

March 28, 2006

**Memorandum**

To: Fred Starheim

From: Allen Dittenhoefer, Michael Hirtler, and Howard Ellis

Re: Analysis of the Potential for Ground-Level Fogging Due to Water Vapor Emissions from the Proposed 850-Foot FirstEnergy Sammis Plant Stack

**1. INTRODUCTION**

The Ohio Edison Company entered into a Consent Decree dated March 18, 2005 that requires modifications to the W.H. Sammis generating station (Sammis Plant). The planned changes (Sammis air pollution control project) will result in source-wide reductions of SO<sub>2</sub>, NO<sub>x</sub>, and PM<sub>10</sub>.

The Sammis Plant, which is currently owned and operated by FirstEnergy Generation Corp, consists of Units 1 and 2 emitting through a 504 foot stack (Stack 1), Units 3 and 4 emitting through a separate 504 foot stack (Stack 2), Units 5 and 6 emitting through an 850 foot stack (Stack 3), and Unit 7 emitting through a 1,000 foot stack (Stack 4). Under the March 18, 2005 Consent Decree with U.S. EPA, the U.S. Department of Justice, and other parties; FirstEnergy will install additional air emissions control equipment at the Sammis Plant, all of which work must be completed before 2012. This additional control equipment, which will include a wet Flue Gas Desulfurization (FGD) system, will require construction of a new stack for Units 1 through 7 to exhaust the treated effluent from the existing units. This new stack, Stack 5, will be of identical height to the existing 850 foot Stack 3 serving Units 5 and 6.

The installation of the wet FGD system will result in a substantial increase in the emissions of water vapor and liquid water that will exhaust from the proposed 850-foot Sammis Plant stack. This raises the concern of the potential for plume-induced ground-level fogging in the vicinity of the plant.

The purpose of this study was to estimate the potential for the occurrence of ground-level fog due to water vapor emissions from the proposed 850-foot stack at the FirstEnergy Sammis Plant. This impact analysis will aid FirstEnergy in the determination of a stack height that will minimize the fogging impact of water vapor emissions.

Allen Dittenhoefer, Ph.D. served as Principal Investigator on this project. He was assisted by Michael Hirtler, C.C.M., Dr. Howard Ellis, QEP, Bruce Egan, Sc.D., C.C.M. (contractor), Surya Ramaswamy, and Adeel Yousuf.

Section 2 describes the methodology used to estimate the fogging potential. Section 3 presents the results and discussion of the analysis.

## 2. STUDY METHODOLOGY

The technical approach used in this analysis consisted of the following elements:

1. A review of previous plume transport and dispersion studies conducted at the Sammis Plant,
2. Air dispersion modeling of the water vapor emissions from the proposed 850-foot Sammis stack, and
3. Post-processing of model-predicted ground-level water vapor concentrations to determine the probability of fog occurrence.

### **2.1 Review of Previous Plume Transport and Dispersion Studies at the Sammis Plant**

The Sammis Plant is located in complex terrain within the Ohio River Valley, near Stratton, OH, where ground elevations rise more than 500 feet on either side of the valley. Based on the proximity and height of terrain features relative to stack height, it is probable that terrain-induced downwash influences the transport and diffusion of the Sammis plumes. During the period 1979-1982, three intensive studies were conducted to quantify the influence of this complex terrain on the transport and dispersion of emissions from the plant. These studies included: a) the 1979 Plume Tracer Field Study<sup>(1)</sup> conducted by Enviroplan, b) the 1981 Good Engineering Practice (GEP) Stack Height Physical Modeling Study<sup>(2)</sup>, supervised by Enviroplan and conducted by Environmental Science and Services Corporation (ESSCO), and c) the 1982 Plume Photography Study<sup>(3)</sup> conducted by ERT.

#### *a) 1979 Plume Tracer Study*

During May and June, 1979, Enviroplan conducted a field study at the Sammis Plant to determine an empirical relationship between rising terrain and elevation of plume centerline above ground level and to quantify the effects of complex terrain on plume diffusion. The study involved the release of sulfur hexafluoride (SF<sub>6</sub>) tracer from the Sammis stacks with airborne plume sampling and plume observation. Data from 16 separate tracer experiments, as well as visual plume height observations from a helicopter for an additional 24 experiments, were collected.

