:	**1**	Collect Date:	**09/11/19**
Client Project No:	**31401952**	Sample Matrix:	**Ground Water**	Collect Time:	**23:00**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 92699-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-24A**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	09/18/19	PS19I18K	09/18/19	S419I18A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 92699-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-24A**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U	J-	mg/L	0.020	1.0	09/18/19	W219I18B	09/18/19	W219I18B	VO

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

J- : The result is an estimated quantity, but the result may be biased low.

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19I18K: Method Blank (MB) — RSK-175

Run Time: PS19I18K.MB 09/18/2019 14:07 [S419I18A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19I18K: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19I18K.LCS: 09/18/2019 14:15 [S419I18A] PS19I18K.LCSD: 09/18/2019 14:26 [S419I18A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	18.8	15.7	84	80-120		18.8	15.9	84		0	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Tracy Tipton at 3:30 PM, Sep 25, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 173644
PAGE 1 of 1

Client Name: WSP
Contact Person: DUNCAN MEIN, 248.971.3035
Project Name/ Number: 31401952
Email distribution list: adam.heft@wsp.com
duncan.mein@wsp.com
Quote#
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	METHANE (CH4)	HYDROGEN SULFIDE (H2S)	HOLD SAMPLE
9.11.19	23:00	1	BH19-24A	GW	2	X		
↓	↓	1	BH9-24A	GW	1		X	

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

Deliverables: Level 2; Level 3; Level 4; EDD

Remarks:
Quote includes mileage from Holt office - see LAN

RCVD BY LAB
SEP 18 2019
Initial: DG

Comments:

Sampled/Relinquished By: DUNCAN MEIN	Date/ Time 9/18/19 11:24	Received By:
Relinquished By:	Date/ Time 9/18/19 15:23	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 92699

Temperature upon receipt at Lab: 4.3°C

RCV'D ON

Please see back for terms and conditions

Fibertec
environmental
services

Monday, October 07, 2019

Fibertec Project Number:	92861
Project Identification:	31401952 /31401952
Submittal Date:	09/26/2019

Mr. Duncan Mein
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Mein,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

By Rikki Lott at 11:04 AM, Oct 07, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-32**	Chain of Custody:	**166804**
Client Project Name:	**31401952**	Sample No:	**1**	Collect Date:	**09/22/19**
Client Project No:	**31401952**	Sample Matrix:	**Ground Water**	Collect Time:	**05:15**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 92861-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-32**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	10/03/19	PS19J03J	10/03/19	S419J03C	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 92861-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-32**

						Preparation		Analysis		
Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	P. Date	P. Batch	A. Date	A. Batch	Init.
‡ 1. Hydrogen Sulfide	U	F-	mg/L	0.020	1.0	NA	NA	09/27/19	W219I27B	SEM

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

F- : Recovery from the spiked aliquot exceeds the lower control limit (matrix spike or matrix spike duplicate).

Analysis Locations:

All analyses performed in Holt.

Accreditation Number(s):

T104704518-19-8 (TX)

PS19J03J: Method Blank (MB) — RSK-175

Run Time: PS19J03J.MB 10/03/2019 16:23 [S419J03C]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19J03J: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19J03J.LCS: 10/03/2019 16:30 [S419J03C] PS19J03J.LCSD: 10/03/2019 16:38 [S419J03C]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	17.3	19.7	114	80-120		17.3	18.6	108		5	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

By Rikki Lott at 11:11 AM, Oct 07, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # **166804**
PAGE 1 of 1

Client Name: WSP
Contact Person: DUNCAN MEIN (248.971.3035)
Project Name/ Number: 31401952
Email distribution list: duncan.mein@wsp.com
adam.heft@wsp.com
Quote#
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	PARAMETERS: METHANE (CH4)	PARAMETERS: HYD. SULFIDE (H2S)	HOLD SAMPLE
9/22/19	05:15	1	BH19-32	GW	3	2	1	

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

Deliverables: Level 2; Level 3; Level 4; EDD

Remarks:

RCVD BY LAB
SEP 26 2019
Initial:

Comments:

Sampled/Relinquished By: DUNCAN R MEIN — Date/ Time 9/26/19 12:35 — Received By: — 9/26/19 12:35
Relinquished By: — Date/ Time 9/26/19 3:03 — Received By:
Relinquished By: — Date/ Time — Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 92861 RCV'D ON ICE

Temperature upon receipt at Lab: 1.0c

Please see back for terms and conditions

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

COPY

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 166804
PAGE 1 of 1

Client Name: WSP
Contact Person: DUNCAN MEIN (248.971.3035)
Project Name/ Number: 31401952
Email distribution list: duncan.mein@wsp.com
adam.heft@wsp.com
Quote#
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	METHANE (CH4)	HYD. SULFIDE (H2S) *	HOLD SAMPLE
9/22/19	05:15	1	BH19-32	GW	3	2	1	

PARAMETERS

Matrix Code

S	Soil	GW	Ground Water
A	Air	SW	Surface Water
O	Oil	WW	Waste Water
P	Wipe	X	Other: Specify

Deliverables
- Level 2
- Level 3
- Level 4
- EDD

Remarks: FIELD TESTS; pH= 7.86, Temp 20.85C; SpCond 0.394

RCVD BY LAB
SEP 26 2019
Initial: TH

Comments: * WE WILL NEED THE FIELD TESTS (pH, temp, specific conductance) in order to do this analysis correctly.

	Date/ Time	
Sampled/Relinquished By: DUNCAN R MEIN	9/26/19 12:35	Received By: 9/26/19 12:35
Relinquished By:	Date/ Time 9/26/19 3:03	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 9286 RCV'D ON ICE

Temperature upon receipt at Lab: 1.0°C

Please see back for terms and conditions

Fibertec
environmental
services

Thursday, October 31, 2019

Fibertec Project Number:	93332
Project Identification:	31402024 /31402024
Submittal Date:	10/24/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

By Rikki Lott at 2:59 PM, Oct 31, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-25**	Chain of Custody:	**175873**
Client Project Name:	**31402024**	Sample No:	**1**	Collect Date:	**10/17/19**
Client Project No:	**31402024**	Sample Matrix:	**Ground Water**	Collect Time:	**10:30**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 93332-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-25**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	10/24/19	W219J24D	10/24/19	W219J24D	VO

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-28**	Chain of Custody:	**175873**
Client Project Name:	**31402024**	Sample No:	**2**	Collect Date:	**10/22/19**
Client Project No:	**31402024**	Sample Matrix:	**Ground Water**	Collect Time:	**03:30**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 93332-002A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-28**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U	J-	µg/L	2.6	1.0	10/29/19	PS19J29G	10/29/19	S419J29A	RDK

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 93332-002** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-28**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U		mg/L	0.020	1.0	10/24/19	W219J24D	10/24/19	W219J24D	VO

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

J- : The result is an estimated quantity, but the result may be biased low.

Analysis Locations:

All analyses performed in Holt.

Accreditation Number(s):

T104704518-19-8 (TX)

PS19J29G: Method Blank (MB) — RSK-175

Run Time: PS19J29G.MB 10/29/2019 11:18 [S419J29A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19J29G: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19J29G.LCS: 10/29/2019 11:25 [S419J29A] PS19J29G.LCSD: 10/29/2019 11:33 [S419J29A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	17.3	14.1	82	80-120		17.3	14.4	83		1	20	

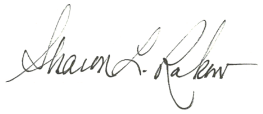
Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:



By Sharon Rakow at 2:57 PM, Nov 14, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertecihs.com

Geoprobe
11766 E. Grand River Rd.
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 175873
PAGE 1 of 1

Client Name: ~~[illegible]~~ WSP
Contact Person: Adam Heft
Project Name/ Number: 31402024
Email distribution list: adam.heft@wsp.com
Quote# Up North / 31402024
Purchase Order#

Date	Time	Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	Methane	Hydrogen Sulfide	HOLD SAMPLE	Remarks:
10/17/19	10:30	1	BH19-25	GW	3	X	X		Temp = 9.49 Cond.= 1.950 pH = 8.86
10/22/19	0330	2	BH19-28	GW	3	X	X		Temp = 12.32 Cond.= 0.243 pH= 7.29

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

Deliverables: X Level 2; Level 3; Level 4; EDD

Received By Lab
OCT 24 2019
Initials: TM

Comments: Methane vials on sample #1 are broken – no sample.

Sampled/Relinquished By:	Date/ Time	Received By:
Adam W. Heft	10/24/19 1134	
Relinquished By:	Date/ Time	Received By:
Relinquished By:	Date/ Time	Received By Laboratory:

Turnaround Time ALL RESULTS WILL BE SENT BY THE END OF THE BUSINESS DAY

_____1 bus. day _____2 bus. days _____3 bus. days _____4 bus. days

X 5-7 bus. days (standard) Other (specify time/date requirement): _____

LAB USE ONLY

Fibertec project number: 93342 RCV'D ON ICE

Temperature upon receipt at Lab: 4.8°C

Please see back for terms and conditions

Fibertec
environmental
services

Wednesday, November 06, 2019

Fibertec Project Number:	93448
Project Identification:	Up North Project (31401952.000) /31401952.000
Submittal Date:	10/30/2019

Mr. Adam Heft
WSP Michigan Inc.
6011 West St. Joe
Suite 400
Lansing, MI 48917-5011

Dear Mr. Heft,

Thank you for selecting Fibertec Environmental Services as your analytical laboratory. The samples you submitted have been analyzed in accordance with NELAC standards and the results compiled in the attached report. Any exceptions to NELAC compliance are noted in the report. These results apply only to those samples submitted. Please note TO-15 samples will be disposed of 7 calendar days after the reporting date. All other samples will be disposed of 30 days after the reporting date.

If you have any questions regarding these results or if we may be of further assistance to you, please contact me at (517) 699-0345.

Sincerely,

Stephanie Wallace

By Stephannie Wallace at 2:40 PM, Nov 06, 2019

For Daryl P. Strandbergh
Laboratory Director

Enclosures

Client Identification:	**WSP Michigan Inc.**	Sample Description:	**BH19-19**	Chain of Custody:	**143575**
Client Project Name:	**Up North Project (31401952.000)**	Sample No:		Collect Date:	**10/27/19**
Client Project No:	**31401952.000**	Sample Matrix:	**Ground Water**	Collect Time:	**16:15**

Sample Comments:

Definitions: Q: Qualifier (see definitions at end of report) NA: Not Applicable ‡: Parameter not included in NELAC Scope of Analysis.

Methane by GC/FID **Aliquot ID: 93448-001A** **Matrix: Ground Water**
Method: RSK-175 **Description: BH19-19**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Methane	U		µg/L	2.6	1.0	11/05/19	PS19K05F	11/05/19	S419K05A	BDA

Hydrogen Sulfide (HACH 8131/Calculation) **Aliquot ID: 93448-001** **Matrix: Ground Water**
Method: SM 4500-S2- H. **Description: BH19-19**

Parameter(s)	Result	Q	Units	Reporting Limit	Dilution	Preparation P. Date	Preparation P. Batch	Analysis A. Date	Analysis A. Batch	Init.
‡ 1. Hydrogen Sulfide	U	J-	mg/L	0.020	1.0	10/31/19	W219J31C	10/31/19	W219J31C	VO

Definitions/ Qualifiers:

A: Spike recovery or precision unusable due to dilution.
B: The analyte was detected in the associated method blank.
E: The analyte was detected at a concentration greater than the calibration range, therefore the result is estimated.
J: The concentration is an estimated value.
M: Modified Method
U: The analyte was not detected at or above the reporting limit.
X: Matrix Interference has resulted in a raised reporting limit or distorted result.
W: Results reported on a wet-weight basis.
***:** Value reported is outside QC limits

Exception Summary:

J- : The result is an estimated quantity, but the result may be biased low.

Analysis Locations:

All analyses performed in Holt.

NELAP ACCREDITED TNI LABORATORY

Accreditation Number(s):

T104704518-19-8 (TX)

PS19K05F: Method Blank (MB) — RSK-175

Run Time: PS19K05F.MB 11/05/2019 09:35 [S419K05A]

Analyte	MB Result	MB Qualifier	MB RDL
	µg/L		µg/L
Methane	U		2.6

PS19K05F: Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) — RSK-175

Run Time: PS19K05F.LCS: 11/05/2019 11:22 [S419K05A] PS19K05F.LCSD: 11/05/2019 12:02 [S419K05A]

Analyte	LCS Spike Amount	LCS Result	LCS Rec.	Rec. Limits	LCS Qualifier	LCSD Spike Amount	LCSD Result	LCSD Rec.	LCSD Qualifier	RPD	RPD Limits	RPD Qualifier
	µg/L	µg/L	%	%		µg/L	µg/L	%		%	%	
Methane	17.3	15.0	87	80-120		17.3	14.7	85		2	20	

Definitions/ Qualifiers:

U: The analyte was not detected at or above the Reporting Limit (RL).
***:** Value reported is outside QC limits

Exception Summary:

Exceptions have been properly noted on reported results or affected samples have been scheduled for reanalysis when appropriate.

