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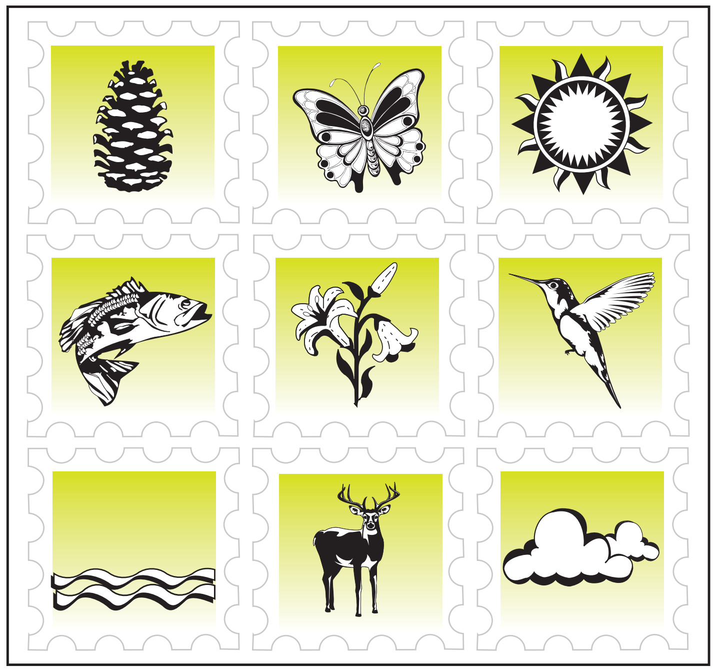

State of MICHIGAN'S ENVIRONMENT 2001

First Biennial Report

State of Michigan's Environment 2001

(First Biennial Report)

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Better Service for a Better Environment
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Message from the Governor

An old adage states, “It is easy to see, but difficult to foresee.” Believing that well-grounded environmental policy cannot be divined but must be based on sound science, I created the Michigan Environmental Science Board (MESB) in 1992. Guided by the most recent and accurate scientific information, the MESB, composed of experts in such diverse areas as biology, engineering, medicine, geology, ecology, and other disciplines as necessary, provides advice on various environmental issues. The MESB has dealt with questions involving many scientific elements impacting Michigan and the Great Lakes.

Realizing the need for a comprehensive, long-term environmental master plan, I charged the MESB with the task of developing a scientifically sound environmental indicators program for Michigan for the purpose of tracking environmental trends in the Great Lakes region. Environmental indicators are scientifically measurable components that reflect biological, chemical, and physical attributes of the environment. By tracking changes that occur over time in land cover, fish populations, ambient air pollutant levels, and stream flows, just to name a few, the direction of environmental trends can be determined and corrective programmatic measures developed to ensure optimal resource preservation and protection.

The MESB report, *Recommended Environmental Indicators Program for the State of Michigan*, was published in July 2001. Using this resource as a guide, the Michigan Department of Environmental Quality and the Michigan Department of Natural Resources, as required by law, have prepared this first biennial report on the state of Michigan’s environment. This report will serve as a baseline from which to record and evaluate future environmental trends, using scientifically measured changes in indicator values.

As we meet future challenges such as maintaining clean air, fishable and swimmable waters, clean drinking water, abundant energy sources, and a diverse and healthy environment, this endeavor ensures Michigan’s continued sound, science-based approach to environmental policy. By “seeing” today, perhaps we will have a better chance of “foreseeing” tomorrow.

John Engler
Governor

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Introduction

Michigan values its unique peninsular environment, its Great Lakes, its abundance of inland lakes and streams, its wide variety of landscapes, and its abundance of natural resources. Beginning in the early 1970s, concerns for how well the natural environment was being protected were being heightened amid numerous and alarming reports of contaminated drinking water, rivers, and streams and sick and dying song, predatory, and shore birds. These and other environmental consciousness-raising concerns led to a series of state and federal laws to identify and begin the process of reversing the problems. During the 1990s and 1980s, state and local governments instituted many new and/or innovative, non-regulatory programs, including pollution prevention and recycling programs. This same time period also saw the beginnings of an enhanced awareness among Michigan communities, businesses, and citizens regarding environmental stewardship and the need to conserve. As a direct result of all these factors, many of the environmental problems that were of concern 30 years ago either have been corrected or are in the end stages of being reversed.

The state is now faced with new and more complex environmental issues. Unfortunately, many of the environmental concerns of today are not as obvious as were those of the past; often they now are of a more diffuse nature (e.g., non-point source pollution, contaminated sediments, air deposition of contaminants, invasive non-native species). Consequently, the extent of the problem is often more difficult to discern and the corrective actions and/or other types of solutions more complex and elusive. Compounding this even further has been a greatly enhanced ability to measure pollutants at ever decreasing levels and then trying to understand the degree of risk that such pollutants actually have to the environment and/or human health at such low levels.

The challenge facing Michigan in this new century will be to accurately identify and track environmental change resulting from human-related activities and to develop meaningful ways to measure the change and the degree of success of regulatory and non-regulatory programs designed to protect the environment. To date, there have been several attempts to do this. However, most of these varied approaches have resulted in a patchwork of disjointed programs and measurements. Many of these have little direct scientific meaning, are not designed to be integrated into a comprehensive understanding of the impact of human-related degradation or mitigation activities on the natural environment, and/or are incapable of differentiating human-caused from natural change.

The Department of Environmental Quality (DEQ) has prepared two annual Environmental Quality reports since 1999. Both documents have reported on a series of measurements best classified as environmental indicators and program outcome measures. Shortly after the 1999 DEQ report was published, Public Act 195 of 1999 (Environmental Indicators Act) was signed into law by Governor John Engler. The law requires the DEQ to work with the Department of Natural Resources (DNR) to prepare a biennial report on the quality of the environment, based on scientifically supportable environmental indicators and using sound scientific methodologies.

On January 28, 2000, the Michigan Environmental Science Board (MESB) was charged by Governor Engler to evaluate a series of environmental indicators proposed by the DEQ and DNR for use in the legislatively mandated report. The MESB report was submitted to the Governor in July 2001. Of a total of 23 environmental indicators proposed for consideration by the DEQ and DNR, the MESB recommended that 20 be included into a statewide environmental indicators program. The recommended indicators were based on a review of the environmental measurements that were currently being monitored or proposed to be monitored in the future by the state. The MESB also recommended that one additional indicator (Climate and Weather Change) be taken into consideration in the state's evaluation of all the other indicators (Exhibit 1).

Exhibit 1. Michigan Environmental Science Board Recommended Environmental Indicators

Ecological Indicators:	Land Cover Breeding Bird Abundance Trends in Habitat of Interior and Edge Bird Species Trends in Game Fish Populations Trends in Benthic Macroinvertebrate and Fish Populations Trends in Frog and Toad Populations Invasive Species Forest Acreage, Mortality, Growth, and Removals Vegetation Structure and Diversity Lichen Communities
Physical/Chemical Indicators:	Ambient Levels of Criteria Air Pollutants Stream Flow Inland Lake Water Quality Contaminant Levels in Fish Inland Lakes Sediment Trends Contaminant Levels in the Connecting Channels, Saginaw Bay, Grand Traverse Bay, and Major Tributaries Climate and Weather Change
Future Indicators:	Ambient Levels of Air Toxic Contaminants Rates of Deposition of Persistent and Bioaccumulative Air Toxics and Acidic Components Trends in Mammalian Populations
Optional Indicator:	Contaminant Levels in Bald Eagles

In addition to identifying the environmental indicators to be used, the MESB recommended that the state begin to develop and ultimately implement a sample collection protocol, referred to as *Master Stations*, from which it can systematically and consistently collect biotic, chemical, and physical information on the state's environment. The Master Stations would need to be permanent to provide long-term trend analyses, incorporate a distributed sampling grid, be intensively monitored, and be integrated and optimized with the existing state environmental monitoring programs. The state will be working on this recommendation during the next several years.

The purpose of this document is to present the first of the biennial environmental indicators reports requested by the Michigan Legislature. The report is divided into two main sections: environmental measures and programmatic measures. The first section delineates the important ecological and physical/chemical indicators identified by the MESB to be used to track the overall quality of the state's environment and fulfills the legislative mandate. The second section of the report discusses additional agency measures that are tracked to fulfill various state or federal environmental programmatic requirements. These latter measurements, while in and of themselves may ultimately have an impact on the overall quality of the environment, are designed more to measure how well a given program is functioning to correct or control localized environmental issues and/or problems. It is anticipated that more programmatic measures will be added to future reports.

This report represents the first comprehensive attempt to describe Michigan's environment and, with time, should become an important tool to help track the ever-changing environmental quality of the state. Being the first document of its type and scope, it is recognized that there are gaps in its coverage. However, with time, these data gaps will be filled as more and better information becomes available and as new indicator measures that are just now beginning to be reported have been operational for a period of time.

Finally, with reports of this nature, there are caveats that must be taken into account in their interpretation. First, care will need to be taken not to exaggerate the importance of a change that may occur in a given measure from one reporting period to the next. In terms of many environmental systems, a period of as long as ten years is a relatively short time frame for a natural or human-influenced disturbance or a corrective action to be realized within an ecosystem. It can generally take several years worth of monitoring data to properly identify and assess the emergence of either a positive or negative trend. Consequently, the importance of this and subsequent biennial reports will be best reflected in terms of their ability to demonstrate long-term changes that may be taking place in the environment rather than short-term anomalies that may occur from year to year.

Care also should be taken as to how the results of this report are reported. It is neither scientifically defensible nor responsible to summarize the results of all the various environmental indicators down to a one or two word conclusion about the overall health of such a highly complex system as the environment. While certainly simple to understand, such relative comparison labels as *good, moderate, bad,* etc., are at best unscientific since they are indefinable, and at worst may be a disservice to the citizens of Michigan since they can be misleading. In almost all cases, further explanation and additional qualifying information will be needed to accurately describe what the cumulative environmental measurements appear to be indicating.

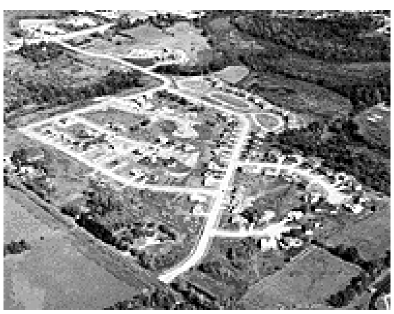
Environmental Measures

Ecological Indicators

Land Cover

A direct measure of changes in land cover types provides a useful indirect measure of trends in ecosystem health. High rates of land conversion place stress on natural ecosystems and may be associated with inefficient land use. Human population growth and/or dispersal usually cause a conversion of land cover types from natural vegetation or agricultural types to urban uses. These changes can have negative impacts on ecosystem health through loss of wildlife habitat and increased water and air pollution.

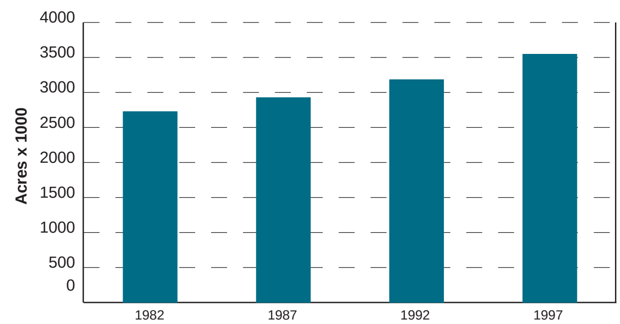
Since European settlement, Michigan's land cover has changed dramatically. At times this change has been quite rapid over relatively short time frames. The original land surveyors of Michigan recorded a landscape dominated by forest in the north and a mix of forest and savanna in the south. Early settlers cleared land for agriculture while logging companies provided wood to a growing nation. The logging era of the late 19th and early 20th Centuries changed Michigan's landscape dramatically. The 20th Century was marked by a return of forest to the northern Michigan landscape and intensive agriculture and urban development in southern Michigan. Michigan's land cover was mapped in 1978 by the DNR. At that time, Michigan was 37 percent forest, 29 percent agricultural, 18 percent wetland, six percent urban, eight percent open field, and two percent inland water.



Change is the only constant with Michigan's land cover. Change occurs through both natural processes like ecological succession and human activities such as residential development. The United States Department of Agriculture (USDA) tracks changes in Michigan's land cover through its National Resources Inventory program. According to the USDA, between 1982 and 1997 there was a 30 percent increase in developed

land with almost half that increase occurring between 1992 and 1997 (Exhibit 2). Most of this development occurred on former agricultural lands. During this same time period, there has been a loss of approximately 1.4 million acres of crop and pastureland.

Exhibit 2. Changes in Developed Land 1982 - 1997



Other noticeable trends include an increase in forests and a decrease in wetlands. Between 1982 and 1997, there was an increase of 538 thousand acres of forestland on non-federal rural lands in Michigan. The increase in forest is most likely a result of natural succession of open fields and abandoned agricultural lands. In 1978, Michigan had approximately 6.2 million acres of wetlands. The United States Fish and Wildlife Service (USFWS) reports that the rate of wetland loss has declined dramatically across the nation compared to previous decades; however, some loss of wetlands is still occurring with conversions to urban and agricultural uses. The most disturbing trend in land cover has been the rapid conversion of natural landscapes and agricultural areas to suburban and urban development. These conversions of agricultural

lands, wetlands, and forestlands to urban landscapes represent permanent losses of habitat to many species of wildlife and have traditionally resulted in increases in water and air pollution. The DNR will continue to track this important indicator.

Forest Acreage, Mortality, Growth, and Removals

This indicator addresses several dimensions relating to one of Michigan's largest land cover types — its forests. As previously indicated, Michigan's forests have been recovering slowly, following over-exploitation and fire devastation that took place towards the end of the 19th Century and beginning of the 20th Century.

Five statewide forest inventories were conducted during the last century. These inventories indicate that forest acreage has remained relatively stable since the 1950s. The only exception to this is a slight decrease between 1966 and 1980, followed by an expansion between 1980 and 1993 (Exhibit 3). Losses or conversions out of forestland between 1980 and 1993 were made up for by other lands being converted into forestland. The predominant land type converting into forestland was agricultural. Total standing timber volumes have more than doubled since the middle of the last century, reflecting a maturing forest. This expanding volume reflects that more growth has been continuously added to the forest than what has been removed or died through natural causes. Annual growth has steadily increased over the past 40 plus years (Exhibit 4).

Exhibit 3. Michigan Forest Acreage and Volume 1934-1993

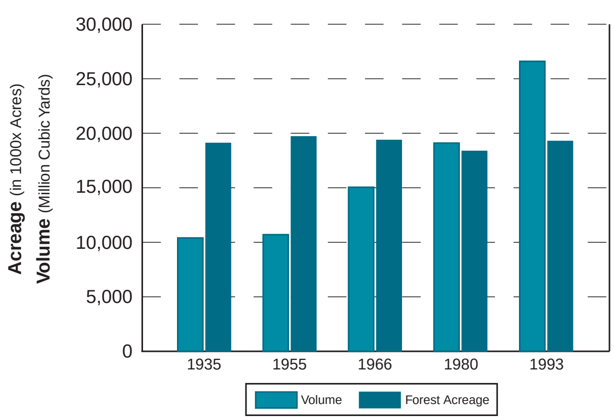
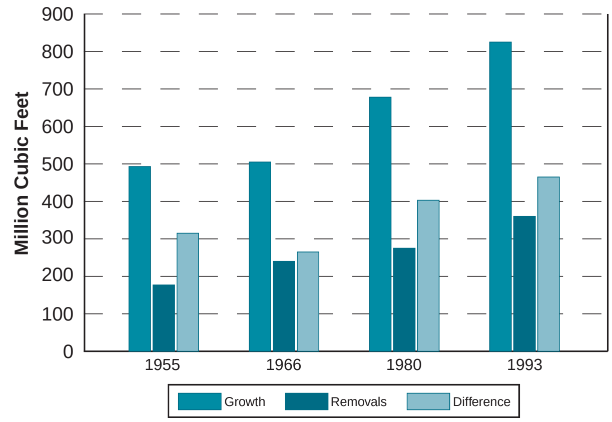


Exhibit 4. Michigan Timber Growth and Removals 1955 - 1993



Vegetation Diversity and Structure

Michigan's forests are some of the most diverse in the United States. Statewide forest inventories identify over 75 different tree species with substantial mixtures of species within each of the major forest cover types. This diverse forest provides habitat for a wide variety of plant and animal species.

In addition to maturing, Michigan's forests have been gradually transitioning towards more shade tolerant, late successional tree species. Aspen, paper birch, jack pine, and other species particularly adapted to full sunlight are declining in acreage while the more shade tolerant maples, northern white cedar, spruces, and oak-hickory types are increasing. As a consequence, plants and animals that depend on pioneer species for habitat have

been also declining. For example, ruffed grouse, American woodcock, golden-winged warbler, and other songbirds dependent upon early successional tree species have suffered from this loss of habitat while others dependent on the shade tolerant species have benefited.

Given existing conditions, the trend towards more shade tolerant, older trees can be expected to continue. For example, the maple-beech-birch cover type, by far the largest in Michigan, has continued to increase by almost one million acres between 1980 and 1993.

The DNR, in conjunction with the University of Michigan, participates in a federal program that makes annual evaluation of the condition, changes, and trends in the health of forest ecosystems in Michigan. The USDA Forest Service manages this national program, referred to as the *Forest Health Monitoring (FHM) Program*. The vegetation diversity and structure indicator is composed of a suite of FHM measurements of forest understory diversity, vegetation structure, down woody debris, and forest fire fuel loading. Variables collected for this indicator can provide information to evaluate wildlife habitat, plant diversity, vitality, soil conservation, and carbon cycling.

Botanists field identify nearly all the plant species on site, including locally rare species and invasive species from overseas. An immediate expected return from this effort will be to identify areas of exotic plant invasion and spread. Multi-scale data on plant diversity will be used to evaluate species richness patterns over time. This information will help to evaluate the effect of exotic plants relative to their native counterparts.

The DNR has piloted vegetation diversity and structure measurements since 1998; however, the first year for the collection of standardized plot data was during the spring of 2001. Consequently, no reportable data are available currently. It is anticipated that three years (2001 - 2003) of data will be available during the next reporting period.

Lichen Communities

Lichens are unique organisms, made up of cooperating algae and fungi. Individual species in this very diverse group are useful as environmental indicators. Epiphytic lichens, or lichens that live on other plants, are very sensitive to changes in air quality since they rely totally on the atmosphere as a source of nutrition. A large body of scientific literature has documented the close relationship between lichen communities and air pollution, especially acidifying nitrogen, fertilizing nitrogen, sulfur dioxide, and other sulfur-based pollutants.

The composition of a lichen community is one of the best indicators of air pollution in forests. Long-term observations of the abundance of a particular group or species of lichen can provide an early indication of changes in air quality or changes in forest composition. A decline or increase in the abundance of a particular species of lichen can be a bellwether of declining or improving environmental conditions.

The USDA Forest Service's FHM Program developed the lichen community indicator. On forested plots, samples of each lichen species are collected for laboratory identification and the relative abundance is estimated. To date, the program has identified 29 epiphytic lichen species representing 17 genera on Michigan plots (Exhibit 5).

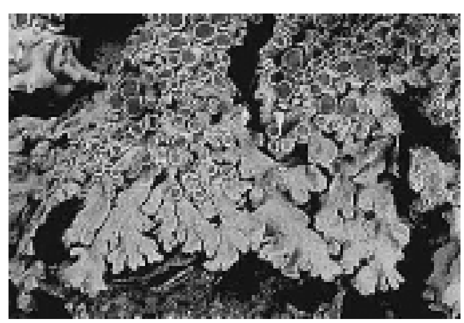
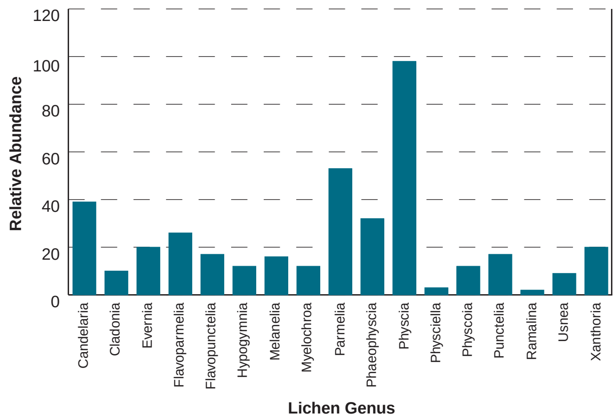
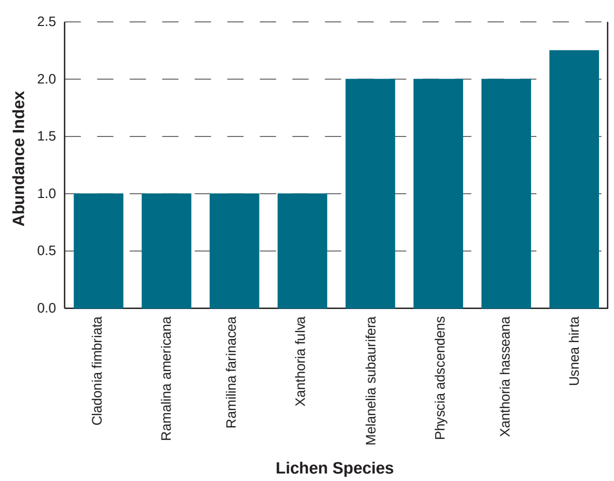


Exhibit 5. Relative Lichen Abundance by Genus at 240 Forest Health Monitoring Plots in Michigan 1998



As this indicator is still in its early stages of development in Michigan, it is difficult to state exactly what the collected lichens data may be suggesting about the environment at this time. The data collected to date represent the beginning of the development of baseline information necessary to measure change in Michigan. Over the next several years, the DNR will carefully monitor changes in the abundance of lichen species, especially in the most rare species (Exhibit 6).