In this study, a comparison was conducted of predicted plume rise, using the standard Briggs plume rise formulae, against the measured/observed plume height at the predicted point of terminal plume rise. This comparison indicated that the observed plume rise from the 850-foot stack was, on average, 87% of the calculated Briggs plume rise. This suggests the possible influence of terrain-induced plume downwash.

b) *1981 GEP Stack Height Physical Modeling Study*

In 1981, a GEP Stack Height fluid modeling study of the Sammis stacks was conducted by ESSCO under contract to Enviroplan. A physical model of the Sammis Plant and surrounding terrain at a scale reduction of 1:960 was constructed at the ESSCO Atmospheric Boundary Layer Wind Tunnel. Physical modeling was conducted for a wind direction sector of 275 degrees. Downwind terrain out to 7 km was included, as was upwind terrain within approximately one-half mile of the plant. The physical modeling was performed based on one stack as replacement for the two existing stacks serving Units 1-4. Stack heights of 504 ft, 620 ft, 840 ft, and 990 ft for Units 1-4 were modeled in the wind tunnel.

The physical modeling results for the 840-foot stack indicated a maximum ratio of ground-level concentration with upwind terrain in place to that without upwind terrain of 1.93 (i.e., an excess concentration with upwind terrain of 93%).<sup>(4)</sup> This occurred with a surface roughness of 77 cm and a wind speed of 31.3 m/s. This study also showed that the measured plume rise under high wind speed conditions, when terrain-induced downwash has its greatest effects, was 85% of the calculated Briggs plume rise.<sup>(5)</sup> These results also suggest that terrain-induced downwash influences the transport of the Sammis plume, resulting in higher ground-level pollutant concentrations.

c) *1982 Plume Photography Study*

In December, 1982, ERT conducted a photographic study of the Sammis plume trajectories. A total of ten hours of photographic observations of plumes from the 850-foot stack were made. A comparison of these observations to calculated Briggs plume rise indicated that the observed plume rise was, on average, 85% of the calculated value. These results also represent possible evidence of terrain-induced downwash.

d) *Summary of Sammis Plume Transport Studies and Dispersion Modeling Implications*

The results from the above three independent studies of the percent reduction in measured plume rise from the Sammis Plant relative to the calculated Briggs plume rise all indicate about a 15% plume rise reduction due to upwind terrain. The physical modeling study indicated that this plume rise reduction results in significantly higher maximum ground-level pollutant concentrations in the vicinity of the plant.

To quantify the impact of a 15% plume rise reduction on predicted ground-level pollutant concentrations, the screening model AERSCREEN was run for the proposed Sammis 850-foot stack. AERSCREEN is the screening model for the U.S. EPA Guideline model AERMOD.<sup>(6)</sup> Maximum predicted ground-level concentrations for a plume rise reduction of approximately 15% were compared to maximum concentrations for the standard (i.e., Briggs) plume rise in the AERMOD and AERSCREEN Models. The 15% plume rise reduction was accomplished by a reduction in the stack gas exit temperature, which resulted in a lowering of the plume buoyancy flux. These results indicated only about a

10% increase in maximum ground-level concentrations with the reduced plume rise, compared to the base case.

To ensure the conservatism of the study, a pollutant concentration scaling factor of 1.93, based on the afore-mentioned results of the physical modeling study, was selected. This scaling factor was applied to each hourly prediction of plume water vapor concentration at each model receptor, as described in the following sections.

In addition to the above terrain-induced downwash scaling factor, a second, multiplicative scaling factor of 1.43 was applied to the model-predicted ambient concentrations to account for plume meandering and the resulting maximum concentration occurring in any 10-minute period of each hour. Hourly average model predictions, based on hourly wind direction data, tend to smooth out shorter-term peaks in ground-level concentrations caused by the meandering of the plume. As sampling time increases, the standard deviation of the lateral plume dimension ( $\sigma_y$ ) increases, resulting in a decrease in predicted concentration. For sampling times between 3 minutes and one hour, the relationship between  $\sigma_y$  and sampling time  $T_s$  can be approximated as follows:<sup>(7)</sup>

$$(\sigma_y)_d/(\sigma_y)_e = [(T_{sd})/(T_{se})]^{0.2}$$

where the subscripts d and e refer to two different sampling times. Thus,  $\sigma_y$  for a sampling time of one hour equals  $6^{0.2} = 1.43$  times the  $\sigma_y$  for a ten minute sampling time. Since, in the Gaussian plume formula, plume centerline concentration is inversely related to  $\sigma_y$ , the ten minute average concentration is roughly equal to 1.43 times the hourly average concentration.

Turner also summarized several studies of plume centerline concentration measurements from single sources for different concentration averaging times and concluded that the maximum ambient concentrations for 10-minute periods within an hour varied inversely with the concentration averaging time raised to a power between 0.17 and 0.20.<sup>(8)</sup>

Therefore, to account for peak ten minute water vapor concentrations predicted for the Sammis plume, hourly average model predictions were multiplied by 1.43.

