Rosemont Copper Company
Revised AERMOD Modeling Report to Assess Ambient Air Quality Impacts

Prepared for:
Arizona Department of Environmental Quality
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Phoenix, Arizona 85007

Prepared by:
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Dec 2, 2011
Memorandum

To: Bev Everson
Cc: Chris Garrett
From: Kathy Arnold
Doc #: 130/11 - 15.3.2
Subject: Transmittal of Applications
Date: December 7, 2011

Rosemont Copper is transmitting the following applications for your records.

- **Section 404 Permit Application for the Rosemont Copper Project ACOE File No. SPL-2008-00816-MB**, prepared by WestLand Resources, dated October 11, 2011 and transmittal
- **AERMOD Modeling Protocol to Assess Ambient Air Quality Impacts**, prepared by JBR Environmental for ADEQ, dated December 2, 2011 and transmittal letter
- **Revised AERMOD Modeling Report to Assess Ambient Air Quality Impacts**, prepared by JBR Environmental for ADEQ, dated December 2, 2011
- **Application for a Class II Permit Rosemont Copper Project, Southeastern Arizona**, prepared by JBR for ADEQ, dated November 15, 2011 and transmittal letter
- **Emissions Inventory Information Years 1, 5, 10, 15 and 20, Volume I**, prepared by JBR Environmental for ADEQ, dated November 1, 2011
- **Emissions Inventory Information Years 1, 5, 10, 15 and 20, Volume II**, prepared by JBR Environmental for ADEQ, dated November 1, 2011

Rosemont is providing CNF with three hardcopies and one electronic copy of the Section 404 Permit Application and two hardcopies and one electronic copy to SWCA. Single copies of the air modeling information, permit application, and emissions inventories are being provided along with an electronic copy of these reports.

Please note the modeling information matches the protocols preferred by ADEQ and is for the MPO version of the plan.
December 2, 2011

HAND DELIVERED

Mr. Eric Massey  
Air Quality Division Director  
Arizona Department of Environmental Quality  
1110 West Washington Street  
Phoenix, Arizona 85007

Re: AERMOD Modeling Protocol to Assess Ambient Air Quality Impact, Revised AERMOD Modeling Reports to Assess Ambient Air Quality Impact, Rosemont Copper Company, Rosemont Copper Project

Dear Mr. Massey:

On behalf of Rosemont Copper Company, enclosed please find two copies of each of the above-referenced modeling protocol and modeling report for the Rosemont Copper Project.

Please call if you have any questions.

Sincerely,

Louis C. Thanukos, Ph.D.  
Division Manager  
JBR Environmental Consultants, Inc.

Attachments  
AERMOD Modeling Protocol to Assess Ambient Air Quality Impacts  
Revised AERMOD Modeling Report to Assess Ambient Air Quality Impacts

cc: Kathy Arnold, Rosemont Copper Company (w/attachments)
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1. INTRODUCTION

This document presents an air dispersion modeling protocol that will be followed to assess ambient air quality impacts from the proposed Rosemont Copper Company Project (Rosemont Project). The proposed Rosemont Project is a new open pit copper mine that will be located in the Santa Rita Mountains approximately 30 miles southeast of Tucson, Arizona in Pima County (Figure 1.1). The Rosemont Project, Mine Plan of Operations was submitted to the Coronado National Forest in July 2007 (complete document available at www.rosemontcopper.com). The Coronado National Forest represents the Federal Land Manager for purposes of the Environmental Impact Statement (EIS) that will be prepared for the Rosemont Project.

Based on the expected emission levels from the facility, the Rosemont Project will be a non-Title V Class II emission source. Although Class II sources are not required to demonstrate protection of the National Ambient Air Quality Standards (NAAQS), Arizona Department of Environmental Quality (ADEQ) sometimes requires such analyses. Thus, the objective of the dispersion modeling will be to quantify the maximum predicted ambient impacts due to criteria pollutant emissions and anticipated background concentrations for comparison with applicable NAAQS.

The ensuing sections of this document describe the methodology that will be used to conduct the modeling. This protocol has been developed following applicable portions of the (ADEQ) guidance document: Air Dispersion Modeling Guidelines for Air Quality Permits, December 2004 (ADEQ Guidance), the EPA Guideline on Air Quality Models (Guidelines, 40 CFR Part 51, Appendix W, November 2005) and recommendations from the Federal Land Managers.

1.1 Facility Description

The Rosemont Project will include an open-pit mine; and ore processing operations comprised of milling, a concentrator, leaching and solvent extraction/electrowinning. The production schedule developed from mining sequence plans indicates a project operating life of approximately 20-25 years using only proven and probable mineral reserves. Peak mining rates were initially estimated at approximately 378,000 tpd of total material (ore and waste) to be realized in Year 1. These mining rates included a 20% capacity factor above the average capacity. During this year of operation, however, operations would still be in the development stages more typical of 316,000 tpd mining rate. Mining rates during Year 2 are estimated at 376,000 tpd and for Years 3-12 at approximately 360,000 tpd of total material. These rates include the additional 20% capacity factor. These rates will taper off toward the final years of the project.

Mining of the ore will be through conventional open-pit mining techniques including drilling, blasting, loading, hauling and unloading. Waste rock will be transported by haul truck to the waste rock storage areas. Ore will be either transported by haul truck to the leach pad (oxide ore), or crushed and loaded onto a conveyor for transport to the mill (sulfide ore). The copper and molybdenum concentrates from the milling and flotation operations will be shipped off site for further processing. Oxide ore will be placed on the lined leach pad. Pregnant leach solution (PLS) from the pad will be collected in a solution pond and then processed through the SX/EW plant. Copper cathodes generated from the SX/EW plant will be transported off site for further processing.
1.2 Site Description

The Rosemont Project will be located in Pima County, approximately 30 miles southeast of Tucson, Arizona as shown in Figure 1.1. Regionally, the facility location is in the Sonoran Desert Section of the Basin and Range Physiographic Province which is characterized by northerly trending fault block mountains separated by broad, down-faulted valleys (see Figures 1.1 and 4.1). The site is at an elevation of approximately 5,350 feet.

Figure 1.1 General location map of the Rosemont Project and surrounding area.
2. REGULATORY STATUS

2.1 Source Designation

The Rosemont Project will be a non-categorical stationary source. The Potential to emit of criteria pollutants from the facility will be below the New Source Review major source threshold of 250 tons/year. Therefore, the facility will not be subject to PSD regulations. Additionally, the potential to emit of hazardous air pollutants (HAPs) will be less than 10 tons/year for any individual (HAP), and less than 25 tons/year for all HAPs combined and therefore, the facility will not be a major HAP source. The potential to emit of criteria pollutants from the facility will also be less than the Title V source threshold of 100 tons per year. Consequently, the facility will operate under a Class II Permit issued by the Arizona Department of Environmental Quality (ADEQ).

2.2 Area Classifications

The Rosemont Project area is classified as "attainment" (better than national standards) or un-classifiable/attainment for particulate matter less than 10 microns nominal aerodynamic diameter ($\text{PM}_{10}$), particulate matter less than 2.5 microns nominal aerodynamic diameter ($\text{PM}_{2.5}$), carbon monoxide (CO), sulfur dioxide ($\text{SO}_2$), nitrogen dioxide ($\text{NO}_2$), and ozone ($\text{O}_3$) (see 40 CFR Part 81.303).

2.3 Baseline Area

The Rosemont Project will be located within the Pima Intrastate Air Quality Control Region (AQCR) which encompasses Pima County. This AQCR represents the "baseline area" for PSD purposes. The Rosemont Project, however, will not be subject to PSD regulations.
3. AMBIENT DATA REQUIREMENTS

3.1 Pre-Application Air Quality Monitoring

The primary pollutant that will be emitted by the Rosemont Project will be particulate matter. Consequently, Rosemont initiated pre-application air quality monitoring for PM$_{10}$ in June 2006. The monitoring ended in June 2009. The location of the monitoring site is shown in Figure 4.1. Complete quarterly data summary and audit reports have been submitted to the PCDEQ since the monitoring began. These will be submitted to the ADEQ upon request. Details of the monitoring program can be found in these quarterly reports. The PM$_{10}$ monitoring data will be used to define background concentrations as explained in Section 3.4 below.

Emissions from the Rosemont Project operations will include tail pipe emissions from mobile equipment conducting mining operations, and minor fuel combustion sources used in ore processing operations. Tail pipe emissions from mobile sources are not considered in applications for air quality permits, but are included in air impact analyses for Environmental Impact Statements. The planned air impact analysis will consider emissions from both process sources and mobile sources. Tail pipe emissions are generally comprised primarily of NO$_x$ and CO.

3.2 Post-Construction Air Quality Monitoring

No post-construction monitoring is proposed.

3.3 Meteorological Monitoring

On-site meteorological monitoring was initiated by Rosemont in April 2006 and is continuing to date. Complete quarterly data summary and semi-annual audit reports have been submitted to the PCDEQ since the monitoring began. These reports will be provided to ADEQ if requested. The location of the monitoring site is shown in Figure 4.1 below. Details of the monitoring program can be found in these quarterly reports. The meteorology data that will be used in the modeling proposed herein is explained further in Section 4 of this protocol.

3.4 Background Concentrations

Criteria pollutants for which background concentrations will be considered for the Rosemont Project modeling are PM$_{10}$, PM$_{2.5}$, NO$_2$, CO, and SO$_2$.

3.4.1 PM$_{10}$

As stated above, PM$_{10}$ measurements in the vicinity of the proposed Rosemont Project began in June 2006 and ended in June 2009. The monitoring program has yielded a little over twelve quarters of data. The quarterly summaries are presented in Appendix B.