Exhibit 6. Average Relative Abundance of the Rarest Lichen Species at 240 Forest Health Monitoring Plots in Michigan 1998



Trends in Mammalian Populations

The Michigan deer herd management program is one of the better known of the DNR programs among the general public. This particular program was offered for consideration by the DNR as a possible indirect measure of habitat quality using population trends of white-tailed deer. However, it was subsequently abandoned as an environmental indicator due to the number of inherent limitations associated with deer population estimates and the highly managed nature of the population by humans. Consequently, the DNR is presently evaluating other mammalian populations to see what would be needed to improve or enlarge its current databases. For example, data on mammalian species such as the beaver, which can have profound influence on ecosystems and landscapes, and the gray wolf, which is a recovering species but holds a position at the top of the food chain, may be useful to enhance baseline biodiversity information. This indicator will be reported on in the next environmental indicators report.

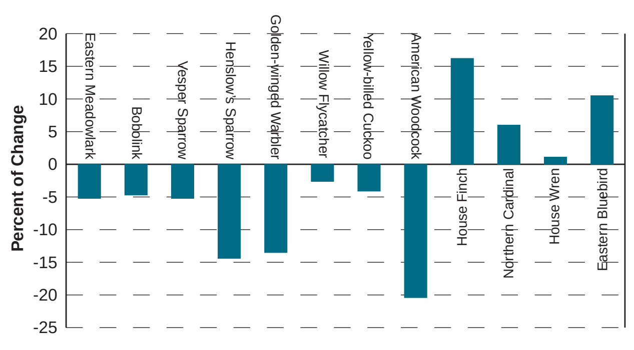
Trends in Breeding Bird Populations

Migratory songbird abundance can provide an excellent source of information on what changes are occurring at a landscape level. Since the mid 1960s, the USFWS has maintained an annual breeding bird survey to monitor bird abundance across the United States. While information at just a state level does not always provide reliable trends, combining data across physiographic regions does provide some level of reliability.

Michigan falls within two physiographic regions (*Great Lakes Transition and Great Lakes Plain*). Data collected over the last 20 years for the two physiographic regions indicates some common patterns among bird species. In most decline are grassland species such as the bobolink, eastern meadowlark, Henslow's sparrow, and vesper sparrow. Similarly, transitional species, such as the golden-winged warbler, willow flycatcher, yellow-

billed cuckoo, and American woodcock, also have shown significant declines. During this same period, several generalist species such as the house finch, Northern cardinal, house wren, and eastern bluebird, which benefit from human activity, have demonstrated increases in population (Exhibit 7).

Exhibit 7. Breeding Bird Population Change 1980 - 1999

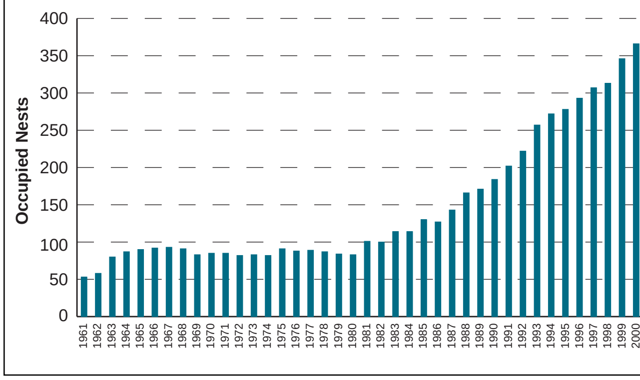


Declines in species can be attributed to several factors including habitat fragmentation and loss of early age shrub and forest systems. Decline of grasslands species has resulted from development and natural succession.

Trends in Bald Eagle Populations and Contaminant Levels

Population. The bald eagle is a top level predator of aquatic ecosystems. The bald eagle's position at the top of the food chain makes it a good indicator species for monitoring changing trends of contaminants that accumulate in the food chain. It is a large bird that can provide enough samples for chemical analysis and there are

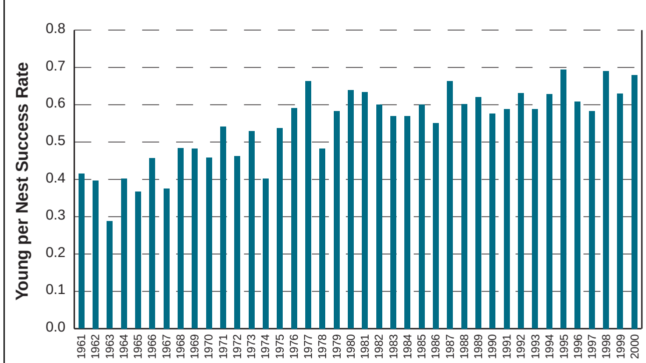
Exhibit 8. Occupied Bald Eagle Nests in Michigan 1961 - 2000



long-term data on nesting sites in Michigan. The International Joint Commission, a bi-national United States-Canadian entity charged with overseeing Great Lakes water quality protection, has found the bald eagle to be the best avian species for tracking changes in certain contaminants in aquatic ecosystems.

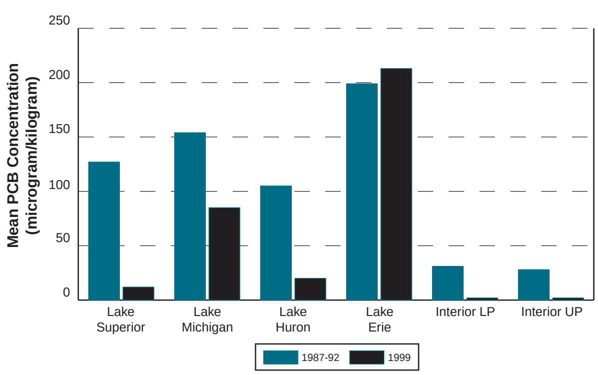
Since 1961, the DNR has conducted an annual census of bald eagle nests in Michigan. From a low of 50 nests recorded in 1961, the bald eagle population has continued to increase to a high of 366 occupied nests in 2000 (Exhibit 8). While an increasing population indicates a recovery for the eagle, just as important is the increase in productivity. Since 1961, bald eagle productivity, measured as number of young fledged per nest, also has increased over 50 percent (Exhibit 9). Combined, these two measures suggest that not only are bald eagles increasing in number, they are also successfully raising more young per pair than in the past.

Exhibit 9. Success Rate for Bald Eagle Young Fledged per Occupied Nest 1961 - 2000



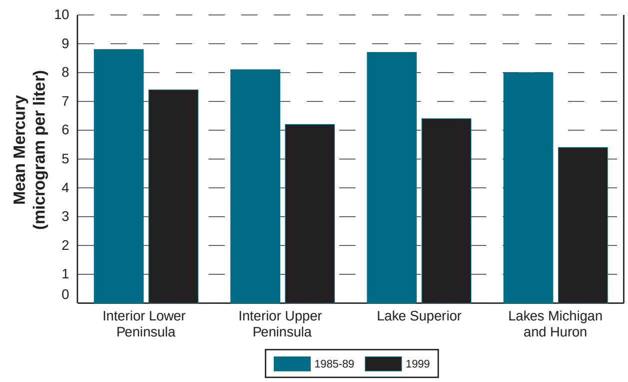
Contaminant Levels. Bald eagle populations were impacted significantly due to widespread pesticide and other contaminant use in the early 1960s and 1970s. In addition to providing general population information, bald eagle monitoring has been used to provide a gross indication of the levels of contaminants within the environment. In 1999, a consortium composed of the DEQ, the USFWS, and researchers from Michigan State and Clemson Universities initiated a bald eagle contaminant monitoring project. Ninety samples (blood and feathers using non-lethal procedures) were collected from permanent inland nests, from nests in additional inland watersheds being assessed as part of the DEQ's 5-year watershed cycle, and from Great Lakes and connecting channel nests. Exhibits 10 and 11 show changes in mercury and polychlorinated biphenyls (PCB) levels, respectively, in bald eagles between the late 1980s

Exhibit 10. Mean Polychlorinated Biphenyls Concentrations in Nestling Bald Eagle Blood 1987 - 1992 and 1999



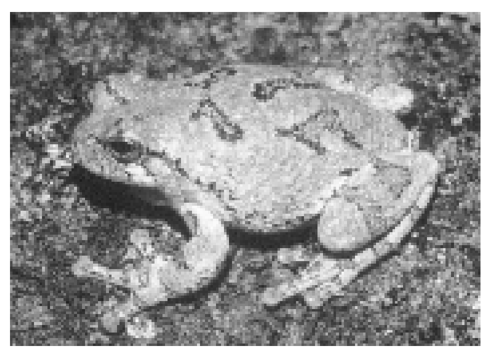
- early 1990s and 1999. Specifically, mean mercury levels in bald eagle feathers declined in all geographic areas examined, including interior Upper and Lower Peninsula nests, Lake Superior nests, and Lake Michigan/Lake Huron nests. Similarly, polychlorinated biphenyls (PCB) levels in the blood of bald eagles were dramatically lower in 1999, compared to a decade ago, for interior nests and Lakes Superior, Michigan, and Huron. The only exception was Lake Erie, which should be judged with caution because only one eagle was sampled in 1999. These data clearly demonstrate that levels of key contaminants in bald eagles declined through the 1990s. Data from the year 2000 will be included in the next reporting period. Sample collections will continue in 2001.

Exhibit 11. Mean Mercury Levels in Nestling Bald Eagle Feathers 1985 - 1989 and 1999



Trends in Frog and Toad Populations

Michigan is home to 13 native species of amphibians (frogs and toads). In recent years, scientists have been concerned about observed declines and/or population die-offs of several of these species worldwide. This concern was not only for the species themselves, but also for the ecosystems on which they depend. Frogs and toads, like many other aquatic organisms, are sensitive to changes in water quality and adjacent land use practices, and their populations can serve as an index to environmental quality.



In order to address the amphibian decline issue in Michigan and to begin monitoring their populations, a statewide volunteer calling survey was initiated in 1996 by the DNR. It is hoped that site-specific research projects may be initiated in areas where declines become significant to determine the causes of those declines and to gain insight into ecosystem degradation.

The initial amphibian survey protocol used by the state mirrored that of a long-running and successful survey in Wisconsin. Later, the United States Geological Survey (USGS) developed nationwide protocols as part of the North American Amphibian Monitoring Program of which Michigan is a participant. Survey routes currently consist of 10 sites at which volunteers stop and listen for frogs and record the species and an abundance index for each species on a data sheet. Each survey route is visited three times during the breeding season. Statewide surveys have not been done in the past so comparison to historical data is only possible for local areas.

Exhibits 12 and 13 illustrate abundances of six frog species that have statewide distribution. The number of routes surveyed each year (solid bars) also tracks the level of volunteer effort. Exhibit 12 shows the average number of sites per route at which three of the most common species of frogs in Michigan (spring peeper, eastern gray tree frog, and green frog) were heard over the five-year period. Trend analysis for these data currently shows no significant increase or decrease for any of these species.

Exhibit 12. Average Number of Sites per Survey Route on which Three More Common Frog Species were Heard 1996 - 2000

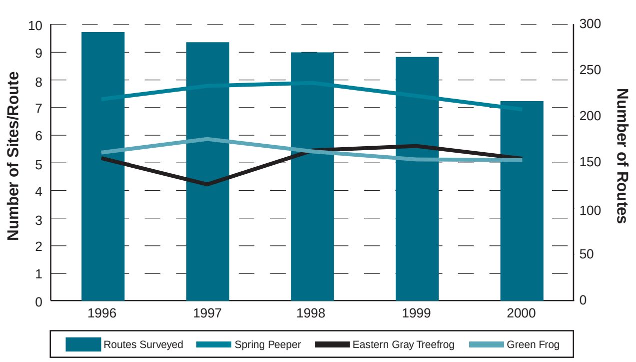
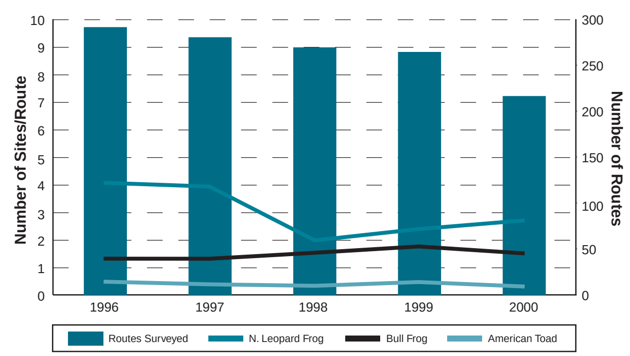


Exhibit 13 shows the average number of sites per route at which three of the less common species of frogs in Michigan (northern leopard frog, bullfrog, and American toad) were heard over the five-year period. The fluctuation of abundance of the American toad is a good example of how factors in one year may impact survey results. The reason for the decline in 1998 of American toads is currently unknown. Hopefully, longer term monitoring should show if the low number of American toads in 1998 was the result of a natural fluctuation or a human-influenced environmental factor. With the exception of the American toad, trend analysis for these data also shows no significant increase or decrease.

Exhibit 13. Average Number of Sites per Survey Route on which Three Less Common Frog Species were Heard 1996 - 2000



Long-term trends will require many years of data before meaningful information can be calculated. With just five years of data, including the year 2000, reliable trends cannot be discerned yet. It is known that natural fluctuations occur in amphibian populations. Several years of data will be necessary to be able to distinguish these fluctuations from those caused by human-related factors such as pesticide use and/or habitat losses. Weather factors also play an important role in calling surveys and can affect the amount and the quality of the data in any one year. The DNR plans to continue the statewide surveys indefinitely and hopes to maintain a consistent and knowledgeable volunteer workforce.

Trends in Fish Populations, Benthic Macroinvertebrate and Contaminant Levels

Walleye in Lake Erie. Since the fall of 1978, the DNR has fished experimental gill nets at two stations in western Lake Erie as part of a cooperative interagency walleye assessment program. The fall index gill net survey typically includes two 1,300-foot sets of variable-mesh, multi-filament gill net at each index station. The survey is generally conducted during early October.

Gill net catch rates reflect trends in walleye abundance. In general, trends in the total walleye catch rate in the Lake Erie index survey show that walleye abundance was relatively low in the late 1970s and early 1980s, increased in the later 1980s and peaked in 1989 (Exhibit 14). Since 1990, abundance has declined slightly, but remains higher than the earliest time period. Annual walleye abundance is strongly related to annual variation in reproductive success. This is reflected in yearling catch rates each year (Exhibit 15). The extremely poor recruitment for Lake Erie walleye yearlings is well illustrated in the low catch rates observed in 1992 and 1995.

Exhibit 14. Annual and Mean Catch Rates for Walleye in Michigan's Waters of Lake Erie 1978 - 2000

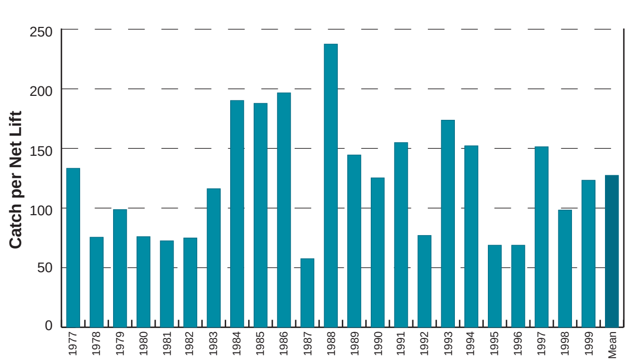
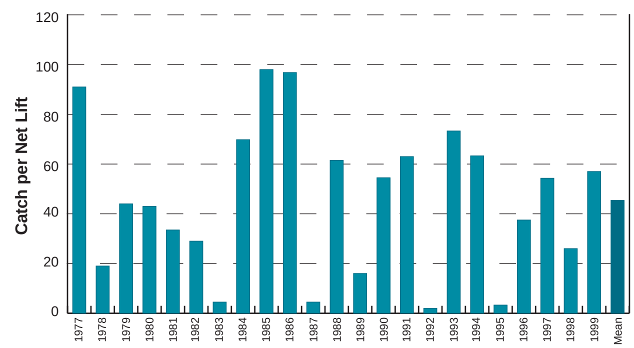


Exhibit 15. Catch Rates by Year Class for Yearling Walleye in Michigan's Water of Lake Erie 1977 - 1999

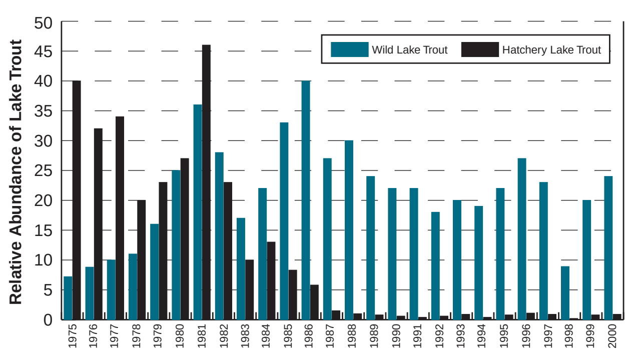


Lake Trout in Lake Superior. The lake trout is the dominant native predator fish in the cold water fish communities of the upper Great Lakes. Lake trout numbers are a good indicator of aquatic ecosystem health. Lake trout are long-lived and accumulate toxins in their bodies. The concentrations of these toxins are monitored by the DEQ to evaluate potential health risks to the public. Imbalance in fish community dynamics is also reflected in shifts in lake trout population dynamics. During the 1940s and 1950s, lake trout populations crashed due to high levels of commercial exploitation and parasitism by the non-native sea lamprey. Subsequently, an extensive lake trout rehabilitation program was implemented to re-establish self-sustaining populations. Lake trout populations increased during the 1970s and early 1980s due to sea lamprey control, restrictions on commercial fisheries, and stocking of hatchery-raised lake trout. During the mid-1980s, wild lake trout populations (sustained by natural reproduction) were increasing in most areas of Michigan's waters of

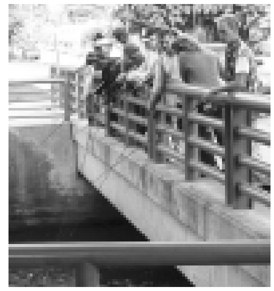
Lake Superior. By the mid-1990s, wild lake trout abundance increased to a point where stocking of hatchery-produced fish was discontinued in all areas of Michigan's waters of Lake Superior, except in Keweenaw Bay and Whitefish Bay. During the period of increasing wild lake trout abundance, hatchery lake trout abundance and survival declined precipitously.

Currently, lake trout populations are nearly rehabilitated in all areas of Michigan's waters of Lake Superior, except in Whitefish Bay (Exhibit 16). Hatchery lake trout compose less than 20 percent of lake trout abundance in Michigan's waters of Lake Superior, except in Whitefish Bay where most fish are of hatchery origin. High levels of commercial exploitation and lack of significant natural reproduction have been inhibiting lake trout abundance in Whitefish Bay. Furthermore, moderate levels of fishery exploitation in Keweenaw Bay and the Munising region may be affecting recovery of lake trout and must be monitored closely. Another concern in the fish community that may be affecting lake trout dynamics is the high predator to prey ratio. Recent survey data indicate that the major prey fish of lake trout (rainbow smelt and lake herring) are at low abundance levels.

Exhibit 16. Trends in Abundance of Wild and Hatchery Lake Trout in Michigan's Waters of Lake Superior 1975 - 2000



Trout in the Au Sable River System. Trends in stream fish populations can be good environmental indicators because the quality of their habitat is shaped by conditions in the watershed upstream. Stream trout may be a particularly good indicator because healthy, self-reproducing trout populations require relatively



specialized environmental conditions. Trout need relatively cold and well oxygenated water. They require clean gravel for spawning, shelter from predators, high velocity water, a diverse and abundant food supply, and free access to different habitats at different stages of their lives.

Human activities in a watershed have the potential to either enhance or degrade trout habitat quality. Activities that reduce groundwater yield to streams can result in warming of the river, which reduces the area available for trout to survive. Cutting or clearing trees from land adjacent to streams reduces shading, reduces the potential for trees to fall into the stream to provide shelter and nutrients, and may increase erosion of sediment into the channel. Any construction in a watershed that increases soil erosion to streams degrades trout habitat. Activities in a watershed that change the magnitude or timing of flood flows also diminish habitat quality. Examples of such activities include construction of drains and storm sewers, increases in water-impermeable surfaces such as parking lots, and operation of lake level control structures. Forest harvesting practices may either enhance or detract from trout habitat quality. A wide variety of chemical pollutants may also harm trout populations. Changes in angling regulations or angler harvest over time can also affect trout abundance.

The DNR has sampled trout populations for many years at fixed sites in portions of the upper Au Sable River system in Crawford County. Fall standing stocks of brook and brown trout (pounds/ acre) in the mainstem and north branch of the Au Sable River were generally higher during the 1960s and 1970s than in subsequent decades (Exhibit17). By contrast, fall standing stocks in the south branch Au Sable River have been relatively stable, generally ranging between 40 to 60 pounds per acre. Standing stocks of trout in the mainstem and north branch Au Sable River declined substantially during the 1980s, and remained at lower than average levels during most of the 1990s. The declines in total trout standing stocks were caused primarily by declines in growth and survival rates for brown trout. This resulted in fewer large fish and, therefore, lower standing stocks. Trends in total numbers of brook and brown trout combined over the period of record are not as obvious, although the range of trout densities observed was quite large (Exhibit 18). Linkages between variations in trout abundance and environmental quality are very complex and not fully understood. Declines in growth rates in the mainstem of the Au Sable River are commonly attributed to reductions in nutrient levels.