The post-processing procedure applied to the dispersion model predictions is discussed more thoroughly in Subsection 2.3.

## **2.2 Air Dispersion Modeling of Water Vapor Emissions**

The AERMOD Model was applied to predict the ground-level concentrations of water vapor from the proposed 850-foot Sammis stack. The AERMOD Model has been shown to perform significantly better than other U.S. EPA dispersion models (e.g., ISC3) for complex terrain settings such as the Sammis modeling domain.<sup>(9)</sup>

AERMOD Model input data and modeling procedures used in the study are discussed below.

a) *Water Vapor Emission Rate and Stack Parameters*

The water vapor emission rate from the proposed Sammis 850-foot stack with wet FGD control was estimated to be 252,062 g/s at 100% operating load. This information was supplied to Enviroplan by Bechtel Corporation. This water vapor emission rate is equivalent to 12.9% water vapor by volume in the stack exhaust. Water vapor emission rates at the 75% and 50% operating loads were reduced proportionately.

The emissions of liquid water from the proposed Sammis stack will be insignificant, compared to the emissions of water vapor. The liquid water carryover from the mist eliminators is estimated to be approximately 1,000 lbs/hr per flue, or 378 g/s total for three flues. This information was also supplied by Bechtel.

All stack parameters used in the modeling (i.e., stack height and diameter and stack exit temperature, exit velocity, and volumetric flow rate) were the same as those used in the previous air dispersion modeling analysis in support of the Sammis air pollution control project.<sup>(10)</sup> These stack parameters reflect the reductions in stack exit temperatures and velocities due to the planned installation of pollution control equipment (e.g., wet FGD). A listing of these stack parameters is provided in the December 27, 2005 final report, which summarizes the air dispersion modeling study of the proposed modifications to the Sammis Plant (Enviroplan Ref. No. 15-2018).

b) *Meteorological Data*

The meteorological data used in the study consisted of five years (1987-1991) of hourly surface data and upper air data from the National Weather Service (NWS) station at the Pittsburgh International Airport (Station ID – 94823). The AERMET meteorological pre-processor (version 04300)<sup>(11)</sup> was used to process the data required for AERMOD.

c) *Site Characteristics*

In this study we assumed that the site characteristics (i.e., land use) of the area surrounding the Sammis Plant and the Pittsburgh International Airport are similar. A comparison of topographic maps and aerial photographs<sup>(12)</sup> for the power station and the airport show mostly urban and deciduous forest land use types surrounding both locations. Therefore, as recommended by EPA in their September 27, 2005 AERMOD Implementation Guide, a 3 km radial was used to determine the appropriate land use parameters in the area surrounding the meteorological tower. This 3 km circular area was divided into two directional sectors for land use specification, as shown in Table 1.

**Table 1: Fractional Land Use**

Land Use Type	Fractional Land Use	
	Sector 1 (15° – 270°)	Sector 2 (270° – 15°)
Urban	0.75	0.10
Deciduous	0.20	0.85
Grassland	0.05	0.05
<b>Total % Land Use</b>	<b>1.00</b>	<b>1.00</b>

The seasonal albedo, Bowen ratio, and surface roughness values for each land use classification that are needed as input to AERMET, as provided in the AERMET User’s Guide<sup>(1)</sup> and are summarized in Table 2 below.

**Table 2: Seasonal Albedo, Bowen Ratio and Surface Roughness found in the AERMET User’s Guide**

Albedo				
	Winter	Spring	Summer	Autumn
Urban	0.35	0.14	0.16	0.18
Deciduous	0.5	0.12	0.12	0.12
Grassland	0.6	0.18	0.18	0.2
<b>Bowen Ratio - Dry Conditions</b>				
	Winter	Spring	Summer	Autumn
Urban	2.0	2.0	4.0	4.0
Deciduous	2.0	1.5	0.6	2.0
Grassland	2.0	1.0	2.0	2.0
<b>Bowen Ratio - Normal Conditions</b>				
	Winter	Spring	Summer	Autumn
Urban	1.5	1.0	2.0	2.0
Deciduous	1.5	0.7	0.3	1.0
Grassland	1.5	0.4	0.8	1.0
<b>Bowen Ratio - Wet Conditions</b>				
	Winter	Spring	Summer	Autumn
Urban	0.5	0.5	1.0	1.0
Deciduous	0.5	0.3	0.2	0.4
Grassland	0.5	0.3	0.4	0.5
<b>Surface Roughness</b>				
	Winter	Spring	Summer	Autumn
Urban	1.0	1.0	1.0	1.0
Deciduous	0.5	1.0	1.3	0.8
Grassland	0.001	0.1	0.1	0.010

Seasonal weighted averages of albedo, Bowen ratio and surface roughness, based on the land classification for the two directional sectors given in Table 1, were calculated for each of the five meteorological years. Seasonal weighted averages of albedo, Bowen ratio and surface roughness for each sector are summarized in Tables 3A and 3B.