As required by the November 9, 2005 Revision to the Air Quality Models (40 CFR 51), the 24-hr PM$_{10}$ background concentration will be based on the average of the highest 24-hr concentrations recorded for each year. With respect to determination of this value, ambient PM$_{10}$ monitoring commenced at the start of the 3rd quarter of 2006. Annual time periods are thus considered to represent the time
period, July of one year to June of the following year. A listing of the highest and second highest concentrations for the three year period is tabulated in Table 3.1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Highest Concentration (µg/m³)</th>
<th>2nd Highest Concentration (µg/m³)</th>
</tr>
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<tbody>
<tr>
<td>July 2006 - June 2007</td>
<td>71.3</td>
<td>27.0</td>
</tr>
<tr>
<td>July 2007 - June 2008</td>
<td>40.3</td>
<td>28.2</td>
</tr>
<tr>
<td>July 2008 - June 2009</td>
<td>31.6</td>
<td>21.2</td>
</tr>
</tbody>
</table>

The large difference between the highest measured value (71.3 µg/m³) and the second highest value (40.3 µg/m³) appears anomalous. Consequently a statistical analysis was conducted on all data to determine its probability of occurrence. This is presented in Appendix C and indicates that the probability of occurrence of the 71.3 µg/m³ is 5.5 x 10⁻¹¹. This low probability indicates that the concentration of 71.3 µg/m³ is an outlier to the distribution and should not be included in the determining the background concentrations as it cannot be expected to recur. Consequently, the 24-hr background concentration will be based on the average of 27.0, 40.3 and 31.6 µg/m³ or 33.0 µg/m³.

The annual PM₁₀ background concentration will be based on the average of the annual averages for each of the years, as required by the November 9, 2005 Revision to the Air Quality Models (40 CFR 51). Annual means as determined by the above referenced calendar years are 13.2, 12 and 10.4 µg/m³. The mean of these values, 11.9 µg/m³, will be used as the annual PM₁₀ background concentration. These values will be used as the background PM₁₀ concentrations for the fence line and near vicinity Impact analysis. Background concentrations for the impact analysis at the Saguaro East NP were based on the (2007-2009) Aerosol data from the Saguaro East NP IMPROVE site. The 24-hr and annual average background PM₁₀ concentrations of 47.6 µg/m³ and 12.6 µg/m³ respectively will be used.

3.4.2 NO₂

Nitrogen Dioxide, NO₂, is formed by the oxidation of nitric oxide (NO) which is a byproduct of combustion. The NO₂ monitoring sites in Arizona are located in urban areas (Phoenix and Tucson) and near major coal-fired electrical power plants (Springerville, Page, and Bullhead City). There are no monitoring sites in the immediate vicinity of the proposed Rosemont Project. The ADEQ recommended NO₂ background concentration for rural areas with no major sources of NO₂ was 4 µg/m³. This value will be used as the annual NOₓ background concentration for the modeling analysis.
Ambient 1-hr NO₂ concentrations are available only at urban areas, near coal fired power plants, and a rural background site where emissions are due to minor vehicle traffic and outboard motorboats on Alamo Lake in Arizona. The Rosemont site is similar to the Alamo Lake site in that the only sources of NO₂ are minor vehicle traffic on a road approximately 2.5 miles from the site. The highest recorded background 1-hr NO₂ concentrations at the Alamo Lake site measured during a two year monitoring program (2005-2006) were 20.7 µg/m³ and 24.5 µg/m³. Thus, the highest of the two years, 24.5 µg/m³ will be used as the 1-hr background NO₂ concentration. This value will also be used for the Saguaro East NP.

3.4.3 CO

CO is produced by the incomplete combustion of fuels with anthropogenic activities (automobiles, construction equipment, lawn and garden equipment, commercial and residential heating, etc.) representing the major source of emissions. Consequently, the CO monitoring sites in Arizona are located exclusively in urban areas (Phoenix, Tucson and Casa Grande). Thus, there are no representative monitoring stations to determine background CO concentrations.

The ADEQ recommended CO background concentrations for rural areas with no major sources of CO for both the 1-hour and 8-hour averaging periods are 582 µg/m³ (communications with the ADEQ see Appendix E). These values will be used as background CO concentrations for the fence line, near vicinity and Saguaro East NP Impact analysis.

3.4.4 SO₂

Historically, the principal source of SO₂ emissions in Arizona has been the smelting of copper and coal fired power plants. Urban areas also represent a major source of SO₂ emissions. Thus, the SO₂ monitoring sites in Arizona are located in the historical smelting areas (Miami, Globe, Hayden), near power plants (Springerville, Page and Bullhead City) and in urban areas (Phoenix and Tucson). Thus, there are no representative monitoring stations to determine background SO₂ concentrations.

The ADEQ recommended SO₂ background concentrations for rural areas with no major sources of SO₂ for the 3-hour, 24-hour and annual averaging periods are 43 µg/m³, 17 µg/m³ and 3 µg/m³, respectively (communications with the ADEQ see Appendix E). These values will be used as background SO₂ concentrations for the fence line and near vicinity Impact analysis as well as for the Saguaro East NP Impact analysis.

Sulfur dioxide emissions from the Rosemont Project operations are produced from blasting operations and the use of ultra-low sulfur diesel fuel. Emissions are very small. Background 1-hr SO₂ data is not available as all historic data has been compiled for comparison with applicable standards, i.e. 3-hr, 24-hr and annual SO₂ standards. The closest source of SO₂ emissions in the vicinity of the Rosemont Project is the Tucson Electrical Power Station (TEP). It is approximately 50 Km from the proposed Rosemont Project site. Emission information for TEP is currently unavailable to evaluate any impact to the background concentrations in the vicinity of the Rosemont Project. Since there are no SO₂ sources in the immediate area of the Rosemont site, the highest 1-hour impact from Rosemont facility will be used as the background concentration.
3.4.5 PM$_{2.5}$

In the absence of any representative PM$_{2.5}$ monitoring station in the close vicinity of the Rosemont site, the Chiricahua National Monument IMPROVE PM$_{2.5}$ monitoring station data was used. The 3 year (2006-2008) 98$^{th}$ percentile average of the maximum 24-hr concentrations was 9.7 $\mu$g/m$^3$. The 3 year average of the annual average concentrations was 3.6 $\mu$g/m$^3$. These values will be used as background PM$_{2.5}$ concentrations for the fence line and near vicinity Impact analysis. Background concentrations for the impact analysis at the Saguaro East NP were based on the (2007-2009) Aerosol data from the Saguaro East NP IMPROVE site. The 24-hr and annual average background PM$_{2.5}$ concentrations of 11.4 $\mu$g/m$^3$ and 5.1 $\mu$g/m$^3$ respectively will be used.
4. **TOPOGRAPHY, CLIMATOLOGY AND METEOROLOGY**

4.1 **Regional Topography**

The Rosemont Project will be located in the Santa Rita Mountains which trend northeast to southwest with elevations ranging from 4,500 feet to over 6,000 feet (Figure 4.1). To the west of the mountains lies the broad Santa Cruz River Valley and to the east lies a smaller valley bisected by Cienega Creek.

4.2 **Regional Climatology**

The climate of the area is semi-arid with precipitation varying with elevation and season. The 30-year normal (1971 to 2000) annual average precipitation for the Santa Rita Experimental Range station is 23.41 inches (Western Regional Climate Center). Over this 30-year period, nearly half of the precipitation occurred in the months associated with the Arizona Monsoon of July, August and September. The least amount of precipitation occurred during the months of April, May and June.

Temperatures regionally are moderate to extreme with maximums and minimums also varying with elevation. The 30-year normal average monthly maximum temperatures at the Santa Rita Experimental Range station ranged from a low of 60.4°F in January to a high of 93.3°F in June. Average monthly minimum temperatures ranged from a low of 37.5°F in December and January to a high of 66.8°F in July.

4.3 **Modeling Meteorological Data**

4.3.1 **On-Site Data**

The modeling will be based upon the on-site weather observations from the Rosemont monitoring site. The Rosemont monitoring site is located at the center of the proposed open pit at an elevation of 5,350 feet as shown in Figure 4.1. Parameters measured at the Rosemont monitoring site include ambient temperature at 2 meters, differential temperature between 2 and 10 meters, and wind speed and wind direction at 10 meters.

As stated above, monitoring began in April 2006 and is on-going. The data base, however, is not continuous as data between December 2006 and February 2007 were lost due to a data logger malfunction (see quarterly and audit reports submitted to the PCDEQ). The modeling will be conducted based upon 3 full years of on-site data, with missing data periods filled in with data from other years for the same time period.

Wind roses for the data collected in 2006-2007, 2007-2008 and 2008-2009 are presented in Figures 4.2, 4.3 and 4.4, respectively. The missing data for the December 2006 to February 2007 was filled in with data for the same period from the next year.
Figure 4.1 Topographic map showing location of the PM$_{10}$ and meteorological monitoring sites.
Figure 4.2 Wind rose for the Rosemont meteorological station for the time period April 1, 2006 - March 31, 2007.
Figure 4.3 Wind rose for the Rosemont meteorological station for the time period April 1, 2007 - March 31, 2008.
Figure 4.4  Wind rose for the Rosemont meteorological station for the time period April 1, 2008 - March 31, 2009.
4.3.2 Sky Cover Data

The modeling will be conducted using the guideline model developed by the EPA in conjunction with the American Meteorological Society called the AMS/EPA Regulatory Model (AERMOD). AERMOD is explained further below. AERMOD requires parameters for determining boundary layer conditions which include opaque sky cover (or total sky cover). The Rosemont on-site surface measurements do not include sky cover data. Consequently, the concurrent sky cover data for the on-site surface measurements will be obtained from the NWS Tucson Airport (WBAN 23160).

4.3.3 Upper Air Data

AERMOD also requires upper air data. Upper air data concurrent with the on-site data will be obtained from the NWS Tucson Airport station (WBAN 23160). The NWS Tucson station is the closest NWS station with upper air data.

4.3.4 Meteorological Data Processing for AERMOD

The Rosemont on-site data and the NWS Tucson Airport surface and upper air data will be combined into AERMOD ready surface and upper air input files using the EPA AERMET computer program (User’s Guide for the AERMOD Meteorological Preprocessor (AERMET), U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina, EPA-454/B-03-002, November 2004). The AERMET program serves as the meteorological preprocessor for AERMOD. AERMET is designed to combine and quality control on-site and NWS surface and upper air data for use by AERMOD. All AERMET input and output processing files will be provided to ADEQ with the final modeling report.
5. MODELING ANALYSIS DESIGN

5.1 Model Selection


5.2 Model Input Defaults/Options

The recommended regulatory default options for AERMOD as stated in the Guidelines were used for the model runs. The regulatory default options in AERMOD include the use of stack-tip downwash, incorporation of the effects of elevated terrain, and calms and missing data processing routines.