Exhibit 17. Fall Standing Stock of Brown and Brook Trout in Three Branches of the Au Sable System 1960 - 2000

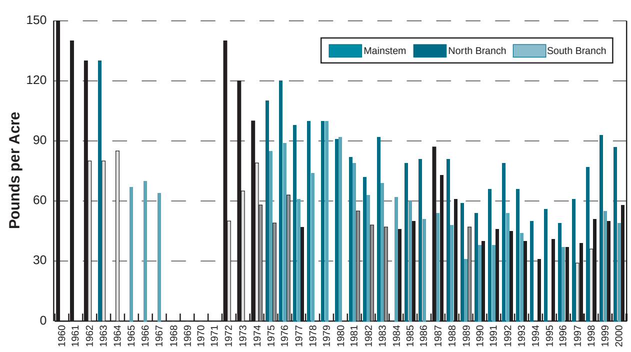
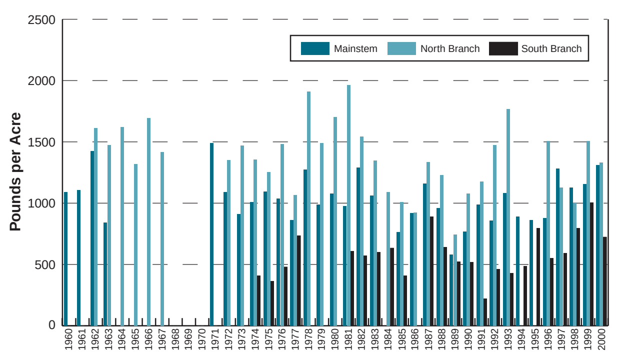


Exhibit 18. Fall Numbers of Brown and Brook Trout in Three Branches of the Au Sable System 1960 - 2000



Fisheries managers have used a variety of angling regulations intended to improve survival or growth rates of trout during this time period. In addition, private- and publicly-funded habitat rehabilitation efforts have been directed toward reducing erosion of sediment into the river system, removing excess sand bedload via sediment basins, protecting trees that fall into the river, and adding large woody material to provide trout shelter and nutrients. Trout abundance at the beginning of the 21st Century suggests that these cumulative efforts may be having a positive impact.

Weather conditions favorable for reproduction, growth, and survival during recent years have also contributed to the recent rebound in trout abundance. Moreover, angling regulations were made more restrictive in 2000. Yet, abundance of trout in the upper Au Sable River system may not reflect regional trends in habitat quality. The DNR is establishing sampling protocols for implementation in 2002 that should provide more comprehensive information on the status and trends in fish populations over a broader geographic area.

In the interim, a study being conducted at the DNR's Hunt Creek Fisheries Research Station seeks to determine if contemporary trout populations in 10 rivers in the northern Lower Peninsula have changed significantly from the 1960s and 1970s to the present time. The study will also look for associations between temporal changes in nutrient levels in water, land use changes, and other factors and trout abundance.

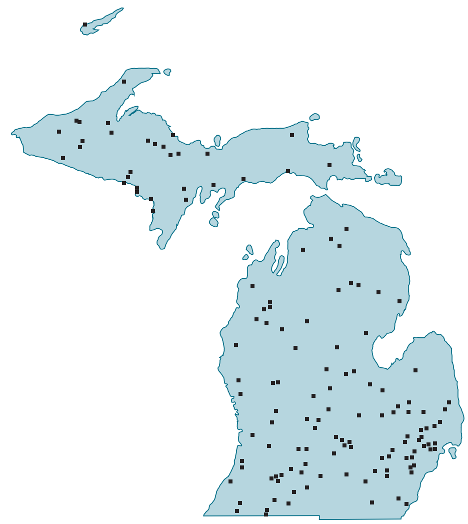
Trends in Benthic Macroinvertebrate and Fish Populations. The DEQ collects data on the relative abundance of benthic macroinvertebrates and fish in wadable streams and rivers throughout Michigan. These surveys, which are a major component of the state's watershed assessments, are conducted on a 5-year cycle to support the National Pollution Discharge Elimination System and non-point source protection programs. The sampling method, known as *Procedure 51*, is a rapid assessment protocol designed to quickly determine stream and aquatic life conditions. Biologists sample a stream reach to identify the benthic macroinvertebrate and fish species present and estimate their relative abundance. Fish are sometimes not collected due to the extra time, equipment, and staff required. As a result, benthic invertebrates are collected from many more sites than fish.

Because Procedure 51 is a rapid assessment technique, it is qualitative rather than quantitative. Quantitative, statistical measures for each species, such as population densities (e.g., numbers per square meter), are currently not determined. This has limited the use of these data as long term, consistent water quality indicators. Another limitation is the absence of fixed sites that are monitored for biota on a regular basis, since watersheds are assessed over a 5-year cycle. Both of these issues will be addressed in the near future.

New Sampling Protocols. With over 10,000 inland lakes and 36,000 miles of stream habitat, assessing status and trends of the state's inland fishery resources is a daunting task. Over the past several decades, the DNR has conducted numerous surveys of fish populations in lakes and streams across the state. Although a few assessments have been conducted with consistent methods over a long period of time, most surveys have been short term, with the intention of addressing immediate site-specific issues. While this strategy has proven useful for providing information to support fisheries management on individual water bodies, it does not provide an adequate statistical framework for inferences regarding status and trends in fish populations and communities across broader spatial or temporal scales. Consequently, the current data collection strategy does not allow fishery managers to put the results of individual lake surveys in the context of larger scale trends that may need to be addressed.

Recognizing the limitations of this approach to provide regional or statewide trends in fish populations, the DNR formed the Resource Inventory Planning Committee in 1995 to develop a more scientifically sound sampling protocol. As a direct result of this committee's work, the DNR will be instituting a newly designed sampling program in 2002. The program will annually evaluate habitat conditions and fish communities at 40 of 80 fixed stream locations (Exhibit 19) and 70 randomly selected lakes throughout the state to obtain statistically sound estimates of status and trends of game and non-game fishes, while still providing information essential for effective fisheries management.

Exhibit 19. Locations of 80 Fixed Sites on Rivers Selected for Monitoring Long-Term Trends in Fish Populations



Similarly, the DEQ also recently signed a contract with the Great Lakes Environmental Center to develop a statistically based network design and sampling procedure to measure long-term trends in benthic macroinvertebrates at a mix of fixed and randomly selected stations. This procedure should be ready for implementation in 2003. The results of the new DNR and DEQ sampling programs will be summarized for this report in the future.

Contaminants in Fish. The DEQ monitors long-lasting, toxic pollutants in fish from waters of the state. Extremely low concentrations of some of these pollutants in water can accumulate to relatively high concentrations in fish tissue. In some cases, contaminant concentrations in fish tissue may reach levels that pose a human or wildlife health risk. Currently, Michigan collects and analyzes over 700 fish tissue samples from approximately 50 locations annually. Since 1980, Michigan has collected and analyzed over 13,000 fish tissue samples from more than 500 locations. These samples have been used to develop sport fish consumption advisories and to track environmental trends.

Exhibit 20. Polychlorinated Biphenyls Concentration in Lake Trout from Four Great Lakes 1970 - 1998

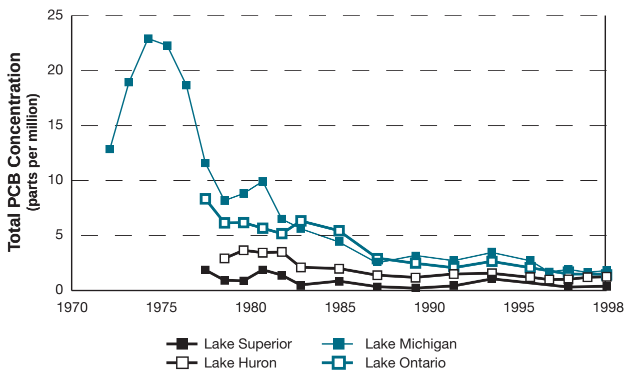
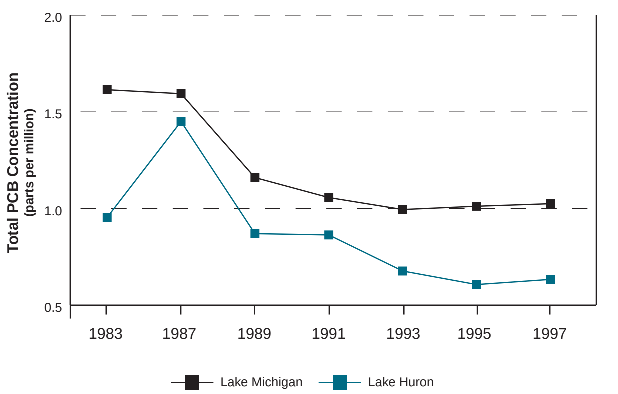


Exhibit 21. Polychlorinated Biphenyls Concentration in Chinook Salmon Fillet Samples from Lakes Michigan and Huron 1983 - 1997



Since the 1970s, pollution control efforts have resulted in significant reductions of many contaminants. For example, PCBs in whole lake trout from the Great Lakes declined dramatically (Exhibit 20). These data indicate that PCB levels in lake trout from the Great Lakes, after declining from the 1970s through the mid-1990s, have remained fairly constant in recent years. In addition, PCB levels have declined in the edible portion of Chinook salmon from Lakes Michigan and Huron, although these declines also have leveled off in recent years (Exhibit 21). Based on these data, the general population consumption advisory for Chinook salmon was removed in 1996. Additional Chinook salmon were collected in 1999 and 2000, but have not been analyzed yet. The 1999 and 2000 data will be included in the next report.

Exotic Species

Over 160 aquatic and terrestrial species of plants and animals have been introduced into the Great Lakes Basin since the 1800s (Exhibit 22). Introductions of non-native aquatic and terrestrial species or exotics, such the sea lamprey, zebra mussel, gypsy moth, and spotted knapweed, whether intentionally or unintentionally, play a major role in modifying aquatic and terrestrial ecosystems of the Great Lakes. Second only to habitat loss, many exotic species severely impact native species and ecosystem functions. Freed from competitors, predators, parasites, and pathogens that regulate populations in their native environments, exotic species alter habitat and reduce biological diversity in the Great Lakes basin. Lack of natural controls in its new range can allow an exotic species to grow at or near its potential exponential growth rate and compete for food with many native species.

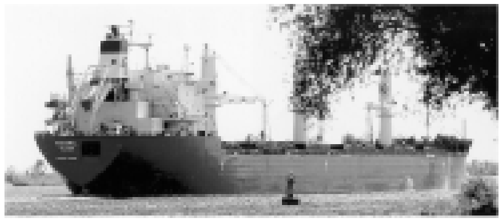
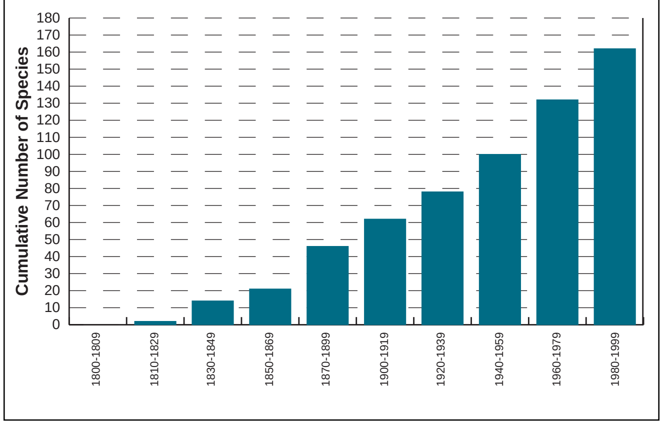


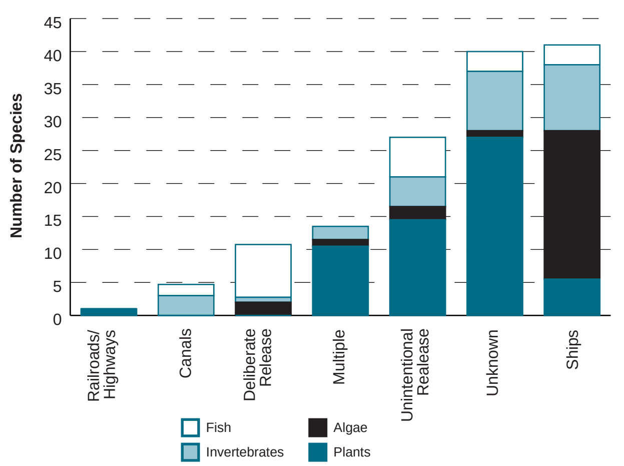
Exhibit 22. Introduction of Exotic Species into the Great Lakes 1800 - 1999



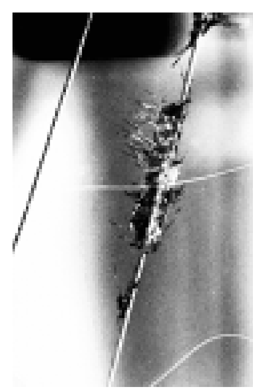
The four primary routes of entry for exotics into the Great Lakes basin include ballast water from ocean-going ships, unintentional releases, multiple sources, and unknown (Exhibit 23). The greatest number of species introduced into the Great Lakes coincides with the expansion of the St. Lawrence Seaway in 1959, which allowed greater transoceanic shipping traffic. More than one third of the species have been introduced into the Great Lakes in the last half of the 20th Century. One study predicts additional introductions of animals from the Eurasian Ponto-Caspian basin alone, many of which have broad salinity tolerances.

Over the past few decades, a number of aquatic exotic species have been unintentionally introduced including the zebra mussel, round goby, spiny water flea, and many others. The Great Lakes sport and commercial fishing industry is at risk due to the increasing numbers of invasions of non-native mussels and fish including the zebra mussel, quagga mussel, sea lamprey, Eurasian ruffe, and round goby. Research has yet to discover an effective control for the zebra mussel. Non-native zooplankton species, such as the spiny water flea and fishhook flea, are also complicating the ecological food web.

Exhibit 23. Sources of Entry of Exotic Species into the Great Lakes



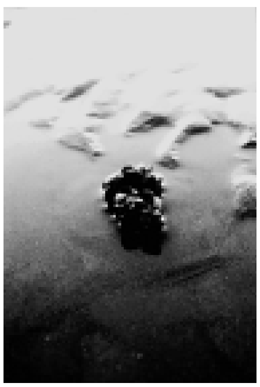
Many terrestrial species, such as gypsy moth, spotted knapweed, and leafy spruge have been unintentionally introduced while others species including the ring-necked pheasant and purple loosestrife were intentionally distributed throughout the United States. Purple loosestrife has replaced native wetland plants used by animals and fish for food, shelter, nurseries, and breeding grounds. Several years ago, a cooperative effort was made to introduce a biological control. After extensive studies had been conducted, results showed that the Galerucella beetle feeds exclusively on purple loosestrife. Releases in heavily infested wetlands have shown dramatic results. On controlled sites, native species have begun to recover. The beetle will not eradicate purple loosestrife, but will help establish a balance between purple loosestrife and native species. Various approved biological controls including five species of fleas, one species of long-horned beetle, and one species of gall midge also have been released to control leafy spurge, an aggressive weed which invades pasture lands and out competes native forage plants. Due to its toxic properties, cattle and deer avoid grazing on leafy spurge, which has now spread through out most of Michigan's Lower Peninsula and eastern portions of the Upper Peninsula. Through the plant industry, plant materials are being carefully inspected to prevent future introductions of potentially invasive terrestrial species using an intensive certification process.



While limited progress has been made to decrease the number of new exotics being introduced into the Great Lakes basin, much remains to be accomplished. Pursuant to federal law, some ships are now required to exchange their ballast water at sea, flushing out organisms and raising the salinity of the ballast water to kill freshwater organisms that might remain alive in the ballast tank. Although open water exchange helps reduce the risk of aquatic exotics found in ballast tanks and sediments, it does not ensure protection of the Great Lakes. Other control methods such as heating the water, biocides, filtration, or passing the water through ultraviolet light are also being studied.

In 1996, the Council of Great Lakes Governors and the Great Lakes Protection Fund sponsored the Ballast Technology Demonstration Project to examine filtration technology to prevent the invasion of aquatic exotics. Past filtering practices have not proven to be effective against the invasion of many small organisms such as zooplankton and other larval organisms. Experimental fine filtration technology has been developed to prevent the invasion of these very small organisms, but rapid ballast pumping requirements on ships remain a challenge. Testing in salt and fresh water environments is underway to determine its effectiveness.

Since ship ballast water is the major source for aquatic exotic species introductions, Governor John Engler, in February 2000, requested the Council of Great Lakes Governors to form a Ballast Water Task Force. The purpose of the Task Force is to explore, outline, and advise the Great Lakes Governors on a range of options to inhibit further introductions of aquatic exotic species from ballast water. In April 2000, the DEQ convened a workgroup of technical experts from international and domestic shipping industries, and the United States Coast Guard to examine potential ballast water treatments including technologies, management practices, and biocides. As a result of this initiative, the DEQ issued a contract to evaluate the effectiveness of using hypochlorite and copper ion as ballast water biocides. The investigation is expected to be completed in late March or early April 2002.



Beginning in late 2001, the DEQ also will be developing a program to monitor ocean-going and fresh water Great Lakes ships that traffic in Michigan waters to determine if and what type of ballast water management and treatment methods are being used. It is anticipated that over the next several years, large scale and rigorous projects aimed at demonstrating potential control through a combination of both treatment and management options will ultimately lead to a reduction in the number of exotics entering the Great Lakes. In future updates, the DEQ will be reporting on current distributions and impacts of exotics on the Great Lakes ecosystem as this information becomes available and is better understood.

Physical/Chemical Indicators

Ambient Levels of Criteria Air Pollutants

Pollutants, both manufactured and naturally occurring, affect the quality of Michigan's air. Air quality can vary depending on location, time, and weather conditions. The air quality in Michigan has shown marked improvement over the last 30 years as sources of air pollution have been identified and solutions implemented.

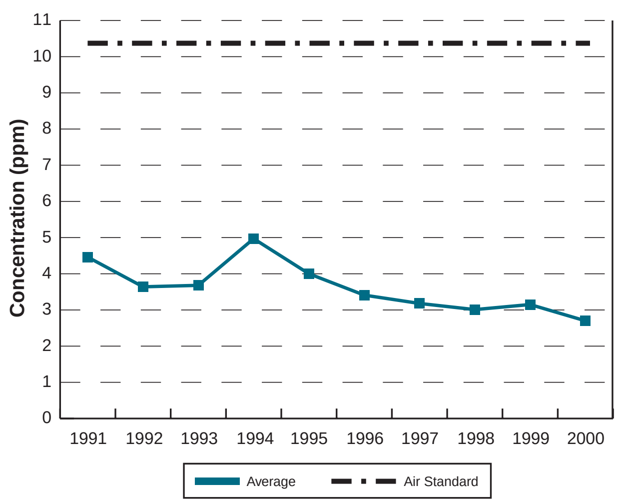
National Ambient Air Quality Standards have been set for six pollutants referred to as *criteria pollutants*. These include carbon monoxide, lead, nitrogen oxide, ozone, particulate matter, and sulfur dioxide. The DEQ operates an air monitoring network in 28 counties, which represents the overall air quality in the state. As a result of continued improvements in air quality, this network shows that all areas in Michigan are currently in compliance with the criteria pollutant health standards. Detailed information on this program is available in the DEQ's Annual Air Quality Report (http://www.deq.state.mi.us/aqd). A brief summary for each criteria pollutant is presented below.

Carbon Monoxide. Carbon monoxide is produced primarily from transportation, fuel burning for space heating, and electrical generation. Some industrial processes, as well as wood, agricultural, and refuse burning also contribute to emissions of carbon monoxide.

Carbon monoxide can exert toxic effects by limiting oxygen distribution to organs and tissues. People with impaired circulatory systems are vulnerable at lower levels than healthy individuals. Exposure to carbon monoxide can impair visual perception, work capacity, manual dexterity, learning ability, and the performance of complex tasks.

Statewide annual second maximum 8-hour carbon monoxide levels over the decade have generally remained at one-third of the 9.0 parts per million (ppm) standard. A peak in the statewide average level during 1994 was due to two exceedances of the standard at one air monitoring site in Detroit. No exceedances of either 8-hour or 1-hour carbon monoxide standards have occurred in the last six years. At present, all Michigan areas are designated as being in attainment with the 1-hour and 8-hour standards (Exhibit 24).

Exhibit 24. Ambient Carbon Monoxide Trends 1991 - 2000

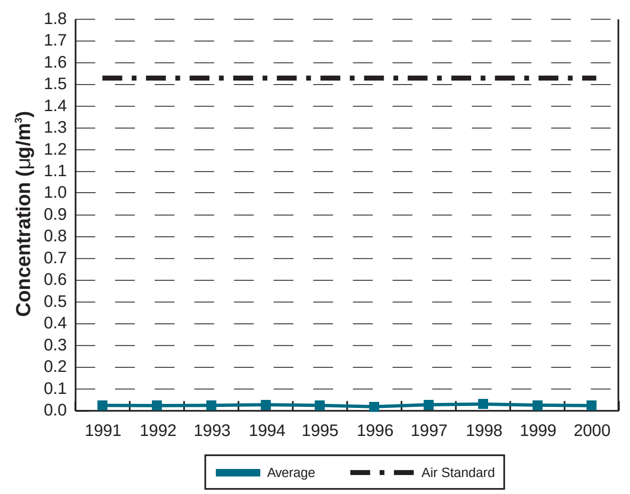


Lead. High exposures to lead can result in behavioral and learning disorders. The most common sources of lead emissions are gasoline additives, non-ferrous smelting plants, and battery manufacturing. Historically, lead was added to gasoline as an additive to prevent engine knocking. The lead content of gasoline began to be controlled in the 1970s when legislation was introduced to gradually reduce lead levels. Currently, smelters, and battery plants are the major sources of lead nationwide.

Exposure to lead can occur by way of ingestion or inhalation. Low levels of lead affect enzymatic functions and balance in the body. Lead may also be a factor in high blood pressure and heart disease in middle-aged white males. The nervous system is most sensitive to effects from lead and changes can occur as a result of low doses.