**Table 3A: Parameters Based on AERMET Manual and Fractional Land Use Sector 1 (15°-270°)**

Albedo				
	Winter	Spring	Summer	Autumn
Urban	0.2625	0.105	0.12	0.135
Deciduous	0.1	0.024	0.024	0.024
Grassland	0.03	0.009	0.009	0.01
<b>Total</b>	<b>0.393</b>	<b>0.138</b>	<b>0.153</b>	<b>0.169</b>
Bowen Ratio - Wet Conditions				
	Winter	Spring	Summer	Autumn
Urban	0.375	0.375	0.75	0.75
Deciduous	0.1	0.06	0.04	0.08
Grassland	0.025	0.015	0.02	0.025
<b>Total</b>	<b>0.500</b>	<b>0.450</b>	<b>0.810</b>	<b>0.855</b>
Surface Roughness				
	Winter	Spring	Summer	Autumn
Urban	0.75	0.75	0.75	0.75
Deciduous	0.1	0.2	0.26	0.16
Grassland	0.00005	0.0025	0.005	0.0005
<b>Total</b>	<b>0.850</b>	<b>0.953</b>	<b>1.015</b>	<b>0.911</b>

**Table 3B: Parameters Based on AERMET Manual and Fractional Land Use Sector 2 (270°-15°)**

Albedo				
	Winter	Spring	Summer	Autumn
Urban	0.035	0.014	0.016	0.018
Deciduous	0.425	0.102	0.102	0.102
Grassland	0.03	0.009	0.009	0.01
<b>Total</b>	<b>0.490</b>	<b>0.125</b>	<b>0.127</b>	<b>0.130</b>
Bowen Ratio - Wet Conditions				
	Winter	Spring	Summer	Autumn
Urban	0.05	0.05	0.1	0.1
Deciduous	0.425	0.255	0.17	0.34
Grassland	0.025	0.015	0.02	0.025
<b>Total</b>	<b>0.500</b>	<b>0.320</b>	<b>0.290</b>	<b>0.465</b>
Surface Roughness				
	Winter	Spring	Summer	Autumn
Urban	0.1	0.1	0.1	0.1
Deciduous	0.425	0.85	1.105	0.68
Grassland	0.00005	0.0025	0.005	0.0005
<b>Total</b>	<b>0.525</b>	<b>0.953</b>	<b>1.210</b>	<b>0.781</b>

*d) Modeling Receptor Grid*

The water vapor dispersion modeling utilized a Cartesian receptor grid centered on the Sammis Plant. The grid was comprised of receptor locations that were established at appropriate distances to ensure sufficient density and aerial extent to adequately characterize the pattern of water vapor impacts from the proposed 850-foot Sammis Plant stack.

The receptor grid consisted of an inner nested grid with dimensions of 1 km on a side (i.e., 0.5 km east, west, north and south of the plant) at 100 meter adjacent grid point spacing; a second inner grid with dimensions of 5 km on a side (i.e., 2.5 km east, west, north and south of the plant center) at a 250-meter adjacent grid point spacing; a third nested grid with dimensions of 10 km on a side (i.e., 5 km east, west, north and south of the plant center) with dimensions of 500-meter adjacent grid point spacing; and an outer more coarse grid with dimensions of 20 km on a side (i.e., 10 km east, west, north and south of the plant center) at 1 km adjacent grid point spacing. Receptor elevations were processed using the AERMAP terrain processor using the same digital elevation model (DEM) data files utilized in the most recent air pollutant modeling study of the Sammis Plant.

### 2.3 Post-Processing of Model-Predicted Ground-Level Water Vapor Concentrations

The post-processing of AERMOD-predicted ground-level water vapor concentrations was conducted as follows:

1. Model the emissions of water vapor with AERMOD, using a water vapor emission rate of 252,062 g/s.
2. Multiply the predicted ground-level water vapor concentrations by 2.76 to account for the following multiplicative effects: a) terrain-induced downwash, based on the results of the physical modeling study (scaling factor of 1.93) and b) plume meandering (scaling factor of 1.43), to adjust one-hour AERMOD-predicted concentrations to peak 10-minute average concentrations.
3. Convert the adjusted plume water vapor concentrations from Step 2 above (expressed as ug/m<sup>3</sup>) to a plume water vapor mixing ratio,  $r_{\text{plume}}$  (grams plume water vapor/grams air), i.e.,

$$r_{\text{plume}} = [\text{Concentration (ug/m}^3\text{)}] \times [T] \times [2.8706 \times 10^{-9}] / [P],$$

where T = ambient temperature (deg K) = T (C) + 273.16

P = atmospheric pressure (mb)