The missing data processing routines that are included in AERMOD allow the model to handle missing meteorological data in the processing of short term averages. The model treats missing meteorological data in the same way as the calms processing routine (i.e., it sets the concentration values to zero for that hour and calculates the short term averages according to EPA's calms policy, as set forth in the Guideline). Calms and missing values are tracked separately for the purpose of flagging the short term averages. An average that includes a calm hour is flagged with a ‘c’, an average that includes a missing hour is flagged with an ‘m’, and an average that includes both calm and missing hours is flagged with a ‘b’. If the number of hours of missing meteorological data exceeds 10 percent of the total number of hours for a given model run, a cautionary message is written to the main output file, and the user is referred to Section 5.3.2 of On-site Meteorological Program Guidance for Regulatory Modeling Applications (EPA, 1987).

The Ozone Limiting method (OLM), which is a non-regulatory option in AERMOD will be used to evaluate the impact of NO₂ in the near vicinity of Rosemont Project as well as at the Saguaro East National Park. The OLM involves an initial comparison of the estimated maximum NOₓ concentration and the ambient ozone concentration to determine the limiting factor in the formation of NO₂. If the ozone concentration is greater than the maximum NOₓ concentration, total conversion is assumed. If the NOₓ concentration is greater than the ozone concentration, the formation of NO₂ is limited by the ambient ozone concentration. The method also uses a correction factor to account for in-stack conversion of NOₓ to NO₂.

EPAs guidance “Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO₂ National Ambient Air Quality Standard, March 01, 2011” recommends use of an in-stack NO₂/NOₓ ratio of 0.5, but allows different ratios to be used provided data justifies use. The value of 0.1 was the default value in the addendum to the AERMOD user guide “Addendum: User’s Guide for the AMS/EPA Regulatory Model AERMOD, EPA-454/B-03-001, September 2004”. Lower NO₂/NOₓ ratios for boilers, blasting and compression ignition internal combustion engines utilized have been recommended by regulatory agencies including the Texas National Resource Conservation Commission and San Joaquin Valley Air Pollution Control District. This modeling
analysis will be conducted using an in-stack NO$_2$/NO$_x$ ratio of 0.05 (see Appendix F for supporting documents justifying the use of this in-stack ratio). The OLM method requires hourly background ozone values to calculate the conversion of NO$_2$ to NO$_x$. Hourly background Ozone values from the Chiricahua National Monument IMPROVE site will be used, as this was the closest and most representative of the conditions at the proposed site. The OLMGROUP option will also be specified which essentially models all the plumes as one combined plume.

5.3 Rural/Urban Classification

For modeling purposes, the rural/urban classification of an area is determined by either the dominance of a specific land use or by population data in the study area. Generally, if the sum of heavy industrial, light-moderate industrial, commercial, and compact residential (single and multiple family) land uses within a three kilometer radius from the facility are greater than 50%, the area is classified as urban. Conversely, if the sum of common residential, estate residential, metropolitan natural, agricultural rural, undeveloped (grasses), undeveloped (heavily wooded) and water surfaces land uses within a three kilometer radius from the facility are greater than 50%, the area is classified as rural. Alternatively, if the population is greater than 750 persons per km$^2$, the area is also classified as urban.

As shown in the aerial photograph in Figure 1.1 and the topographic map in Figure 4.1, rural land use in the area surrounding the proposed Rosemont Project is much greater than 50%. Thus, the rural classification will be used in the modeling.

5.4 Receptor Network

Following the ADEQ Guidance, the receptor grid (see Figure 5.1) consisting of the following will be modeled:

- receptors spaced at 25 meters along the Process Area Boundary (PAB);
- receptors spaced at 100 meters from the PAB to 1 kilometer;
- receptors spaced at 500 meters from 1 kilometer to 5 kilometers;
- receptors spaced at 1000 meters from 5 kilometers to 10 kilometers.

Based on the recommendations by the Forrest Services, a second receptor grid consisting of receptors at the Saguaro East National Park will also be modeled (see Figure 5.2). These receptors were obtained from the Class I Area Receptor Database developed by the Forrest Services.

5.5 Receptor Elevations

Receptor elevations will be determined from digital elevation model (DEM) data distributed by the USGS, and will be based on North American Datum 1927 (NAD27). The 7.5-minute DEM provides coverage in 7.5 X 7.5-minute blocks. Each file provides the same coverage as a standard 1:24,000 scale quadrangle map.
The DEM data will be processed with AERMAP (User’s Guide for the AERMOD Terrain Preprocessor (AERMAP), U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina, EPA-454/B-03-003, October 2004). AERMAP, like AERMET, is a preprocessor program which was developed to process terrain data in conjunction with a layout of receptors and sources to be used in AERMOD. For complex terrain situations, AERMOD captures the essential physics of dispersion in complex terrain and therefore, needs elevation data that convey the features of the surrounding terrain. In response to this need, AERMAP first determines the base elevation at each receptor. AERMAP then searches for the terrain height and location that has the greatest influence on dispersion for each individual receptor. This height is referred to as the hill height scale. Both the base elevation and hill height scale data are produced by AERMAP as a file or files which are then inserted into an AERMOD input control file. The files produced by AERMAP for the modeling proposed herein will be provided to ADEQ in the final modeling report.

5.6 Modeling Domain

The AERMAP terrain preprocessor requires the user to define a modeling domain. The modeling domain is defined as the area that contains all the receptors and sources being modeled with a buffer to accommodate any significant terrain elevations. Significant terrain elevations include all the terrain that is at or above a 10% slope from each and every receptor.

BEE-Line’s software automatically calculates the modeling domain based on the receptor grid being used and identifies each 7.5-minute DEM quadrangle that must be used in AERMAP to meet the 10% slope requirement. A listing of the DEM quadrangles defining the modeling domain for the modeling proposed herein will be provided to ADEQ in the final modeling report.

5.7 Surface Characteristics

Surface conditions at the measurement site, referred to as the surface characteristics, influence the boundary layer parameter estimates generated by AERMOD. Obstacles to the wind flow, the amount of moisture at the surface, and reflectivity of the surface all affect the boundary layer estimates. These influences are quantified through the surface albedo, Bowen ratio and roughness length, and are introduced into AERMOD through the files generated by AERMET.

The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. Typical values range from 0.1 for thick deciduous forests to 0.90 for fresh snow. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of the sensible heat flux to the latent heat flux and is used for determining planetary boundary layer parameters for convective conditions. While the diurnal variation of the Bowen ratio may be significant, the Bowen ratio usually attains a fairly constant value during the day. Midday values of the Bowen ratio range from 0.1 over water to 10.0 over desert. The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero. Values range from less than 0.001 m over a calm water surface to 1 m or more over a forest or urban area. The values for surface albedo, Bowen ratio and roughness length can be entered into the AERMET preprocessor based on frequency and sector. The frequency defines how often these characteristics change, or alternatively, the period of time over which these characteristics remain constant.
Figure 5.1 Receptor Grid Network developed for Rosemont Project modeling Analysis
Figure 5.2 Receptor Network for evaluating impacts at the Saguaro East National Park
The frequency defines how often these characteristics change, or alternatively, the period of time over which these characteristics remain constant. The frequency can be annual, seasonal (winter [December, January, February], spring [March, April, May], summer [June, July, August], fall [September, October, November]), or monthly, corresponding to 1, 4, or 12 periods, respectively.

Sectors refer to the number of non-overlapping sectors into which the 360° compass is divided. A minimum of 1 and a maximum of 12 sectors can be specified (i.e., 1 sector of 360°, up to 12 non-overlapping sectors of 30°). Thus, AERMET allows the values for surface albedo, Bowen ratio and roughness length to be entered annually, seasonally or monthly for each sector, the number of which can range between 1 and 12. As shown in Figure 4.1, the area surrounding the proposed Rosemont Project is undeveloped, pinyon-juniper mountainous terrain in all directions. Consequently, surface characteristics will be entered for a single sector.

The EPA has developed a computer program called AERSURFACE to aid users in obtaining realistic and reproducible surface characteristic values for the albedo, Bowen ratio, and surface roughness length for input to AERMET. The program uses publicly available national land cover datasets and look-up tables of surface characteristics that vary by land cover type and season.

The surface characteristics that will be used in the modeling will be entered on a seasonal basis and are listed in Table 5.1. The values listed in Table 5.1 were generated by AERSURFACE.

<table>
<thead>
<tr>
<th>Surface Characteristic</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albedo</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Bowen Ratio</td>
<td>2.88</td>
<td>3.76</td>
<td>5.70</td>
<td>5.70</td>
</tr>
<tr>
<td>Surface Roughness</td>
<td>0.153</td>
<td>0.153</td>
<td>0.153</td>
<td>0.152</td>
</tr>
</tbody>
</table>

* Generated by AERSURFACE, dated 08009
Center UTM Easting (meters): 522896.0; Center UTM Northing (meters): 3521802.0; UTM Zone: 12, Datum: NAD83
Study radius (km) for surface roughness: 1.0
Airport? N, Continuous snow cover? N
Surface moisture? Average, Arid region? Y, Month/Season assignments? Default
Late autumn after frost and harvest, or winter with no snow: 12 1 2
Winter with continuous snow on the ground: 0
Transitional spring (partial green coverage, short annuals): 3 4 5
Midsummer with lush vegetation: 6 7 8; Autumn with un-harvested cropland: 9 10 11
5.8 Source Characterization

A preliminary description of the planned equipment and emission generating processes at the Rosemont Project can be found in the previously referenced Mine Plan of Operations. A plan view map depicting the facility layout by Year 5 is presented in Figure 5.2. A preliminary plan view of the ancillary operations, to include locations of the primary crusher and flotation operations, is presented in Figure 5.3. Final design documents for the Rosemont Project Facilities are being developed and therefore, a detailed listing of all emission sources and their corresponding modeling input release parameters and emission rates cannot be provided with this protocol. A general description of how each source type will be treated is presented below.

5.8.1 Point Sources

Point sources at the Rosemont Project will include dust collectors, hot water heaters, and emergency generator(s). Emissions from these sources will be modeled as individual point sources. Dust Collectors or baghouses will likely have ambient exit temperatures and therefore, will be modeled using a stack temperature of 0°C per ADEQ guidance, which forces the model to use the ambient temperature as the exit temperature. Stack parameters for the point sources will be based on design parameters and/or conservative estimated values. Particulate emissions from the emergency generators will not be included in the PM$_{10}$ modeling as most other operations would be shut down if the generators are needed. Gaseous emissions from these sources, however, will be included in the gaseous modeling runs. The Point source emissions will be modeled using the particle size distribution shown in Table A.5 of Appendix A.