Concentrations of lead in the air have been steadily decreasing since the removal of lead from gasoline. Average quarterly lead levels across Michigan are less than a tenth of the air quality standard of 1.5 micrograms per cubic meter. From 1988 through 1997, the average of the maximum quarterly lead levels at all sites in Michigan experienced an 18.7 percent decline. The highest levels during 2000 (0.04 micrograms per cubic meter) occurred at the Detroit and Grand Rapids monitoring stations. Similar trends in the reduction of lead levels have occurred in all metropolitan areas in Michigan. The air quality standard for lead has been met from 1985 through the present. All metropolitan areas in Michigan are in attainment with the lead standard (Exhibit 25).

Exhibit 25. Ambient Lead Trends 1991 - 2000

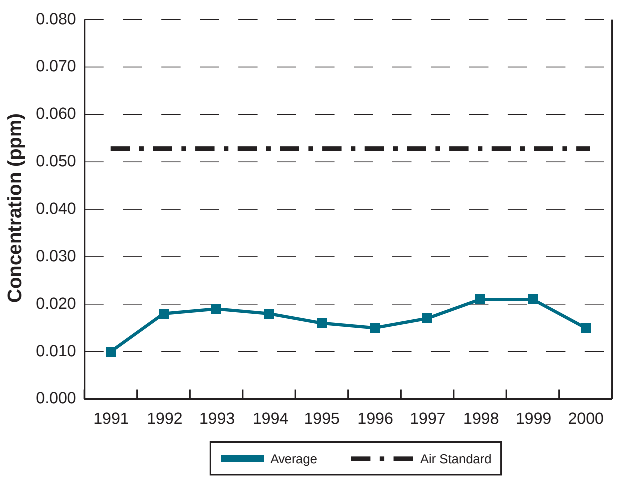


Nitrogen Dioxide. Nitrogen dioxide is formed during combustion processes that create extremely high temperatures, such as those that result from burning coal, oil, and gas fuel and from burning fuels in motor vehicle engines. Nitrogen oxides are necessary for the formation of ground level ozone and acid rain.

The respiratory system is susceptible to effects caused by exposure to nitrogen dioxide. Asthmatics are more sensitive to the effects from exposure to nitrogen dioxide.

Monitoring results show that ambient nitrogen dioxide levels have remained at the 0.02 ppm level for most of the decade, which is much less than one-half of the standard. Michigan has never recorded a violation of the nitrogen dioxide standard. All Michigan areas are in attainment with the standard (Exhibit 26).

Exhibit 26. Ambient Nitrogen Dioxide Trends 1991 - 2000

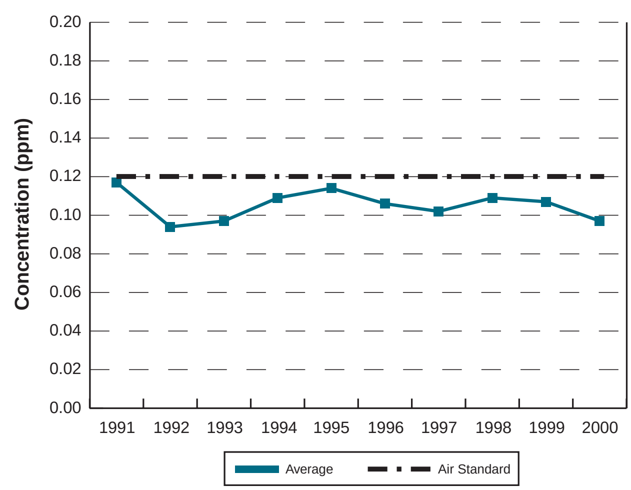


Ozone. Ozone is a colorless gas that is formed from photochemical reactions between nitrogen oxides and volatile organic compounds such as hydrocarbons from gasoline and solvents used in cleaning materials or painting applications. The primary sources of volatile organic compounds and hydrocarbons include motor vehicle exhaust, gasoline storage and transfer, paint solvents, and degreasing agents. Natural sources include lightning and terpene emission from pine trees and other vegetation. Sunlight initiates the reaction, which is why elevated ozone concentrations occur during the warmer, sunnier months of the year. In addition to the formation of ozone, these reactions form many other products which, when combined with ozone, are called *photochemical smog*. Smog is a brownish, acrid mixture of many gases and particles. The color, odor, and astringency of smog are due to compounds other than ozone.

Ozone irritates the respiratory system and can cause coughing and chest pains upon deep inspiration in exercising individuals. Ozone is the major component of photochemical smog. It is also responsible for crop damage and increased deterioration of rubber, dyes, paints, and fabrics.

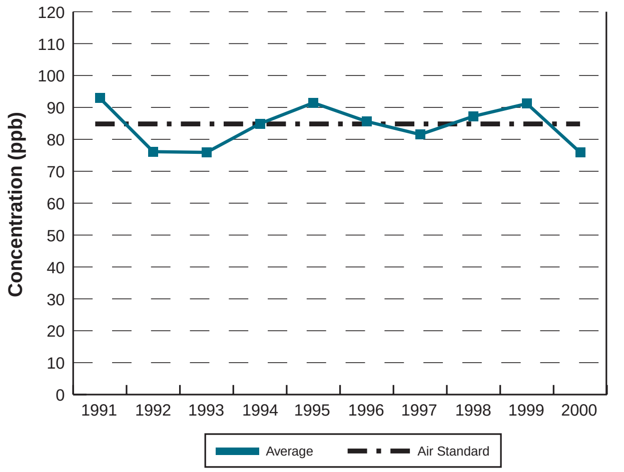
Ambient ozone levels are influenced by temperature, with the warmer summers having a greater incidence of exceedance of the 1-hour ozone standard. Extremely hot, dry summer weather is conducive to the formation of ozone. Cooler temperatures prevailed during 2000 and only three single day exceedances occurred at monitoring sites in Holland, Muskegon, and Scottville. Elevated ozone concentrations at these and other monitors located along the Lake Michigan shoreline can be attributed to long range transport (Exhibit 27). All Michigan areas have been redesignated for attainment with the 1-hour ozone standard.

Exhibit 27. Ambient Ozone Trends 1991 - 2000 (Annual Second Daily 1-Hour Maximum Average)



Statewide, ground level, 8-hour average ozone trends, measured as the average fourth highest maximum, were periodically found to be above 85 parts per billion (ppb) over the past decade (Exhibit 28). These trends are influenced by summer climatological conditions and long-range emissions transport. Lake Michigan shoreline ozone monitors at Benzonia, Scottville, Muskegon, Holland, and Coloma, as well as five downwind monitors from Detroit recorded 8-hour ozone levels above 85 ppb over the past three years. Designations with respect to the 8-hour standard cannot be made until United States Federal Courts make a final determination regarding the 8-hour standard.

Exhibit 28. Ambient Ozone Trends 1991 - 2000 (Average of Fourth Highest 8-Hour Maximum)



Particulate Matter. Particulate matter is a broad classification of material that consists of solid particles, fine liquid droplets, or condensed liquids sorbed onto solid particles. Particulates with a diameter of less than 10 micrometers in diameter are referred to as *PM_{10}* while very fine particles equal to less than 2.5 micrometers in diameter are referred to as *$PM_{2.5}$*. The particles or droplets have many different chemical compositions, depending on the source of the emissions. Also, chemical reactions can occur in the atmosphere to form new chemical compounds or change the form from gases and liquids into solid particles. Particulate emissions are primarily composed of smoke, dust, dirt, soot, fly ash, and condensing vapors. Industrial processes that cause these emissions include combustion, incineration, construction, mining, metal smelting, metal processing, and grinding. Other sources include motor vehicle exhaust, road dust, wind-blown soil, forest fires, ocean spray, and volcanic activity.

Exposure to particulate matter can affect breathing and the defenses of the lungs and aggravates existing respiratory and cardiovascular disease. More serious effects may occur, depending on the length of exposure, the concentration, and the chemical nature of the particulate matter. Asthmatics and individuals with chronic lung and/or cardiovascular disease, people with influenza, the elderly, and children are most susceptible. Particulate matter that is less than 10 microns in diameter is especially harmful because it can penetrate deep into the lungs and remain there. Particulate matter can impair visibility, damage materials, and create soiling.

Statewide average annual arithmetic mean PM_{10} levels over the decade have remained at nearly one half of the standard. Recent three year averages of the annual arithmetic means from individual monitoring sites revealed that Wayne County monitors, located in Dearborn and Detroit, had the highest PM_{10} particulate levels (Exhibit 29). Over the decade, the statewide 24-hour maximum value trend has been nearly one-half of the standard. In October 1999, the Wayne County Dearborn monitor site had a 24-hour concentration that was just above the 150 micrograms per cubic meter standard. During 2000, the 24-hour maximum values approached but did not exceed the standard in Detroit (Exhibit 30). Michigan is designated attainment with PM_{10} particulate standards.

Exhibit 29. Ambient Particulate Matter (PM_{10}) Trends 1991 - 2000 (Average Annual Arithmetic Mean)

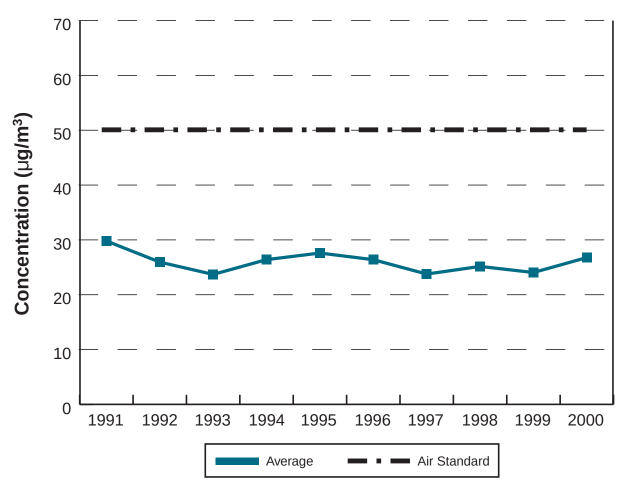
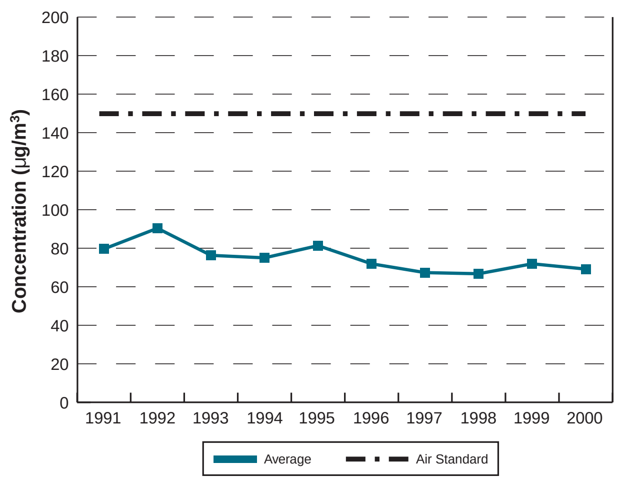


Exhibit 30. Ambient Particulate Matter (PM_{10}) Trends 1991 - 2000
(24 Hour Maximum Values)



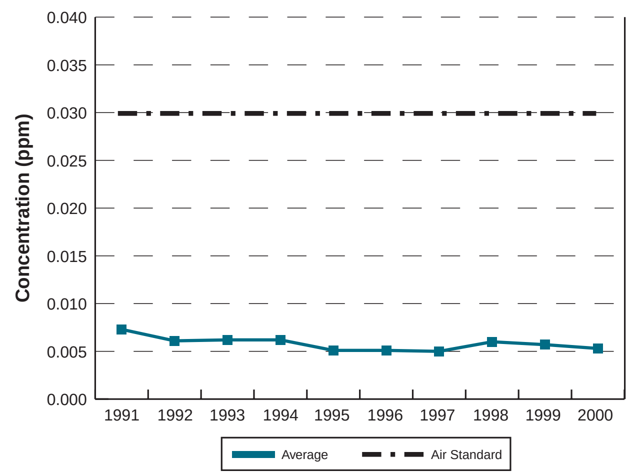
Due to the recent emergence of $PM_{2.5}$ monitoring, long-term historical trend information is unavailable. Based on monitoring results for the recent two years when monitor deployment began, statewide average annual mean concentrations have recorded values near 14 micrograms per cubic meter. Preliminary monitoring results (1999-2000) indicate annual arithmetic mean concentrations greater than 15 micrograms per cubic meter in southeastern Michigan (Wayne County). The highest annual mean concentration occurred at the Dearborn monitoring site. Three years of $PM_{2.5}$ monitoring have not been completed yet. Non-attainment area designations for fine particulate matter have not been made.

Sulfur Dioxide. Nationwide, the largest source of sulfur dioxide comes from coal-burning power plants. State regulations require that most of the coal burned in Michigan contain low amounts of sulfur. Sulfur dioxide is also emitted from non-ferrous smelters, iron ore smelters, petroleum refineries, pulp and paper mills, transportation sources, and steel mills. Other sources include residential, commercial, and industrial space heating. Volcanic eruptions are natural sources of sulfur dioxide.

Exposure to sulfur dioxide aggravates existing respiratory and cardiovascular disease. Asthmatics and individuals with chronic lung and/or cardiovascular disease, children, and the elderly are most susceptible. Sulfuric acid is a component of acid rain, which acidifies lakes, streams, and soils and corrodes building surfaces.

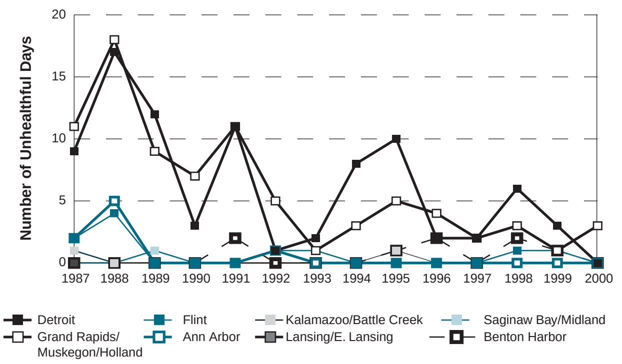
Statewide levels of sulfur dioxide have remained near one-fourth of the standard over the decade (Exhibit 31). During 2000, the highest annual mean sulfur dioxide concentration (0.008 ppm) of all monitoring sites occurred in Wayne County. The Detroit West Fort monitor site in Wayne County had the highest detected 24-hour concentration in February 2000. The state has continued to maintain an attainment designation since 1982.

Exhibit 31. Ambient Sulfur Dioxide Trends 1991 - 2000



Air Quality Index. The Air Quality Index (previously referred to as the Pollutant Standards Index) was developed by the United States Environmental Protection Agency (USEPA) to provide a simple and uniform way to report daily ambient air measurements. It allows governmental agencies to advise the public about the health effects associated with various levels of air pollution and to recommend precautionary steps if conditions warrant. Index values are available to the public and news agencies by way of the Internet on a near real-time basis. The Air Quality Index recently has added the category *unhealthy for sensitive groups* to the existing health indicators, *good*, *moderate*, *unhealthy*, *very unhealthy*, or *hazardous*. The eight metropolitan areas where Michigan reports the index record mostly *good* and *moderate* air quality levels with few days in the *unhealthy* category. All areas have demonstrated general improvement since 1987, with the largest improvements occurring in the Detroit and Grand Rapids areas (Exhibit 32). While based on actual measurements, caution should be exercised with the use of the Air Quality Index since the health classification labels are based on judgement and are, therefore, open to some interpretation.

Exhibit 32. Air Quality Index 1987 - 2000



Ambient Levels of Air Toxics Contaminants

There are many more atmospheric contaminants than just the six criteria pollutants discussed above. These air pollutants are often referred to as *air toxics*. While there are health benchmark concentrations for many air toxics, these are generally not as well established as the criteria pollutants' national ambient air quality standards. The available air toxics monitoring data are also limited. Therefore, air toxics emissions and monitoring data are not as well characterized as the monitoring data for the six criteria pollutants.

The DEQ's Air Toxics Monitoring Program was established in January 1990. Since the program's inception, over 40 toxic organic compounds and 13 trace metals have been monitored at various urban locations throughout the state. Since September 1995, monitoring program sites have been located in Grand Rapids (1995), Missaukee County near Houghton Lake (1998, this is a background monitoring site), Detroit (1999, 2 sites), and Ypsilanti (2000). The most often detected compounds at the above four operating sites have been acetaldehyde, acetone, benzene, chloromethane, dichlorodifluoromethane, formaldehyde, toluene, and trichlhlorofluoromethane. For trace metals, the most often detected metals are barium, copper, iron, lead, manganese, and zinc.

In addition to the DEQ monitoring data, there are national archives of air toxics data and data gathered by researchers during special field studies. The USEPA's National Volatile Organic Compound Database contains information concerning ambient levels of 70 of the 188 regulated compounds. The remaining 118 compounds have been addressed in a more limited fashion, namely by the use of special field studies nationwide. The limited nature of this information underscores the importance as well as the difficulty of establishing statewide and nationwide networks for monitoring air toxics. The USEPA and the DEQ are in the process of developing air toxics monitoring networks. A national air toxics monitoring network would provide measurements of ambient concentrations of air toxics at monitoring sites throughout the nation that can be used in the estimation of human and environmental exposures to air toxics.

Ambient air toxic monitoring data are needed in the evaluation of atmospheric dispersion and deposition models for greater understanding of the fate and transport of air toxics in the atmosphere. It is not feasible to have ambient measurements of air toxics at all locations, so models need to be used in those locations where ambient air monitoring data does not exist. The model estimated concentrations along with ambient measurements can be used to estimate population exposure across the nation. The ambient air toxics monitoring network targets a subset of the 188 hazardous air pollutants focusing primarily on the USEPA's urban hazardous air pollutants list. Similarly, the DEQ is currently developing an air toxics monitoring strategy to better characterize ambient air toxics levels statewide, and is implementing a relatively intensive study of air toxics in the Detroit area. More detailed information on the DEQ's current air toxics monitoring program is available in the DEQ's Annual Air Quality Report (http://www.deq.state.mi.us/aqd). The DEQ will be expanding this program in the future.

Rates of Deposition of Persistent and Bioaccumulative Air Toxics and Acidic Components

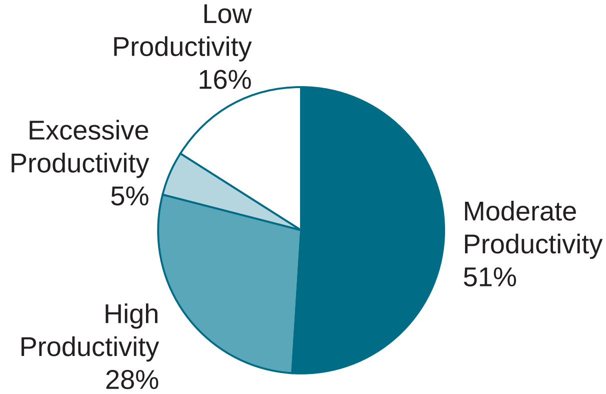
At present, the DEQ conducts no routine deposition measurements. However, the comprehensive hazardous air pollutants measurement plan, which is under development, includes five to 16 deposition sites, depending on the parameters being measured. For example, pesticide data will be collected at five sites while mercury will be sampled at 16 sites. Contaminants that will be analyzed are referred to as the *Great Waters Pollutants of Concern*, which include, cadmium and cadmium compounds, mercury and mercury compounds, lead and lead compounds, nitrogen compounds, and twelve other long-lasting and toxic compounds that can build up in the fat of animals. The MESB, in its environmental indicators report, recommended that sulfur and acidity depositional measurements also be added at sampling locations. The DEQ will be expanding and reporting on this program in the future.

Inland Lake Water Quality

The federal Clean Water Act requires states to assess lake water quality and to classify lakes according to productivity. Productivity refers to the amount of plant and animal life that can be produced within a lake. A lake's ability to support plant and animal life defines its level of productivity. Low productive lakes are generally deep and clear with little aquatic plant growth. These lakes are generally very desirable for boating and swimming and they may support cold water fish such as trout and whitefish. By contrast, highly productive lakes are generally shallow, turbid, and support abundant aquatic plant growth. These lakes commonly support warm water fish such as bass and pike.

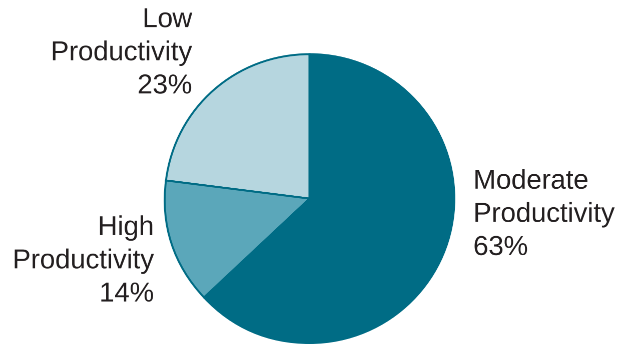
Historically, over 700 public lakes in Michigan have been assessed and classified. The majority (67%) of these lakes are classified as having moderate productivity or low productivity. Only five percent of the lakes evaluated were classified as having excessive productivity (Exhibit 33).

Exhibit 33. Historical Classification of 730 Michigan Public Lakes



Currently, a jointly administered DEQ - Michigan Lakes and Stream Associations, Inc. Cooperative Lakes Monitoring Program provides for long-term water quality measurement and continues the lakes classification process. The program enlists citizen volunteers from public and limited access lakes across the state to monitor indicators of lake productivity, including water clarity, total phosphorus, and chlorophyll *a*, from which the lakes can be classified in terms of productivity. Since 1998, 79 lakes have been involved in the program. Of these lakes, the majority exhibited moderate (63%) to low (23%) productivity. Only 14 percent of the monitored lakes were classified as having high productivity and no lakes exhibited excessive productivity (Exhibit 34).

Exhibit 34. Classification of 79 Lakes Monitored through Michigan's Cooperative Lakes Monitoring Program



The Cooperative Lakes Monitoring Program is a cost-effective program for increasing baseline water quality data and lake productivity classifications for Michigan's inland lakes, and the long term volunteer monitoring can provide information to evaluate water quality variability and trends in these lakes. However, results from the volunteer program alone only provide information on lakes where volunteers choose to participate in the program and may not be representative of lakes statewide. Consequently, the DEQ is using funds from the Clean Michigan Initiative to expand the program and to re-establish monitoring of public access lakes across the state. This effort will build upon the historical lake data that exist and supplement the information generated from the volunteer monitoring program.