4. Calculate the ambient water vapor mixing ratio,  $r_{\text{ambient}}$  (grams ambient water vapor/grams air), i.e.,

$$r_{\text{ambient}} = r_s (\text{RH})$$

where  $r_s$  = saturation mixing ratio =  $(0.622)e_s/(P - e_s)$

$e_s$  = saturation vapor pressure (mb)

P = atmospheric pressure (mb)

RH = atmospheric relative humidity

The saturation vapor pressure  $e_s$  (mb) is estimated as follows:

$$\log e_s = -(2937.4/T) - 4.9283 \log T + 23.5518$$

where T = ambient temperature (deg K)

Exclude hours during which the ambient relative humidity, RH, is 100%, as it is assumed that atmospheric precipitation and/or fog is already present during these periods.

5. For the remaining hours, add the plume mixing ratio ( $r_{\text{plume}}$ ) to the ambient mixing ratio ( $r_{\text{ambient}}$ ) to get the total mixing ratio ( $r_{\text{total}}$ ), i.e.,

$$r_{\text{total}} = r_{\text{plume}} + r_{\text{ambient}}$$

6. Compare  $r_{\text{total}}$  to the saturation mixing ratio,  $r_s$ . If  $r_{\text{total}} \geq 0.995(r_s)$ , then ground-level fogging is assumed to occur (Note: the factor of 0.995 was used instead of 1.000 to account for possible relative humidity rounding error).

### 3. **STUDY RESULTS AND DISCUSSION**

The results of the modeling study indicated that there would be no 10-minute periods, at any receptor, during which the contribution of the Sammis plume water vapor, when combined with the ambient moisture, would cause a ground-level fogging incident. This is due to the fact that the predicted ground-level water vapor concentrations from the Sammis plume were a very small fraction of the ambient water vapor, such that the addition of plume moisture did not appreciably change the total atmospheric water vapor mixing ratio.

This is demonstrated in Table 4, which shows the predicted plume water vapor mixing ratios and meteorological conditions associated with the ten highest predicted ground-level water vapor concentrations in each meteorological year. The highest predicted plume water vapor mixing ratios at ground-level are of the order  $6 \times 10^{-5}$  to  $9 \times 10^{-5}$ , which is very low compared to typical ambient water vapor mixing ratios of 1 – 2%. Table 4 also indicates that the highest predicted plume water vapor mixing ratios predominantly occur during the summer months, in the afternoon, under relatively warm temperatures (80+ degrees F) and dry relative humidities (i.e., 20 – 40%), and during cross-valley plume transport (i.e., wind directions from the NE-E). Under these conditions, the addition of plume moisture is not nearly sufficient to raise the ambient mixing ratio to the saturation point.

It is important to note that a number of conservative assumptions and modeling procedures were applied in this study with the goal of seeking to assure that the occurrence of plume-induced fogging in the vicinity of the Sammis Plant would, if anything, be *overestimated*. These conservative assumptions/procedures included:

1. Application of a scaling factor of 1.93, obtained from the 1980 Sammis physical modeling study, to every hourly model prediction, to account for terrain-induced plume downwash,
2. Application of an additional, multiplicative scaling factor of 1.43 to account for peak 10-minute concentration peaks due to plume meandering (combined, the two scaling factors of 1.93 and 1.43 resulted in an overall scaling factor of 2.76, which was applied to every model prediction hour at every receptor throughout the modeling domain), and

3. Use of actual stack exit temperature, instead of virtual temperature, to calculate the plume buoyancy flux (this ignores the additional buoyancy flux and associated plume rise due to the latent heat of condensation of plume water vapor).

In addition, hourly NWS temperature and dew point temperature observations are reported to the nearest degree Fahrenheit. A one-degree change in dew point is approximately equal to 3 percent relative humidity. This information was provided by a NWS representative from the Pittsburgh NWS site. Consequently, the 5-year record of relative humidity values reported for the Pittsburgh NWS station did not include values of 98% and 99%. To account for this data deficiency, we conservatively assigned the hours of reported 96% and 97% relative humidities (1,150 and 1,108 total hours, respectively for 1986-1990) to 98% and 99%, respectively. Even after this modification, the results still indicated no hours of predicted plume-induced ground-level fogging in the vicinity of the plant.