5.8.2 Volume Sources

5.8.2.1 Road Sources

A refined road network will be developed to depict the anticipated haul truck routes and dumping locations during the year of the mine plan with the estimated greatest emissions, which will be the basis of the emissions inventory that will be used for all of the modeling. Emissions due to haul road and general plant traffic on the unpaved road network will be modeled as volume sources and the modeling parameters will be based on guidance from ADEQ and the AERMOD User’s Guide. The modeling parameters will be set as follows:

- the volume height will be set equal to twice the height of the vehicles generating the emissions;
- the initial vertical dimension will be set equal to the volume height divided by 2.15;
- the release height will be set equal to half of the volume height; and
- the initial lateral dimension will be set to the width of the road divided by 2.15. The road will be further divided into two lanes representing 2-way traffic. (as per request from the Forrest Services)
Figure 5.3 Plan view map of Operations depicting facility layout by Year 5.
Figure 5.4 Plan view map of Operations showing updated ancillary operation locations for the Rosemont Project.
The majority of emissions on the haul road network were due to large haul trucks. The height of the Haul Trucks obtained from the manufacturers data was 6.6 meters (21.6 feet). Thus, for each road source the volume height will be set to 13 meters (twice the height of the vehicles generating the emissions rounded to the nearest meter), the initial vertical dimension will be set to 6.05 meters (volume height divided by 2.15), and the release height will be set to 6.5 meters (half of the volume height).

The road width was estimated to be 35 meters. Thus, the initial lateral dimension for each volume will be set to 16.3 meters (width of 35 meters divided by 2.15). The road sources will be placed along the road network at approximately 35 meter intervals. According to the mine plan, during Year 1 of operations, 78% of the haul emissions would be generated outside the pit whereas during Year 5, 58% would be generated outside the pit. These distributions were taken into account while spreading out haul road emissions generated by the haul trucks among the open pit source and the road sources.

The emissions from dumping to the sulfide ore stockpile, waste rock stockpiles and to the leach pad will also be modeled as volume sources. The height of the Haul Trucks obtained from the manufacturers data was 7.37 meters (24 feet). Rounding to the nearest meter as recommended by ADEQ guidance, this dimension becomes 7 meters. Thus, for each source representing dumping, the volume height will be set to 14 meters (twice the height of the vehicles generating the emissions), the initial vertical dimension will be set to 6.5 meters (volume height divided by 2.15), and the release height will be set to 7 meters (half of the volume height). The width of the trucks (simulating the dump width) obtained from the manufacturers data was 8.7 meters (28.5 feet). Thus the initial horizontal dimension will be set to 4 meters (volume width divided by 2.15). The Haul Road emissions will be modeled using the particle size distribution shown in Table A.1 of Appendix A.

5.8.2.2 Other Fugitive Particulate Sources

Other fugitive particulate emission sources that will be modeled as volume sources will include the following:

- Fugitive emissions from truck unloading at the primary crusher will be represented by a single volume source. The side length will be set to 8.23 meters (approximate width of dump pocket) and therefore, the initial horizontal dimension will be set to 1.91 meters (8.23/4.3). The vertical length will be set to 3 meters (vertical drop of dump pocket). Consequently, the initial vertical dimension will be set to 1.4 meters (3/2.15) and the release height will be set to 0 meters (dump pocket is at grade level).

- Fugitive emissions due to wind erosion from the sulfide ore stockpile will be represented by a single volume source. The side length obtained from the map was 318 meters (average width of the stockpile) and therefore the initial horizontal dimension will be set to 74 meters (318/4.3). The vertical will be set to 12 meters (average height of stockpile). Consequently, the initial vertical dimension will be set to 5.6 meters (12/2.15) and the release height will be set to 6 meters (half of the volume height of 12 meters).
• Fugitive emissions from conveyor transfer points will be represented by single volume sources. The side length will be set to 2 meters (approximate width of the conveyors) and therefore, the initial horizontal dimension will be set to 0.5 meters (2/4.3). The vertical length will be set to 3 meters (approximate height of material drops from the conveyors). Consequently, the initial vertical dimension will be set to 0.7 meters (3/4.3). The release height will be set to 3 meters (assumed height of conveyors, except for the conveyors feeding the coarse ore stockpile). The release heights for these sources will be set to the actual height of the conveyor at the top of the stockpile.

The above material transfer emissions will be modeled using the particle size distribution shown in Table A.2 of Appendix A.

5.8.2.3 Gaseous Emissions Due to Blasting

The gaseous emissions due to blasting in the pit were modeled as volume sources. The fugitive gaseous emissions due to blasting in the pit were equally spaced at 250 meter intervals (arbitrarily selected) over the pit area. The side length of each volume source was set at 61.0 meters (represents the average width of a blast) and therefore, the initial horizontal dimension was set to 14.2 meters (61.0/4.3).

A typical blast can send emissions 30 meters into the air. Consequently, a conservative vertical dimension of 20 meters was assigned to the volume sources representing the blasting emissions. Thus the initial vertical dimension of each source will be set to 9.3 meters (20/2.15) and the release height will be set to 10 meters (1/2 of the vertical dimension of 20 meters). The base elevation for the volume sources in the pit will be set to the average elevation between the lowest and highest elevation of the terrain defining the bottom and top of the pit, based on the assumption that these emissions must rise above the walls of the pit before being dispersed downwind. Since the Rosemont Project anticipates blasting to occur only between 12 PM and 4 PM, the variable emission rate option HROFDY in AERMOD will be used to model the emissions between the above 4 hour interval every day. The PM$_{10}$ emissions from blasting will also be modeled as volume sources and will use the particle size distribution shown in Table A.3, Appendix A of the modeling protocol (Oct, 2009). For evaluating the 1-hr averaged impacts from NO$_2$, SO$_2$ and CO, blasting emissions will be set to occur every hour between 12 PM to 4 PM. Test modeling runs indicated that the maximum impact due to blasting emissions occurred at 4 PM every day. Therefore for all impact evaluations greater than the 1-hr averaged impacts, blasting will be set to occur at 4 PM every day. The HROFDY variable emissions rate option in AERMOD will be used for this.

5.8.3 Open Pit Source

Fugitive particulate emissions from the open pit at the Rosemont Project will be modeled using the open pit source model as defined by the AERMOD model (only particulate emissions are considered with the open pit source model). The open pit source parameters, easterly length, northerly length and volume, will be based on the length and width dimensions of the rectangle drawn to simulate the pit shape in the model and the anticipated depth of the pit in the worst case year. The release height will be set to zero. The Year 5 mine plan (see Figure 5.2 of Modeling Protocol), shows a berm developed on the east and south side of the process area boundary. This 150 foot berm essentially
covers the waste dump and leach pads on the east and south. Therefore the emissions generated at the Leach Pad and Waste Dump will be modeled as a second pit with a depth of 150 feet.

The open pit source option in the AERMOD model requires particle size distribution data in the form of the mass-mean particle diameter, mass weighted size distribution, and particle density. Table A.1 of Appendix A shows the particle size distribution developed for Haul Road Emissions. This distribution will be used for the open pit source since a majority of the emissions in the pit are Haul Road Emissions.

A particle density of 2.44 gm/cm$^3$, the other required input variable, is initially proposed for use in the modeling as a representative value of the average density of the various rock materials (overburden, waste rock, ore) that will be mined. A more specific value will be used if specific density data for the materials to be mined at the Rosemont Project become available.

### 5.8.4 Plume Depletion

One other option in the AERMOD model requires particle size data as explained above in Section 5.8.3. This option is known as DDEP, which specifies that dry deposition flux values will be calculated. If this option is selected, dry removal (depletion) mechanisms (known as dry plume depletion (DRYDPLT) in the old ISC modeling program and earlier versions of AERMOD) are automatically included in the calculated concentrations. This option may or may not be selected in the proposed modeling depending upon initial modeling results.

### 5.8.5 Tail Pipe Emissions

Tail pipe emissions from mobile sources will be distributed among road emission sources and the open pit source. The amount of emissions assigned to each individual road segment and to the pit will be based on an evaluation of the vehicle miles travelled (VMT) along each road segment and inside the pit. All Tailpipe particulate emissions will be modeled as PM 2.5 as recommended by ADEQ. See supporting email correspondence with ADEQ in Appendix E.

### 5.9 Building Downwash

Building downwash effects will be evaluated by incorporating the appropriate building/structure dimensions into the AERMOD input files using BEE-Line’s commercial version of EPA’s Building Profile Input Program for PRIME (BPIPPRM) software. The BPIPPRM program is EPA approved and includes the latest EPA building downwash algorithms. The downwash files generated by BPIPPRM program will be provided in the final modeling report.
6. EMISSIONS INVENTORY

Emissions from Rosemont operations will result from process equipment and mining operations. Process equipment will be modeled at maximum capacity. Emissions from mining will depend upon the mining rate and haul truck travel necessary to transport the ore and waste from the pit to the primary crusher and the waste rock storage area. A preliminary summary of average and maximum mining rates and haul truck travel (vehicle miles) is presented in Appendix D. This summary is subject to change depending upon any further refinements to the mine plan. The mining information in Appendix D indicates:

- The highest projected mining rate and second highest haul truck travel will occur in year 1 (378,000 tons of ore and waste per day; 1,806,042 haul truck VMT).
- The highest projected haul truck travel will occur in year 5 (2,252,274 VMT).

Since haul truck travel will be the primary source of emissions (PM$_{10}$ and tail pipe), year 5 will be modeled. Appendix D also shows that haul truck outside the pit will be a maximum during year 1 (1,404,736 VMT). Since emissions outside the pit are expected to have a greater impact on ambient concentrations than emissions in the pit, this year will also be modeled. Ambient impacts from operations during all other years will have lower impacts than during these two years.

6.1 Annual Criteria Pollutant Emissions Modeling

Annual impacts of particulate and gaseous emissions will be based upon emissions calculated using the average daily process rates for years 1 and 5.

6.2 Short-Term Criteria Pollutant Emissions Modeling

Short-term impacts (1-hour, 3-hour, 8-hour and 24-hour) will be based upon the emissions calculated using the maximum daily process rates for years 1 and 5.
7. DISPERSION MODELING IMPACT ANALYSIS

The purpose of the dispersion modeling outlined in this protocol is to demonstrate that emissions from the Rosemont Project will not cause exceedances of applicable NAAQS. The final impact analysis will include all information necessary for this demonstration including: (a) background concentrations (as discussed in Section 3.4); (b) a source location map; (c) a complete list of source parameters; (d) complete modeling input and output files; and (e) graphic presentations of the modeling results for each pollutant showing the magnitude and location of the maximum ambient impacts.
APPENDIX A

PARTICLE SIZE DISTRIBUTIONS
A.1 PARTICLE SIZE DISTRIBUTIONS

The following sections describe the methodology used to estimate the particle size distributions for various emission sources.