Report Generated By:

Stephanie Wallace

By Stephannie Wallace at 2:42 PM, Nov 06, 2019

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertec.us

Geoprobe
11766 E. Grand River
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 143575
PAGE 1 of 1

Client Name: WSP Michigan
Contact Person: Adam Heft
Project Name/ Number: "Up North Project" # 31401952.000
QUOTE#
Purchase Order#

Lab Sample #	Date	Time	Client Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	PRESERVED (Y/N)	PARAMETERS: Methane	PARAMETERS: Hydrogen Sulfide
	10/27/19	16:15		BH19-19	W	3	Y	X	X

Turnaround:
- 24 hour RUSH (surcharge applies)
- 48 hour RUSH (surcharge applies)
- 72 hour RUSH (surcharge applies)
- X Standard (5-7 bus. days)
- Other: Specify

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

☐ FES Drilling Services

Deliverables: ☐ Level 2 ☐ Level 3 ☐ Level 4 ☐ EDD

Remarks: temp: 13.94 cond. 0.242 pH: 7.18

Received By Lab
OCT 30 2019
Initials: TM

Comments:

Relinquished By: Kenneth G. Hanson Jr.	Date/ Time 10:04 10/30/19	Received By: Dan VanGorp
Relinquished By: Dan VanGorp	Date/ Time 10/30/19 12:04	Received By: Russ Scott
Relinquished By:	Date/ Time 10/30/19 4:10	Received By Laboratory:

LAB USE ONLY:
Fibertec project number: 93448
Laboratory Tracking:
Temperature at Receipt: 1.8°C RCV'D ON ICE

COC Revision: February, 2013

TERMS & CONDITIONS ON BACK

Fibertec environmental services

Analytical Laboratory
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0388
email: lab@fibertec.us

8660 S. Mackinaw Trail
Cadillac, MI 49601
Phone: 231 775 8368
Fax: 231 775 8584

COPY

Industrial Hygiene Services, Inc.
1914 Holloway Drive
Holt, MI 48842
Phone: 517 699 0345
Fax: 517 699 0382
email: asbestos@fibertec.us

Geoprobe
11766 E. Grand River
Brighton, MI 48116
Phone: 810 220 3300
Fax: 810 220 3311

Chain of Custody # 143575
PAGE 1 of 1

Client Name: WSP Michigan
Contact Person: Adam Heft
Project Name/ Number: "Up North Project" **
31401952.000
QUOTE#
Purchase Order#

Lab Sample #	Date	Time	Client Sample #	Client Sample Descriptor	MATRIX (SEE RIGHT CORNER FOR CODE)	# OF CONTAINERS	PRESERVED (Y/N)	PARAMETERS: Methane	Hydrogen Sulfide
	10/27/19	16:15		BH19-19	GW	3	Y	X	X

Turnaround: [ ] 24 hour RUSH (surcharge applies) [ ] 48 hour RUSH (surcharge applies) [ ] 72 hour RUSH (surcharge applies) [X] Standard (5-7 bus. days) [ ] Other: Specify

Matrix Code: S Soil; A Air; O Oil; P Wipe; GW Ground Water; SW Surface Water; WW Waste Water; X Other: Specify

[ ] FES Drilling Services

Deliverables: [ ] Level 2 [ ] Level 3 [ ] Level 4 [ ] EDD

Remarks: temp: 13.94 cond. 0.242 pH: 7.18

Received By Lab
OCT 30 2019
Initials: TM

Comments: ** IS THIS THE CORRECT PROJECT NAME to use? Yes ALSO- IS THIS GW matrix? Yes.

Relinquished By: Kenneth G. Hanson Jr	Date/ Time 10:04 10/30/19	Received By: Dan VanGunst
Relinquished By: Dan VanGunst	Date/ Time 10/30/19 12:00	Received By: Russ Scott
Relinquished By: Nicholas Shada	Date/ Time 10/30/19 4:10	Received By Laboratory:

LAB USE ONLY:
Fibertec project number: 93448
Laboratory Tracking:
Temperature at Receipt: 1.8°C RCV'D ON ICE

COC Revision: February, 2013

TERMS & CONDITIONS ON BACK

APPENDIX

F-4 *AQUIFER TEST REPORT*

APPENDIX F-4

AQUIFER TEST REPORT

Figures
F-1 Aquifer Testing Locations
F-2 Uncorrected Background Groundwater Elevations v. Time, Lake Level and Precipitation
F-3 Uncorrected Background Groundwater Elevations v. Time, Lake Level and Barometric Pressure
F-4 Step Drawdown Test Corrected Groundwater Elevation v. Time and Pumping Rate
F-5 Constant Discharge Test Corrected Groundwater Elevation v. Time
F-6 Constant Discharge Test Uncorrected Groundwater Elevation and Manual Reading v. Time

Attachments
Attachment A Displacement vs. Time Curve-fitting plots

AQUIFER TEST REPORT

1.1 GENERAL

As part of the Line 5 Replacement and Tunnel (L5RT) Project geotechnical investigation, a long-term aquifer test was performed near the south terminus of the project near Enbridge's Mackinaw Station in Mackinaw City, MI. Long-term aquifer testing was performed to evaluate the hydraulic conductivity of the rock mass around the L5RT project tunnel's south exit. The long-term aquifer test was performed utilizing existing 2onshore borings, and 3 new piezometers constructed for the test. The results of the long-term aquifer test and subsequent analysis of the aquifer test data is described in detail with conclusions and recommendations that follow.

In the testing area, subsurface geology consists of 3 to 8 feet of silty sand with gravel overburden underlain by the Bois Blanc Formation, a Devonian-aged fossiliferous dolomite with chert. At this location, the Bois Blanc Formation is extremely fractured, and extends to a depth below the L5RT project southern terminus excavation and the testing wells.

The testing program included five locations, four observation wells (PZ19-09 installed in BH19-09, PZ19-40, PZ19-41, and PZ19-42) and one pumping borehole (PW19-12 installed in BH19-12) that were drilled using sonic and/or HQ rock coring described in earlier sections. Aquifer testing consisted of single well (slug) tests, step drawdown testing, and a constant discharge pumping test. Packer testing was conducted in several nearshore and onshore boreholes to supplement the aquifer test data over a broader distance.

1.2 DRILLING ACTIVITIES

Nineteen borings were completed between May and July 2019 as part of the onshore and nearshore investigation for the L5RT Project. Details of the drilling procedures and logging standards for the borings, the boring logs, core photographs, and/or associated testing (borehole geophysics, pressuremeter testing, laboratory testing, packer testing, slug testing, and water quality sampling) are included in the Geotechnical Data Report (GDR).

For the aquifer testing, the overburden portions of PZ19-09 was drilled with sonic methods, and the rock portion was advanced with HQ3 rock coring. PW19-12, PZ19-40, PZ19-41, and PZ19-42, were advanced with sonic drilling to target depths. For PZ19-09, packer testing was performed with a double pneumatic packer system from the bottom of the boring upwards after drilling was completed. Borehole geophysical testing was also performed in PZ19-09 including optical televiewer, acoustic televiewer, pressuremeter testing, downhole seismic survey, caliper, natural gamma, spontaneous potential, instantaneous potential, short (16") and long (64") normal resistivity, temperature, and fluid conductivity.

No in-situ testing was completed for PW19-12, PZ19-40, PZ19-41, or PZ19-42.

1.3 AQUIFER TESTING

This section summarizes the piezometer and pumping well construction, background water-level measurements, single well tests, step drawdown tests, and long term constant discharge testing.

1.3.1 PIEZOMETER LOCATIONS AND CONSTRUCTION

PW19-12 was an uncased open borehole during the aquifer testing, but was subsequently converted into an open-standpipe piezometer after testing was completed. Monitoring of long term water-level measurements are facilitated with a vibrating wire piezometer, along with PZ19-09 as discussed in the following section.

Two piezometers were installed on each side of PW19-12, two to the north towards Lake Michigan (PZ19-09 and PZ19-42) and two to the east (PZ19-41 and PZ19-40) as shown in Figure F-1. The piezometers were constructed with 2-inch-diameter Schedule 40 PVC with a 10 foot, 0.010 inch slotted screen. The filter was constructed with Number 1 sand, and

length of filter pack ranged in length from 20-98 feet bgs. Piezometer location information and well construction details are presented in Table F-4.1 and F-4.2, respectively. Level Troll 700 vibrating wire transducers were placed in the wells and open borehole to record water levels at elevations presented in Table F-4.1.

Table F-4.1: Observation and Pumping Well Location Details

WELL NAME	TOP OF CASING ELEVATION (FT.)	SENSOR ELEVATION (FT. MSL)	NORTHING	EASTING	DISTANCE FROM PUMPING WELL (FT.)
PZ19-09	619.24	531.49	901031.87	19580336.04	205.8
PW19-12	652.10	517.20	900827.53	19580360.52	0
PZ19-40	652.20	557.40	900779.42	19580500.60	148.1
PZ19-41	652.33	553.53	900794.30	19580441.99	88.0
PZ19-42	621.40	571.50	900944.44	19580317.74	124.5

Vibrating wire piezometers were installed in PZ19-09 and PW19-12 after aquifer testing was completed to monitor long-term water levels in the area. We understand that downloading of water level data is to be undertaken by Enbridge representatives at the site.

All piezometer borings were completed with an 8-inch, flush mounted surface casing.

Table F-4.2: Observation and Pumping Well Construction Details

WELL NAME	TOP OF SCREEN DEPTH (FT. BELOW TOC)	TOP OF SCREEN ELEVATION (FT. MSL)	BOTTOM OF SCREEN DEPTH (FT. BELOW TOC)	BOTTOM OF SCREEN ELEVATION (FT. MSL)	TOP OF FILTER PACK DEPTH (FT. BELOW TOC)	TOP OF FILTER PACK ELEVATION (FT. MSL)	BOTTOM OF FILTER PACK DEPTH (FT. BELOW TOC)	BOTTOM OF FILTER PACK ELEVATION (FT. MSL)
BH19-09 / PZ19-09	85.0	534.24	95.0	524.24	33.0	586.24	104	515.24
PZ19-40	85.0	522.10	95.0	512.10	50.0	602.10	95.0	512.10
BH19-12 / PW19-12	NA	NA	NA	NA	NA	NA	NA	NA
PZ19-41	85.0	567.33	95.0	557.33	50.0	602.33	95.0	557.33
PZ19-42	40.0	581.40	50.0	571.40	30.0	591.40	50.0	571.40

NA: PW19-12 was an open borehole during the aquifer testing program.

1.3.2 PIEZOMETER DEVELOPMENT

The piezometers were developed to clean the screen of any drilling debris, and to develop hydraulic connection between native subsurface materials and piezometers. This was completed by bailing water from the well until the water was clear, colorless and free from debris. Subsequent to well development, approximately six days passed for the water levels to recover and stabilize before conducting any water-level measurements.

1.3.3 BACKGROUND WATER LEVEL MEASUREMENTS

To evaluate and correct for regional changes in groundwater elevation not related to aquifer test pumping, background water levels were measured for 19 days, from July 3rd to July 22nd, 2019, in all wells and/or open boreholes before step drawdown tests were conducted. The vibrating wire piezometers recorded head of water in psi every 10 minutes. The background levels were compared to water level in Lake Michigan, local precipitation, and changes in barometric pressure during this interval. Figure F-2 presents the background water levels with lake level for Lake Michigan – Lake Huron and precipitation, and

Figure F-3 shows the same background data and lake level with barometric pressure. A consistent, slight decrease in water level was recorded in every well.

Overall, the background measurements do not indicate that lake level, precipitation, or barometric pressure have a significant effect on the observed water levels. While some water level records suggested barometric influence, efforts to calculate barometric efficiency from the data set did not provide a consistent correction factor for each well and given the small magnitude of these fluctuations barometric corrections were not applied to the data set analyzed. Precipitation occurred in brief, intense summer storms, with the largest on July 11th with 0.91 inches of rain recorded in a 24-hour period. This rainfall does not appear to influence the background water-level measurements. Smaller rain events occurred on July 16th (0.33 in) and July 21 (0.27 in) were also not apparent in the background water-level data.

The data recorded from PW19-12 and PZ19-40 over this time shows daily undulations up and down by ~0.25 feet that was not observed in other piezometer records. The cause of these undulations has not been determined.

The average barometric efficiency was calculated for each well using the barometric pressure and observed water levels.

As shown in Figure F-2, water levels in the site piezometers showed a consistent decline during the background monitoring period. The rate of change in individual well water levels was recorded and applied to data from both the step-drawdown and aquifer test data prior to analysis in AQTESOLV. Because the regional water levels were in decline, the incremental decline between water level measurements was added to the observed response to correct the data for this regional declining trend.

1.3.4 STEP-DRAWDOWN TEST

SUMMARY

Step-drawdown testing was conducted in PW19-12 to evaluate the preferred pumping discharge rate for the constant discharge aquifer test. Subjecting the aquifer to several pumping rates, or steps, is done to observe the degree of drawdown associated with each rate of pumping. Different pumping rate steps were sustained for 5 to 48 minutes while water levels were measured. These periods varied in response to the magnitude of water level changes observed during the pumping period.

The pumped water was discharged via a 1-inch PVC pipe to a location approximately 250 feet east of PW19-12 and 100 feet east of PZ19-40, to the driveway of a house (Figure F-1). The water levels were allowed to completely recover prior to beginning the constant discharge aquifer test.

To conduct the step-drawdown test, a submersible Grundfos 22 SQE pump was installed in PW19-12 at 137 feet below top of casing. The well was pumped at 2.5 GPM (13:04 to 13:13), 4.2 GPM (13:18 to 13:37), 10.6 GPM (13:37 to 13:52), 26.5 GPM (13:52 to 14:08), 23.5 GPM (14:08 to 14:13), and 20.3 GPM (14:13 to 15:01). At 13:13, the pumping rate was mistakenly increased to approximately 8 GPM momentarily. Pumping was immediately stopped, and water levels recovered before resuming pumping at 4.2 GPM at 13:18. At 15:01, the pumping increased to an unknown rate, estimated to be ~23 GPM, after the drillers shifted the discharge line to refill the water tank on the rig.

Resultant water levels in the piezometers PZ19-09, PZ19-40, PZ19-41, and PZ19-42 and the open borehole PW19-12 were recorded, corrected for regional trends, and are presented in Figure F-4.

Based on the results of the step-drawdown test a long-term pumping rate of approximately 20 GPM was selected for the constant discharge test.

1.3.5 CONSTANT DISCHARGE PUMPING TEST

SUMMARY

After water levels in the piezometers had recovered from the step-drawdown test (approximately 17 hours), constant discharge testing was performed. The constant discharge test was completed between 7/24/2019 at 8:05 AM and 7/26/2019 at 8:26 AM in general accordance with ASTM D5786. The intake for the pump was positioned at a depth of 137 feet bgs in

APPENDIX F-4

PW19-12, and the target pumping rate was 20.5 GPM. During the test, the flow rate decreased to 19.7 GPM by 7/25/2019 at 1:15 AM. Temperature, specific conductance, pH, and oxidation-reduction potential were measured from the discharge water from PW19-12 every hour during the constant discharge pumping test using a YSI 556 MPS Meter instrument.