Much of the primary and secondary fine particulate matter in the Sammis plume, such as sulfuric acid and ammonium sulfate, is hygroscopic. This particulate matter absorbs plume and ambient moisture and becomes wetted aerosol at relative humidities less than 100%, which can lead to atmospheric visibility degradation. A worst-case estimate of the amount of liquid water associated with these aerosols was made for the Sammis plume, assuming an SO<sub>2</sub>-to-sulfate chemical conversion rate of 3%/hour at a relative humidity of 98%. This is consistent with observed conversion rates in coal-burning power plant plumes due to aqueous phase sulfur chemistry.<sup>(13)</sup> At a relative humidity of 98%, the mass of liquid water contained in sulfate aerosols is equivalent to about ten times the mass of sulfate. The results of this calculation indicated that this aerosol-related water represents only about 1.3% of the total mass of plume water vapor, under worst-case conditions. The effects of plume aerosol hygroscopicity, therefore, were not considered to be significant contributors to plume-induced fogging in the vicinity of the Sammis Plant.

In this study, we employed the use of hourly NWS surface observations at the Pittsburgh International Airport for dispersion modeling and post-processing of predicted water vapor concentrations.

Atmospheric relative humidity is a key parameter for determining the incidence of plume-induced fogging. It is a well-known fact that wide mesoscale variations in relative humidity are common, especially in areas of complex terrain, such as the Sammis Plant modeling domain. The occurrence of ground-based radiation fog is common in valley areas under clear sky, near-calm nighttime conditions. In addition, low-level orographically-induced cloud formations can lead to fog conditions at higher elevations associated with such terrain. Such site-specific terrain effects may lead to significantly more hours per year of atmospheric saturation or near-saturation conditions than would normally occur with flat terrain, thus raising the potential for plume-induced fogging episodes. The results of the present study, therefore, are limited by the unavailability of more site-specific atmospheric relative humidity data.

Similarly, wind direction, wind speed, and stability categorization are also key parameters for determining the incidence of plume-induced fogging. The actual wind fields and stability regimes governing the Sammis Plume environment may differ from the available meteorological data at the Pittsburgh NWS Station. This, in turn, has the possibility of altering the results of this study.

Finally, the prediction of no plume-induced ground-level fogging from the proposed Sammis 850-foot stack does not preclude the possibility that there would be cases of a visible plume aloft, especially during cold, high ambient humidity conditions. Plume visibility is better defined by the plume centerline water vapor concentration, which is generally much higher than that at ground-level and, therefore, more likely to contribute to atmospheric saturation. Under such cases, an elevated plume may be visible at large distances downwind from the stack, without the occurrence of ground-level fog.

**Table 4: Predicted Plume Water Vapor Mixing Ratios and Meteorological Conditions Associated with the Highest Predicted Plume Ground Level Concentrations**