A.1.1 Haul Roads

Section 13.2.4 of AP 42 lists the emission factors for emissions from unpaved roads. These emission factors were used to determine the distribution of emissions for particles with nominal diameters less than 30, 10 and 2.5 µm. Figure A.1 shows the distribution.

![Particle Size Distribution for Haul Roads](image)

**Figure A.7.1** Average size distribution for air borne dust generated by haul trucks for entire study period.

A 2nd degree polynomial equation was used to fit the data and determine particle size distributions for use with haul road emissions from the Rosemont mine. Table A.1 shows the calculated particle size distribution that will be used for haul road emissions.
Table A.1  Particle Size Distribution - Haul Road Emissions

<table>
<thead>
<tr>
<th>Diameter (microns)</th>
<th>Mass Fraction</th>
<th>Density (gm/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>0.069</td>
<td>2.44</td>
</tr>
<tr>
<td>3.17</td>
<td>0.128</td>
<td>2.44</td>
</tr>
<tr>
<td>6.1</td>
<td>0.385</td>
<td>2.44</td>
</tr>
<tr>
<td>7.82</td>
<td>0.224</td>
<td>2.44</td>
</tr>
<tr>
<td>9.32</td>
<td>0.194</td>
<td>2.44</td>
</tr>
</tbody>
</table>

A.1.2  Material Transfer

Section 13.2.4 of AP 42 lists the emission factors for Aggregate Handling process. These emission factors were used to determine the distribution of emissions for particles with nominal diameters less than 30, 15, 10, 5 and 2.5 μm. Figure A.2 shows the distribution.

Figure A.7.2  Material Transfer Emissions (tpy) vs Particle Size (μm)

A 2nd degree polynomial was used to fit this data and determine the size distribution for other particle sizes. Table A.2 shows the calculated particle size distribution that will be used for material transfer emissions.
### Table A.2 Particle Size Distribution - Material Transfer Points

<table>
<thead>
<tr>
<th>Diameter (microns)</th>
<th>Mass Fraction</th>
<th>Density (gm/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>0.188</td>
<td>2.44</td>
</tr>
<tr>
<td>3.17</td>
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<tr>
<td>6.1</td>
<td>0.347</td>
<td>2.44</td>
</tr>
<tr>
<td>7.82</td>
<td>0.188</td>
<td>2.44</td>
</tr>
<tr>
<td>9.32</td>
<td>0.155</td>
<td>2.44</td>
</tr>
</tbody>
</table>

### A.1.3 Blasting

Table 11.9-1 from section 11.9 of AP 42 lists the emission factors for Western Surface Coal Mining processes. The Blasting emission factors were used to determine the distribution of emissions for particles with nominal diameters less than 30, 10 and 2.5 μm. Figure A.3 shows the distribution.

![Particle Size Distribution for Blasting Emissions](image)

**Figure A.7.3 Blasting Emissions (tpy) vs Particle Size (μm)**

A 2\textsuperscript{nd} degree polynomial was used to fit this data and determine the size distribution for other particle sizes. Table A.3 shows the calculated particle size distribution that will be used for material transfer emissions.
Table A.3 Particle Size Distribution - Blasting Emissions

<table>
<thead>
<tr>
<th>Diameter (microns)</th>
<th>Mass Fraction</th>
<th>Density (gm/cm³)</th>
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</thead>
<tbody>
<tr>
<td>2.2</td>
<td>0.015</td>
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<tr>
<td>3.17</td>
<td>0.153</td>
<td>2.44</td>
</tr>
<tr>
<td>6.1</td>
<td>0.426</td>
<td>2.44</td>
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<td>7.82</td>
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<tr>
<td>9.32</td>
<td>0.181</td>
<td>2.44</td>
</tr>
</tbody>
</table>

A.1.4 Point Sources

Page B.2-6, Appendix B.2 of AP 42 lists the collection efficiency of fabric filters used in baghouses for various particle sizes. These collection efficiencies were used along with particle size fractions for Aggregate handling processes (Section 13.2.4 of AP 42) to calculate particle size distribution that will be used for point source emissions. Figure A.4 shows the distribution.

![Particle Size Distribution for Point Source Emissions](image)

Figure A.4 Point Source Emissions (tpy) vs Particle Size

A 2nd degree polynomial was used to fit this data and determine the size distribution for other particle sizes. The obtained size distribution was then used along with the collection efficiency of the
baghouses for various sizes of particles. Table A.4 shows the collection efficiencies of fabric filters used in baghouses.

<table>
<thead>
<tr>
<th>Table A.4 Collection Efficiency of Fabric Filters</th>
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<tbody>
<tr>
<td><strong>Diameter (microns)</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>0 - 2.5</td>
</tr>
<tr>
<td>2.5 – 6</td>
</tr>
<tr>
<td>6 - 10</td>
</tr>
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</table>

Table A.5 shows the calculated particle size distribution that will be used for point source emissions.

<table>
<thead>
<tr>
<th>Table A.5 Particle Size Distribution – Point Source Emissions</th>
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<td><strong>Diameter (microns)</strong></td>
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<td>7.8</td>
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<td>9.32</td>
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APPENDIX B

QUARTERLY PM$_{10}$ SUMMARIES
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<tr>
<th>Time Period</th>
<th>Valid Samples</th>
<th>Arithmetic Mean</th>
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<th>2nd Highest</th>
<th>3rd Highest</th>
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<td>8.3</td>
<td>18.7</td>
<td>17.7</td>
<td>10.6</td>
</tr>
<tr>
<td>1st Quarter 07</td>
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<td>2.3</td>
<td>7.0</td>
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<td>2nd Quarter 07</td>
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<tr>
<td>Highest Overall</td>
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<td>N/A</td>
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<table>
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<th>Valid Samples</th>
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<th>3rd Highest</th>
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<td>5.3</td>
<td>11.9</td>
<td>11.9</td>
<td>8.0</td>
</tr>
<tr>
<td>1st Quarter 08</td>
<td>16</td>
<td>4.1</td>
<td>13.5</td>
<td>9.6</td>
<td>7.7</td>
</tr>
<tr>
<td>2nd Quarter 08</td>
<td>15</td>
<td>19.5</td>
<td>32.6</td>
<td>28.2</td>
<td>25.2</td>
</tr>
<tr>
<td>Average</td>
<td>14.75</td>
<td>12.02</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Highest Overall</td>
<td>N/A</td>
<td>N/A</td>
<td>40.3</td>
<td>28.2</td>
<td>25.2</td>
</tr>
</tbody>
</table>
### Table B.3  Summary of 24-Hour PM$_{10}$ Concentrations (µg/m$^3$)  
**July 2008-June 2009**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Valid Samples</th>
<th>Arithmetic Mean</th>
<th>Highest</th>
<th>2nd Highest</th>
<th>3rd Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd Quarter 08</td>
<td>14</td>
<td>15.3</td>
<td>24.5</td>
<td>21.2</td>
<td>20.0</td>
</tr>
<tr>
<td>4th Quarter 08</td>
<td>15</td>
<td>8.5</td>
<td>31.6</td>
<td>15.1</td>
<td>12.7</td>
</tr>
<tr>
<td>1st Quarter 09</td>
<td>15</td>
<td>8.0</td>
<td>17.9</td>
<td>17.8</td>
<td>17.6</td>
</tr>
<tr>
<td>2nd Quarter 09</td>
<td>16</td>
<td>10.0</td>
<td>15.4</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>Average</td>
<td>15</td>
<td>10.45</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Highest Overall</td>
<td>N/A</td>
<td>N/A</td>
<td>31.6</td>
<td>21.2</td>
<td>20.0</td>
</tr>
</tbody>
</table>

### Table B.4  Summary of Annual PM$_{10}$ Concentrations (µg/m$^3$)

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Valid Samples</th>
<th>Arithmetic Mean</th>
<th>Highest</th>
<th>2nd Highest</th>
<th>3rd Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2006-June 07</td>
<td>14.25</td>
<td>13.2</td>
<td>71.3</td>
<td>27.0</td>
<td>26.8</td>
</tr>
<tr>
<td>July 2007- June 08</td>
<td>14.8</td>
<td>12.0</td>
<td>40.3</td>
<td>28.2</td>
<td>25.2</td>
</tr>
<tr>
<td>July 2008- June 09</td>
<td>15</td>
<td>10.45</td>
<td>31.6</td>
<td>21.2</td>
<td>20.0</td>
</tr>
<tr>
<td>Average</td>
<td>14.7</td>
<td>11.9</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Highest Overall</td>
<td>N/A</td>
<td>N/A</td>
<td>71.3</td>
<td>28.2</td>
<td>26.8</td>
</tr>
</tbody>
</table>
APPENDIX C

STATISTICAL EVALUATION OF AMBIENT PM$_{10}$ MEASUREMENTS
C.1 BACKGROUND INFORMATION

Ambient monitoring at the Rosemont Project for PM$_{10}$ concentrations has been performed and recorded from June 16, 2006 to June 30, 2009. Within this data, there are several concentration measurements that appear to be outlying data and cannot be explained by any reasonable statistical distribution. This document analyzes the outlying data points to determine the probability of their occurrence to determine whether they are reasonable recurring events.

C.2 ANALYSIS

The PM$_{10}$ concentration measurements as a function of the date they were recorded are presented in Figure C.1. The possible outlying data points are the concentrations 71.3 and 40.3.

