Description of Calculations for Wind Erosion Fugitive Emissions

In addition to the indoor storage of coal, two outdoor coal piles will be used for the ASCPC unit; the Reserve Stockout Pile and the Reserve Storage Pile. Both piles will have surface areas best represented by a trapezoidal shape.

The first step in this process was to obtain mean hourly wind data from the Saginaw, Michigan (MBS) meteorological surface station, for the years 2003-2007. Following the assumption in the 1994 EPA document, *Modeling Fugitive Dust Impacts from Surface Coal Mining Operations – Phase II*, the fastest mile wind speed is assumed to be 1.2 times the hourly mean wind speed. The governing equation utilized to predict the emission factor due to wind erosion is equation (2) from Section 13.2.5.3:

$$Emission\ Factor\ (mass/area) = k \sum P_i \text{ from } i \text{ to } N, \text{ where}$$

k = particle size multiplier, 0.5 for PM_{10}

N = number of disturbances per year

P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances, g/m^2

For Consumers, it was conservatively estimated that a disturbance could occur, on both portions of the pile, each hour of the day, 365 days per year. This is an extremely conservative approach as the bulldozers are only expected to operate 16 hours per day, on the daily active portion of the pile.

The erosion potential function, P_i for a dry, exposed surface is defined as:

$$P_i\ (mass/area) = 58 \times (u^* - u^*_t)^2 + 25 \times (u^* - u^*_t), \text{ where}$$

u^* = friction velocity (m/s)

u_t^* = threshold friction velocity (m/s), = 1.12, from Table 13.2.5-2

Also, any time that ($u^* \leq u^*_t$), then P = 0

The erosion potential must be calculated separately for each potential erosion event; therefore, because the wind datum from MBS is known on an hourly basis, this calculation was repeated 8,760 times for each year, for each pile.

The friction velocity, u^*, is determined using the wind speed of the fastest mile from MBS and equation (1) from 13.2.5.2.

$$u(z) = (u^*/0.4) \times \ln (z/z_o), \text{ held to the constraint } (z > z_o), \text{ where}$$

u = wind speed, m/s

u^* = friction velocity, m/s

z = height above test surface, m

z_o = roughness height, m

0.4 = von Karman's constant, dimensionless

At the reference height of ten (10) meters and assuming a typical roughness height of 0.005 meters, this equation can be rearranged to the following:

$$u^* = (0.4 \times u^+_s) \div (\ln (10/0.005),$$

$$u^* = (0.053\ \ u^+_s), \text{ where}$$

u^+_s = surface wind speed distribution (m/s)

The surface wind speed distribution is found using equation (6) from 13.2.5.3:

$$u^+_s = u^+_{10} \times (u_s/u_r), \text{ where}$$

u^+_{10} = fastest mile of the reference anemometer for the period between disturbances (m/s)

u_s = surface wind speed (m/s)

u_r = approach wind speed (m/s)

The ratio of (u_s/u_r) has been defined in the AP-42, Chapter 13.2.5, for two (2) types of piles with different wind flow directions; Figure 13.2.5-2 depicts contours of normalized surface wind speeds for the two piles and wind approach directions. The contours in this figure were developed from the results of wind tunnel studies as published in the *Journal of the Air Pollution Control Association, 38* from 1988.

Because the anemometer at MBS is at a height of 10.06 meters, another variation of equation (1) must be used to "correct" the fastest mile wind speeds to a reference height of 10 meters.

$$u^{+}_{10} = u^{+}_{MBS} \times (\ln (10/0.005) \div \ln (z_{MBS} /0.005)), \text{ where}$$

u^{+}_{MBS} = fastest mile, derived from the mean wind speed recorded by MBS (m/s, calculated separately for each hour)

z_{MBS} = height of the anemometer at MBS (10.06 m)

Therefore,

$$u^{+}_{s} = u^{+}_{MBS} \times (\ln (10/0.005) \div \ln (10.06 /0.005)) \times (u_s/u_r), \text{ or}$$

$$u^{+}_{s} = u^{+}_{MBS} \times 0.987 \times (u_s/u_r)$$

Finally, the normalized surface wind speed is used to determine the threshold friction velocity from rearranging equation (1) as shown in equation (7) from 13.2.5. Furthermore, because the ratio (u_s/u_r) was found at a height of 25 cm above the surface (from AP-42), the height was also corrected.