As a result of this initiative, enrollment in the Cooperative Lakes Monitoring Program is anticipated to double over the next three years. For 2001, 198 lakes are enrolled in the program. Volunteers are measuring water clarity on a weekly or every other week basis in these lakes. Volunteers on 115 of the enrolled lakes have expanded their monitoring efforts to include total phosphorus and chlorophyll *a*, which along with water clarity are used for lake productivity classifications. This is nearly a 50 percent increase in participation from the year 2000 program. Volunteers are also monitoring dissolved oxygen and temperature in 56 of the enrolled lakes and are conducting pilot studies during 2001 on three newly added monitoring parameters: rapid algal assay (11 lakes), fish age and growth (2 lakes), and aquatic plant identification and mapping (3 lakes).

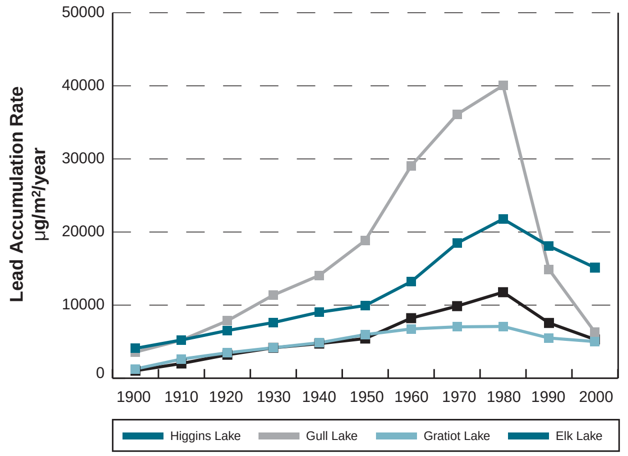
Clean Michigan Initiative funds also are supporting work by the USGS to re-establish a Lake Water Quality Assessment monitoring program for public access lakes in Michigan. Baseline data for conventional water quality parameters such as plant nutrients (i.e., total phosphorus and nitrogen), chlorophyll *a*, dissolved oxygen, temperature, water clarity, and dissolved ions (i.e., chloride, sulfate, sodium, potassium, calcium) are being collected on 56 public access lakes in 2001. Additionally, the DEQ, with input from the USGS, will explore the feasibility and practicality of using remote sensing satellite imagery for lake water quality assessments that will enable it to estimate productivity in Michigan's inland lakes statewide. An additional $47 million of Clean Michigan Initiative funds was also awarded to 33 communities through a competitive grant process for waterfront improvements to promote economic development.

Inland Lake Sediments

Contaminated sediments can directly impact bottom dwelling organisms and represent a continuing source for toxic substances in aquatic environments that may impact wildlife and humans through food or water consumption. Therefore, measuring trends in the accumulation of toxic chemicals in sediments is necessary to assess the overall quality of aquatic systems. As material is deposited on the bottom of lakes over time, the sediments serve as a chemical recorder of temporal trends of toxic contaminants. Consequently, the assessment of chemical trends in inland lake sediments is an integral component of the DEQ's water quality monitoring program.

In 1999, a joint initiative between the DEQ and Michigan State University was begun to monitor inland lake sediments. Sediment core samples were taken from five inland lakes in 1999. Samples were analyzed for mercury, trace metals, and selected organic contaminants including PCBs and pesticides. Using advanced analytical methods, researchers are able to determine historical concentrations of different contaminants over time. The results of this investigation are described in a report by Michigan State University and the DEQ. Exhibit 35 shows the accumulation rates of lead from the atmosphere into four lakes. Lead accumulation rates increased until the 1970s, when leaded gasoline was banned, and then decreased to the present. There also is a geographical trend exhibited, with lakes in the more populated southern part of the state (Gull and Higgins Lakes) generally having higher accumulation rate trends than those farther north (Elk and Gratiot Lakes). Results from two additional lakes sampled in 2000 are not available yet. Results from these two lakes will be included in the next reporting period. Five lakes will be sampled in 2001.

Exhibit 35. Lead Accumulation Rates in Four Lakes 1900 - 2000



In addition to the lake sediment assessment program, the DEQ also participates in the removal of contaminated sediments from lakes and streams.

Exhibit 36. Cubic Yards of Contaminated Sediments Removed from Surface Waters 1995 - 2000

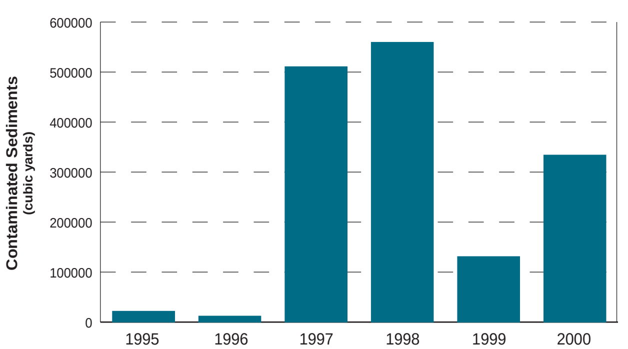


Exhibit 36 shows the cubic yards of sediment that have been removed from Michigan's lakes and streams annually since 1995. Twenty-five million dollars from the Clean Michigan Initiative have been allocated for contaminated sediment cleanup.

Stream Flow

Natural flow regimes play a significant role in maintaining stream channel configuration, wetland and riparian vegetation, and stream-dependent biological communities. Stream flow is an indicator of amount and type of habitat available for fish and other aquatic organisms. It is also an indirect indicator of water quality in streams and in lakes and reservoirs occurring in stream systems. Changes in flow patterns are expected to reflect changes in runoff from land, groundwater level, water extraction, discharge from upstream reservoirs (if present), and climatic variability.

Several common stream flow measures are used to monitor and assess status of flow patterns. These include measures of the magnitude of high (10% exceedence frequency), median (50% exceedence frequency), and low (90% exceedence frequency) flows. High and low flow measures can be standardized by the median flow to facilitate comparisons among different rivers. An additional measure of runoff (mean annual discharge/mean annual precipitation) is also evaluated.

The status of flow is determined by comparing recent flow patterns to a benchmark or reference condition. This benchmark can be based on presettlement flows or from the earliest period of record. Models have been developed that predict stream flow as a function of geology, stream size, and current land cover characteristics. These models can be used to estimate baseline flow patterns by substituting current land cover data with presettlement land cover data.

The primary source of flow data needs to come from the USGS gauging stations. At present, the USGS maintains approximately 140 stations statewide (Exhibit 37). It will be necessary to identify a subset of these gauging stations as reference. These gauges will need to have long-term data records (30 plus years) and should be located in watersheds that have been least impacted by human-induced changes in land cover. Future use of stream flow as an indicator also will require that reference gauges be maintained continuously through time.

Exhibit 37. Geographic Distribution of Active Stream Gauging Stations Overseen by the US Geological Survey

As with all environmental indicators, there are several limitations associated with use of USGS data to characterize statewide changes in stream flow patterns. First, the 140 plus existing gauges are not representative of all stream types in Michigan. Second, there are a limited number of gauges that have 30 plus years of data. Only trends established by many years of data will be meaningful because high, random variation caused by annual differences in magnitude and timing of precipitation will obscure gradual changes caused by shifts in land use. Finally, high variability inherent in flow data precludes assessment of stream flow status based on a two year reporting cycle. Currently, personnel at the DNR's Institute for Fisheries Research and the University of Michigan are analyzing the state's stream flow data. Results from this work will provide necessary information for development of baseline flow patterns and selection of reference gauging stations. These results will be reported by the DNR in the next environmental indicators report.

Contaminant Levels in the Connecting Channels, Saginaw Bay, Grand Traverse Bay, and Major Tributaries

Consistent with a water chemistry trend monitoring plan developed by the DEQ and the USGS, water samples were collected from 31 major Michigan rivers in 2000. This effort expanded previous water monitoring activities conducted in 1998 and 1999. Water samples also were collected from Saginaw Bay, Grand Traverse Bay, and the Great Lakes connecting channels. Samples were analyzed for nutrients, heavy metals, and other selected parameters using state of the art methods. These data are used to measure spatial and temporal trends in inland rivers, connecting channels, and bays.

Some of the water chemistry data from 2000 are shown in Exhibits 38 - 40. Exhibit 38 shows a comparison of total phosphorus concentrations among 23 inland rivers. Phosphorus is a key nutrient that affects algal growth and regulates productivity in surface waters. Phosphorus concentrations tend to be generally greatest in rivers that drain urban or heavily agricultural areas, and lowest in relatively undeveloped, heavily forested watersheds. Of the 15 rivers monitored in both 1998 and 2000, phosphorus levels increased slightly for seven, decreased slightly for five, and remained the same for three. Phosphorus levels were highest in the Clinton, Flint, Grand, and Escanaba Rivers. The lowest values were measured in the Cheboygan and Au Sable Rivers.

Exhibit 38. Average Total Phosphorus Concentrations in Major Michigan Great Lakes Tributaries 1998 - 1999 and 2000

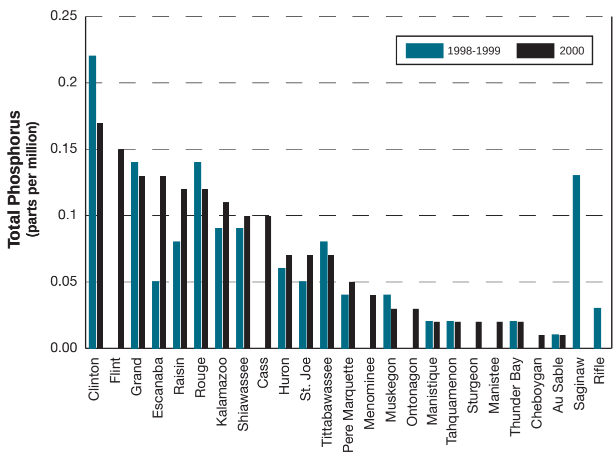


Exhibit 39 shows average concentrations of total mercury in Michigan rivers. Of the eight rivers monitored in both 1998 and 2000, mercury levels increased for one and decreased for seven. The highest mercury concentrations for 2000 occurred in the Raisin, Rouge, Kalamazoo, and Clinton Rivers, while the lowest levels were found in the Au Sable, Cheboygan, Thunder Bay, and Manistee Rivers. Mean mercury levels exceeded the Michigan water quality standard (1.3 parts per trillion) from 17 of the 23 rivers shown in Exhibit 39.

Exhibit 39. Average Mercury Concentrations in Major Lake Erie and Lake Huron Tributaries 1998 and 2000

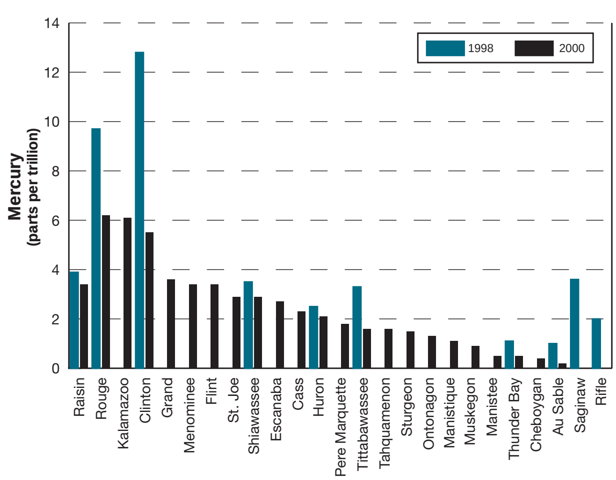
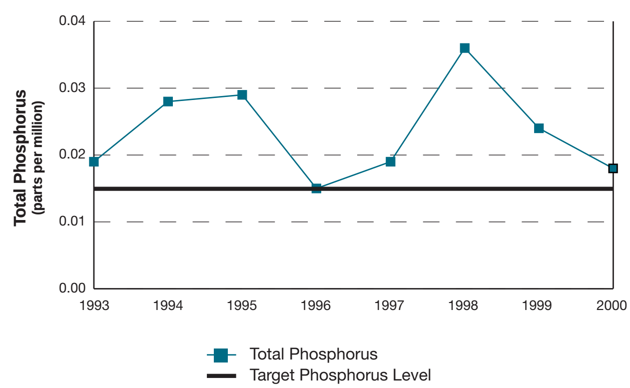


Exhibit 40 shows total phosphorus levels over time from eight locations throughout the inner Saginaw Bay. Between 1993 and 2000, average phosphorus concentrations were lowest in 1996 (15 ppm) and highest in 1998 (36 ppm). Although the levels of total phosphorus levels have continued to decline since 1998, there is no clear pattern showing that trend will continue or not. The DEQ has taken a number of steps to reduce phosphorus levels in the Saginaw Bay watershed, and will continue to monitor the Saginaw Bay to evaluate the effectiveness of these actions.

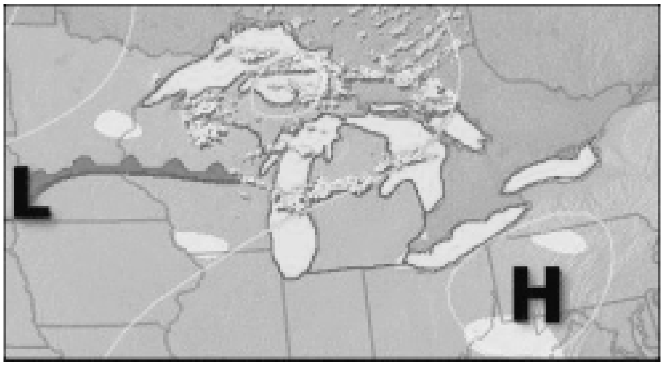
Exhibit 40. Total Phosphorus Levels in Saginaw Bay 1993 - 2000



Climate and Weather Trends

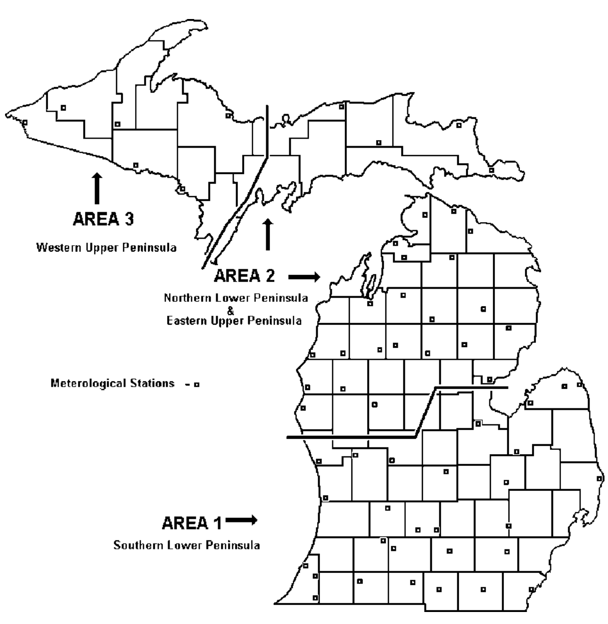
The MESB, in its review of the DNR and DEQ proposed indicators, recommended that trends in climate be included in the state environmental indicators report for three reasons. First, the state is both the southern and northern extent of numerous ecosystems so any small change in climate could have a significant impact on and help explain observed changes in those ecosystems. Second, many agriculture operations are located where they are because of the local climate, and third, because of the current scientific debate over global climate change.

The MESB, in close cooperation with the DEQ, Consumers Energy Corporation, and Air



Improvement Resource, Inc., carried out the following evaluation. The data, obtained from the National Climatic Data Center, were first compiled for ten different climatic divisions (i.e., zones). Michigan's ten climatic zones were then aggregated to three areas deemed to be representative of the southern Lower Peninsula (21 sites), the combined northern Lower and eastern Upper Peninsulas (33 sites), and the western Upper Peninsula (6 sites) (Exhibit 41). Nine climatic measurements were evaluated including annual average temperature, annual average daily maximum temperature, annual average daily minimum temperature, average diurnal temperature change, length of growing season, heating degree days, cooling degree days, total annual precipitation, and total annual snowfall.

Exhibit 41. Meteorological Station Locations in Michigan



While carrying out the compilation and aggregation steps for this indicator, a completeness check was conducted on the available climate data. It was the intent to report climate data from 1900 to the present, but this would not have been valid. The climate data collected from 1895 to 1948 carries a sampling bias since most of the sampling stations were located in large cities early in the sampling period and additional rural stations were added gradually over time. The degree of Urban Heat Island effect from these smaller than large cities and the continuum of supposed cooler data from the new rural stations are serious confounders in observations of expected minute change. To ensure that no seasonal bias was introduced into the analyses, only those sites having at least 50 percent valid data were included in the analysis. Consequently, it was determined that sufficient quality data only exists for all the Michigan climatic regions from 1949 to present despite the fact some stations have data as far back as 1895. This check was completed for each of the nine individual meteorological measurements.

Exhibits 42a to 42i present the trends for the nine meteorological measurements for the southern Lower Peninsula, the combined northern Lower and eastern Upper Peninsulas, and the western Upper Peninsula. Based on a statistical analysis of all the meteorological data, which clearly shows cyclic behavior, there is no evidence to suggest that the climate in Michigan has changed significantly over the last 51 years. This indicator will be closely monitored.

Exhibit 42a. Meterological Measurements 1945 - 2000 (Average Annual Temperatures)

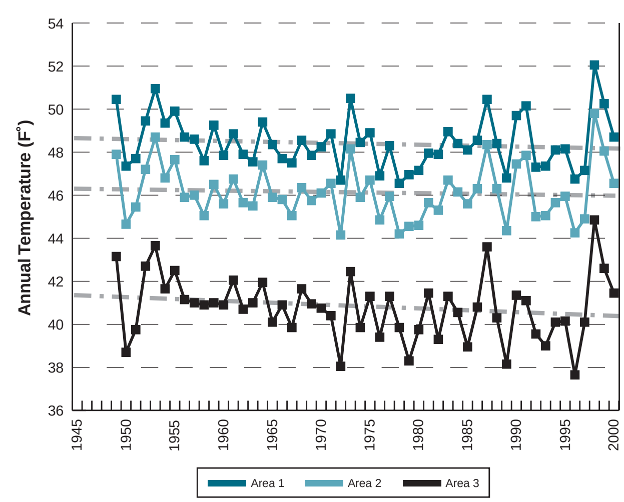


Exhibit 42b. Meterological Measurements 1945 - 2000 (Average Annual Maximum Temperatures)

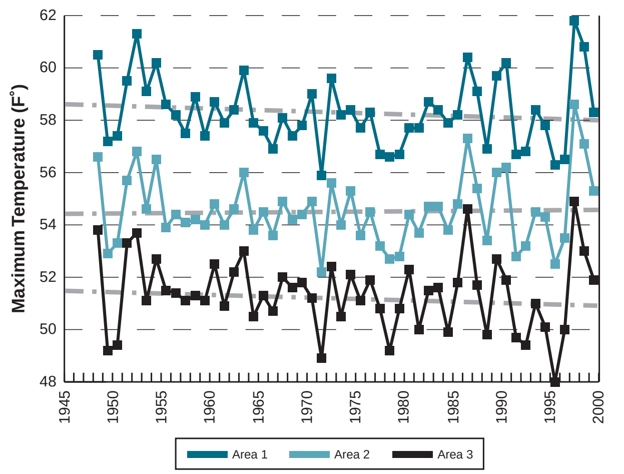


Exhibit 42e. Meterological Measurements 1945 - 2000 (Growing Season Duration)

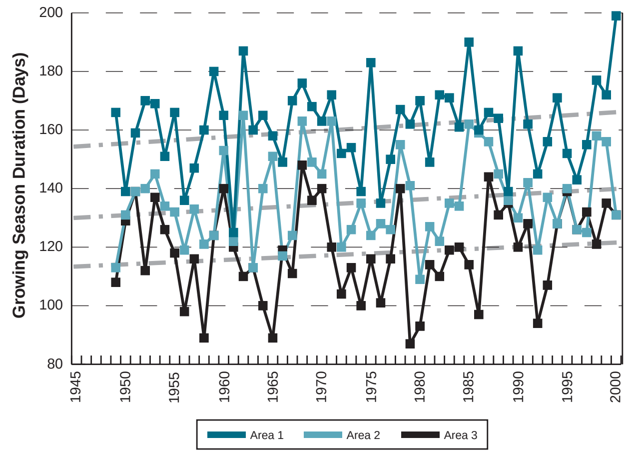


Exhibit 42c. Meterological Measurements 1945 - 2000 (Average Annual Minimum Temperatures)

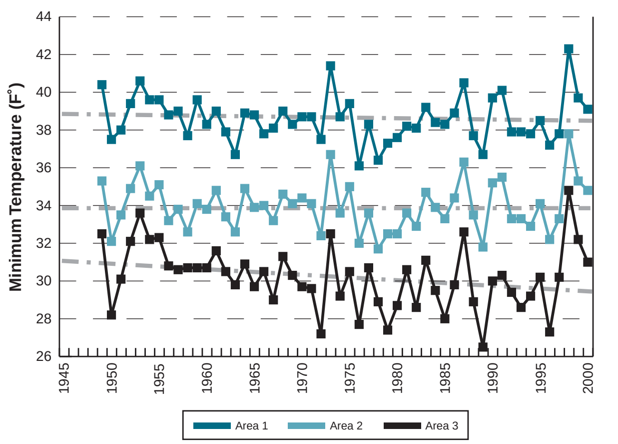


Exhibit 42f. Meterological Measurements 1945 - 2000 (Heating Degree Days)