During the aquifer test, pressure transducers recorded temperature and head of water (in psi) in PW19-12 and the observation wells PZ19-09, PZ19-40, PZ19-41, and PZ19-42 every 30 seconds (Figure F-5). Confirmation water levels were manually measured every four hours to confirm the vibrating wire transducer data. Such manual water levels agreed with the trends observed in the vibrating wire transducer data over the course of the test (Figure F-6). Water-level recovery data was recorded from 7/26/2019 at 8:26 AM through 2:35 PM (7 hours and 9 minutes).

Drawdown observed in pumping well PW19-12 was approximately 39 feet. Drawdown in observation wells were generally less than 1 foot. The degree of drawdown in the pumping well is judged to provide adequate stress to the aquifer during the test. While the drawdown observed in the observation wells was generally small, the drawdown vs. time plots presented in Attachment A show that the curves generally conform to typical shapes expected during aquifer testing. Further discussion of the drawdown response is presented below in the Results section.

Water quality results are presented in the Table F-3.1 YSI 556 MPS Meter Reading Summary, included as part of this GDR. Water quality samples were collected prior to and at the completion of the aquifer testing program from PW19-12 for laboratory analysis. Review of these results indicate that water quality parameters changed slightly but were primarily consistent throughout the constant discharge aquifer test.

ANALYSIS METHODS

Data acquired from on-site dataloggers was downloaded and compiled for the project area. During the constant discharge test, the flow rate dropped slightly to 19.5 GPM, but returned to 20.3 GPM, therefore 20.3 GPM was used for the analysis of pumping and resultant water level data. Using the pre-test background water level measurements, the water level data was corrected for a long-term, regional declining trend resulting in water level elevation that would have over-represented actual drawdown during the test. The corrected values were used in the aquifer test analysis discussed in the following sections.

The constant discharge pumping test was analyzed using the software program, AQTESOLV (version 4.5.1). Corrected water level observations, aquifer characteristics, pumping rate, and well construction details are imported into the program. The program facilitated curve matching for different analytical solutions based on data input and conceptual hydrogeologic model to develop estimates of the transmissivity of the pumped aquifer. Several solutions are available in the program and are based on published aquifer test analysis protocols.

Based on stratigraphic, geologic, and water level information obtained from the site investigation, groundwater flow at the site is assumed to occur under unconfined conditions. This observation guides the selection of appropriate analytical solutions to use in analyzing the constant-discharge test data.

Three aquifer analysis solutions were used in the analysis of the data:

- Theis (1935) for an unconfined aquifer
- Neuman (1974) for an unconfined aquifer
- Moench (1997) for an unconfined aquifer

All three of these solutions were developed for an infinite porous medium. These solutions are typically used for alluvial aquifers, but are also applicable to fractured rock aquifers where the fractures are abundant and connected enough to behave as an essentially uniform porous medium, such as the fractured dolomite in the southern terminus area of the L5RT project.

The solutions are analytical options within AQTESOLV, Theis (1935) is a common solution developed for unsteady flow for pumping and recovery in an infinite aquifer. The solution was originally developed for a confined aquifer, but can applied to unconfined aquifer drawdown, as presented in this report. Neuman (1974) and Moench (1997) were developed similarly to Theis (1935), but include well bore storage effects into the solution. Because well bore storage effects are typically

significant when the pumping rate is low and the diameter of the whole is large, well bore storage may not have a significant effect on the results of the aquifer test.

During the analysis, the anisotropy ratio (vertical to horizontal hydraulic conductivity) was taken as 1. This is reasonable since the solutions used assume primarily horizontal flow in the aquifer, so anisotropy would not affect the analysis.

RESULTS

The results from curve matching the pumping and recovery data are presented in the Table below. Time-drawdown curve matches used to prepare the data table below are presented in Attachment A of this report.

For the observation wells, transmissivity values varied considerably between different solutions, and ranged from 0.12 in PZ19-42 (Moench) to 2.75 in PZ19-40 (Theis). For the pumping well PW19-12, transmissivity ranged from 0.034 (Moench) to 0.044 (Theis). Storage coefficients were generally in the 10^{-3} and 10^{-4} range; however the values for the pumping well ranged widely from 0.001 to 0.301. Results from analysis of the pumping well are likely not representative of the actual formation conditions. The variable nature of both the transmissivity values and storage coefficient values indicates that flow conditions in the open borehole are likely not uniform and laminar, as many of the analytical solutions assume. Therefore, results from analysis of the pumping well drawdown should not be used for estimating hydraulic conductivity.

Table F-4.3: Summary of Constant Discharge Test Results

WELL NAME	THEIS (1935)		NEUMAN (1974)		MOENCH (1997)	
	T	S	T	S	T	S
PW19-12	0.04	0.26	0.04	0.30	0.03	6.14E-04
PZ19-09	1.59	2.70E-04	0.73	2.89E-4	0.72	2.21E-04
PZ19-40	2.85	1.81E-03	1.34	1.35E-03	1.29	1.13E-03
PZ19-41	2.02	5.09E-04	0.45	4.21E-04	0.48	3.46E-04
PZ19-42	1.37	3.76E-03	0.24	2.03E-03	0.11	9.19E-04

T: Transmissivity (ft^2/min)
S: Storativity (unitless)

In addition to the curve-fitting exercise, review of the drawdown vs. time plots suggest that sources of recharge were noticed during the test. This observation is evident in two different sections of the drawdown curves. First between times 10 and 1000 minutes during the test, the drawdown curve is more linear than typical analytical solutions, suggesting that some additional source of recharge was suppressing the expected curvature. This effect does not appear to be particularly significant, and may result from either a change in the regional groundwater conditions from the general decline observed during the background monitoring period, or recharge from an alternate source, possibly the nearby lake. The second evidence of recharge is noticed most clearly in the record from PZ19-40 beyond 500 minutes into the test. This record shows a significant reduction in drawdown while pumping was sustained suggesting a local source of recharge. A similar but much less dramatic drawdown decline was observed after this same time in the record for PZ19-41, and to an even lesser extent in PZ19-42 and PZ19-09. Considering the geometry of the wells relative to the discharge location for pumping, this decline in drawdown appears consistent with local recharge from the discharge line that recharged water levels during the latter part of the aquifer test.

1.4 DISCUSSION

The following sections discusses the results from AQTESOLV analysis and compares packer test data from nearby borings.

APPENDIX F-4

1.4.1 AQTESOLV ANALYSIS RESULTS

As part of the overall tunnel groundwater inflow assessment for the L5RT project, long-term constant discharge aquifer tests were performed at the planned location of the tunnel's south terminus. No aquifer testing was performed at the planned location of the north terminus due to access and permitting issues. Because the geology differs in rock type and structural character, the analysis presented herein does not apply to the aquifer properties or tunnel inflow for construction of the north terminus.

A hydraulic conductivity value can be calculated based on the results of the aquifer testing. The aquifer test analysis involves the following assumptions that were used to approximate the hydraulic conductivity of the rock mass:

- The aquifer has infinite areal extent
- The aquifer is homogeneous and of uniform thickness
- Flow to the pumping well is horizontal during pumping
- The aquifer is unconfined, and
- Water is released instantaneously from storage with a decline in hydraulic head (i.e., well bore storage has no effect on the drawdown)

The Theis and Neuman solutions further assumes that the diameter of the pumping well is small enough such that storage in the well can be ignored.

As discussed above, the results obtained from drawdown in the pumping well are not considered reliable due to the open borehole configuration and substantial amount of drawdown that likely induced non-laminar flow conditions. Drawdown observations during the test suggest influence of recharge from at least two different sources during the test. Considering the apparent impacts from the discharge line location, the results from PZ19-40 appear to be compromised during late times and thus the higher transmissivity values from the curve matching at this location probably overestimate the actual transmissivity and should not be relied upon. The other piezometers at greater distance from the discharge point were much less impacted by this factor and the curve matching was performed to ignore the late decline in drawdown. These data likely represent the actual formation transmissivity better than the other data. Using the average transmissivity from these three piezometers and the different analytical solutions yields an average transmissivity value of 0.85 ft^2/min. Dividing this value by the aquifer thickness used in the analysis of 68 feet yields an average hydraulic conductivity value of 0.016 ft/min (or 8.22E-03 cm/sec).

1.4.2 COMPARISON WITH PACKER TEST RESULTS

Packer test results from one well within the aquifer test program, BH19-09/PZ19-09, were compared to the long-term constant-rate discharge test results. This allows for direct comparison of the individual packer test values that overlap with the screen and/or filter zones that responded during the aquifer test program. Comparison of packer test and aquifer test results for that specific well are not able to be directly correlated because the packer test represents conditions while injecting water into discreet, ~10-foot-long zones, whereas the aquifer test results were derived from a much larger scale drainage of the entire rock mass in the test vicinity.

Of the observation piezometers used during the aquifer testing, one of those holes, BH19-09, was also evaluated using packer testing. BH19-09 test 1 (el. 525.2–537.4 feet), overlapped with the screen and filter pack of BH19-09/PZ19-09. Two additional tests in that boring, test 2 (el. 537.4 – 549.5 feet) and test 3 (el. 549.5 – 561.7 feet), overlapped with the filter pack. The average hydraulic conductivities for each test step are summarized in Table F-4.4. The results show a maximum

hydraulic conductivity of 2.3E-03 cm/sec, a minimum of 8.6E-05 cm/sec, a median of 4.6E-04 cm/sec, and an average of 7.9E-04 cm/sec.

Compared to the hydraulic conductivity measured from the aquifer test, packer test results indicate a variety of values within the aquifer test horizon ranging multiple magnitudes. Individual values within the boring indicate that different sections of the rock mass responded differently to the packer testing.

Because the long-term aquifer test assumes a homogeneous and infinite aquifer extent as a fundamental assumption to the analysis, it is reasonable that the long-term aquifer analysis will be dominated by the most permeable zones encountered by the filter and/or screen intervals. In addition to the difference between pumping water into the medium during packer tests and withdrawing it in aquifer testing, comparing the results from these tests should also recognize the geometric differences. The filter pack interval for the observation well (approximately 62 feet-long for PZ19-09) intersected more rock than the length of that boring subjected to packer testing. Given the variety of hydraulic conductivity values yielded by the packer testing intervals, the response during aquifer testing over the long filter pack will be dominated by the most conductive zones. Therefore, the comparison of the maximum hydraulic conductivities from BH19-09 packer test results against the aquifer test value provide the most reasonable comparison for the data that we have. The maximum hydraulic conductivity was measured in step 4 of packer test 3 (el. 549.5 – 561.7 feet; BH19-09 3-4) to be 2.3E-03, whereas the aquifer test measured a hydraulic conductivity of 8.22E-03 cm/sec, about four times higher. In addition to being dominated by the most hydraulically conductive zones, it should be noted that additional rock was either not tested or areas where tests were attempted, but compromised by poor packer seals suggests highly fractured rock, other zones of high conductivity material may be present that influenced the aquifer test results.

In the packer test, water is pumped into the rock mass. Alternatively, in the aquifer test, water is pumped out of the rock mass, reflecting a similar type of 'draining' event that may occur during excavation at the south terminus. For this reason, aquifer testing is thought to provide a more appropriate evaluation of the hydrology of the rock mass tested at the south terminus.

Table F-4.4: Summary of BH19-09 Packer Test Results

TEST STEP ID	TOP ELEVATION (FT. MSL)	BOTTOM ELEVATION (FT. MSL)	AVERAGE HYDRAULIC CONDUCTIVITY (CM/SECOND)
BH19-09 1-1	525.2	537.4	1.2E-04
BH19-09 1-2	525.2	537.4	1.1E-04
BH19-09 1-3	525.2	537.4	1.0E-04
BH19-09 1-4	525.2	537.4	9.6E-05
BH19-09 1-5	525.2	537.4	8.6E-05
BH19-09 2-1	537.4	549.5	4.8E-04
BH19-09 2-2	537.4	549.5	4.6E-04
BH19-09 2-3	537.4	549.5	4.6E-04
BH19-09 2-4	537.4	549.5	4.5E-04
BH19-09 2-5	537.4	549.5	4.6E-04
BH19-09 3-1	549.5	561.7	1.9E-03
BH19-09 3-2	549.5	561.7	2.1E-03
BH19-09 3-3	549.5	561.7	1.9E-03
BH19-09 3-4	549.5	561.7	2.3E-03

APPENDIX F-4

1.5 CONCLUSIONS

The aquifer testing program utilized one pumping rock borehole and four piezometers at various distances and directions from the pumping well. Overall, the pumping well produced adequate drawdown to stress the local aquifer and produce significant drawdown in the piezometer locations. Drawdown data from the constant-rate discharge test was used to estimate the transmissivity and storage coefficients for the bedrock near the south terminus of the Line 5 Replacement and Tunnel. The transmissivity data was used to estimate the hydraulic conductivity of the rock mass in the area where the test was conducted. A limited comparison of aquifer test results with packer test data indicates the packer testing generally underestimated the hydraulic conductivity of the terminus area by a factor of four or more.

Similar to the condition imposed by the aquifer testing, groundwater inflow during tunnel construction will also drain water from the surrounding rock. To take advantage of packer test data collected during the investigations, the findings from the aquifer test should be applied to the packer testing results from boreholes associated with piezometers in this study. Specifically, the fractured rock mass will result in the zones of highest hydraulic conductivity dominating the drainage of the rock mass for dewatering. Comparing the aquifer pumping test results to the packer testing results, the hydraulic conductivity resulting from the aquifer pumping test is 3 to 5 times higher than expected based on the maximum packer test results. These data should inform the design values of hydraulic conductivity to be used to estimate dewatering requirements and tunnel inflow estimates for the southern portion of the L5RT project tunnel and the south terminus excavation.