$$u^{*} = (0.4 \times u^{+}_{s}) \div (\ln (0.25/0.005))$$

$$u^{*} = 0.10 \times u^{+}_{s}$$

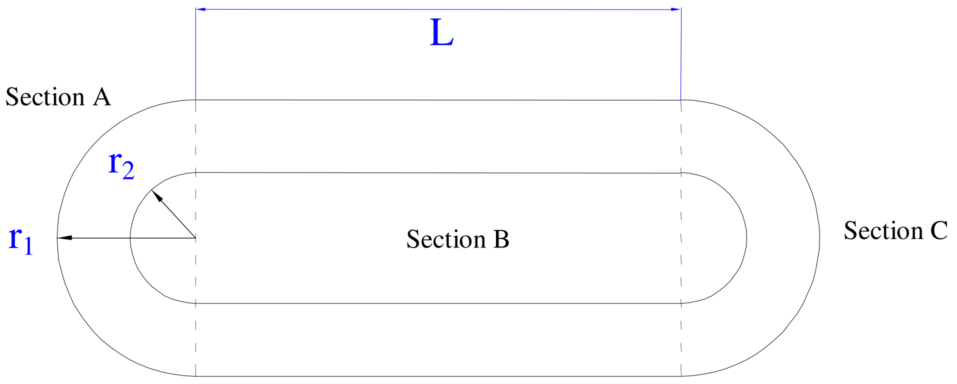
The characteristics of the coal pile are very important in determining the potential fugitive emissions due to wind erosion. In essence, a fraction of the coal material at the surface of the coal pile will be in the form of fines. These fines, and their loading per unit of coal pile surface area, are referred to as the "erosion potential" for the coal pile.

Wind erosion of the fines is a function of the wind speed at the coal pile surface, the surface area of the coal pile that is not crusted (i.e. that has fines available for erosion), the number of disturbances per time period, and the threshold friction velocity associated with the material. The threshold friction velocity is a measure of the wind speed required at the surface of the material to cause erosion.

Dimensions of the Piles

The Reserve Storage Pile will hold an estimated maximum of 1,000,000 tons of coal. At an average compacted density of 65 pounds per cubic foot, the pile will have a volume of 31,000,000 cubic feet of coal. The equations from the AP-42 are only applicable to either a conical or a flat-topped, oval shaped pile. For purposes of defining the Reserve Storage Pile dimensions, volume, and surface area, the coal storage pile will be treated as an oval shaped pile with the sides sloped at 37°.

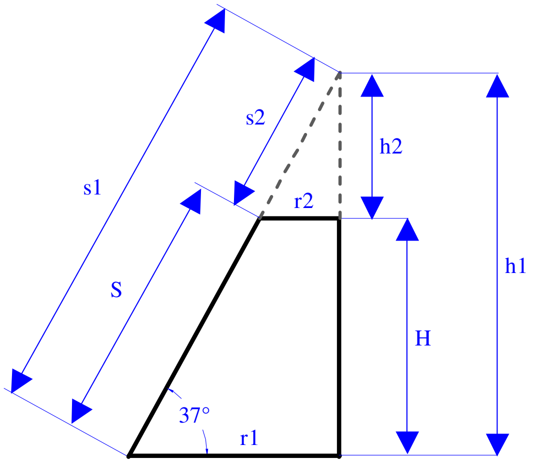
Because of the irregular shape of the pile, it is necessary to divide the pile into three (3) sections.



Plan View

Equations for a Cone

Sections A and C each have the shape of one-half of a flat-topped cone, therefore, the calculations for these sections are modified equations for a cone.



Profile of Section A

The calculations for a flat-topped cone follow the logic, that there are really two (2) cones that share the same vertex: one small cone that has its base located at a certain height from the base of the large cone. For the coal pile at Consumers, the maximum height of the coal pile will be 45 ft, so the base of the small cone will be located at 45 feet from the base of the large cone. Therefore, one can find the volume of the flat-topped cone by finding the volume of the large cone and subtracting the volume of the small cone. The volume of a cone is defined as:

$$V = 1/3 \times \pi \times r^2 \times h$$

V = Volume

r = radius

h = height (note this is the height from the center of the cone to the peak, and not the length of the slant)