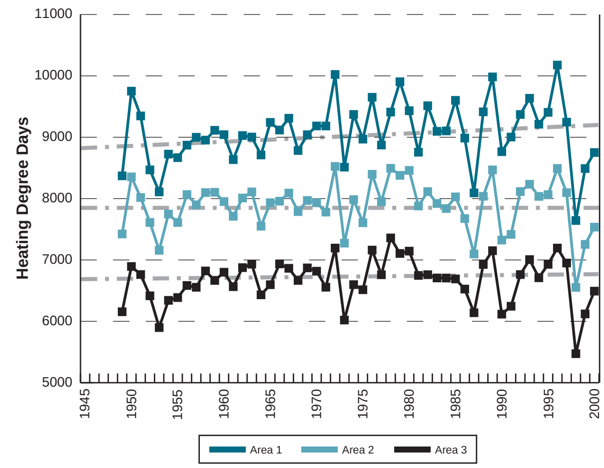


Exhibit 42d. Meterological Measurements 1945 - 2000 (Average Diurnal Temperatures)

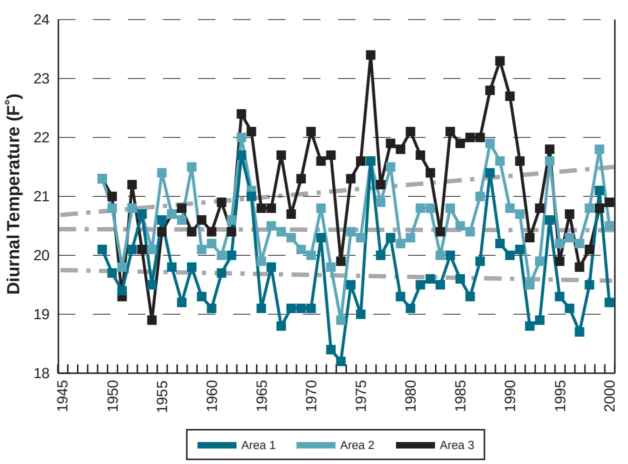


Exhibit 42g. Meterological Measurements 1945 - 2000 (Cooling Degree Days)

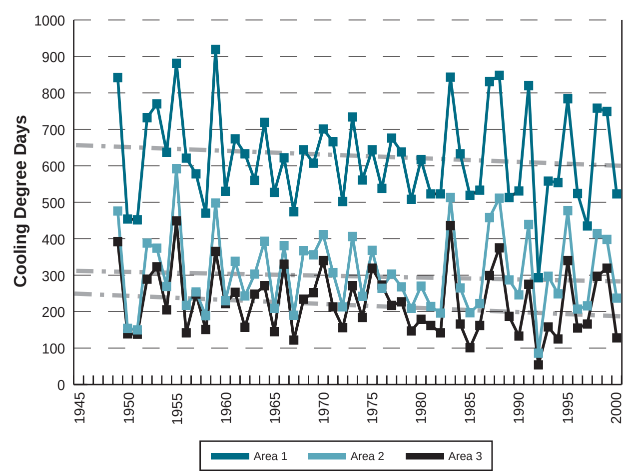


Exhibit 42h. Meterological Measurements
(Total Annual Precipitation)

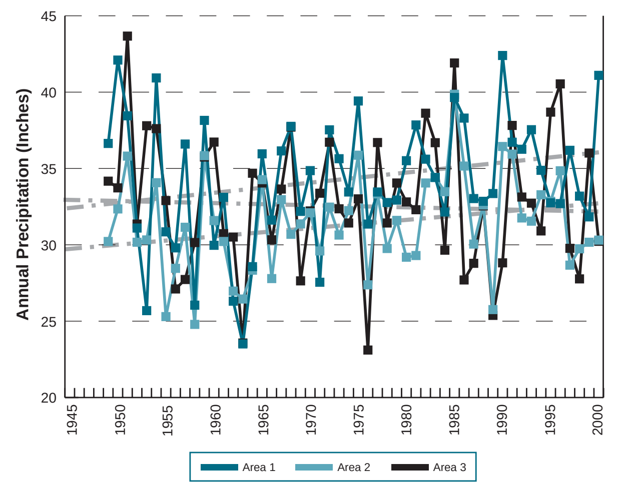
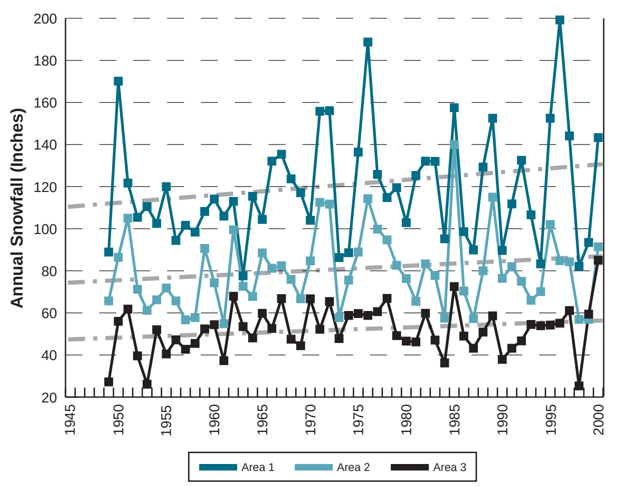


Exhibit 42i. Meterological Measurements
(Total Annual Snowfall)



Great Lakes Elevation Trends. The Great Lakes basin lies within eight U.S. states and two Canadian provinces and comprises the lakes, connecting channels, tributaries, and groundwater that drain through the international section of the St. Lawrence River. Michigan is prominently situated in the Great Lakes basin and, therefore, what impacts the basin also impacts Michigan and vice versa.

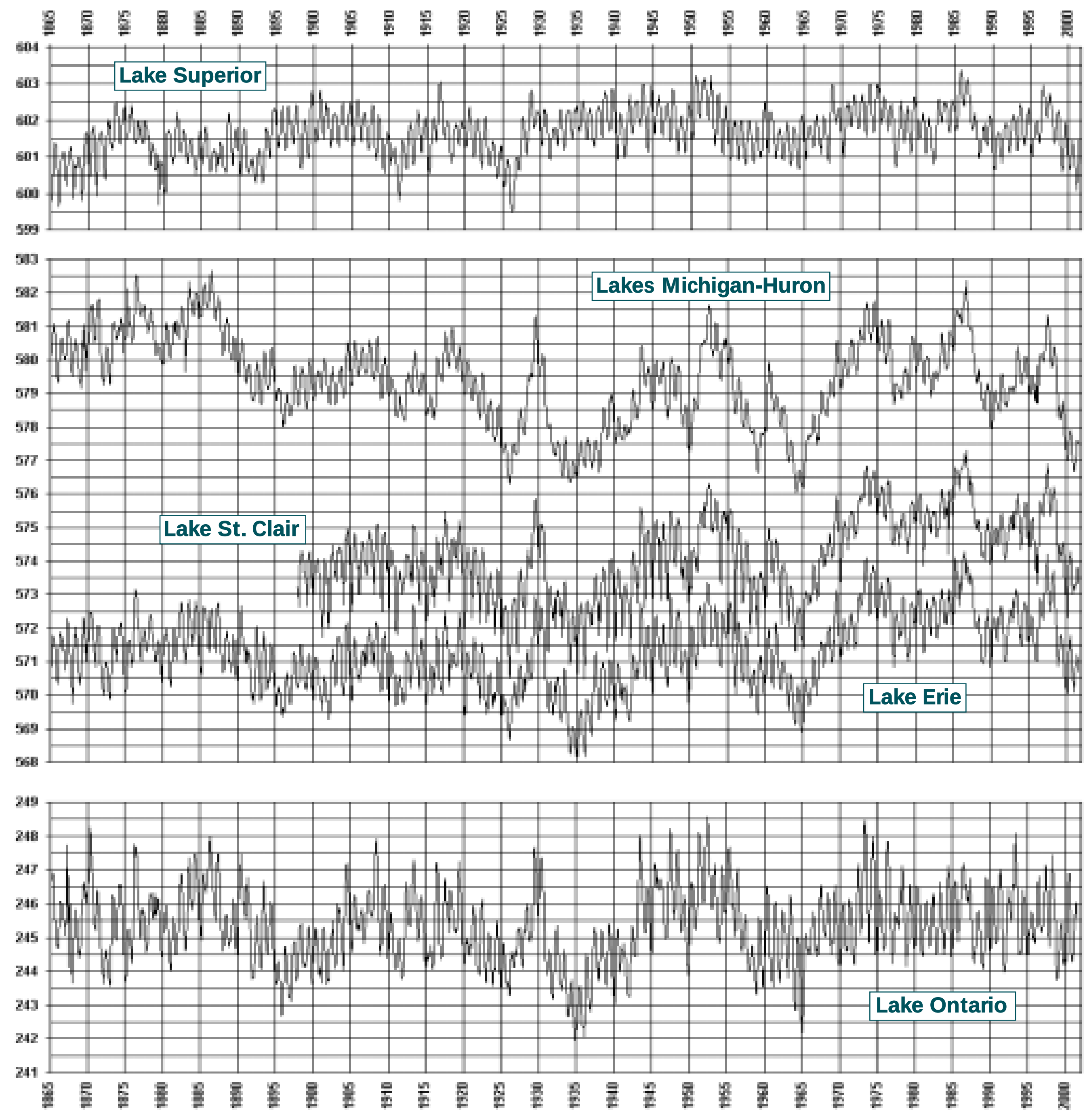
The Great Lakes basin is home to a diverse range of plants, invertebrates, fish, amphibians, reptiles, birds, and mammals. The interplay between human activities, such as dredging, consumptive uses, in and out of basin diversions, wetland reduction, urbanization and agriculture, and the ecology of the lakes is highly complex and only partially understood.

Lake levels are determined by the combined influence of precipitation (the primary source of natural water supply to the Great Lakes), upstream inflows, groundwater, surface water runoff, evaporation, diversions into and out of the system, consumptive uses, dredging, and water level regulation. Because of the vast water surface area, water levels of the Great Lakes remain remarkable steady, with a normal fluctuation ranging from 12 to 24 inches in a single year. Climatic conditions control precipitation (and thus groundwater recharge), runoff, and direct supply to the lakes, as well as the rate of evaporation. These are the primary factors in determining water levels. During dry, hot weather periods, inflow is decreased and evaporation increased, resulting in lower lake levels and reduced flows. During wet, colder periods, higher levels and increased flows occur. Between 1918 and 1998, there have been several periods of extremely high and extremely low water levels and flows. Exceptionally low levels were experienced in the mid-1920s, mid-1930s, and early 1960s. High levels occurred in 1929-1930, 1952, 1973-1974, 1985-1986, and 1997-1998 (Exhibits 43). Studies of water level fluctuations have shown that the Great Lakes can respond relatively quickly to periods of above average, or extreme precipitation, water supply, and temperature conditions.

Great Lakes levels are highly sensitive to weather fluctuations, as illustrated by the impact of high water levels in the early 1950s and mid-1980s and of low water levels in the 1930s and mid-1960s. Significant and cyclic climatic variability will continue whether or not human-intervention is superimposed on natural fluctuations. An example of how quickly water levels can change in response to climatic conditions occurred during 1998 - 1999, when the water levels of Lakes Michigan-Huron dropped 22 inches in 12 months.

The hydraulic characteristics of the Great Lakes system are the result of both natural fluctuation and, to a lesser extent, human intervention. Despite this, human activities such as control works like obstructions, dredging, and diversions can still have a large impact on lake levels. For example, dredging in the connecting channels can have a significant impact on lakes above the point of dredging. Out of basin diversions or other removals and large consumptive uses, by contrast, can reduce water levels both above and below the actual point of withdrawal and also reduce flows in the system. In addition, the introduction and establishment of exotic invasive plant and animal species can and have altered the systems even more. The ecological impact of changing lake levels, natural or human-caused, is an issue of intense investigation currently with several states and international agencies. Given the potential impact to Michigan, this factor will be continually monitored in light of the newest scientific information available and will be reported in the years to come.

Exhibit 43. Monthly Mean Great Lakes Water Levels (in feet) 1865 - 2001



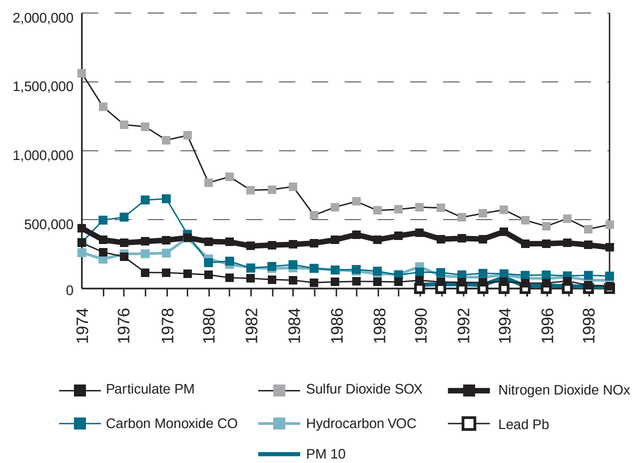
Programmatic Measures

Air Quality

Air Emissions Estimates

The federal Clean Air Act requires states to prepare and maintain inventories of emissions from major pollutant sources. Emissions are calculated for particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, and lead. The DEQ compiles information from over 1,900 facilities. Exhibit 44 presents a summary of this information.

Exhibit 44. Pollution Emission Inventory Trend 1974 - 1999 (in tons)



Air pollutant emission sources are categorized as mobile sources, large facility point sources, and area sources (small industries, boats, farm equipment, etc.). The relative percentage that these sources contributed to the overall emissions of volatile organic compounds and nitrogen oxides is shown in Exhibit 45. Motor vehicles contributed 33 percent of the volatile organic compound emissions and 43 percent of the nitrogen oxides. Although not shown in Exhibit 45, the number of vehicle miles traveled per year has been increasing, and tail pipe emissions have been decreasing due to the improvements in technology and fuel formulations.

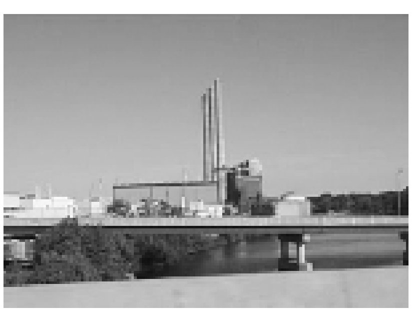
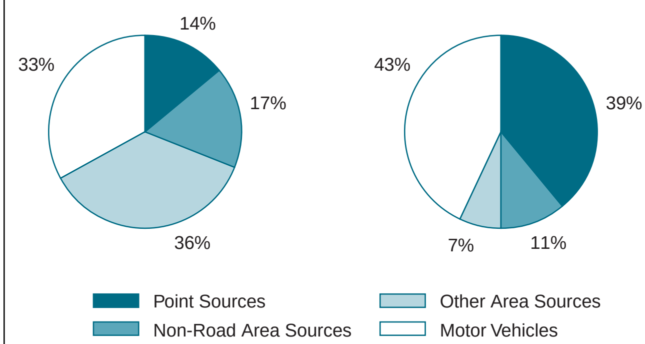
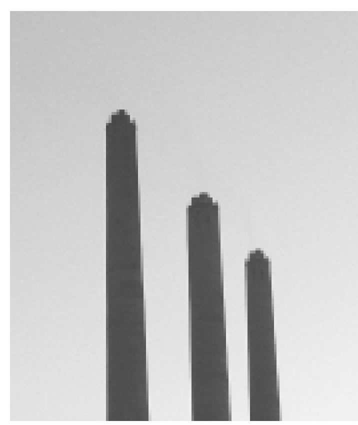


Exhibit 45. Estimated Levels of Volatile Organic Compounds and Nitrogen Oxides Emissions by Source Category



Air Toxics Emissions

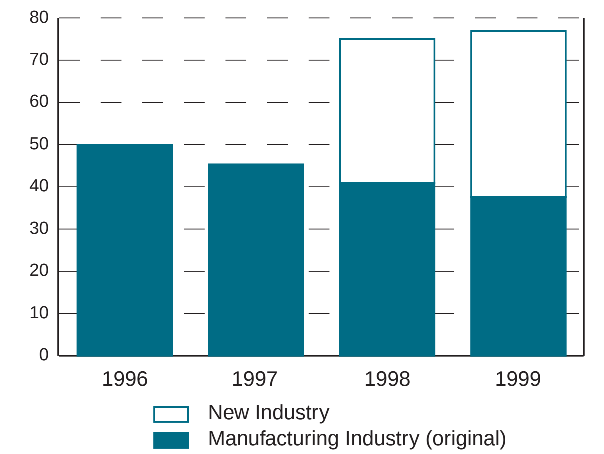
Several efforts have been made to develop air toxics emission inventories, each with varying limitations and longevity. One of the most frequently cited inventories is the USEPA's Toxic *Chemical Release Inventory*, compiled under the authority of the federal Emergency Planning and Community Right-to-know Act. Under this law, Michigan facilities in designated industrial sectors are required to annually report their process-related releases of specific toxic chemicals. Only facilities that exceed established thresholds are required to report. This information is collected by the DEQ, compiled in the Toxic Chemical Release Inventory, and made available to the public by the USEPA and the DEQ.



The Toxic Chemical Release Inventory information presented in this report is a statewide total of the toxic release data for a specific reporting year and does not indicate upward or downward trends for individual pollutants or facilities. Additional information on individual pollutants and facilities, including historical information, is available on the Internet at http://www.deq.state.mi.us/ead/sara/313.html.

Prior to 1998, the Toxic Release Inventory covered 20 manufacturing categories. In 1998, seven non-manufacturing industrial sectors began reporting their toxic chemical releases. The addition of these new industry sectors resulted in a significant increase in the reported levels of Toxic Chemical Release Inventory air releases from those reported in 1997. There was a one percent increase in reported air releases from 1998 to 1999. (Exhibit 46)

Exhibit 46. Air Toxics Release Inventory 1996 - 1999 (in millions of pounds)



Air Radiation

The DEQ is responsible for monitoring the potential for environmental impact due to the operation of nuclear power plants in Michigan. Baseline radiological data for all four nuclear power plant sites in Michigan (Enrico Fermi, Big Rock Point, Palisades, and D.C. Cook Nuclear Power Plants) were established a minimum of one to three years prior to plant operation, which, for the Enrico Fermi Nuclear Plant site, dates back to 1958. To date, off-site environmental impacts attributable to the operation of nuclear power plants in Michigan have not been detected. The data monitored by the DEQ include radioactivity in air particulates, radioactivity in milk, and discussed later in this report, radioactivity in surface waters. Annual reports on the overall quality of the radiological environment may be obtained by contacting the DEQ.

Since the inception of the monitoring program, through the early 1980s, a general trend of decreasing levels of radioactive fallout from atmospheric testing of nuclear weapons has been observed, with the radioactivity associated with air particulates. A brief exception to this downward trend was noticed in 1986 as a result of radioactive fallout from the Chernobyl Nuclear Power Plant accident. Since 1986, the quarterly radioactivity levels associated with air particulates have returned to natural radiation background levels of 0.01 to 0.03 picocurie per cubic meter. A level of concern would be a quarterly average exceeding 1.0 picocurie per cubic meter or several consecutive quarters exceeding 0.1 picocurie per cubic meter. A total of five sites are monitored throughout the state. Exhibits 47a and 47b present measurements for the Lansing Background Reference and the Big Rock Nuclear Power Plant sites, respectively, and may be considered representative for the other three monitoring locations. Data for 2000 from the monitoring locations demonstrate that radioactivity levels have continued to remain at natural background levels (Exhibits 47a and 47b).

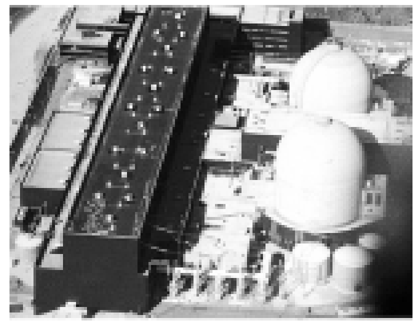


Exhibit 47a. Quarterly Average Air Particulate Radioactivity 1960 - 2000 (Lansing Background Reference Site)

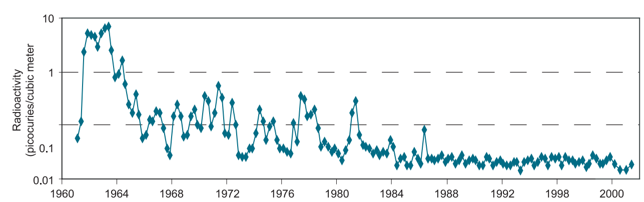
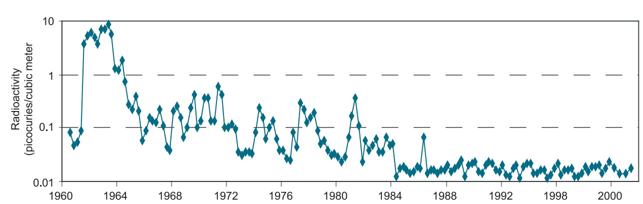


Exhibit 47b. Quarterly Average Air Particulate Radioactivity 1960 - 2000 (Big Rock Nuclear Power Plant Site)



The DEQ monitors the level of radioactivity found in milk in order to assess the potential impact of radioactivity on the environment and human food chain. The radioactivity is characterized by determining the level of a radioactive isotope of cesium (cesium-137).

Cesium-137 is a radionuclide resulting from nuclear fission. It is highly suitable for this measurement since its chemical behavior is similar to that of potassium. Exhibits 48a and 48b present radioactivity measurements taken from the Lansing and Monroe Milk Stations, respectively, which are representative for other milk monitoring locations in the state. Over the last 15 to 20 years, cesium-137 annual averages have remained below minimum detectable activity levels. Prior to 1980, but especially during the early 1960s, radioactivity levels in milk were significantly higher due to atmospheric nuclear testing. A level of concern would be an annual average exceeding 20 picocuries per liter.