![Figure C.1: PM$_{10}$ Concentration Measurements](image)

In order to statistically analyze the PM$_{10}$ concentrations, the type of data distribution needs to be determined. The simplest distribution is called a normal distribution. To test for normal distribution, the standard normal concentrations ($Z$) are plotted against the measured PM$_{10}$ concentrations. If a linear regression line fits the plotted data points reasonably, a normal distribution can be assumed. The standard normal concentrations are calculated by Equation 1:

$$Z = \frac{(X - \mu)}{\sigma}$$

(1)
where:

\[
\begin{align*}
Z &= \text{Standard normal random variable} \\
X &= \text{Normal random variable (PM}_{10}\text{ concentration measurements)} \\
\mu &= \text{Mean value of the normal random variables (11.6 \(\mu\)g/m}^3) \\
\sigma &= \text{Standard deviation of the normal random variable (9.3 \(\mu\)g/m}^3)
\end{align*}
\]

The plotted PM\textsubscript{10} concentrations versus the standard normal concentrations are shown in Figure C.2.
A linear regression trend line with an \(R^2\) value of 1 is added to the graph to show the reasonable fit of the data. From this graph, it can be assumed that the PM\textsubscript{10} concentration data is normally distributed.

\[y = 0.108x - 1.2551\]
\[R^2 = 1\]

\[\text{PM}_{10} \text{ Concentration (X, \(\mu\)g/m}^3)\]
\[\text{Standard Normal PM}_{10} \text{ Concentration (Z, \(\mu\)g/m}^3)\]

**Figure C.2: Probability Plot Showing Normal Distribution**

Since the PM\textsubscript{10} concentration measurements are normally distributed, the normal distribution probability density function can be utilized. This function can be plotted with either the normal random variable (the PM\textsubscript{10} concentration measurements) or the standard normal random variable (calculated in Equation 1). The function is shown in Equation 2:

\[
f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}
\]
where:

\[ f(x) = \text{Probability density function} \]
\[ x = \text{Normal random variable (PM}_{10}\text{ concentration measurements)} \]
\[ \mu = \text{Mean value of the normal random variables (11.6 } \mu g/m^3) \]
\[ \sigma = \text{Standard deviation of the normal random variable (9.3 } \mu g/m^3) \]

The normal and standard normal probability density functions for the PM\textsubscript{10} concentration measurements are shown in Figures C.3 and C.4. Both of these figures represent the same function. The only difference is that Figure 4 is plotted with the standard normal data (Z). This implies that the mean of the standard normal data is 0 and variance (standard deviation squared) is equal to 1. The standard normal data and standard normal probability density function will be used in further analysis.
The probability density function ($f(x)$) also produces the probability of an event occurring in a future sample. For the PM$_{10}$ concentration data, this means the probability of the PM$_{10}$ concentration occurring during a future measurement. The possible outlier data points and their probability to occur during a random measurement are shown in Table C.1.

The probability of a future measurement being equal to or exceeding the measured data point is also shown in Table C.1. This value is calculated using Cumulative Standard Normal Distribution tables. Based on the standard normal value of a data point, the Cumulative Standard Normal Distribution tables produce the probability that a future measurement will be less than or equal to the data point. Since the standard normal probability function is symmetric (centered at a mean of 0), the probability of the measurement being greater than the data point can be calculated by Equation 3:

$$P(Z > z) = 1 - P(Z \leq z)$$  \hspace{1cm} (3)

where:

- $P$ = Probability
- $Z$ = Future data
- $z$ = Current data being analyzed

Figure C.4: Standard Normal Probability Density Function
Table C.1: Possible Outlier Data Points to be Analyzed

<table>
<thead>
<tr>
<th>Date</th>
<th>PM$_{10}$ Concentration ($X$, μg/m$^3$)</th>
<th>Standard Normal PM$_{10}$ Concentration ($z$, μg/m$^3$)</th>
<th>Probability to Occur</th>
<th>$P(Z \leq z)$</th>
<th>$P(Z &gt; z)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/16/06</td>
<td>71.3</td>
<td>6.44</td>
<td>4.18E-11</td>
<td>1.00</td>
<td>5.87E-11</td>
</tr>
<tr>
<td>07/05/07</td>
<td>40.3</td>
<td>3.10</td>
<td>3.57E-04</td>
<td>1.00</td>
<td>9.81E-04</td>
</tr>
<tr>
<td>10/27/08</td>
<td>31.6</td>
<td>2.16</td>
<td>4.21E-03</td>
<td>0.98</td>
<td>0.02</td>
</tr>
</tbody>
</table>

C.3 CONCLUSION

The probabilities in Table C.1 show that it is highly unlikely that a PM$_{10}$ concentration measurement greater than 71.3 or 40.3 μg/m$^3$ will occur in future measurements (0.00000000587% and 0.0981%, respectively). A concentration measurement greater than 31.6 μg/m$^3$ has a 2% probability of occurring and therefore, the data point should not be considered an outlier during further PM$_{10}$ concentration data analysis.
APPENDIX D

AVERAGE AND MAXIMUM MINING RATES
### Table D.1 Average and Maximum Ore Process Rates and Haul Truck Travel

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Ore Process Rates (tons/day)总 (Ore &amp; Waste) tons/day</th>
<th>Total (Ore &amp; Waste) tons/day</th>
<th>Haul Truck VMT</th>
<th>Total VMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Ore</td>
<td>Average Waste</td>
<td>Maximum Ore</td>
<td>Maximum Waste</td>
</tr>
<tr>
<td>PP-2</td>
<td>0</td>
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<td>0</td>
<td>5,781</td>
</tr>
<tr>
<td>PP-1</td>
<td>29,219</td>
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<td>1</td>
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<td>199,510</td>
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<td>6</td>
<td>101,737</td>
<td>195,181</td>
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<td>75,003</td>
<td>224,652</td>
<td>99,979</td>
<td>280,815</td>
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<td>75,003</td>
<td>224,647</td>
<td>99,979</td>
<td>280,808</td>
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<td>11,967</td>
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<td>21</td>
<td>7,863</td>
<td>42,277</td>
<td>10,481</td>
<td>52,846</td>
</tr>
</tbody>
</table>
APPENDIX E

CORRESPONDENCE WITH ADEQ
Shantanu,
Please see below and in the future, feel free to direct your questions to Feng Mao or myself.
Cordially,
Leonard

-----Original Message-----
From: Feng Mao
Sent: Wed 8/12/2009 4:32 PM
To: Leonard H. Montenegro
Subject: RE: Tail Pipe Emissions

Leonard,

Table 3.3-1 in AP-42 provides the emission factors for PM10 with an assumption of "all particulate is assumed to be <1um in size". This assumption indicates that all particulate emissions are PM2.5 (the emission rate of PM10 is identical to that of PM2.5).

Based on Appendix B.2 of AP-42, the emission rate for PM2.5 is around 94% of the emission rate for PM10.

I did not see much difference between the two methods. To be conservative for modeling PM2.5, it is recommended to assume that all of the particulate emissions from tail pipes are PM2.5.

Feng

Can you look this up?

Thanks
-----Original Message-----
From: Tim Martin [mailto:Martin.Tim@ev.state.az.us]
Sent: Monday, March 29, 2004 7:31 AM
To: Iverville@aecom.org
Cc: Peter Hyde
Subject: Rural Background Concentrations

March 29, 2004

Herb:

I have attached an example of rural background concentrations for NO2, SO2, and CO in Arizona. The footnotes for the table explain the basis of the values. These values are typically used by ADEQ when modeling Class II (minor) sources. As always, try your best to utilize representative background data that was actually measured. When all else fails, utilize the NO2 and CO data in the table. Please contact me with questions.

-Tim

Timothy S. Martin
Arizona Dept. of Environmental Quality
Air Quality Division
Phone: (602) 771-2357
Fax: (602) 771-2396
E-mail: tsm@ev.state.az.us
**Rural Arizona**  
Example Background Concentrations

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging Time</th>
<th>Ambient Data 1999</th>
<th>Ambient Data 2000</th>
<th>Ambient Data 2001</th>
<th>Background Value (µg/m³)</th>
<th>Standard (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂ a</td>
<td>annual</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>CO b</td>
<td>1-hour</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>582</td>
<td>40,000</td>
</tr>
<tr>
<td></td>
<td>8-hour</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>582</td>
<td>10,000</td>
</tr>
<tr>
<td>SO₂ c</td>
<td>3-hour</td>
<td>43</td>
<td>14</td>
<td>15</td>
<td>43</td>
<td>1,300</td>
</tr>
<tr>
<td></td>
<td>24-hour</td>
<td>17</td>
<td>7</td>
<td>8</td>
<td>17</td>
<td>365</td>
</tr>
<tr>
<td></td>
<td>annual</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>80</td>
</tr>
</tbody>
</table>

a Long-term average value (0.002 ppm) of several monitors located near power plants in rural areas of Arizona  
b Typical continental ambient CO background value (0.5 ppm) used in most regional models  
c Max. values over 3-year period from Page monitoring station (Coconino County)
APPENDIX F

IN-STACK NO$_2$/NO$_x$ RATIO JUSTIFICATION
May 11, 2011

Kathy Arnold
Rosemont Copper Company
3031 West Ina Road
Tucson, AZ  85741

Re:  Response to the Forest Service April 22, 2010 Request for Clarifications

Dear Ms. Arnold:

Presented below please find a citation of the Forest Service Request for Clarification and the corresponding response.

Section 7.1.2: Please provide documentation supporting the NO$_2$/NO$_x$ ratios used in the NO$_2$ analysis of the various types of equipment proposed to be used. This information is necessary for us to evaluate the four scenarios offered for NO2 modeling and select the best option.

Documentation and Clarifications:

The one-hour NO$_2$ standard was published in the Federal Register on February 9, 2010 (75 FR 6474-6537), becoming effective April 12, 2010. Following its promulgation, EPA issued memoranda on June 29, 2010 and March 1, 2011 clarifying the applicability of current guidance in the Guideline on Air Quality Models for modeling NO$_2$ impacts. The two memoranda reflect major uncertainties regarding appropriate in-stack NO$_2$/NO$_x$ ratios for use by the current AERMOD Model.

Except for emergency generators that operate only during emergency conditions when there is a disruption to mining processes, sources of NO$_x$ emissions are comprised of blasting (884 lb/hr), a small boiler (0.876 lb/hr) and mobile sources (315.25 lb/hr). Emergency generators were not included in the modeling analyses because they would not operate when mining operations would be taking place, and are also excluded from consideration by the March 1, 2011 EPA memorandum. The NO$_2$/NO$_x$ ratio due to blasting emissions is uncertain, however blasting is constrained to occur only between the hours of 12:00 (noon) and 4:00 P.M (i.e. starting at noon and ending at 5:00 P.M.). The maximum predicted 1-hour NO$_x$ impacts due to blasting for any single hour for the three meteorological years that were modeled during these hours is 8.58 $\mu$g/m$^3$, or 4.5% of the 1-hour NO$_2$ standard. Because not all NO$_x$ emissions will be in the form of NO$_2$, the actual NO$_2$ impact will be lower. Consequently, the overwhelming sources of NO$_x$ emissions that can contribute to significant NO$_2$ impacts are mobile sources.