Figure F-1: Aquifer Testing Locations

Figure F-2: Uncorrected Background Groundwater Elevations v. Time , Lake Level, and Precipitation

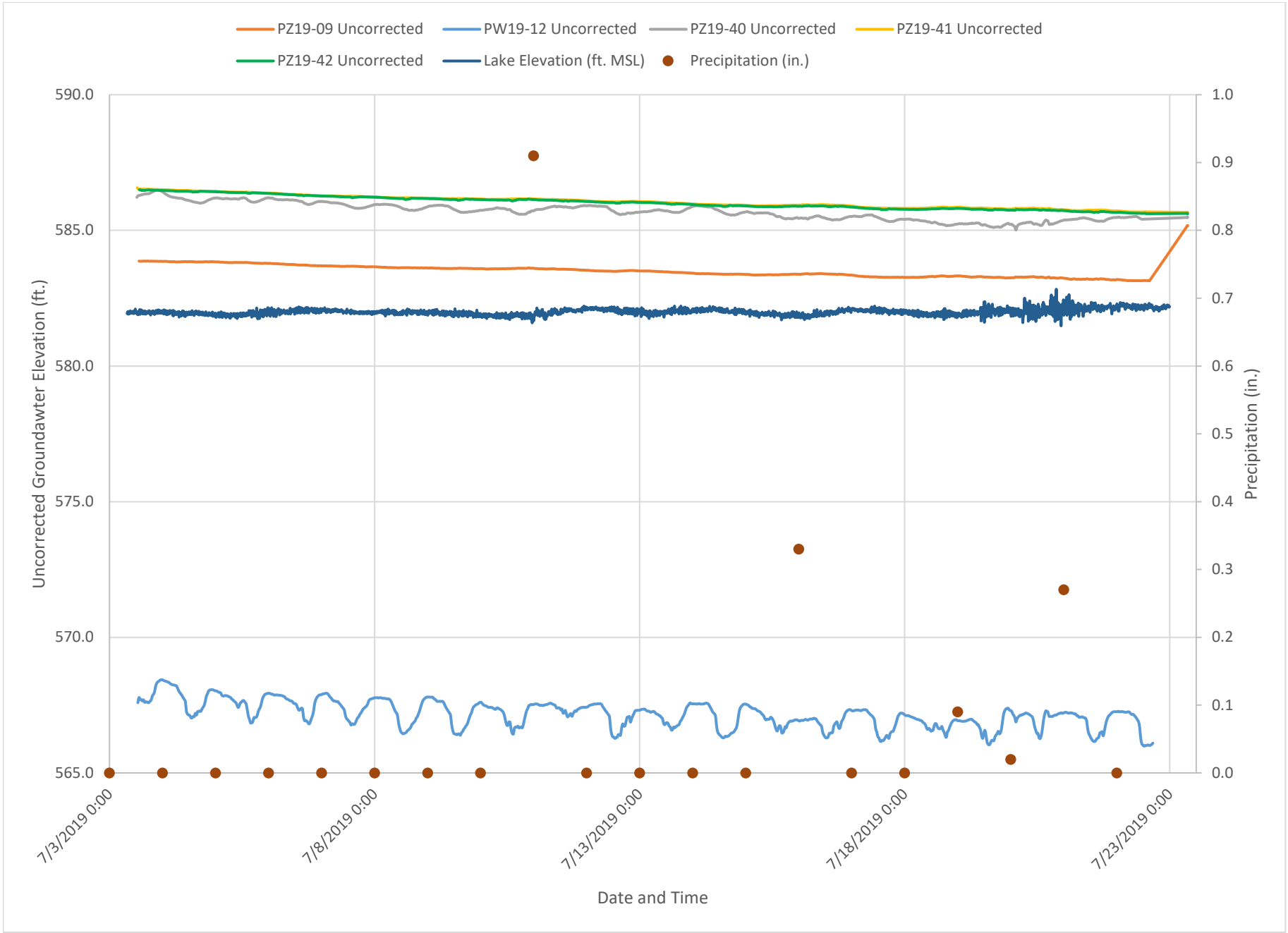


Figure F-3: Uncorrected Background Groundwater Elevations v. Time , Lake Level, and Barometric Pressure