Exhibit 48a. Annual Average Cesium-137 Radioactivity in Milk 1963-2000
(Monroe Milk Station)

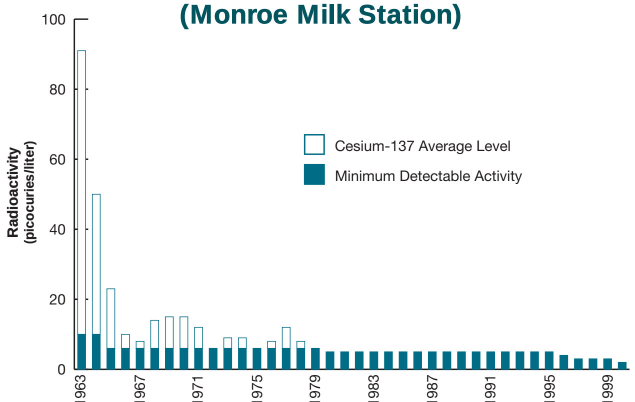
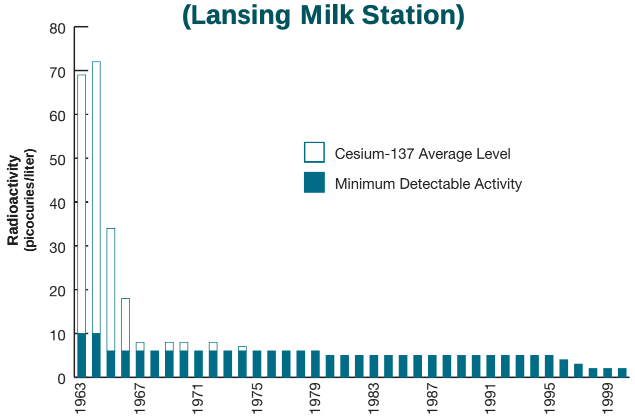


Exhibit 48b. Annual Average Cesium-137 Radioactivity in Milk 1963-2000
(Lansing Milk Station)

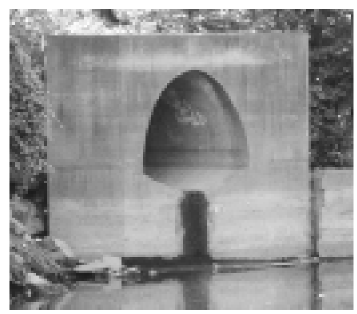


Water Quality

Surface Water

The state operates several extensive surface water and surface water-related monitoring programs, including programs designed to evaluate inland lake and tributary water quality and inland lakes sediment contaminant levels. In addition, the state also operates several monitoring programs designed to evaluate the population levels and composition of aquatic life. These programs were described earlier in the Environmental Indicators portion of this report.

Combined Sanitary and Storm Water Sewer Systems. In addition to the above monitoring programs, the DEQ has continued to work very closely with municipalities to eliminate untreated sewage discharges from combined sanitary, combined, and storm water sewer systems. As a result, all cities have either corrected their combined sewer overflow problems or have an approved program in place that will lead to adequate control. The city of Detroit alone will invest over $1 billion to eliminate or adequately treat combined sewer overflow discharges. In a related area, the DEQ also has continued to work with municipalities and industrial facilities to minimize the discharge of pollutants to surface water from storm water discharges. Both of these efforts have resulted in a continued reduction of nutrients, biological, heavy metal, and industrial pollutants to the waters of the state.



In 1999 and early 2000, a number of Michigan municipalities reported overflows or discharges of sanitary sewage into various waters of the state. Sanitary sewer overflows are discharges of untreated or partially treated sewage from municipal sanitary sewer systems. These systems are designed to carry domestic sewage but not storm water. When a sanitary sewer overflow occurs, untreated or partially treated sewage is released into areas such as city streets, low land areas including, in some cases, parks and other areas of public contact and surface waters such as drainage ways, streams, and lakes rather than being transported to a treatment facility. Sanitary sewer overflows are illegal and can constitute a serious environmental and public health threat. Additional health threats occur when sewage from a public sewer system backs up into structures such as residential basements as a result of excess wet weather flow in the sewer system or other sewer system deficiencies.

In May 2000, the DEQ announced a statewide strategy to identify and correct the discharge of untreated or inadequately treated sanitary sewage. While the state has worked to address this issue for more than 20 years, a more aggressive approach is clearly warranted. The two-pronged strategy emphasizes corrective action and public disclosure. The goals are to eliminate illegal sanitary sewer overflows, prevent new ones from developing, protect the environment and public health, and restore contaminated aquatic ecosystems. Frequently, the cause of adverse water impact is the same as the cause of other community health threats, and the corrective actions needed must consider both.

In order to accomplish the goal of water quality protection, the DEQ will keep the public informed of the identified problems by posting on the Internet (http://www.deq.state.mi.us/swq/cso_sso/cso_sso_index.html) a list of discharges of untreated or partially treated sewage discharges and the waters to which they discharge. The reporting of incidents of untreated or partially treated sewage discharge, and the public posting are required by statute adopted in July 2000. Dischargers are required to notify local county health departments and local press media of such incidents. The DEQ will take appropriate actions to establish immediate control actions where necessary, and require action programs to eliminate illegal sewer dischargers. The DEQ will report further on this initiative in the next report.

Bacteriological Monitoring. All of Michigan's surface waters are designated and protected for total body contact recreation (swimming) from May 1 to October 31. In

Michigan, a water body is considered suitable for total body contact recreation when the number of the indicator bacteria, *Escherichia coli (E. coli)*, per 100 milliliters of water is less than or equal to 130, as a 30-day average. The DEQ works in partnership with local county health departments and other local entities to ensure that Michigan's surface waters are adequately monitored for *E. coli* and protected for total body contact recreation. Several activities have been initiated through this DEQ/local county health department/local entity partnership, including:

A. The award of $352,000 in Clean Michigan Initiative-Clean Water Fund grants during the period 1998 - 2001 to six counties and one local watershed council to monitor *E. coli* in selected Michigan rivers or lakes and to locate and control sources of *E. coli* contamination;

B. The award of 13 grants totaling $293,000 in 2000 - 2001 to support *E. coli* monitoring at public beaches. These grants have assisted 29 counties and one city (Marquette) to more effectively monitor public beaches for *E. coli*. Additional public beach monitoring grants are expected to be awarded by the DEQ to local entities in future years; and

C. The award of $2.6 million in grants to 13 local entities to identify and require the correction of illicit connections to separate storm sewer systems. Additional illicit connection

correction grants are expected to be awarded by the DEQ in future years.

In addition to the above, the DEQ monitors Michigan's surface waters for *E. coli* contamination as part of the 5-year rotating basin schedule. Water bodies determined to be in non-attainment of the *E. coli* standard are scheduled for corrective action through the DEQ's Total Maximum Daily Load (TMDL) Development and Implementation program. Currently, the DEQ is developing *E. coli* TMDLs on 69 streams or lakes. In 2001, approximately 3,000 water samples were collected from selected surface water sites and analyzed for *E. coli* to support these TMDL development efforts.

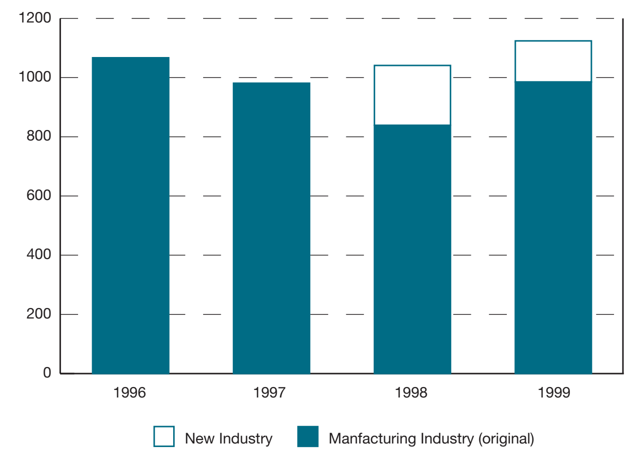
The DEQ currently has a beach monitoring website (http://www.deq.state.us/swq/asp/beach/) where county health departments can post *E. coli* data and notify the public immediately when the water at a beach is unsafe for swimming.

Water Toxics Releases

The federal Emergency Planning and Community Right-to-Know Act establishes reporting requirements for the release of toxic chemicals to water. Under this law, Michigan facilities in designated industrial sectors are required to annually report their process related releases of specific toxic chemicals to surface water bodies. Only facilities that exceed established thresholds are required to report. This information is collected by the DEQ, compiled in the Toxic Chemical Release Inventory, and made available to the public by the USEPA and the DEQ.

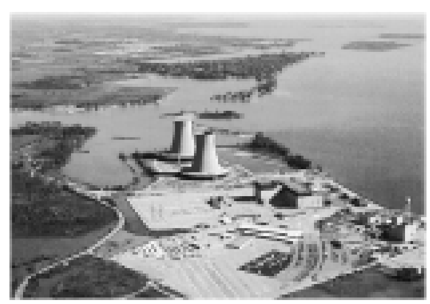
Prior to 1998, the Toxic Chemical Release Inventory covered 20 manufacturing categories. In 1998, seven non-manufacturing industrial sectors began reporting their toxic chemical releases. Consequently, the increases in the total reported water discharges from 1997 to 1998 are due in part to the increased number of reporting facilities. From 1998 to 1999, releases from all sectors increased eight percent (Exhibit 49). The Toxic Chemical Release Inventory information presented in this report is a statewide total of the toxic release data for a specific reporting year and does not indicate upward or downward trends for individual pollutants or facilities. Additional information on individual pollutants and facilities, including historical information, is available on the Internet at http://www.deq.state.mi.us/ead/sara/313.html.

Exhibit 49. Water Toxics Release Inventory 1996 - 1999
(in thousands of pounds)



Surface Water Radiation

As indicated earlier in this report, the DEQ is responsible for monitoring the potential for environmental impact due to the operation of nuclear power plants in Michigan. One of the factors monitored is the level of radiation associated with nearby surface water. Surface water radioactivity averages have remained in the natural background range of one to six picocuries per liter since the inception of the monitoring program in 1972. A level of concern would be an annual average exceeding 50 picocuries per liter. Exhibits 50a and 50b present the annual radioactivity measurements for the monitoring station near the Palisades and Fermi 2 Nuclear Power Plants, respectively. These results are similar to and, therefore, representative of what has



been measured at the two other nuclear power plant locations in Michigan. Annual reports on the overall quality of the radiological environment may be obtained by contacting the DEQ.

Exhibit 50a. Annual Average Surface Water Radioactivity 1972-2000
(Palisades Reactor Site)

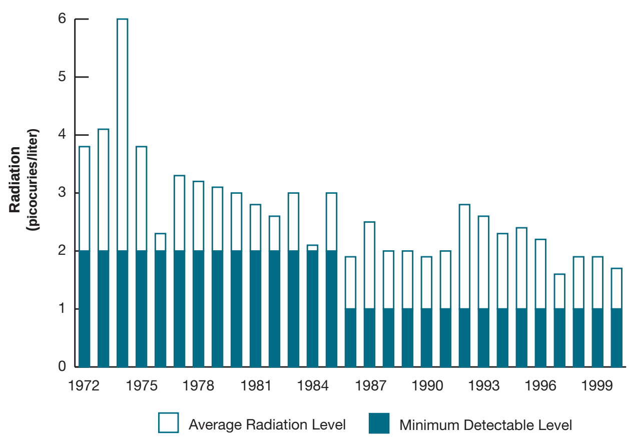
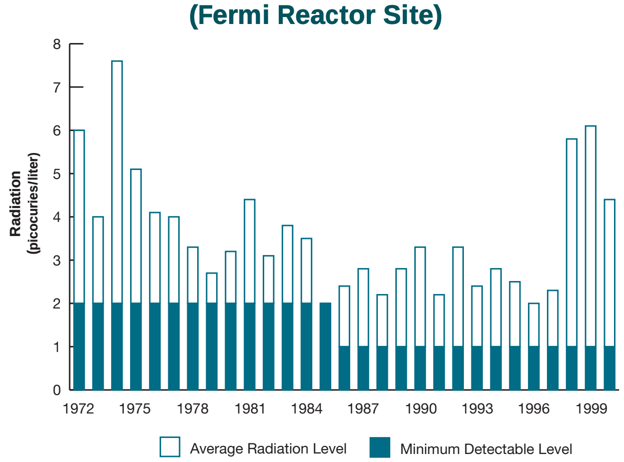


Exhibit 50b. Annual Average Surface Water Radioactivity 1972-2000
(Fermi Reactor Site)



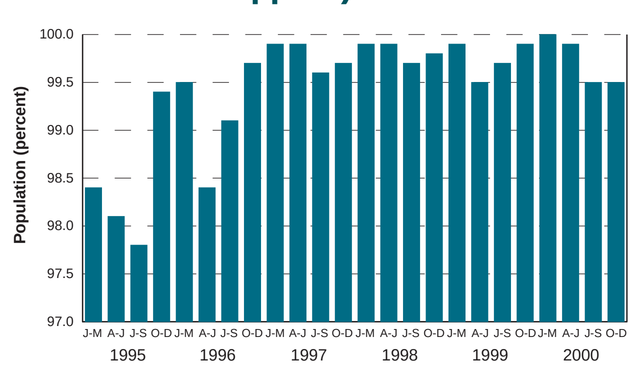
Drinking Water

The DEQ oversees public water systems by emphasizing early detection and correction of sanitary defects and ensuring that the systems provide trained and certified operators in accordance with state law. Competent operators are critical to identifying problems and making corrections before problems develop.

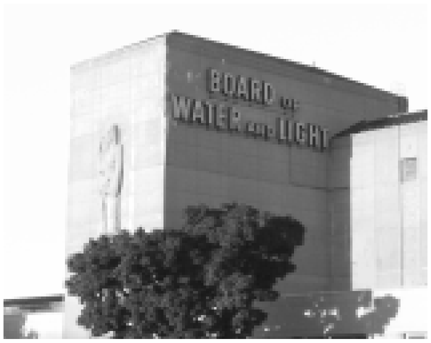
The DEQ maintains data on populations served by community water supplies that receive drinking water meeting all health-based standards. These data are derived from state reporting of drinking water violations to the USEPA's national data system. Community water systems are those systems furnishing drinking water year-round to residential populations of 25 or more. The Michigan inventory consists of 1,475 community water systems, including municipal systems, mobile home parks, nursing homes, public institutions, and housing developments such as subdivisions and condominiums.

During the first three quarters of 1996, the percentage of populations served by community water supplies meeting all health-based standards ranged from a low of 98.4 percent to a high of 99.5 percent. After the summer of 1996, the city of Ann Arbor came into compliance with surface water treatment regulations through the installation of advanced treatment. Consequently, during the period beginning October 1996 to the present, the population served by community water supplies meeting all health standards increased to a high of 99.9 percent and has remained between 99.5 percent and 99.9 percent ever since (Exhibit 51).

Exhibit 51. Percentage of Population Receiving Drinking Water Meeting Michigan Standards (Community Water Supplies) 1995 - 2000



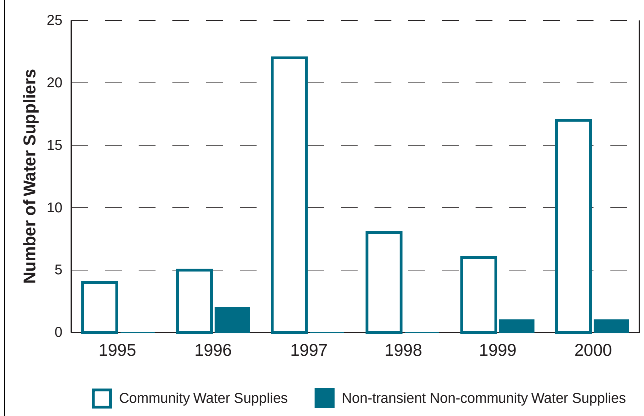
In 1992, the USEPA promulgated a national drinking water treatment program to control lead in drinking water. The standard requires community public water suppliers to monitor lead content in their customers' water supplies, install corrosion control treatment, and initiate a program of lead service line replacement if the lead cannot be reduced below the action level established by the USEPA (15 micrograms of lead per liter of water). Lead is not normally in surface water or groundwater used for public water supply sources. However, lead can be introduced into the drinking water at the customer taps through contact with plumbing materials. Common sources of lead in water distribution and plumbing systems include: lead service lines in old urban areas; lead as a component of the solder used to join copper plumbing; and lead as an additive in brass used in plumbing fixtures, including faucets and valves.



The USEPA action level for lead was established based upon the concern that the blood lead level for children must remain very low to prevent potential neurological development problems. While drinking water is not normally the primary route of exposure, it can contribute to the total body burden and aggravate problems for children with lead exposure from other sources.

The DEQ monitors lead in both community and non-transient non-community water supplies. Non-transient non-community water supplies provide drinking water to schools, day care centers, and places of employment that own and operate their own wells. Due to a need to phase in different parts of the governing regulation at different times, monitoring variations exist in the current database. For example, the increase in lead action level exceedences seen in Exhibit 52 during 1997 is due to the resumption of lead monitoring in many water systems following the installation of corrosion control treatment. Similarly, the implementation of rule revisions during 2000 required many water systems that were previously exempt from the lead regulations to begin monitoring.

Exhibit 52. Michigan Water Supplies Exceeding the Lead Action Level for Drinking Water 1995 - 2000

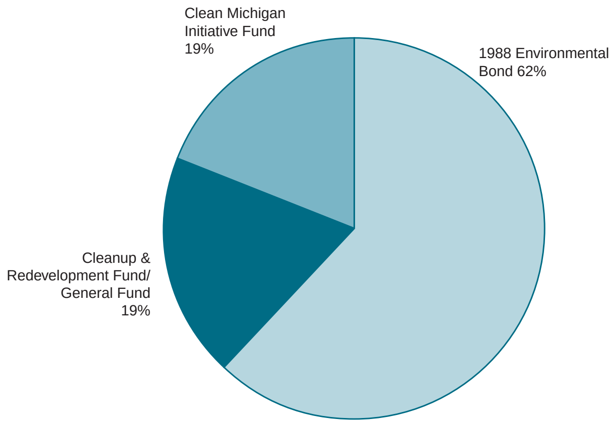


Land Quality

Environmental Cleanups

Cleanup of environmentally contaminated land is accomplished through state funded actions and through actions conducted by liable parties and property owners. The sources of public funds that have been used for cleanup since 1989 are shown in Exhibit 53. Prior to passage of the Clean Michigan Initiative in November 1998, the DEQ's cleanup program was funded primarily by an Environmental Bond approved in 1988. Currently, General Fund monies (through the Cleanup and Redevelopment Fund) and the Clean Michigan Initiative have supported these cleanups.

Exhibit 53. Environmental Cleanup Funding Sources 1989 - 2001

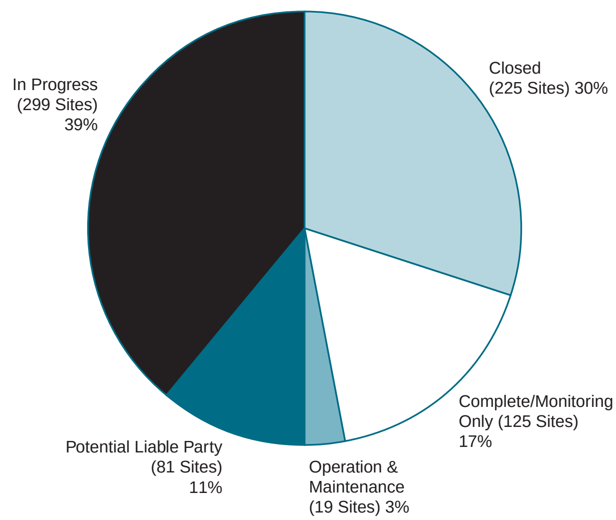


Most of the 1988 Environmental Bond money was directed at performing cleanups to protect public health and the environment. Under the 1998 Clean Michigan Initiative, the primary focus is preparing contaminated sites for redevelopment. Under the Clean Michigan Initiative, a total of $335 million has been earmarked for site cleanup. To date, $77.5 million has been appropriated for work on 162 redevelopment-related projects. Work on these sites is in its early stages. The DEQ's goal is to complete projects within 18 months after they are initiated. A portion of the $335 million is also set aside to address serious health and environmental problems at contaminated sites that do not have redevelopment potential. A total of $29.2 million has been appropriated for action at 13 sites in this category. A portion of the $335 million will also be used for local units of government to address municipal landfills on the Superfund National Priorities List and to clean up sites where a specific redevelopment proposal exists. An additional $47 million of Clean Michigan Initiative funds was also awarded to 33 communities through a competitive grant process for waterfront improvements to promote economic development.

A total of 749 sites has been targeted for cleanup with public funds, beginning with the 1988 Environmental Bond program. At 81 of those sites, liable parties have come forward to perform necessary cleanup actions and have either cleaned up the site or are currently in the process of doing so. The current status of the cleanup work at publicly funded sites is illustrated in Exhibit 54.

Cleanup activities are complete at 225 sites. At 125 additional sites, monitoring is being conducted to assure that further state funded actions are not required. The two categories combined represent over 47 percent of the sites where work has been undertaken. Cleanup systems have been constructed and operation and maintenance activities are ongoing at 19 sites. Cleanup work is in progress at 299 additional sites.

Exhibit 54. Environmental Cleanup Sites Status 2001



In 1995, Michigan's cleanup law was changed. One of the goals of the change was to promote redevelopment of contaminated property (referred to as *brownfield sites*). Up until the time of the 1995 changes, any person who owned or operated contaminated property was responsible for cleaning up the contamination, regardless of whether they caused the problem. This was a serious impediment to purchase and re-use of contaminated property that resulted in many new development projects going to undeveloped land or open space. In an effort to reduce this problem, and to put contaminated property back into productive use, liability for property owners was changed to a *causation-based* system. Under the 1995 changes to the state cleanup law, the person who caused contamination, rather than the person who buys or owns the contaminated property, is responsible for conducting the cleanup. In addition to cleanups conducted by these liable parties, property owners may still elect to conduct cleanups to increase their property value or to assure the safety of people who work or live at these sites.