Data of in-stack NO$_2$/NO$_x$ ratios for mobile sources (i.e. internal combustion engines) is very limited, if not unavailable. In order to address the information requested by the Forest Service, requests were made to Caterpillar Inc, the major supplier of mobile equipment to Rosemont, and to Leonard Montenegro, former Supervisor of the Air Quality Evaluation Group at the Arizona Department of Environmental Quality, to research and provide such information.
A letter from Caterpillar Inc. is attached citing “engine out” NO\textsubscript{2} as being 5 to 15\% of NO\textsubscript{x} emissions for engines without an oxidation catalyst or catalyzed DPF. Mobile sources at the Rosemont facility will not be equipped with oxidation catalysts or catalyzed DPF. As indicated below, the NO\textsubscript{2}/NO\textsubscript{x} ratio of “engine out” emissions overestimates the in-stack ratio because such measurements have been made after the engine exhaust has been mixed with ambient air and the NO to NO\textsubscript{2} conversion has already commenced. In-stack NO\textsubscript{2}/NO\textsubscript{x} ratios should thus be less than those cited by Caterpillar Inc.

The research conducted by Mr. Montenegro is attached. The research describes the techniques used to measure emissions from the exhaust of IC engines, the results of measurements designed to determine in-stack NO\textsubscript{2}/NO\textsubscript{x} ratios (2-6\%), and ratios used by EPA to evaluate the sensitivity of AERMOD’s algorithms for modeling NO to NO\textsubscript{2} conversion and exposure assessment studies (5-10\%). Mr. Montenegro’s research supports an in-stack NO\textsubscript{2}/NO\textsubscript{x} ratio of somewhere around 5\%.

Independent of the representativeness of the NO\textsubscript{2}/NO\textsubscript{x} ratio used to evaluate potential 1-hour NO\textsubscript{2} concentrations, all parties to the EIS should also consider the conservativeness of the modeling. As indicated during past conference calls with the Forest Service and National Park Service, short term standards were evaluated by assuming maximum hourly emissions, i.e. all equipment (except emergency generators) are operating concurrently at all time, i.e. 8760 hours/year. This cannot occur. Haul trucks, for example, have a design annual operating hour capacity of 6600 hours and not 8760 hours. Emissions from haul trucks represent 260.8 lb/hr of the 315.25 lb/hour that were modeled for mobile sources. Use of 6600 hours would reduce hourly emissions from all mobile sources to 250.95 lb/hour, or a 20\% decrease in total mobile source emissions. Other equipment will also not be operating on a continuous basis.

Other assumptions that increase the conservativeness of the modeling even further include the following:

- The assumption that the highest background NO\textsubscript{2} concentration occurs every hour of the year. A more typical background concentration that would be anticipated to occur would be the average concentration. The highest hourly and average NO\textsubscript{2} concentrations at the Alamo background site are 24.5 µg/m\textsuperscript{3} and 4.9 µg/m\textsuperscript{3} respectively. The assumption that the highest 1-hour concentration occurs continuously is unrealistic.

- All haul trucks are assumed to have Tier 2 engines. Because of delays, however, six of the engines will not be manufactured until the Tier 4 standards become effective, at which time manufacturers, will be prohibited from manufacturing Tier 2 engines. NO\textsubscript{x} emissions for Tier 4 engines are 58\% of those of Tier 2 engines. EPA’s Final Rule for Nonroad Engines ((69 Fr 38957 -39206) states that the NO\textsubscript{x} emission reductions for engines used in mobile machinery are based on engine-based emissions control technology rather than after-treatment methods that utilize oxidation catalysts. The net result of 6 haul trucks with Tier 4 engines is a 21 lb/hr reduction in NO\textsubscript{x} emissions from haul trucks.

Application of these more realistic assumptions in combination with a NO\textsubscript{2}/NO\textsubscript{x} in-stack ratio of 5\% would result is substantially lower predicted impacts than those presented in the modeling report.

**Section 7.1.5:** The report indicates that a three-year average was used to determine attainment of the National Ambient Air Quality Standard (NAAQS) for 2.5 micron-diameter particulate matter (PM\textsubscript{2.5}). According to EPA’s Model Clearinghouse memorandum of February 26, 2010, the use of a three-year average does not preempt the requirement in Appendix W that five years of National Weather Service (NWS) data be used. The five-year average of modeled impacts serves as an unbiased estimate of the three-year average for the purpose of modeling compliance with the NAAQS. Please clarify that this guidance for PM\textsubscript{2.5} modeling was followed.
Clarification:

Section 9.3.1.2.b of 40 CFR 51, Appendix W states the following:

The use of 5 years of NWS meteorological data or at least 1-year of site specific data is required. If one year or more (including partial years), up to five years, of site specific data is available, these data are preferred for use in air quality analyses. Such data should have been subjected to quality assurance procedures as described in subsection 9.3.3.2.

The above citation clarifies that a minimum of 1-year of site specific data is preferred for conducting air impact analyses over 5 years of nearby NWS data. Use of 3-years of site specific data as was conducted in the air impact analyses for the Rosemont project thus exceeds the minimum preferred requirements of Appendix W and does not preempt it.

With regards to the February 26, 2010 memorandum, we have not been able to locate it. We presume, however, that a March 23, 2010 memorandum titled “Modeling Procedures for Demonstrating Compliance with PM2.5 NAAQS” from Stephen D. Page, Director of Office Air Quality Planning and Standards, includes that guidance or a refinement of the guidance provided by the February 26, 2010 memorandum.

This memorandum cites the following in the section titled “Comparison to NAAQS” in the Cumulative Impact Assessment:

For the 24-hour NAAQS analysis, the modeled concentrations to be added to the monitored 24-hour design value should be computed using the same procedure used for the preliminary analysis based on the highest average of the maximum modeled 24-hour averages across 5 years for NWS meteorological data or the maximum modeled 24-hour average for one year of site-specific meteorological data. As noted above, use of the average modeled concentration across the appropriate time period more accurately characterizes the modeled contribution from the facility in relation to the NAAQS than use of the highest modeled contribution, while using the average of the first highest 24-hour averages rather than the 98th percentile (8th highest) values is consistent with the screening nature of PM$_{2.5}$ dispersion modeling.

The above hypothesizes that the available meteorological data is limited to either five years of NWS data or only one year of site-specific meteorological data. The second highlighted sentence above states that “use of the average modeled concentration across the appropriate time period more accurately characterizes the modeled contribution from the facility than use of the highest modeled contribution”. With regards to the modeling conducted for Rosemont, three years of site-specific data were used. Consequently, averaging of the maximum modeled 24-hour averages across 3 years of site-specific meteorological data more accurately characterizes the modeled contribution than taking only one year of modeled data. The modeling that was conducted for Rosemont thus conforms to EPA’s March 23, 2010 guidance memorandum.

Please call if you have any questions.

Sincerely,

Louis C. Thanukos, Ph.D.
Division Manager
Applied Environmental Consultants, a JBR Company
cc: Shantanu Kongara
    Dave Strohm
    Leonard Montenegro
May 10, 2011

Louis C. Thanukos Ph.D.
Applied Environmental Consultants, a JBR company
1553 W. Elna Rae
Tempe, AZ 85281-6935

Subject: Evaluation of representative primary NO$_2$/NOx ratios for use in modeling haul-
truck emissions as part of the Rosemont Copper Project Ambient Impact
Analysis.

Dear Dr. Thanukos,

As requested, the following documents provides an abridged overview of AERMOD’s oxidation
module, its methodology for estimating NO$_2$/NOx ratios and a basis for selecting appropriate data
for the in-stack input parameter. Also provided is a review of literature pertinent to sampling
methods used for measuring primary NOx emissions. This document may also be used to
provide support for modeling NO$_2$ impacts from Rosemont’s haul-truck emissions, using an in-
stack NO$_2$/NOx ratio of 5%.

Cordially,

Leonard Montenegro
About the author

Leonard Montenegro is an independent consultant who specializes in air quality modeling and air quality modeling systems. Leonard’s area of expertise is in High Performance Computing (HPC) using air quality models. He has 10 years of experience in the public sector, with a main focus on air quality modeling. Other areas include mobile source, emissions and meteorological modeling with models such as MOVES, SMOKE and the Weather Research and Forecasting Model (WRF). Leonard has developed autonomous weather forecasting systems for clients worldwide and has developed a variety of web-based software tools related to air quality. Leonard’s recent areas of work include predictive analytics and air quality tools for mobile platforms.

Leonard’s professional and public service includes 6 years with the Center for Environmental Fluid Dynamics at Arizona State University and 10 years for the Arizona Department of Environmental Quality where he supervised the Air Quality Evaluation group. The Evaluation group’s responsibilities included both administering and reviewing modeling and scientific analyses relevant to air pollution permitting and planning. Leonard has also managed an assortment of air pollution studies relating to, for example: attainment demonstrations for State Implementation Plans (SIP), public health assessments from exposure to air toxics and air pollution impacts along the U.S. - Mexico border.

Leonard received his Bachelor’s degree in chemistry from Arizona State University and has co-authored papers relating to air pollution science and technology.
Evaluation of Representative Primary NO$_2$/NO$_x$ Ratios for use in Modeling Mobile Source Emissions as Part of the Rosemont Copper Project Ambient Impact Analysis.

Executive Summary

Nitrogen-dioxide (NO$_2$) pollution from industrial sources is a product of two distinct processes—primary NO$_2$ from combustion and the formation of secondary NO$_2$ from oxidation of nitric oxide (NO) by ozone (O$_3$) in ambient air. Dispersion models, like AERMOD (USEPA’s guideline dispersion model), can be used to estimate ambient NO$_2$ impacts from plumes emitted by large industrial stacks, by using stack test data for the in-stack model input parameter. However, data from stack tests does not exist for other source types, such as mobile on- and off-road source categories. Therefore, an in-stack equivalent must be selected from available data.

This document discusses the basis for differentiating among data-sampling methods to determine representative primary, or “in-stack,” NO$_2$/NO$_x$ fractions for modeling mobile sources and presents current research to support an in-stack ratio of 5% for Rosemont’s mobile source NO$_x$ emissions.