Rank	AERMOD Conc.	Yr	Month	Day	Hr	UTM X	UTM Y	Wind Direction	Wind Speed,m/s	Dry Bulb Temp, K	Relative Humidity	Station Pr, mb	Sat. Vapor Pr	Sat. Mixing Ratio	Cons. r <sub>s</sub>	r <sub>ambient</sub>	Conc.	r <sub>plume</sub>	r <sub>total</sub>	r <sub>total</sub> /r <sub>s</sub>
1	26,991.86	86	7	22	16	530250	4485400	40	2.6	301.45	40	978	38.84	0.0257	0.0256	0.0102	74,497.53	6.59E-05	0.0103	0.40
2	26,332.38	86	7	23	13	530000	4485900	60	4.1	301.45	46	980	38.84	0.0257	0.0255	0.0117	72,677.37	6.42E-05	0.0118	0.46
3	26,332.38	86	7	23	13	530000	4485900	60	4.1	301.45	46	980	38.84	0.0257	0.0255	0.0117	72,677.37	6.42E-05	0.0118	0.46
4	25,649.31	86	7	22	15	530500	4485150	20	3.1	300.95	41	978	37.72	0.0250	0.0248	0.0102	70,792.10	6.25E-05	0.0102	0.41
5	25,369.91	86	7	22	17	530500	4485150	20	5.7	301.45	38	978	38.84	0.0257	0.0256	0.0097	70,020.95	6.20E-05	0.0098	0.38
6	25,267.50	86	5	26	14	530000	4486400	90	6.7	300.35	32	974	36.42	0.0242	0.0240	0.0077	69,738.31	6.17E-05	0.0078	0.32
7	25,267.50	86	5	26	14	530000	4486400	90	6.7	300.35	32	974	36.42	0.0242	0.0240	0.0077	69,738.31	6.17E-05	0.0078	0.32
8	25,267.50	86	5	26	14	530000	4486400	90	6.7	300.35	32	974	36.42	0.0242	0.0240	0.0077	69,738.31	6.17E-05	0.0078	0.32
9	24,986.04	86	6	21	15	530000	4486650	100	2.1	299.85	35	978	35.37	0.0233	0.0232	0.0081	68,961.48	6.07E-05	0.0082	0.35
10	24,932.49	86	7	23	16	530250	4485400	30	3.1	302.55	43	978	41.39	0.0275	0.0273	0.0118	68,813.68	6.11E-05	0.0118	0.43
1	28,619.07	87	6	17	14	530500	4485400	30	2.6	301.45	37	975	38.84	0.0258	0.0257	0.0095	78,988.64	7.01E-05	0.0096	0.37
2	28,619.07	87	6	17	14	530500	4485400	30	2.6	301.45	37	975	38.84	0.0258	0.0257	0.0095	78,988.64	7.01E-05	0.0096	0.37
3	27,619.58	87	6	24	15	530250	4485400	40	3.1	302.05	40	972	40.21	0.0268	0.0267	0.0107	76,230.05	6.80E-05	0.0108	0.40
4	27,588.17	87	7	23	14	532500	4486400	260	2.1	306.45	40	976	51.64	0.0348	0.0346	0.0138	76,143.36	6.86E-05	0.0139	0.40
5	27,588.17	87	7	23	14	532500	4486400	260	2.1	306.45	40	976	51.64	0.0348	0.0346	0.0138	76,143.36	6.86E-05	0.0139	0.40
6	27,364.04	87	7	31	15	530500	4485150	20	2.6	304.25	36	973	45.62	0.0306	0.0304	0.0110	75,524.76	6.78E-05	0.0110	0.36
7	27,301.36	87	7	31	13	530000	4485900	60	2.6	303.75	38	973	44.34	0.0297	0.0295	0.0112	75,351.75	6.75E-05	0.0113	0.38
8	27,301.36	87	7	31	13	530000	4485900	60	2.6	303.75	38	973	44.34	0.0297	0.0295	0.0112	75,351.75	6.75E-05	0.0113	0.38
9	27,089.77	87	6	24	14	530000	4486150	70	4.1	301.45	43	972	38.84	0.0259	0.0258	0.0111	74,767.77	6.66E-05	0.0111	0.43
10	26,908.90	87	7	23	16	532500	4486400	260	2.6	307.05	37	975	53.40	0.0360	0.0359	0.0133	74,268.55	6.71E-05	0.0133	0.37
1	35,160.11	88	7	7	15	530000	4486150	70	2.6	310.35	20	977	64.03	0.0436	0.0434	0.0087	97,041.91	8.85E-05	0.0088	0.20
2	34,022.35	88	7	7	16	530500	4485150	20	2.6	311.45	19	977	67.96	0.0465	0.0463	0.0088	93,901.68	8.59E-05	0.0089	0.19
3	33,713.03	88	7	7	16	530500	4485400	20	2.6	311.45	19	977	67.96	0.0465	0.0463	0.0088	93,047.96	8.51E-05	0.0089	0.19
4	33,713.03	88	7	7	16	530500	4485400	20	2.6	311.45	19	977	67.96	0.0465	0.0463	0.0088	93,047.96	8.51E-05	0.0089	0.19
5	33,268.06	88	7	7	13	530500	4485150	20	2.6	309.85	21	978	62.31	0.0423	0.0421	0.0088	91,819.85	8.35E-05	0.0089	0.21
6	32,825.11	88	7	7	13	530500	4485400	20	2.6	309.85	21	978	62.31	0.0423	0.0421	0.0088	90,597.30	8.24E-05	0.0089	0.21
7	32,825.11	88	7	7	13	530500	4485400	20	2.6	309.85	21	978	62.31	0.0423	0.0421	0.0088	90,597.30	8.24E-05	0.0089	0.21
8	32,628.36	88	7	6	13	530250	4486150	70	1.5	308.15	28	980	56.76	0.0382	0.0381	0.0107	90,054.26	8.13E-05	0.0107	0.28
9	32,155.27	88	7	8	16	530250	4485400	40	3.1	309.25	28	974	60.30	0.0411	0.0408	0.0114	88,748.55	8.09E-05	0.0115	0.28
10	31,961.03	88	7	8	14	530000	4486150	70	2.6	308.75	31	975	58.67	0.0398	0.0396	0.0123	88,212.44	8.02E-05	0.0124	0.31