Another change established in the 1995 amendments to the state cleanup law was the creation of risk based cleanup criteria that are linked to land use. This helps assure that cleanups can be conducted in a cost effective manner. The risk based system accounts for the fact that the use of a property dictates the type of exposures that will occur, and that risk depends on exposure. For example, industrial sites do not have children present and workers spend only a portion of the day at the workplace. Because of these differences in exposure, different levels of cleanup may be allowed, while still providing the same degree of protection at residential, commercial and industrial sites. Site-specific cleanups allow the DEQ and property owners to account for special circumstances at a site. The DEQ has approved cleanup plans for 121 sites in land use categories other than residential. Cleanups meeting residential criteria have been completed at hundreds more sites, including sites where spill response activities undertaken by liable parties have eliminated unacceptable risks to public

Before Redevelopment

After Redevelopment

health and the environment. Property owners and other liable parties have conducted cleanup work at additional sites for which the DEQ does not maintain detailed statistics.

Since 1996, the DEQ has periodically surveyed 33 communities to determine how effective the 1995 cleanup program changes have been in helping those communities meet their redevelopment goals. The communities are asked to identify the amount of investment and job creation that occurred at brownfield sites within their community as a result of the 1995 amendments. Based on those surveys, there has been a continued increase in private investment and job creation (Exhibits 55 and 56). The success of the 1995 amendments is illustrated by the fact that more than $3.5 billion of private investment and 9,600 jobs have resulted.

Exhibit 55. Investment in Brownfield Properties 1996 - 2001

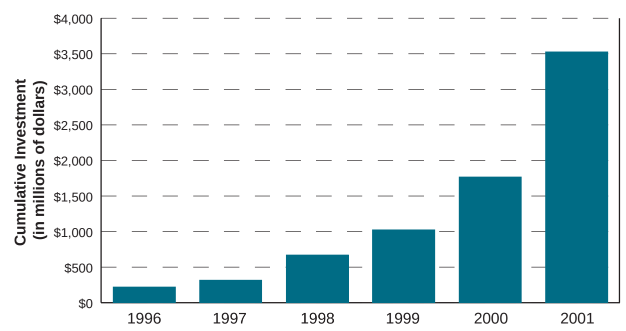
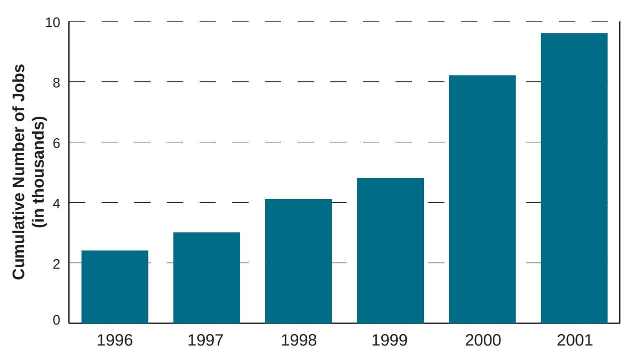


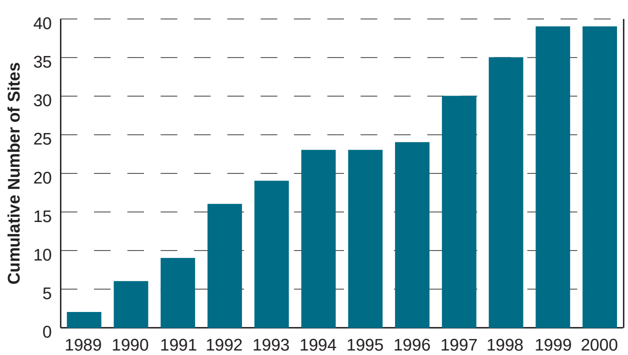
Exhibit 56. Number of Jobs Created at Brownfield Properties 1996 - 2001



Michigan currently has a total of 143 municipal solid waste and industrial waste landfills. This total includes landfills that are closed and others that are open and accepting waste, but it does not include facilities that operated before 1979, which are addressed under the broader Environmental Cleanup Program, described above. Seventy-one of these landfills have been found to be contaminating groundwater. Of these, 39 landfills (55%) have been remedied or are under control since 1989. Corrective action at 19 sites (27%) is in process, and investigations or other preliminary steps eventually leading to cleanup are underway. These sites fall into one of two categories; either the DEQ is using

enforcement authorities to force the landfill owner/operator to address groundwater contamination or the DEQ is using public funds to remedy contamination because a responsible party is no longer available. This leaves 13 sites (18%) at which no actions to correct groundwater contamination are underway. All of these latter sites are closed and no longer operating. Exhibit 57 shows the cumulative number of groundwater contaminated landfills returned to compliance since 1989.

Exhibit 57. Groundwater Contaminated Solid Waste Landfills Returned to Compliance 1989 - 2000

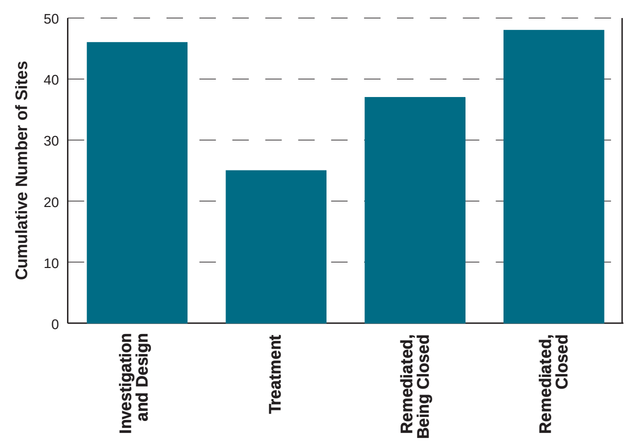


State-Owned Sites Cleanups

In addition to ensuring the cleanup of contaminated sites of others, the state is responsible for the cleanup of sites that it has contaminated in the past. The state has identified a total of 156 such sites where it is responsible, as either the owner or operator, for environmental remediation. Of the 156 sites, 127 are underground or above ground storage tanks, 14 are old landfills, dumps or storage pits, seven are shooting ranges, six are surface spills, and two involve either asbestos removal or radioactive license decommissioning.

In July 1996, a state sites cleanup fund was established into which a total of $30 million was made available to ensure that the state fulfills its environmental cleanup responsibilities. Since the program was created, 48 of the 156 contaminated sites have been cleaned up and closed; 37 have been remediated and are in the process of being closed; 25 have been investigated, a proposed remediation plan developed, and are into long-term treatment to reduce the level of contamination; and 46 are being investigated and are in the process of having a treatment design developed (Exhibit 58).

Exhibit 58. Cleanup Status of Contaminated State Owned/Operated Sites July 1996 - June 2001



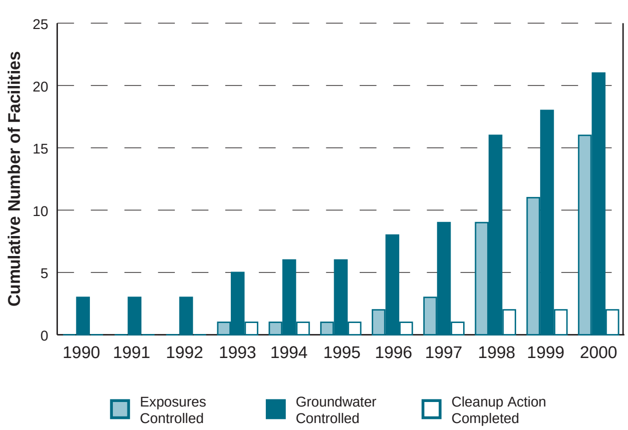
Hazardous Waste Treatment, Storage, and Disposal Sites

Two hundred thirty-five hazardous waste treatment, storage, and disposal sites in Michigan are subject to corrective action (cleanup) requirements. The corrective action requirements have been in effect under Michigan law since 1995. Similar requirements have been in effect under federal law since 1984. In 1998, the USEPA delegated to Michigan the administration of the federal corrective action requirements at licensed facilities. The DEQ has primary responsibility for overseeing the completion of corrective action at the licensed facilities.

Sites are subject to corrective action based on an assessment of the environmental contamination present and the risks each site poses to human health and the environment. Of the 235 sites, 70 have been ranked as a high priority. These 70 sites have the worst contamination or risks. The environmental contamination problems at the remaining 165 sites are not as significant as those at the 70 high priority sites.

To date, significant corrective action that has been taken at the high priority sites includes eliminating or controlling human exposure to contaminants such that there remains no unacceptable human health risk (16 sites), eliminating or controlling groundwater contamination (21 sites), or completing the cleanup such that no further corrective action is required (2 sites) (Exhibit 59).

Exhibit 59. Corrective Action Taken at High Priority Hazardous Waste Management Facilities 1989 - 2000

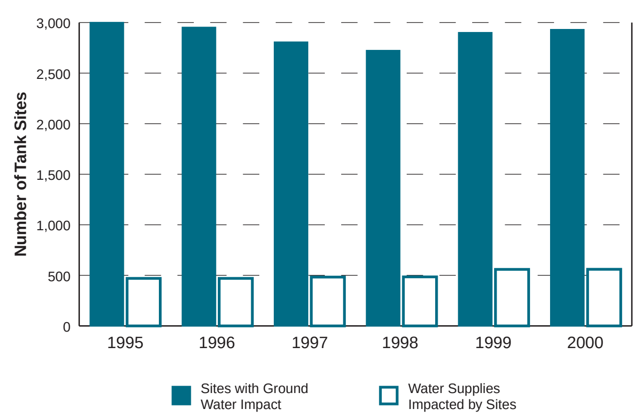


Leaking Underground Storage Tanks

The predominant hazardous substances stored in underground storage tanks are petroleum products (gasoline and diesel) and used oil. The primary constituents of petroleum include benzene, ethylbenzene, toluene, xylenes, and polynuclear aromatic hydrocarbons. These constituents can pose acute and chronic human health effects, with benzene being a known human carcinogen.

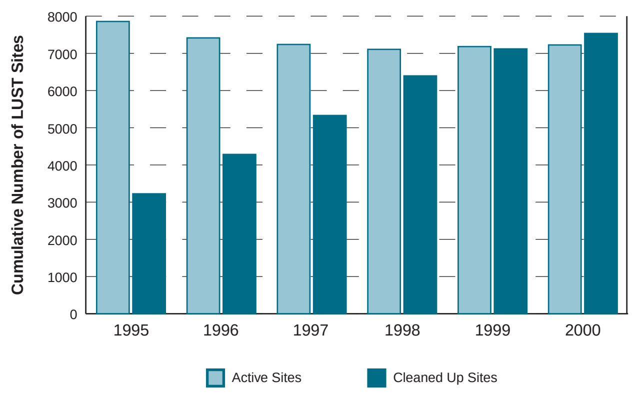
Leaking underground storage tanks can contaminate both the surrounding soil and the underlying groundwater. Of the two, groundwater contamination is much more difficult to clean up and may impact drinking water supplies depending on its proximity to drinking water wells. The number of sites discovered with groundwater contamination decreased from 1995 to 1998 and then increased slightly from 1998 to 2000. The number of groundwater drinking water supplies impacted by leaking underground storage tanks has increased from 470 to 560 from 1995 to 2000 (Exhibit 60).

Exhibit 60. Leaking Underground Storage Tank Sites that have Impacted Groundwater 1995 - 2000



The number of leaking underground storage tank sites has declined, having decreased from 7,857 in 1995 to 7,226 in 2000. During the same time period, the number of leaking underground storage tank sites that have been cleaned up has increased from 3,224 in 1995 to 7,535 in 2000 (Exhibit 61). This is a result of the DEQ's implementation of Risk Based Corrective Action and its efforts in assisting, providing information, and where required, taking appropriate enforcement action to ensure that owners/ operators meet their regulatory obligations.

Exhibit 61. Leaking Underground Storage Tank Sites 1995 - 2000



State and federal rules required that owners/ operators of underground storage tank systems comply with new technical standards. The technical standards require that underground storage tanks be equipped with corrosion protection, overfill prevention, and spill protection primarily to protect groundwater from leaking tanks. December 22, 1998 was set as the deadline when existing tanks had to be removed, replaced, or upgraded to meet the technical standards. In 1999, the DEQ launched a major initiative to assure that substandard underground storage tanks were no longer used. This led to approximately 3,000 tanks being removed from use. An enforcement initiative was initiated in 2000 to compel owners/operators to properly remove any remaining substandard underground storage tanks so that they no longer pose a threat to the environment. This initiative has resulted in the reduction of substandard tanks from 2,951 in September 1999 to less than 287 tanks. The DEQ is continuing its enforcement action and where there is no liable or viable owner; the DEQ is using state funds for tank closure.

The gasoline additive methyl tertiary-butyl ether (MTBE) has been mandated in western and northeastern states to meet the reformulated gas requirements to help reduce the carbon monoxide emissions and ozone formation. Since Michigan does not have as serious a problem, it was never mandated by the USEPA to use reformulated gasoline. Relatively recent concern about the potential health risk from groundwater being contaminated by this additive has led to re-examination of its mandated use by the USEPA. Within Michigan, there exist low level amounts of MTBE in some premium gasoline supplies, as well as residuals remaining in pipelines that transfer fuel to Michigan from other states. For the past five years, the DEQ has required monitoring for MTBE at underground storage tank release sites. At sites where levels exceed safe concentrations, the DEQ has taken action to address the contamination. Sampling results for MTBE to date have not identified any significant threat to the public health or the environment in Michigan. The acceptable level of MTBE in groundwater at sites of contamination is 40 ppb, based on aesthetic criteria of taste and odor. The aesthetic criterion is significantly lower than the health-based criterion of 240 ppb. Consequently, a person would taste or smell the MTBE long before it posed a health risk.

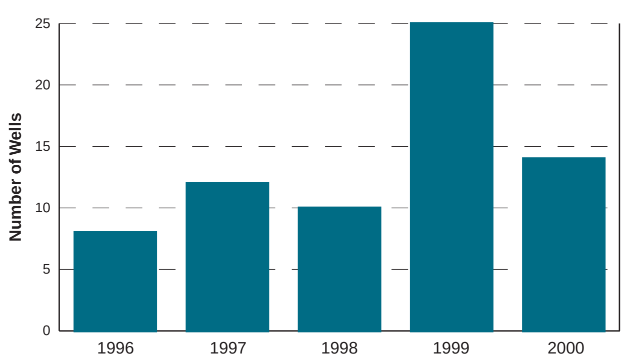
Abandoned Oil and Gas Wells

Since commercial oil and gas production began in Michigan in 1925, over 50,000 oil and gas wells have been drilled. More than 16,500 of these wells are still in use today. State law requires the well owner to plug the well and restore the site if the well is not used for its intended purpose. However, occasionally a well owner dies, moves, or becomes insolvent and leaves behind an orphan well. In those cases, the DEQ may step in and plug the well and restore the well site.

Orphan wells can pose serious threats to the environment and to public health and safety because they can serve as a conduit for oil, gas, or brine to leak to the surface or into underground water supplies. The DEQ has inventoried all known orphan wells, and each year the DEQ plugs wells according to the degree of hazard they pose. Funding to plug the wells comes from taxes levied upon all oil and gas producers in the state.

Contractors selected by competitive bid carry out well plugging and restoration activities. The DEQ draws up plugging specifications and supervises the plugging and restoration activities. Since the beginning of the orphan well program in 1994, the DEQ has plugged 69 wells and identified an additional 216 orphan wells that are candidates for plugging and/or site restoration (Exhibit 62).

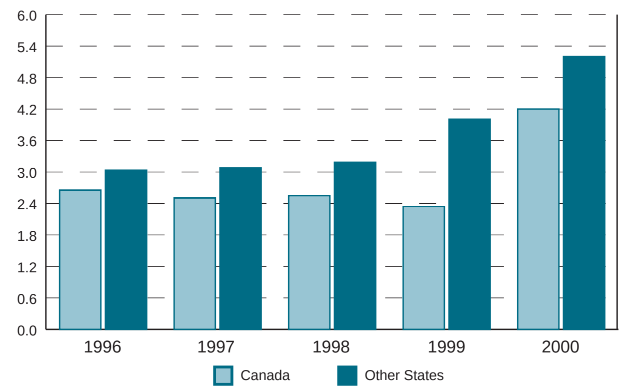
Exhibit 62. Number of Oil and Gas Wells Plugged 1996 - 2000



Solid Waste Imports

During the period 1996 - 2000, solid waste imports have ranged between 12.2 percent and 16.7 percent of the total amount of solid waste disposed of into Michigan landfills. The bulk of these imports, between 37 percent and 47 percent, come from Canada. Most of the out of state waste not from Canada comes from Michigan's nearby states (e.g., Ohio, Wisconsin, Illinois, and Indiana). An additional 0.3 percent of the imported solid waste comes from other states. Solid waste imports from the nearby states range from 53 percent to 63 percent of the total imports. Out of state waste imports have remained at a relatively constant level from 1996 to 1998, with an increase in imports from other states in 1999 and 2000 (Exhibit 63). Waste imports from Canada rose significantly in 2000 due to the impending closure of Toronto's Keele Valley landfill.

Exhibit 63. Annual Solid Waste Imports to Michigan 1996 - 2000
(in million cubic yards)



Hazardous Waste Imports/Exports

The importation of hazardous waste to Michigan has risen from 301,000 tons per year in 1992 to 630,000 tons per year in 1999. The sources include Canada and other states. While the quantity imported from Canada has remained relatively constant, the quantity imported from other states has steadily increased (Exhibit 64). During the same period, the quantity of hazardous waste exported by Michigan has remained relatively constant (averaging about 233,000 tons/year) (Exhibit 65). Comparing the import amounts to the export amounts, it can be seen that Michigan is a net importer of hazardous waste. In 1999, Michigan's net import rate was approximately 388,000 tons per year.

Exhibit 64. Annual Hazardous Waste Imports to Michigan 1992 - 1999
(in tons)

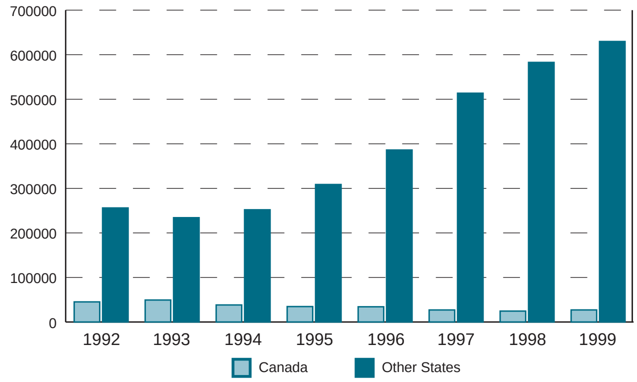
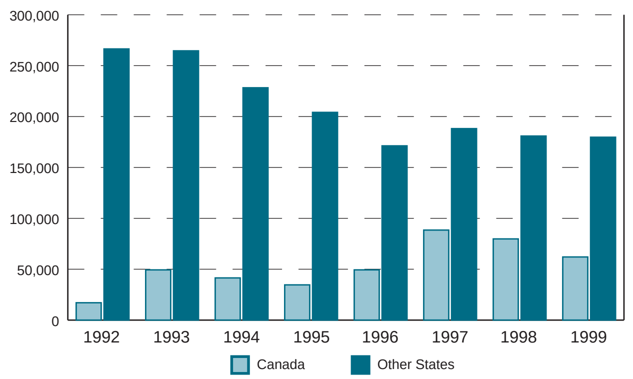


Exhibit 65. Annual Hazardous Waste Exports from Michigan 1992 - 1999
(in tons)



Scrap Tires

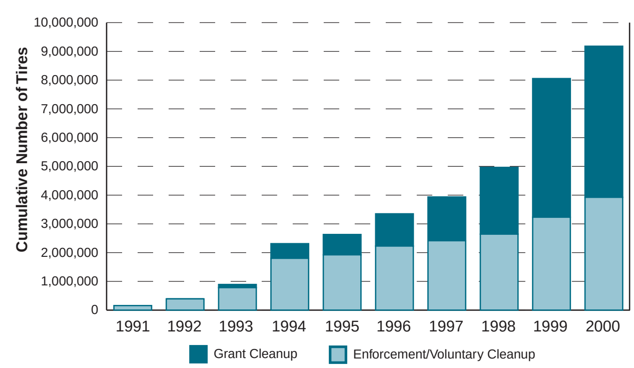
Over 250 million scrap tires are generated each year in the United States. Michigan contributes over 7.5 million scrap tires annually to that waste stream. Millions of these scrap tires were abandoned or illegally stockpiled each year on vacant lands and inner-city back alleys. These illegal accumulations resulted in public health, environmental, and aesthetic problems for many communities.

In 1991, Michigan enacted legislation to address the concern of scrap tires. The DEQ is responsible for implementation of this law in order to help reduce illegal scrap tire accumulations and the public health and environmental concerns associated with these solid waste piles. During the same year, the regulated community identified approximately 16 million scrap tires stockpiled across the state. Each year, the DEQ discovers additional collection sites that are regulated by law and develops more accurate figures on scrap tire stockpile inventories. Most of these newly identified sites are not active and often not in a visible location. Therefore, as expected, the documented number of scrap tires stockpiled in identified non-compliant sites has increased since 1991. In 2000, 100 collection sites containing 25,198,000 scrap tires were found by the DEQ to be in non-compliance.

In addition, the scrap tire end-user markets have continued to increase. Currently, more than 12 million scrap tires can be used annually by Michigan's market-place. A consistent enforcement and cleanup program will continue lowering the stockpile of scrap tires. Exhibit 66 shows the cumulative totals of tires removed by the grant program and those removed voluntarily or through enforcement actions.

The primary uses of scrap tires in Michigan include the re-treading market for truck tire casings and tire derived fuel, which is used in the generation of electricity, and the manufacturing of cement. Scrap tire chips also have been used as lightweight aggregate for construction activities at landfills, septic drain fields, landscaping activities, athletic turf, and rubberized asphalt for parking lots.

Exhibit 66. Scrap Tire Cleanup Program 1991 - 2000



NOTES

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