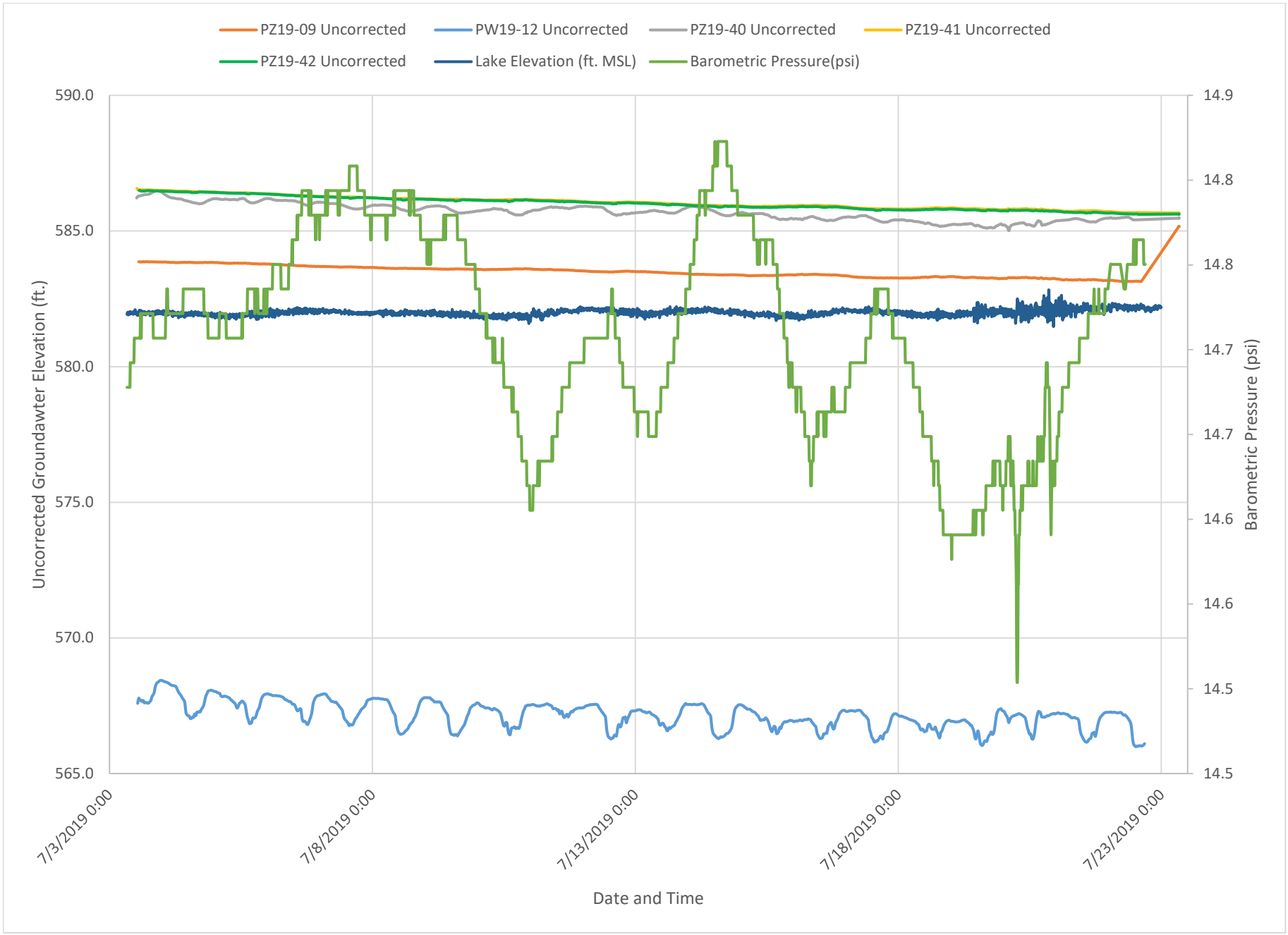


Figure F-4: Step-Drawdown Test Corrected Groundwater Elevation v. Time

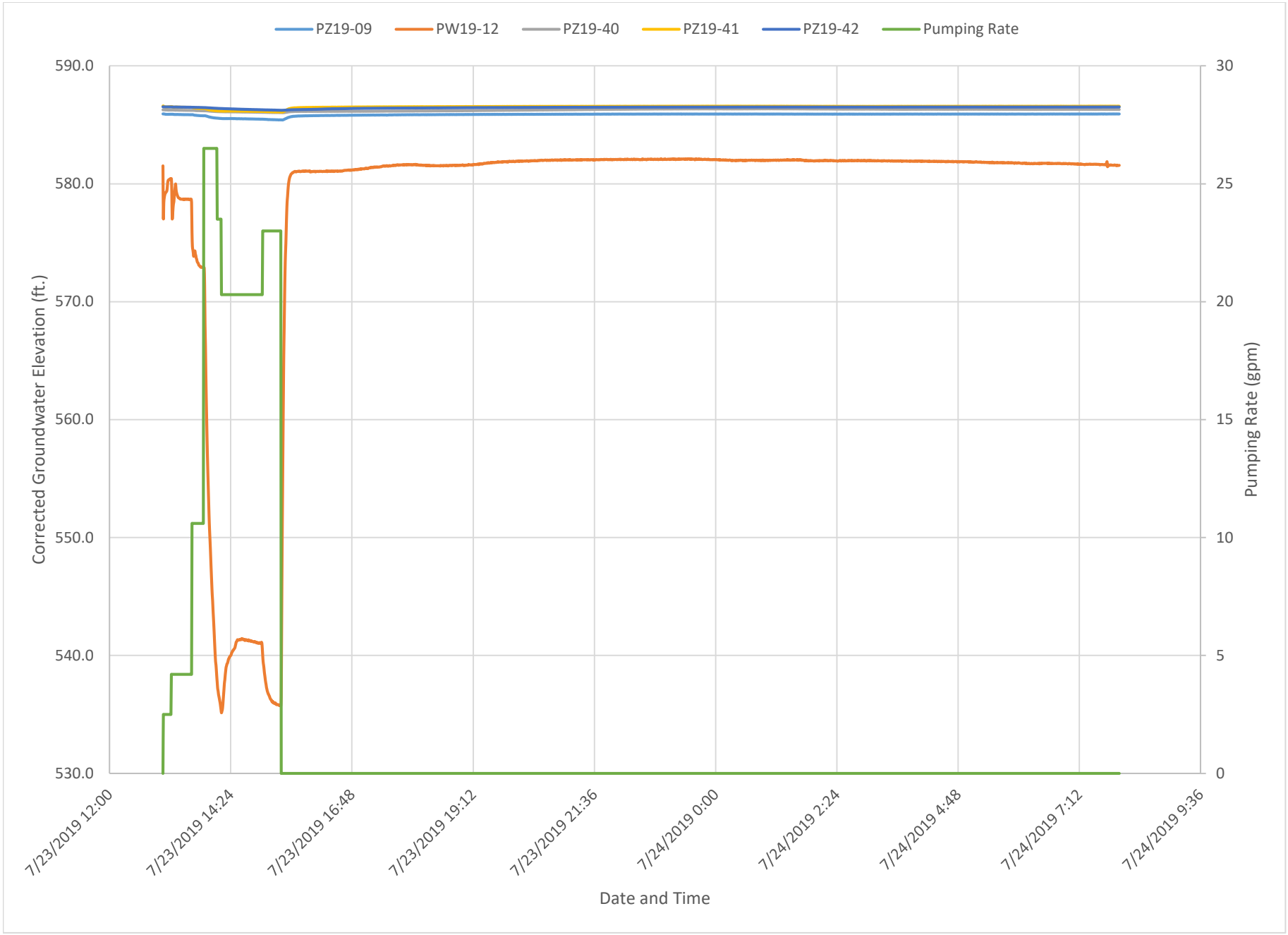


Figure F-5: Constant Discharge Test Corrected Groundwater Elevation v. Time

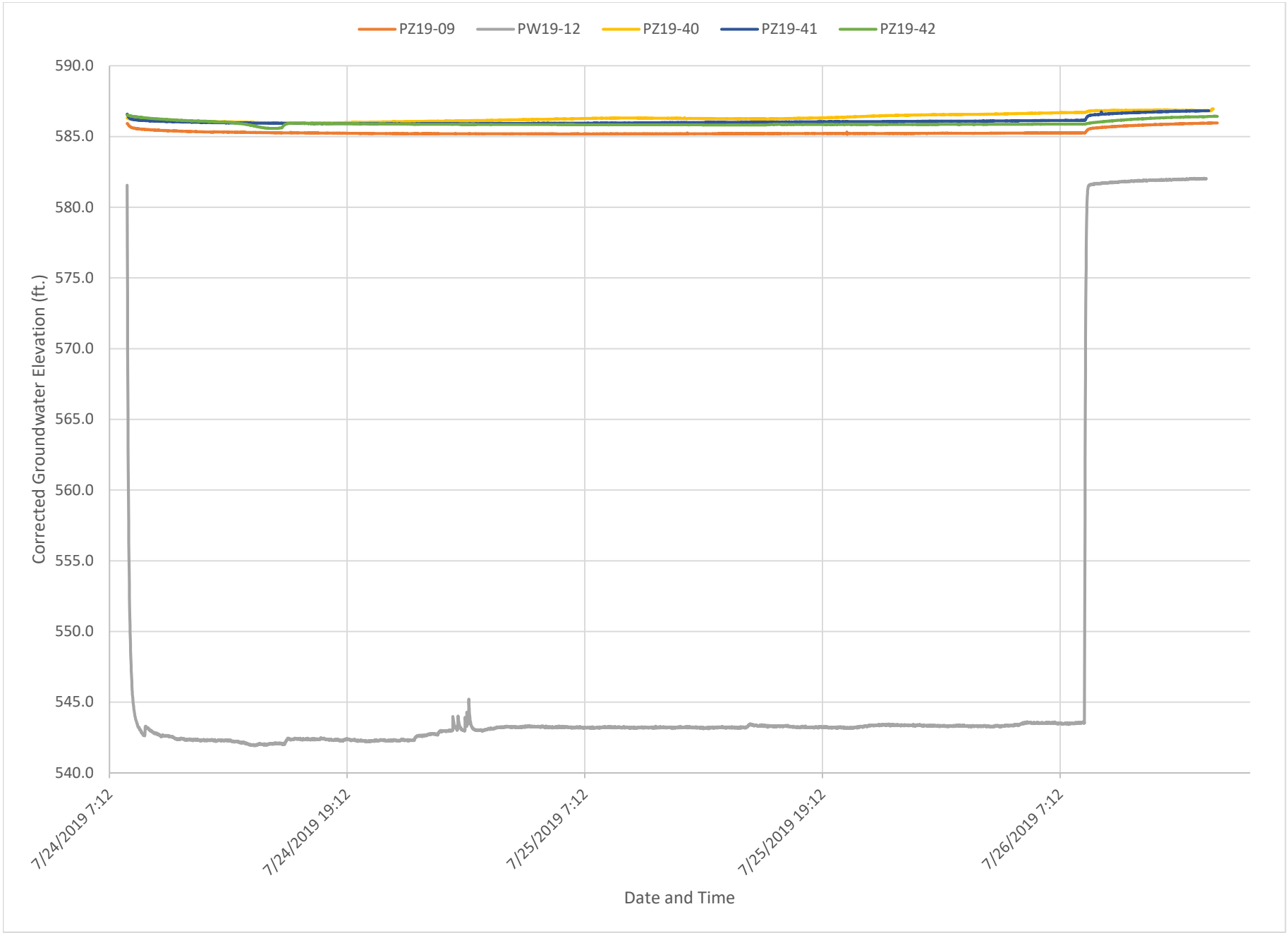
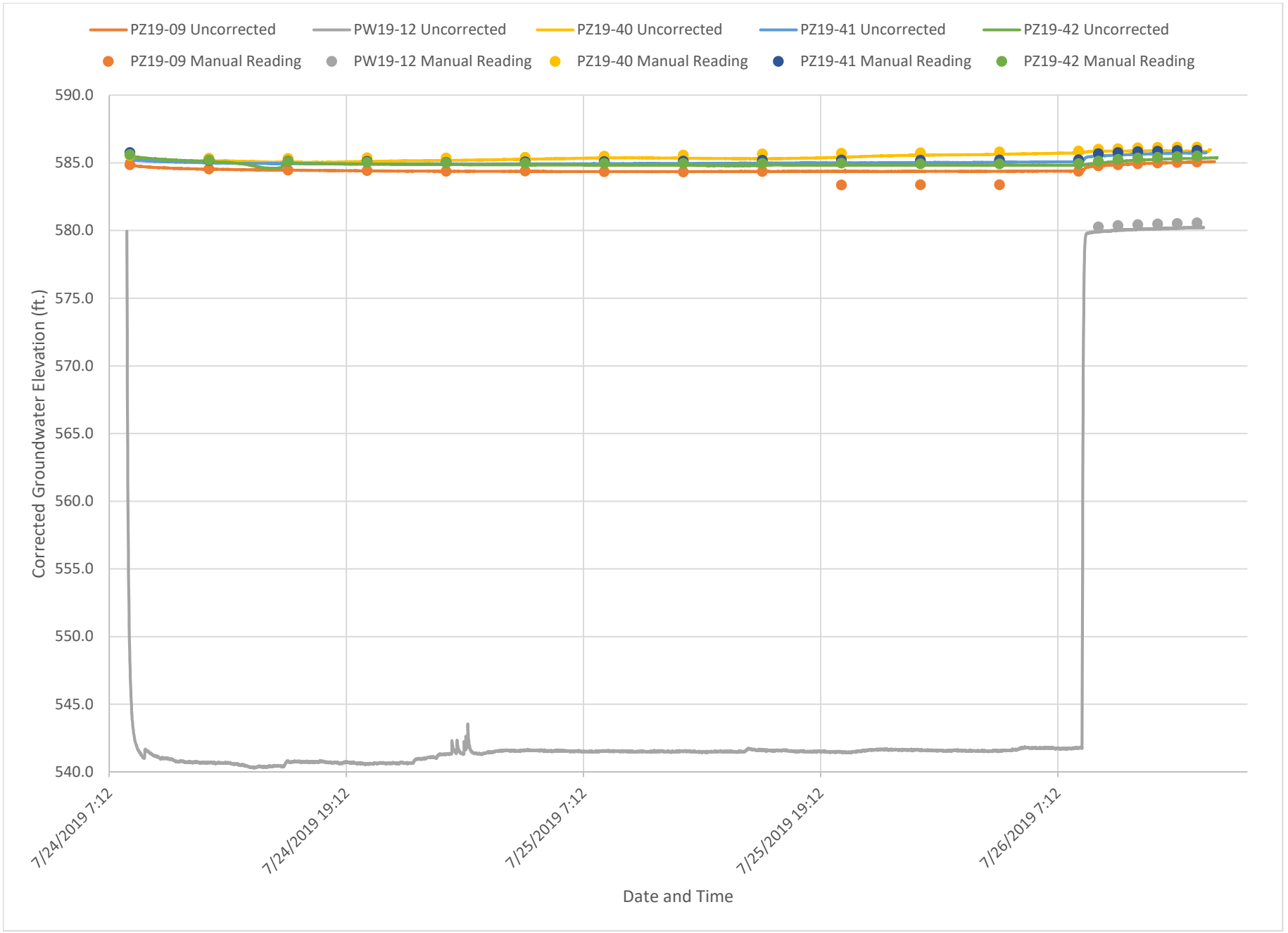
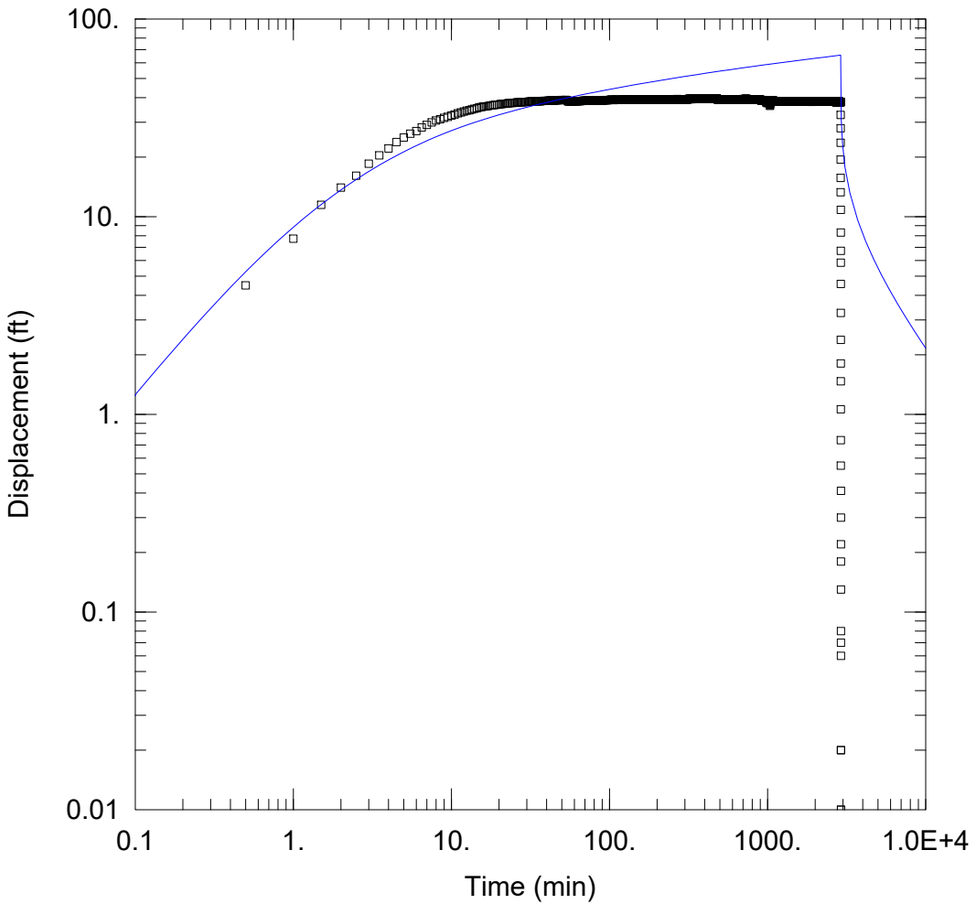


Figure F-6: Constant Discharge Test Uncorrected Groundwater Elevation and Manual Reading v. Time





WELL TEST ANALYSIS

Data Set: Q:\...\PW-12 Moench.aqt
Date: 11/27/19 Time: 13:11:10

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft Anisotropy Ratio (Kz/Kr): 7000.9

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

Observation Wells

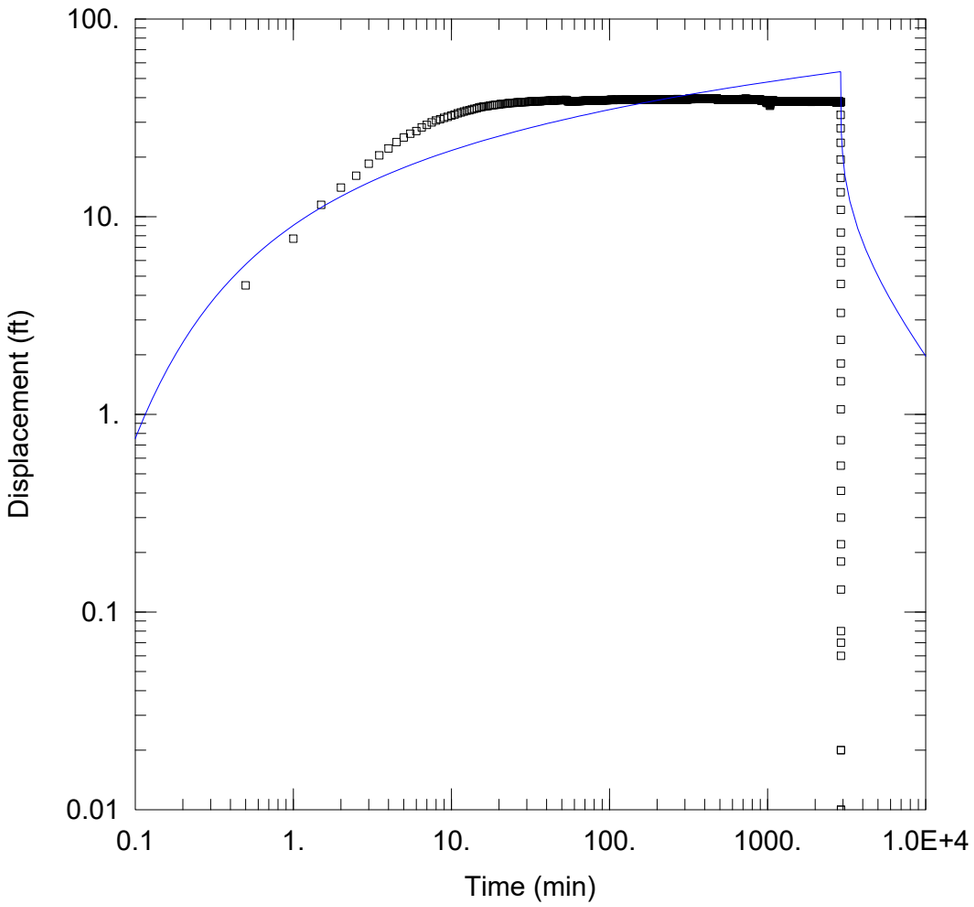
Well Name	X (ft)	Y (ft)
▫ PW-12	19580360.52	900827.53

SOLUTION

Aquifer Model: Unconfined Solution Method: Moench

T = 0.03431 ft^2/min
Sy = 0.1
Sw = 0.
r(c) = 0.257 ft

S = 0.0006141
ß = 0.1
r(w) = 0.257 ft
alpha = 1.0E+30 min^{-1}



WELL TEST ANALYSIS

Data Set: Q:\...\PW-12 NeumanRev1.aqt
Date: 11/27/19 Time: 13:12:49

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

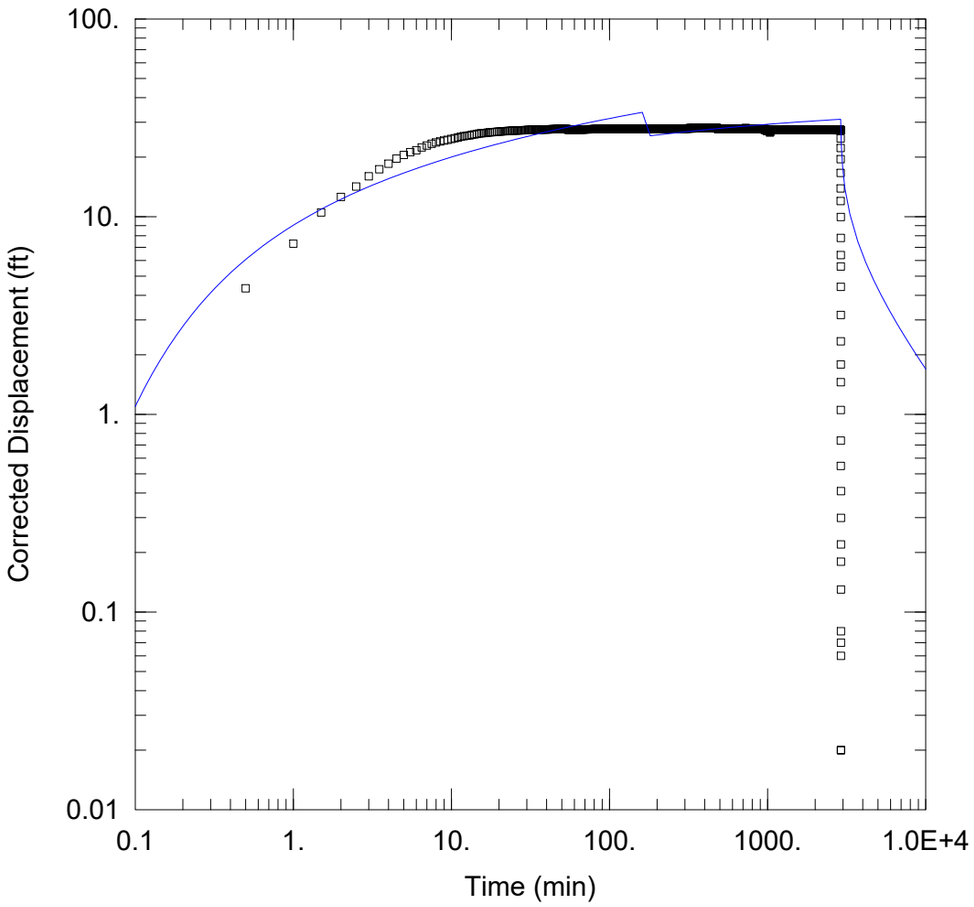
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PW-12	19580360.52	900827.53

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 0.03758 ft^2/min
S = 0.3005
Sy = 0.001
ß = 1.