**Table 4: Predicted Plume Water Vapor Mixing Ratios and Meteorological Conditions Associated with the Highest Predicted Plume Ground Level Concentrations**

Rank	AERMOD Conc.	Yr	Month	Day	Hr	UTM X	UTM Y	Wind Direction	Wind Speed,m/s	Dry Bulb Temp, K	Relative Humidity	Station Pr, mb	Sat. Vapor Pr	Sat. Mixing Ratio	Cons. r <sub>s</sub>	r <sub>ambient</sub>	Conc.	r <sub>plume</sub>	r <sub>total</sub>	r <sub>total</sub> / r <sub>s</sub>	
1	30,639.16	89	7	24	12	530750	4485400	20	1.5	306.45	41	982	51.64	0.0345	0.0344	0.0141	84,564.09	7.58E-05	0.0142	0.41	
2	30,537.45	89	7	23	16	530000	4486400	90	2.1	307.05	40	981	53.40	0.0358	0.0356	0.0143	84,283.35	7.57E-05	0.0143	0.40	
3	30,537.45	89	7	23	16	530000	4486400	90	2.1	307.05	40	981	53.40	0.0358	0.0356	0.0143	84,283.35	7.57E-05	0.0143	0.40	
4	30,537.45	89	7	23	16	530000	4486400	90	2.1	307.05	40	981	53.40	0.0358	0.0356	0.0143	84,283.35	7.57E-05	0.0143	0.40	
5	29,813.35	89	7	25	15	530500	4485150	20	2.6	307.05	41	980	53.40	0.0358	0.0357	0.0146	82,284.84	7.40E-05	0.0147	0.41	
6	29,497.57	89	7	24	14	530000	4486650	110	2.6	305.35	42	982	48.55	0.0324	0.0322	0.0135	81,413.29	7.27E-05	0.0136	0.42	
7	29,389.35	89	2	18	12	531000	4482400	360	1.5	271.45	51	988	5.45	0.0035	0.0034	0.0018	81,114.62	6.40E-05	0.0018	0.53	
8	29,389.35	89	2	18	12	531000	4482400	360	1.5	271.45	51	988	5.45	0.0035	0.0034	0.0018	81,114.62	6.40E-05	0.0018	0.53	
9	29,223.86	89	2	18	12	531000	4482900	360	1.5	271.45	51	988	5.45	0.0035	0.0034	0.0018	80,657.86	6.36E-05	0.0018	0.53	
10	29,058.26	89	7	24	13	530750	4485150	10	1.5	307.05	40	982	53.40	0.0358	0.0356	0.0142	80,200.80	7.20E-05	0.0143	0.40	
1	28,686.62	90	8	28	23	530000	4485900	60	9.3	299.25	72	969	34.14	0.0227	0.0226	0.0163	79,175.06	7.02E-05	0.0163	0.72	
2	28,686.62	90	8	28	23	530000	4485900	60	9.3	299.25	72	969	34.14	0.0227	0.0226	0.0163	79,175.06	7.02E-05	0.0163	0.72	
3	28,598.72	90	7	27	12	530500	4485400	30	2.1	302.05	49	981	40.21	0.0266	0.0265	0.0130	78,932.48	6.98E-05	0.0130	0.49	
4	28,598.72	90	7	27	12	530500	4485400	30	2.1	302.05	49	981	40.21	0.0266	0.0265	0.0130	78,932.48	6.98E-05	0.0130	0.49	
5	28,175.07	90	11	19	12	535000	4483900	300	1.5	280.35	46	976	10.26	0.0066	0.0066	0.0030	77,763.20	6.41E-05	0.0031	0.47	
6	28,021.45	90	8	9	15	530000	4485900	60	4.1	300.95	57	977	37.72	0.0250	0.0249	0.0142	77,339.21	6.84E-05	0.0142	0.57	
7	28,021.45	90	8	9	15	530000	4485900	60	4.1	300.95	57	977	37.72	0.0250	0.0249	0.0142	77,339.21	6.84E-05	0.0142	0.57	
8	27,945.62	90	6	16	16	530000	4486400	90	2.6	304.25	52	973	45.62	0.0306	0.0304	0.0158	77,129.91	6.92E-05	0.0159	0.52	
9	27,945.62	90	6	16	16	530000	4486400	90	2.6	304.25	52	973	45.62	0.0306	0.0304	0.0158	77,129.91	6.92E-05	0.0159	0.52	
10	27,945.62	90	6	16	16	530000	4486400	90	2.6	304.25	52	973	45.62	0.0306	0.0304	0.0158	77,129.91	6.92E-05	0.0159	0.52	

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