Let the subscript "1" refer to the larger cone and subscript "2" refer to the smaller cone, then the volume of the flat-topped cone becomes:

$$V = 1/3 \times \pi \times r_1^2 \times h_1 - 1/3 \times \pi \times r_2^2 \times h_2$$

This equation can be rearranged and simplified to the following:

$$V = 1/3 \times \pi \times (r_1^2 \times h_1 - r_2^2 \times h_2)$$

The surface area will follow the same logic, with the surface area of the flat-top factored into the equation. The surface area of a cone is defined as:

Surface Area (SA) = Area of the Base + Lateral Area

Since the area of concern is only the area that is potentially exposed to erosion from wind, the area of the base is left out of the calculation, which becomes:

$$SA = \pi \times (r \times s), \text{ where}$$

r = radius

s = slant height

Letting subscript “1” refer to the larger cone and subscript “2” refer to the smaller cone and the area of the flat-top is added to the equation, then the surface area of a flat-topped cone becomes:

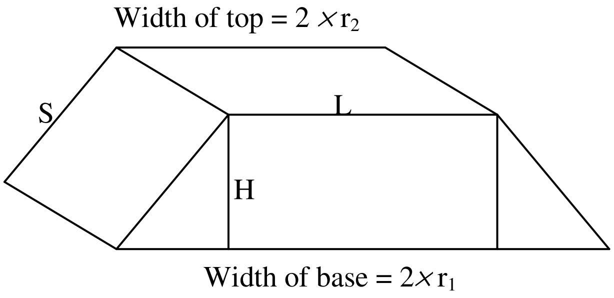
$$SA = (\pi \times r_1 \times s_1 - \pi \times r_2 \times s_2) + \pi \times r_2^2$$

This equation can be rearranged and simplified to the following:

$$SA = \pi \times (r_1 \times s_1 - r_2 \times s_2 + r_2^2)$$

Equations for a Trapezoid

The remaining portion of the pile, Section B, will be in the shape of a trapezoid.



The top of the trapezoid will have a width equal to the diameter at the top of the cone while the bottom of the trapezoid will have a width equal to the diameter of the base of the cone. The trapezoid will have a slope of 37° with the length of the slant equal to the length of the slant of the flat-topped cone.

Therefore, the volume of the trapezoid will be defined as:

$$V = 2 \times (1/2 \times H \times L \times (2 \times r_1 - 2 \times r_2) \div 2) + (2 \times r_2 \times H \times L)$$

This equation can be rearranged and simplified to the following:

$$V = H \times L \times ((r_1 - r_2) + (2 \times r_2))$$

For the surface area, only three (3) sides of the trapezoid will be included as the base is not exposed to the wind and the other two (2) sides are each one-half of the flat-topped cone. Therefore, the surface area of the remaining three (3) segments is calculated using the following equation:

$$SA = (S \times L) + (S \times L) + (L \times (2 \times r_2))$$

Simplifying this equation becomes:

$$SA = 2 \times L \times (S \times r_2)$$

Equations for an Oval-Shaped Pile

Adding the surface area of the trapezoid (Section B) and the surface area of the cone (Sections A and C) will result in the total exposed surface area for the flat-topped oval shaped pile:

$$Total\ Exposed\ SA = \pi \times (r_1 \times s_1 - r_2 \times s_2 + r^2_2) + 2 \times L \times (S \times r_2)$$

Finally, r_1 and L are approximated from the site map (r_1 = 435 ft and L = 300 ft). Once those two variables are known, the rest of the unknown variables are defined by the geometry of the shapes:

$$S = s_1 - s_2$$
$$s_1 = (r_1^2 + h_1^2)^{0.5}$$
$$h_1 = tan(37°) \times r_1$$
$$s_2 = (r_2^2 + h_2^2)^{0.5}$$
$$r_2 = r_1 - (H \div tan(37°))$$
$$h_2 = tan(37°) \times r_2$$

The remaining dimensions and resulting surface areas are shown in Table B-9. The emission calculations are shown in two PDF files, one for the Reserve Stockout Pile and One for the Reserve Storage Pile.

After the wind erosion emission rate is calculated in pounds per hour for each hour of the five year period from a pile, these rates are converted to g/sec-m^2 rates based on the plan view area of the pile that will be included in the model. The hourly bulldozing and drop emission rates are then added to the wind erosion hourly emission rate. It is this combined hourly emission rate that is converted to a text file and modeled as an area source as described in Section 6 of this application.