WELL TEST ANALYSIS

Data Set: Q:\...\PW-12 TheisRev1.aqt
Date: 11/27/19 Time: 13:12:02

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

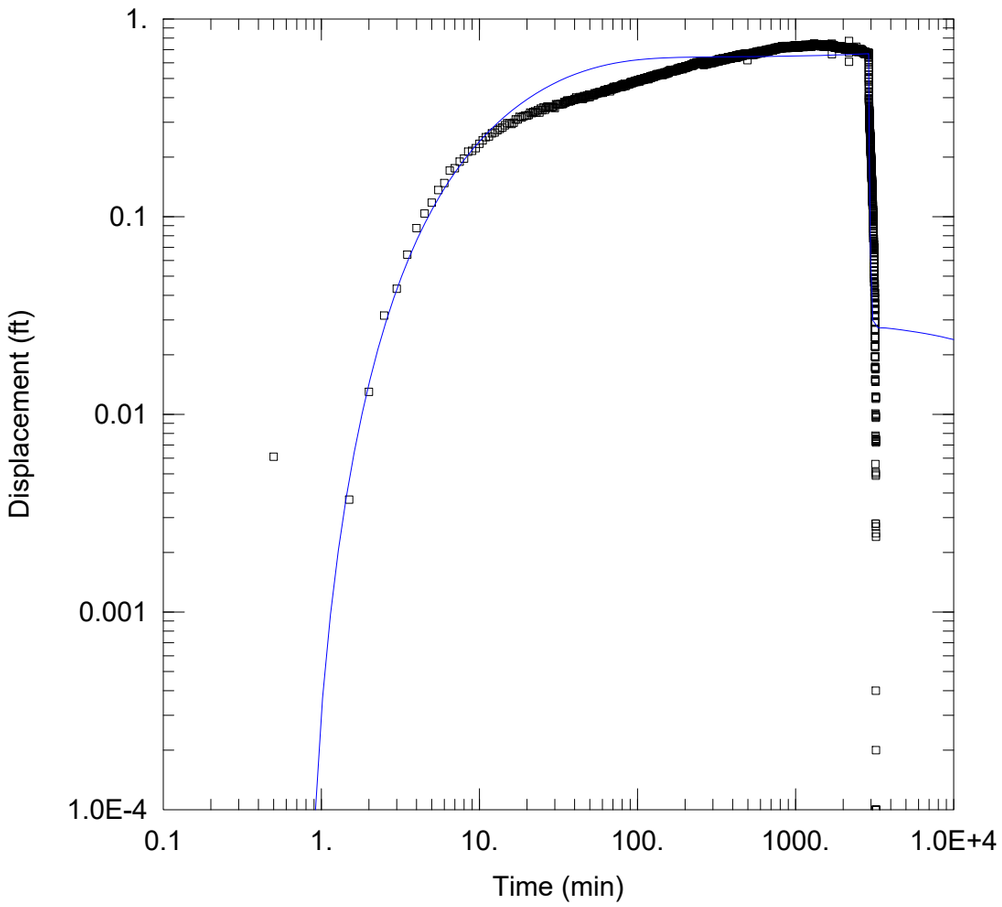
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PW-12	19580360.52	900827.53

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 0.04363 ft^2/min
S = 0.2629
Kz/Kr = 1.
b = 68. ft



STEP DRAWDOWN

Data Set: Q:\...\PZ-09 Moench.aqt
Date: 11/27/19 Time: 13:10:16

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft Anisotropy Ratio (Kz/Kr): 0.01092

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

Observation Wells

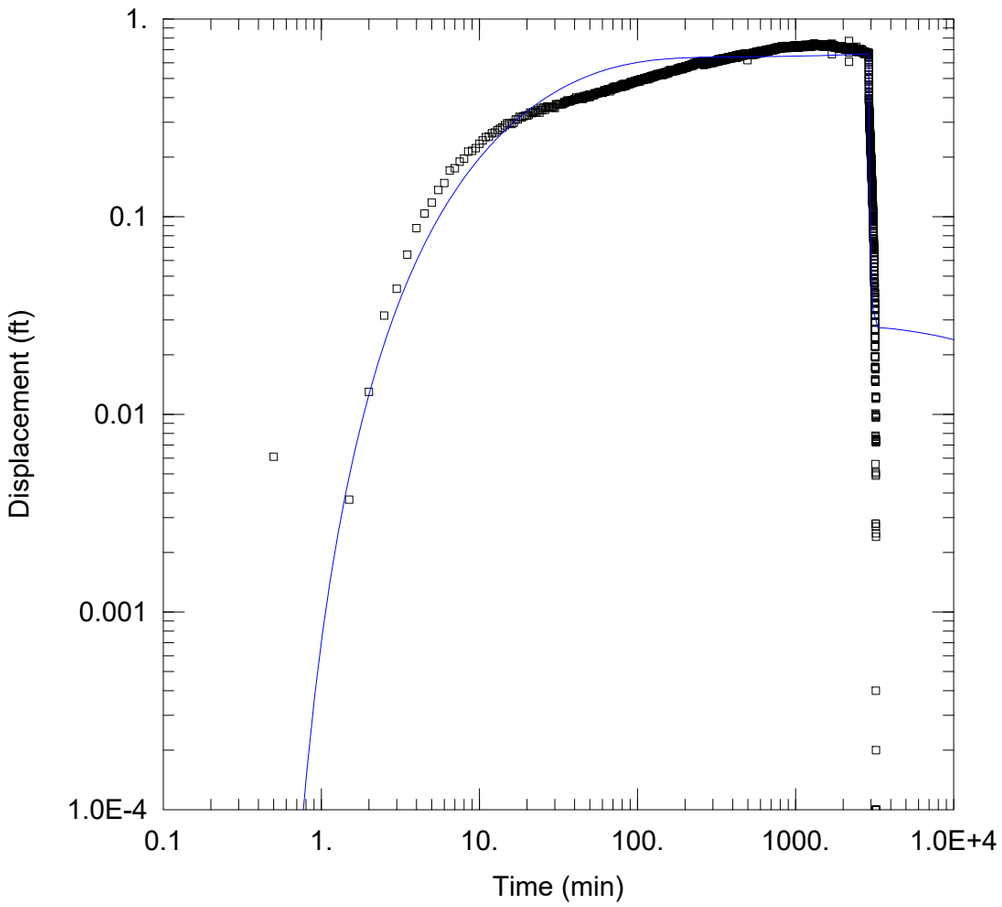
Well Name	X (ft)	Y (ft)
▫ PZ-09	19580336.04	901031.868

SOLUTION

Aquifer Model: Unconfined Solution Method: Moench

T = 0.7237 ft^2/min
Sy = 0.1
Sw = 0.
r(c) = 0.257 ft

S = 0.0002211
ß = 0.1
r(w) = 0.257 ft
alpha = 1.0E+30 min^{-1}



STEP DRAWDOWN

Data Set: Q:\...\PZ-09 Neuman.aqt
Date: 11/27/19 Time: 13:06:29

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

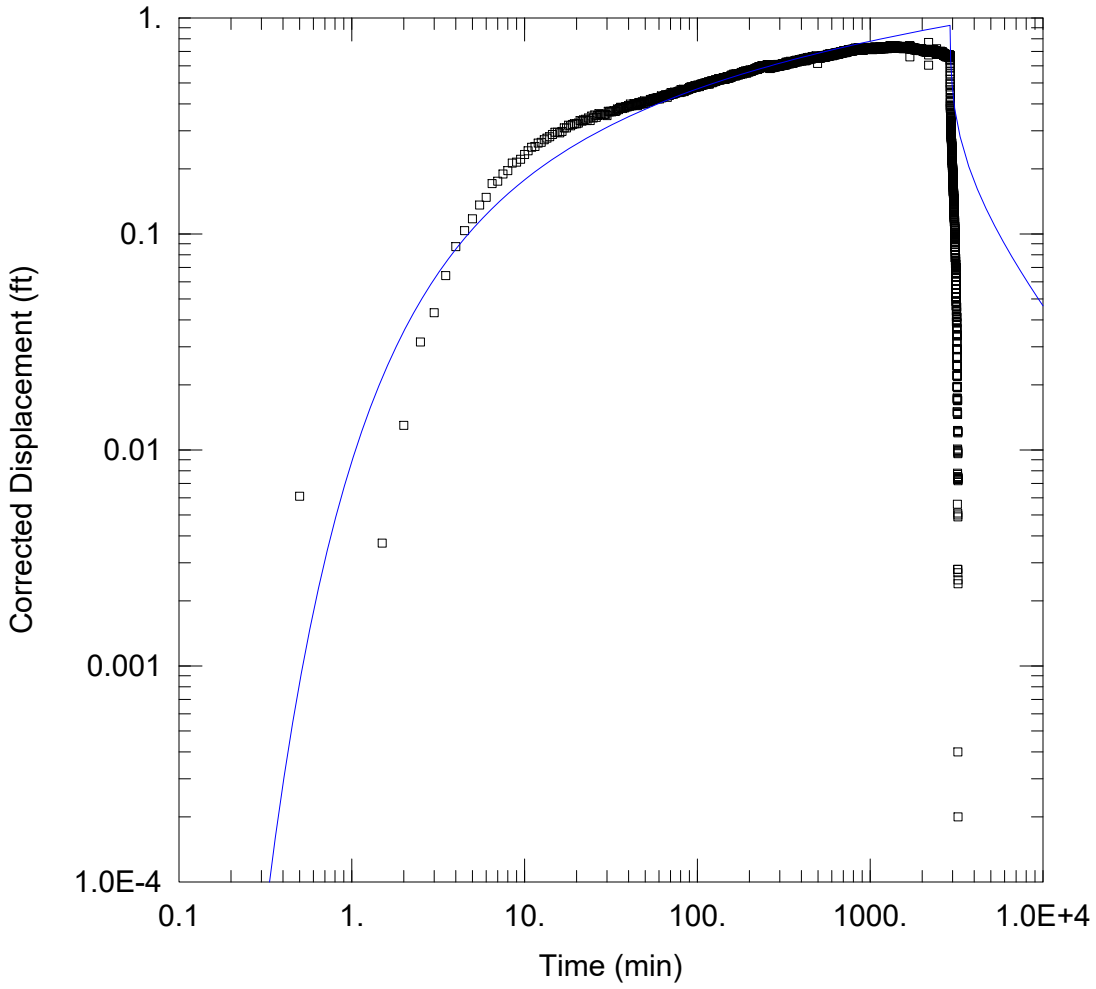
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-09	19580336.04	901031.868

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 0.7247 ft^2/min
S = 0.0002891
Sy = 0.1
ß = 0.1



STEP DRAWDOWN

Data Set: Q:\...\PZ-09 TheisRev1.aqt
Date: 11/27/19 Time: 13:08:35

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

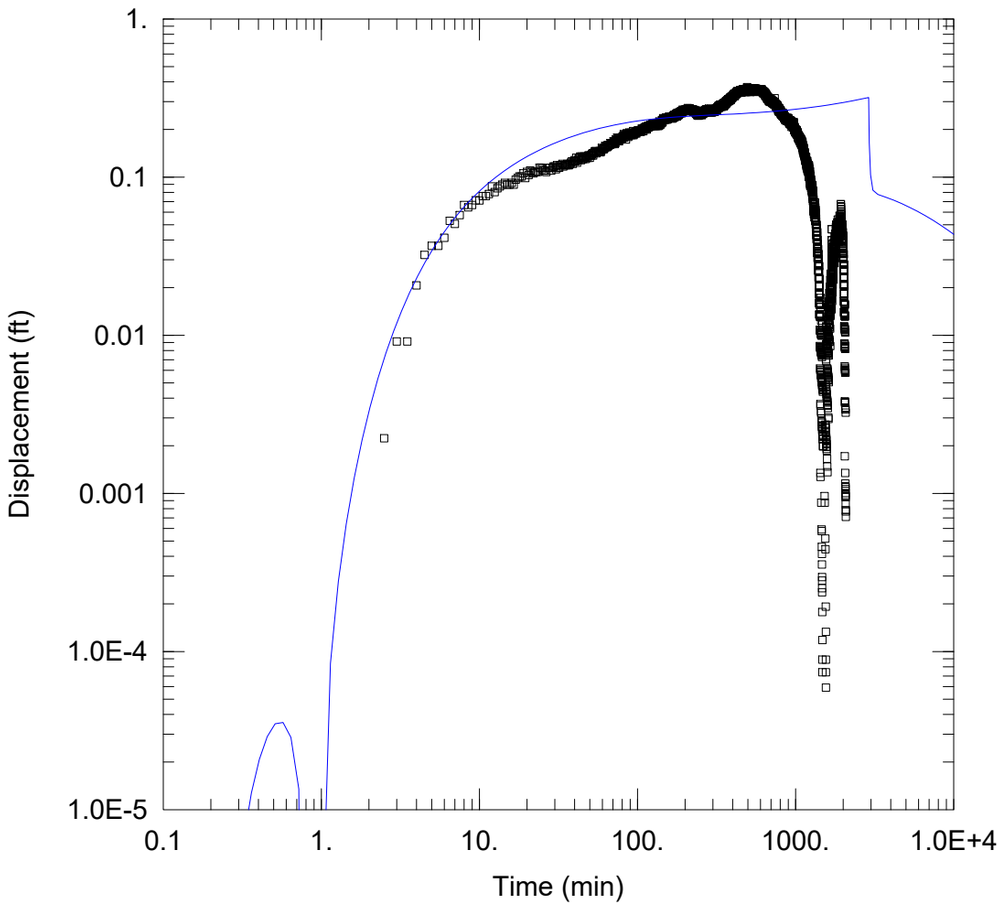
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-09	19580336.04	901031.868

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1.592 ft^2/min
S = 0.0002702
Kz/Kr = 0.01092
b = 68. ft



STEP DRAWDOWN

Data Set: Q:\...\PZ-40 Moench_20191127.aqt
Date: 11/27/19 Time: 13:04:36

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft Anisotropy Ratio (Kz/Kr): 0.02108