Introduction

The current short-term NAAQS (National Ambient Air Quality Standard) for NO$_2$ (nitrogen dioxide) became effective April 12, 2010. Industrial sources can demonstrate compliance with the standard by using either source-oriented ambient NO$_2$ monitoring data or by relying on estimates provided by air-quality dispersion modeling. NO$_2$ monitors measure ambient hourly NO$_2$ concentrations, which can be compared directly to the NO$_2$ NAAQS. However, industrial-source emissions are reported as total NO$_x$, which is a composite of NO$_2$ and NO. Air-quality models must, therefore, simulate the dispersion and transformation of NO$_x$ to NO$_2$ before any comparisons to the NAAQS can be made. Most photochemical models use elaborate chemical transformation schemes to simulate secondary NO$_2$ formation, but they are generally intended for long-range air-quality studies and not for localized air-quality impacts from industrial sources. In any event, model selection is dictated by federal guidance, which generally limits industrial-source permit modeling to AERMOD (which uses a rather simple NO$_2$ oxidation scheme to simulate NO$_x$ transformations).

AERMOD is primarily a steady-state plume-dispersion model; therefore, it must rely on built-in oxidation models like OLM (Ozone Limiting Method) and PVMRM (Plume Volume Molar Ratio Method) to estimate ambient ratios of NO$_2$/NO$_x$, based initially upon representative NO$_2$/NO$_x$ data from in-stack NO$_x$ emissions. The ambient NO$_2$ ratio is estimated by computing the sum of the fraction of in-stack NO$_2$ formed during combustion—called the primary NO$_2$/NO$_x$ ratio—with the fraction of secondary NO$_2$ transformed from NO in the ambient air by mixing and by oxidation by ozone. At minimum, AERMOD requires a representative estimate for the primary NO$_2$ fraction. Modeling industrial stacks using either OLM or PVMRM is typically straight forward, since in-stack NO$_x$ data collected from compulsory EPA stack testing is usually available. To the contrary, modeling NO$_2$ impacts from mobile sources is not straight forward,
since stack testing does not apply to mobile sources and mobile source plume behaviors is distinctively different from plumes emitted from elevated stacks.

The body of literature from studies pertinent to mobile source NOx emissions is comprised of data collected from a variety of sampling methods. The primary objective of this document is to present representative NO\textsubscript{2}/NO\textsubscript{x} estimates, based on only those studies in which primary NO\textsubscript{2} was sampled by either direct (in-stack or in-pipe) measurement methods or by methods designed for mitigating oxidation from ambient ozone, via measuring NO\textsubscript{x} inside of tunnels.

The following reports support a primary NO\textsubscript{2} in-stack fraction of 5%

  - Reports a maximum primary NO\textsubscript{2} ratio of 5.3%
- “The use of tunnel concentration profile data to determine the ratio of NO\textsubscript{2}/NO\textsubscript{x} directly emitted from vehicles” – X. Yao, et al.
  - Reports a primary NO\textsubscript{2} range of 2% to 6%
- Letter from Caterpillar dated April 27, 2011
  - States that engine-out NO\textsubscript{2} can typically range from 5% to 15%
- Sensitivity Analysis of PVMRM and OLM in AERMOD. - USEPA
  - Modeling analysis used an in-stack ratio of 5% for arbitrary sources
- Philadelphia Exposure Assessment Case-Study - USEPA
  - Modeling analysis used a 10% in-stack ratio for off-road vehicles
- “Risk and Exposure Assessment to Support the Review of the NO\textsubscript{2} Primary National Ambient Air Quality Standard” - USEPA
  - Modeling analysis used a 10% in-stack ratio for off-road vehicles

Discussion

Traditional NO\textsubscript{x} measurements from power plants are often derived from in-stack measurements, in accordance with USEPA Test Method 7 (1). Stack test data is ideal for oxidation models, since OLM and PVMRM require, as input, the ratio of primary NO\textsubscript{2}/NO\textsubscript{x}—representative of NO\textsubscript{x} emissions before the exhaust gases leave the stack (2). However, selecting representative in-stack NO\textsubscript{2}/NO\textsubscript{x} data for modeling mobile sources can be complicated. Stack testing does not apply to mobile sources, and established EPA mobile-source test methods are not well suited to provide primary NO\textsubscript{2} measurements.

For example, EPA’s continuously integrated test method for NO\textsubscript{x} emissions samples engine-out exhaust, which has been mixed with ambient air and allowed to cool to near ambient temperature (3). Also, EPA’s bag-sample method, where diluted exhaust gas is collected and analyzed at ambient temperature, also allows cooling and is not a representative measure of “in-stack” primary NO\textsubscript{2}. Since the model’s in-stack parameter requires measurements that are representative of NO\textsubscript{x} emissions before they leave the stack, data derived from EPA’s test procedures are inappropriate for model input.

There are alternative data sources for mobile-source emissions, but discretion should be used to differentiate samples that are representative of primary NO\textsubscript{2} from combustion, from those that
may likely include an appreciable degree of oxidation. There are two important considerations for determining appropriate NO\textsubscript{2}/NO\textsubscript{x} ratios for off-road diesel vehicles. First, the ratio of NO\textsubscript{2}/NO\textsubscript{x} must be representative of primary NO\textsubscript{2} formed from combustion—engine-out measurements made inside the tail pipe (in-pipe) are preferred. The second consideration must account for NO\textsubscript{2} formed by diesel after treatment technologies, such as Continuously Regenerating Technology (CRT), which reduce particulate emissions but can increase the in-pipe fraction of NO\textsubscript{2} by forcing oxidation of NO to NO\textsubscript{2} across a catalyst. Most research suggests that diesel engines fitted with CRT can increase the in-pipe NO\textsubscript{2} to 30\%, on average. However, not all diesel after-treatment technologies have adverse impacts on in-pipe NO\textsubscript{2}.

The study “Nitrogen Oxides Reactions in Diesel Oxidation Catalyst” (4) discussed the influences of platinum and palladium oxidation catalysts on NO\textsubscript{x} transformations in diesel exhaust from a Caterpillar 3304 mining diesel engine. The apparatus design was comprised of a direct (i.e., in-pipe) sampling method using Fourier Transform Infrared (FTIR) and was set up to allow sampling before and after each catalyst. At a maximum conversion temperature of approximately 380 degrees C, the platinum catalyst increased NO\textsubscript{2} from approximately 5 ppm to 25 ppm, while NO was reduced from 625 ppm to 475 ppm. The values are approximations, since the report only provided the data in chart form. However, even with a fourfold increase in NO\textsubscript{2}, the maximum NO\textsubscript{2}/NO\textsubscript{x} ratio was 5.3\%. The maximum pre-catalyst NO\textsubscript{2}/NO\textsubscript{x} was approximately 3.5\% at 150 degrees C, where NO was 200 ppm and NO\textsubscript{2} was 7 ppm.

Tunnel sampling methods can also provide an estimate of primary NO\textsubscript{2}, since the air near the center of long tunnels often has less oxidation potential than ambient air, outside the tunnel. The study “The Use of Tunnel Concentration Profile Data to Determine the Ratio of NO\textsubscript{2}/NO\textsubscript{x} Directly Emitted from Vehicles” (5) details a procedure for estimating the primary NO\textsubscript{2} fraction from NO\textsubscript{x} measurements made in two separate tunnels; each tunnel was approximately 4 km in length. At the center of each tunnel, atmospheric oxidation potential is limited (albeit not likely entirely absent). Ambient pollutant concentrations are measured inside the tunnel at different locations. Higher NO\textsubscript{2}/NO\textsubscript{x} ratios were measured near each tunnel’s entrance and exit. The lowest NO\textsubscript{2}/NO\textsubscript{x} ratios (2\% to 6\%) were measured near the center of each tunnel. Measurements near the tunnels’ centers can be considered very conservative estimates for thermal NO\textsubscript{2}/NO\textsubscript{x}, since measurements are made in the open air and at ambient temperatures, yet with very limited oxidation potential.

In a letter provided by Caterpillar, Caterpillar states that emission test procedures for on- and off-road equipment follow applicable regulations. As a general rule, Caterpillar claims that engine-out NO\textsubscript{2}/NO\textsubscript{x} can range from 5\% to 15\% NO\textsubscript{2}, but that oxidation catalysts and diesel particulate filters can increase the ratio of engine-out NO\textsubscript{2}. It is unclear, however, if Caterpillar estimates are for engine-out or tailpipe NO\textsubscript{2}. EPA also suggests that mobile-source NO\textsubscript{2} emissions from diesel vehicles with DPF can have elevated NO\textsubscript{2}/NO\textsubscript{x} ratios, as compared to non-catalyzed diesel vehicles. In Shorter et al., (6) diesel vehicles fitted with DPF/CRT had an average NO\textsubscript{2}/NO\textsubscript{x} ratio of 30\%, while ambient measurements from non-catalyzed vehicles were below 10\% NO\textsubscript{2}/NO\textsubscript{x}.

In section 8.4 of EPA’s “Risk and Exposure Assessment to Support the Review of the NO\textsubscript{2} Primary National Ambient Air Quality Standard” (7) AERMOD was set up to model ambient NO\textsubscript{2} impacts in Atlanta, GA. OLM was used for roadway and airport emissions, and PVMRM was used for point sources. All sources were modeled with an in-stack ratio of 10\%, including
off-highway diesel airport vehicles. Roadways were modeled as large area sources, with length-to-width ratios of 1:100.

In Appendix B - Supplement to the NO$_2$ Exposure Assessment, Section B-3 Philadelphia Exposure Assessment Case-Study (8), NO$_2$ air-quality impacts were modeled in the Philadelphia area, with AERMOD. OLM was used for roadway, fugitive, and airport emissions, including off-highway diesel vehicles, with an in-stack NO$_2$/NO$_x$ ratio of 10%. PVMRM was used to model stacks with an in-stack ratio of 10%.

Conclusions

- In-stack data is available for industrial stacks, not mobile sources.
- In-stack NO$_2$/NO$_x$ must be representative of exhaust gases before leaving the stack and before any mixing or oxidation by ambient air has occurred.
- Typical mobile-source emissions, which are often measured after mixing with ambient air, are inappropriate for use with OLM or PVMRM.
- According to data sampled from in-pipe diesel exhaust, the maximum ratio of NO$_2$/NO$_x$ is 5.3%.
- According to data sampled from a tunnel study, estimates of the primary NO$_2$ fraction range from 2% to 6%.
- Reports of NO$_2$/NO$_x$ ratios as high as 30% are often reflective of diesel vehicles fitted with diesel after treatment devices.
Works Cited

(1) EPA - Method 7. (n.d.). *METHOD 7 - DETERMINATION OF NITROGEN OXIDE EMISSIONS FROM STATIONARY SOURCES.*