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

Observation Wells

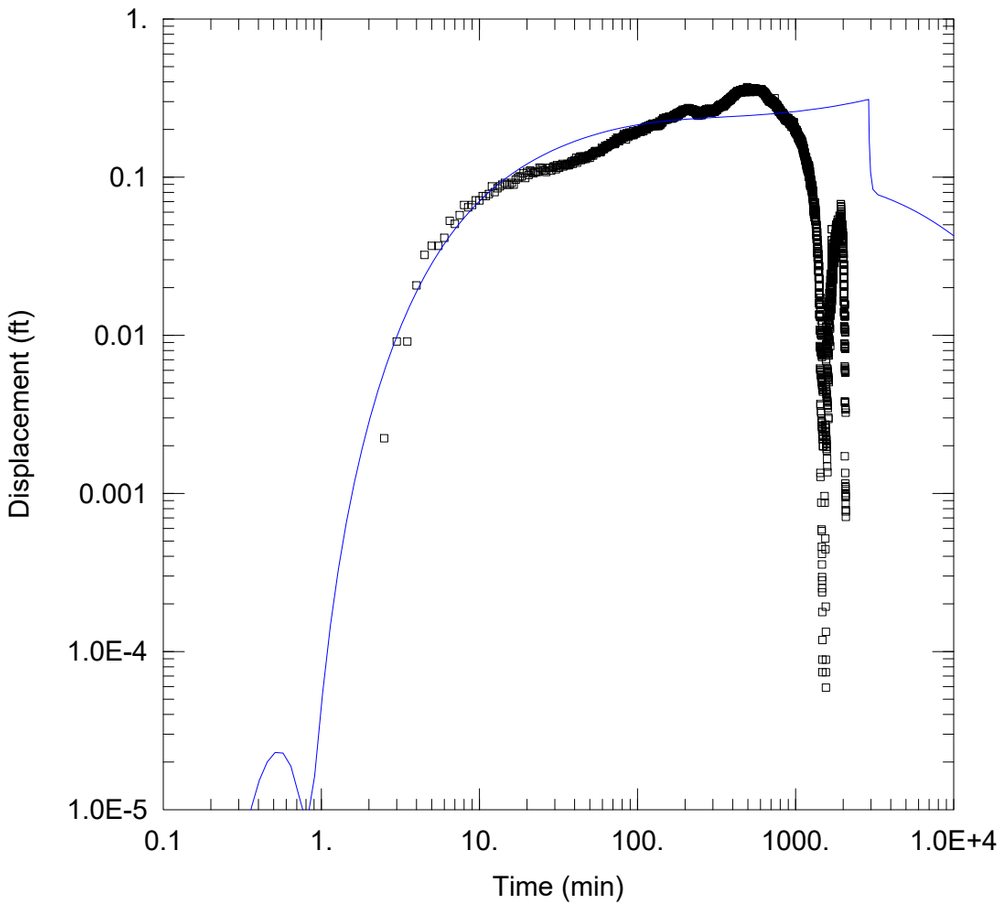
Well Name	X (ft)	Y (ft)
▫ PZ-40	19580500.6	900779.42

SOLUTION

Aquifer Model: Unconfined Solution Method: Moench

T = 1.292 ft^2/min
Sy = 0.1
Sw = 0.
r(c) = 0.257 ft

S = 0.001127
ß = 0.1
r(w) = 0.257 ft
alpha = 1.0E+30 min^{-1}



STEP DRAWDOWN

Data Set: Q:\...\PZ-40 Neuman_20191127.aqt
Date: 11/27/19 Time: 13:03:33

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

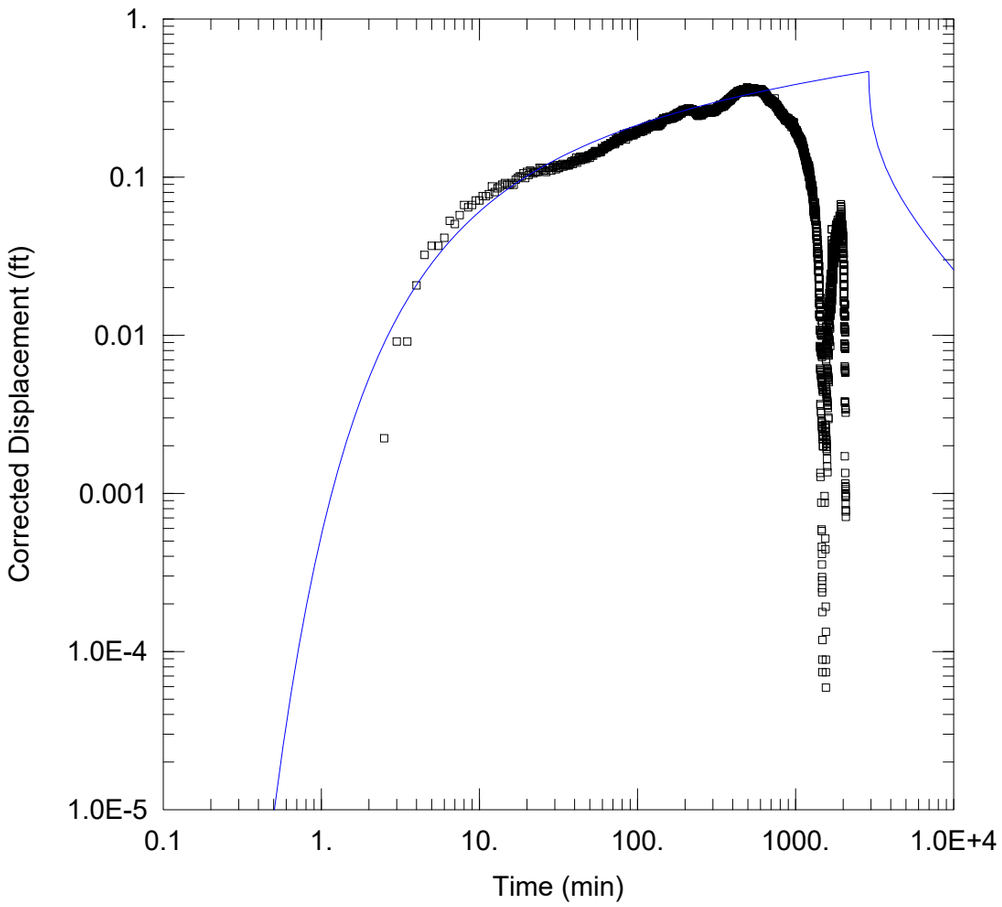
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-40	19580500.6	900779.42

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1.338 ft^2/min
S = 0.001346
Sy = 0.1
ß = 0.1



STEP DRAWDOWN

Data Set: Q:\...\PZ-40 Theis_20191127.aqt
Date: 11/27/19 Time: 13:05:24

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

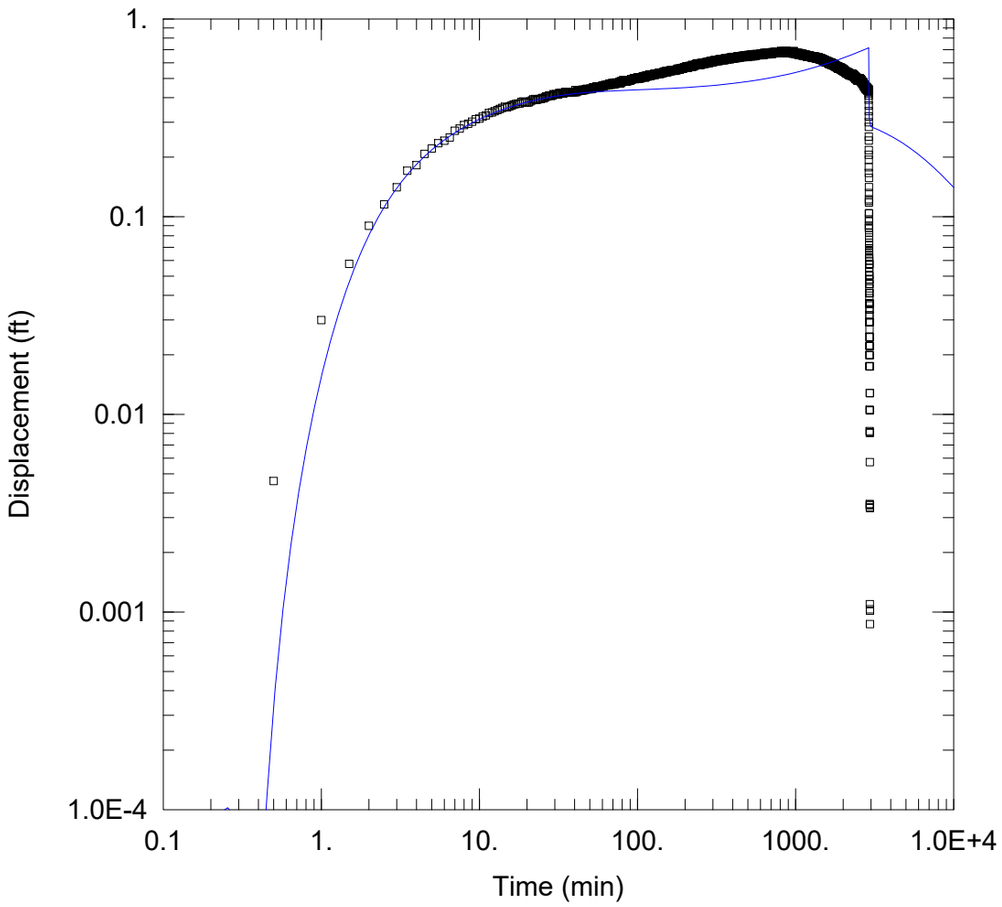
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-40	19580500.59	900779.42

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 2.852 ft^2/min
S = 0.001808
Kz/Kr = 1.
b = 68. ft



STEP DRAWDOWN

Data Set: Q:\...\PZ-41 Moench_20191127.aqt
Date: 11/27/19 Time: 12:58:37

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft Anisotropy Ratio (Kz/Kr): 0.05973

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

Observation Wells

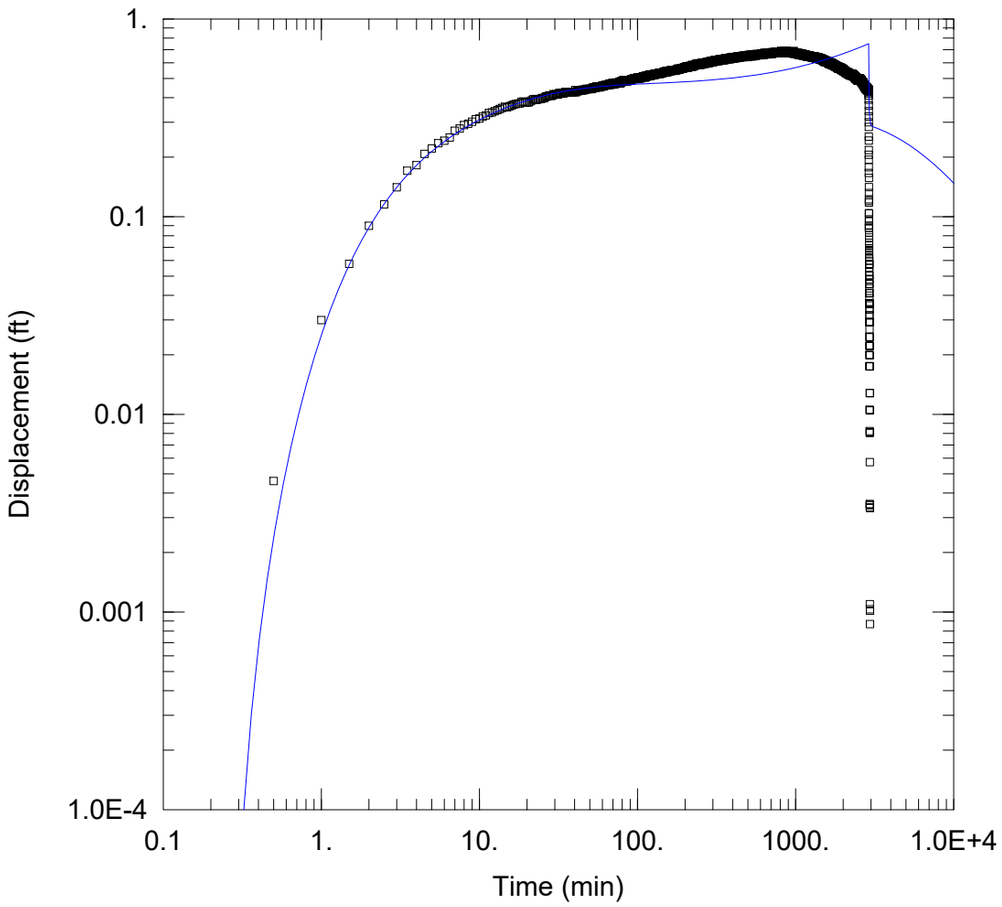
Well Name	X (ft)	Y (ft)
▫ PZ-41	19580441.99	900794.3

SOLUTION

Aquifer Model: Unconfined Solution Method: Moench

T = 0.4837 ft^2/min
Sy = 0.1
Sw = 0.
r(c) = 0.257 ft

S = 0.0003463
ß = 0.1
r(w) = 0.257 ft
alpha = 1.0E+30 min^{-1}



STEP DRAWDOWN

Data Set: Q:\...\PZ-41 Neuman_20191127.aqt
Date: 11/27/19 Time: 12:59:29

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

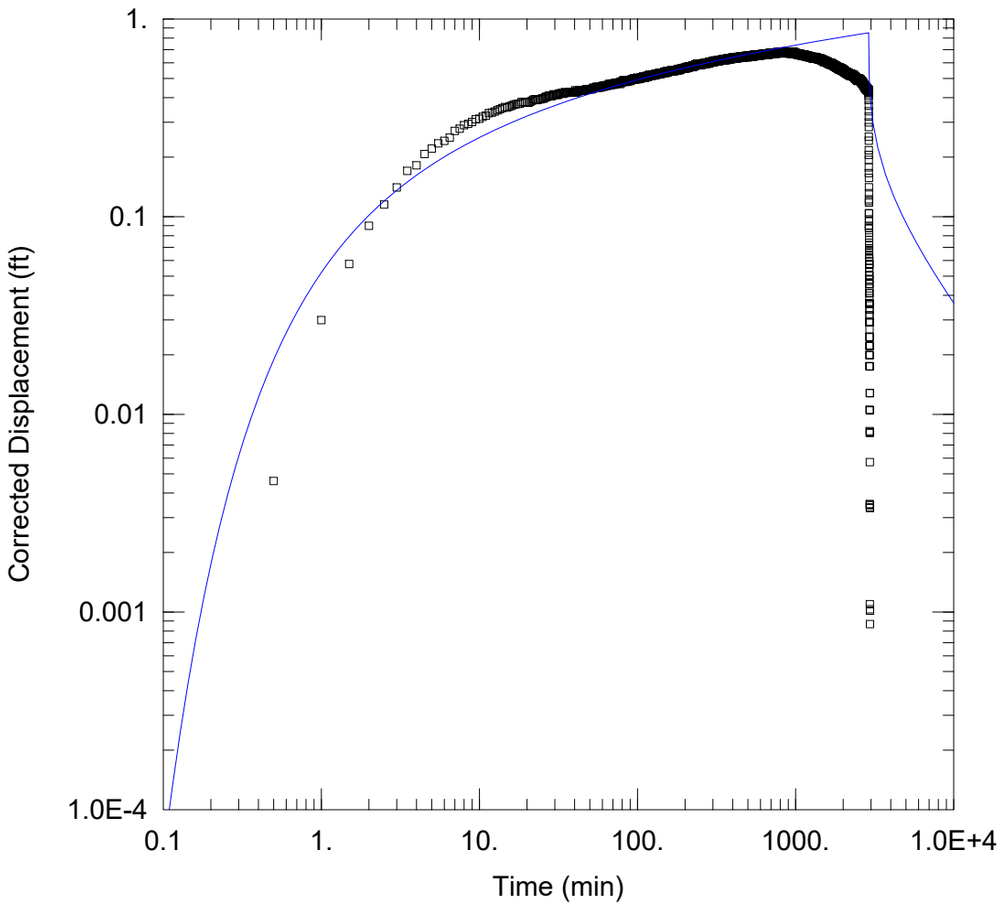
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-41	19580441.99	900794.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 0.4505 ft^2/min
S = 0.000421
Sy = 0.1
ß = 0.1



STEP DRAWDOWN

Data Set: Q:\...\PZ-41 TheisRev1_20191127.aqt
Date: 11/27/19 Time: 13:00:17

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

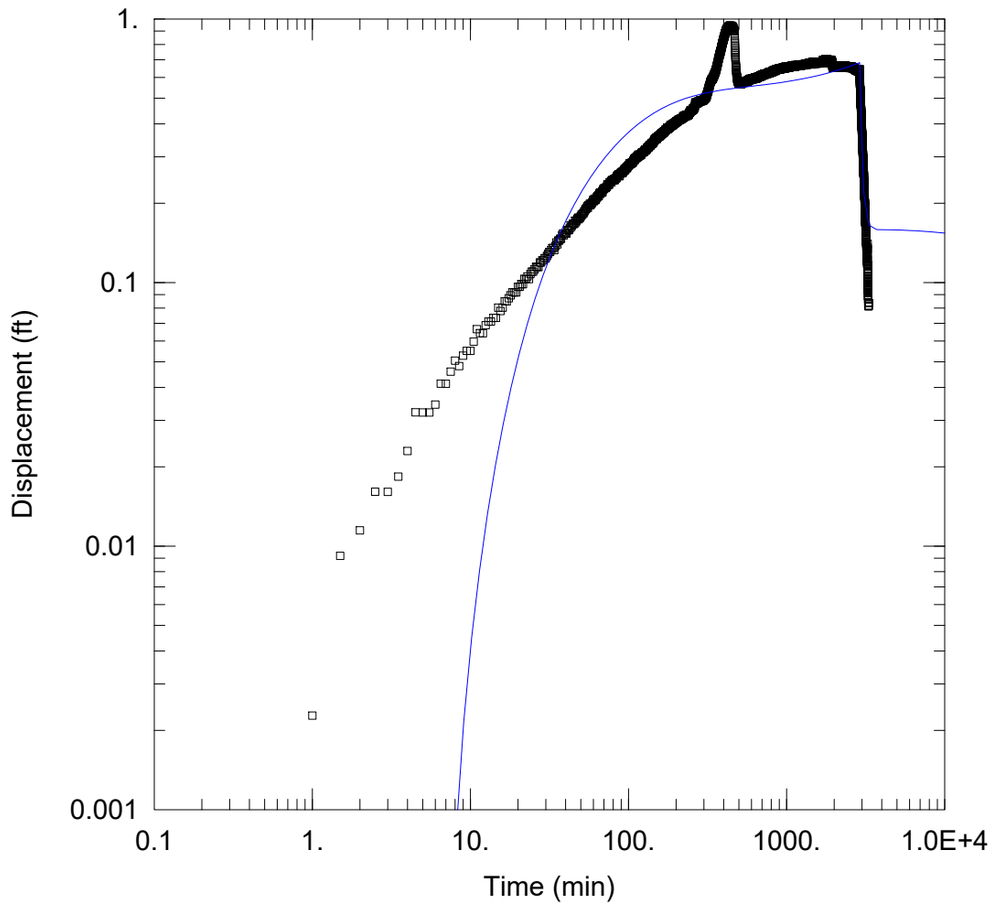
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-41	19580441.99	900794.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 2.022 ft^2/min
S = 0.0005904
Kz/Kr = 1.
b = 68. ft



STEP DRAWDOWN

Data Set: Q:\...\PZ-42 Moench_20191127.aqt
Date: 11/27/19 Time: 13:00:54

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft Anisotropy Ratio (Kz/Kr): 0.1159

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

Observation Wells

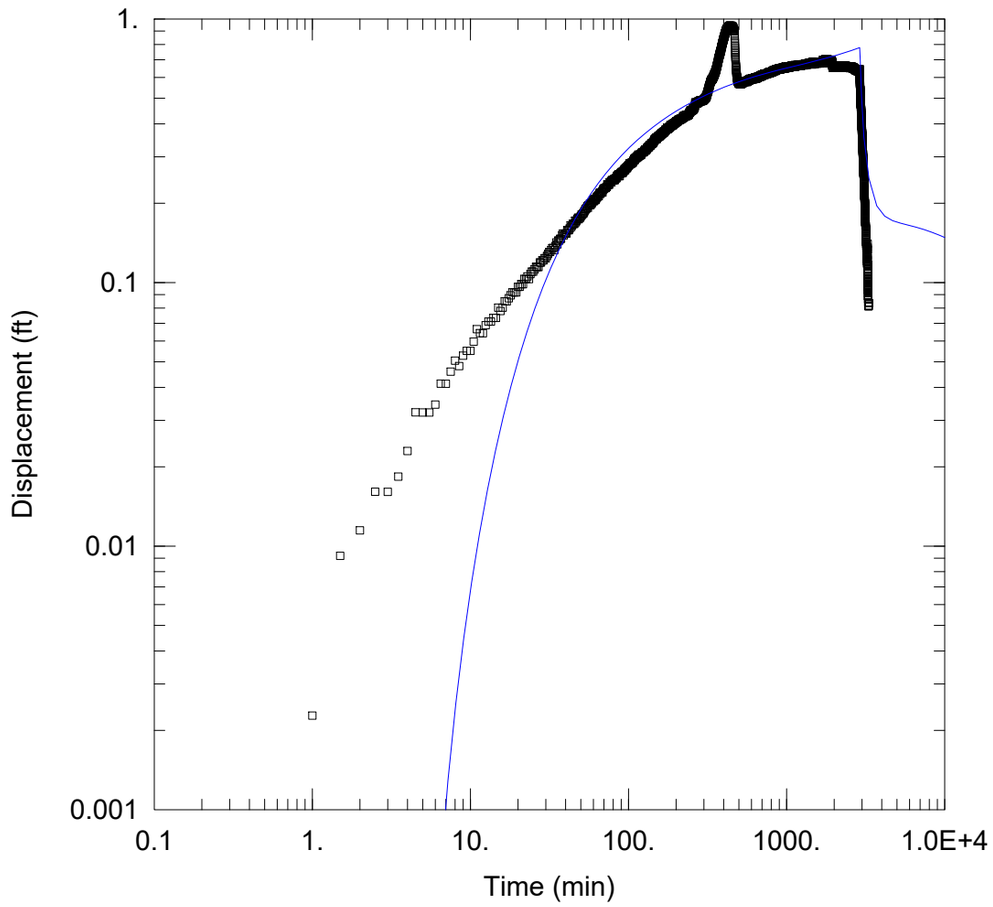
Well Name	X (ft)	Y (ft)
▫ PZ-42	19580317.74	900944.44

SOLUTION

Aquifer Model: Unconfined Solution Method: Moench

T = 0.1131 ft^2/min
Sy = 0.1937
Sw = 0.
r(c) = 0.257 ft

S = 0.0009186
ß = 0.3883
r(w) = 0.257 ft
alpha = 1.0E+30 min^{-1}



STEP DRAWDOWN

Data Set: Q:\...\PZ-42 Neuman unconfined_20191127.aqt
Date: 11/27/19 Time: 13:01:35

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

AQUIFER DATA

Saturated Thickness: 68. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

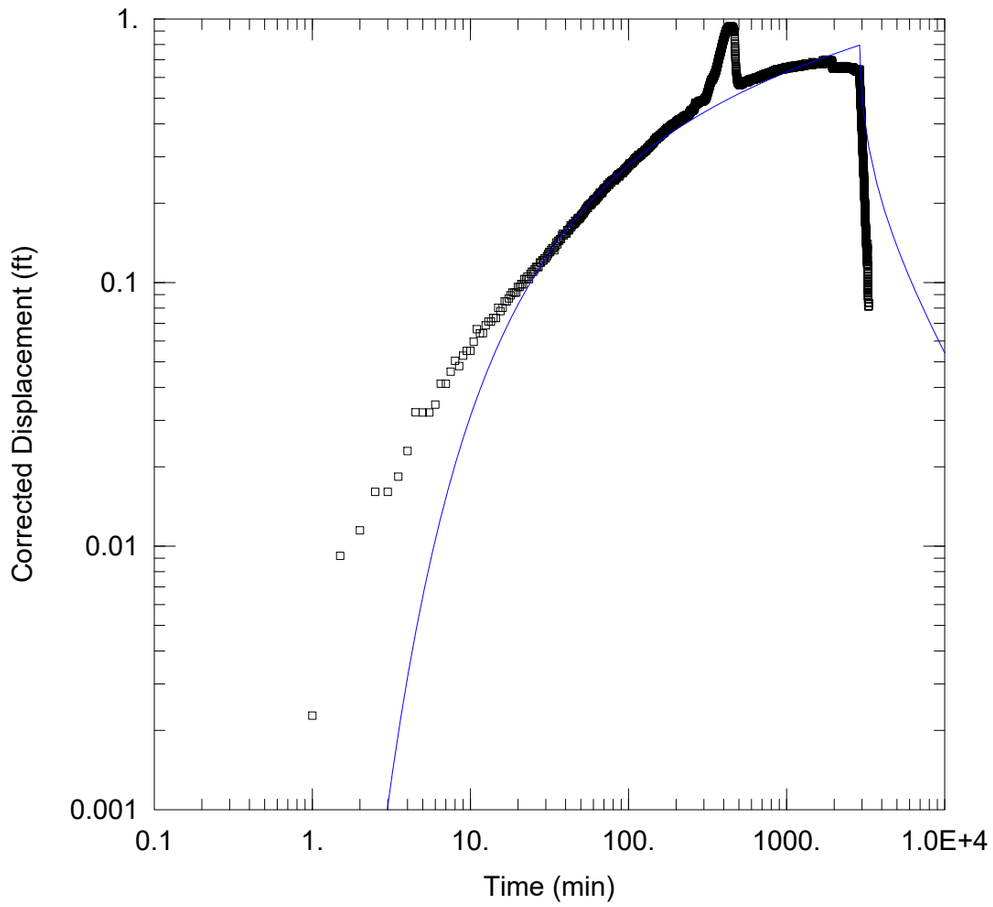
Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-42	19580317.74	900944.44

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 0.2447 ft^2/min
S = 0.002029
Sy = 0.1
ß = 0.1



STEP DRAWDOWN

Data Set: Q:\...\PZ-42 Theis_20191127.aqt
Date: 11/27/19 Time: 13:02:19

PROJECT INFORMATION

Company: WSP
Client: Enbridge
Project: 31402024
Location: South Terminus
Test Well: PW-12
Test Date: 07/23/19

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW-12	19580360.52	900827.53

Observation Wells

Well Name	X (ft)	Y (ft)
▫ PZ-42	19580317.74	900944.44

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1.366 ft^2/min
S = 0.003759
Kz/Kr = 1.
b = 68. ft

APPENDIX

F-5 *DEPTH TO GROUNDWATER MEASUREMENTS*

Table F-5.1 - Depth to Groundwater Measurement Summary
Geotechnical Data Report
Line 5 Replacement and Tunnel Project

Boring ID	Date	Time	Depth to Water (ft)
BH19-08	10/8/2019	08:17	1.87
PZ19-09		08:12	35.18
PW19-12		07:52	88.30
PZ19-40		07:59	67.87
PZ19-41		07:57	67.77
PZ19-42		08:13	36.90

Notes:

Boring ID	Date	Time	Depth to Water (ft)
BH19-08	11/19/2019	16:07	2.89
PZ19-09		15:50	35.41
PW19-12		16:19	67.20
PZ19-40		16:27	68.04
PZ19-41		16:24	67.95
PZ19-42		15:58	37.02

Notes:

Table F-5.1 - Depth to Groundwater Measurement Summary
Geotechnical Data Report
Line 5 Replacement and Tunnel Project

Boring ID	Date	Time	Depth to Water (ft)
BH19-08	1/9/2020	09:15	1.25
PZ19-09		-	Automated Readings
PW19-12		-	Automated Readings
PZ19-40		08:45	64.32
PZ19-41		08:55	64.35
PZ19-42		09:25	33.13

Notes:

Boring ID	Date	Time	Depth to Water (ft)
BH19-08	2/10/2020	12:10	1.82
PZ19-09		-	Automated Readings
PW19-12		-	Automated Readings
PZ19-40		11:35	67.10
PZ19-41		11:45	66.94
PZ19-42		12:15	36.00

Notes: