Modeling Report for SO_2 NAAQS Designation for Arizona Electric Power Cooperative (AEPCO) - Apache Generating Station

Submitted To:

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Region 9

Prepared By:

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1.0 Introduction

On August 21, 2015, EPA finalized and promulgated the SO_2 Data Requirements Rule (DRR) (80 FR 51052), which requires the characterization of ambient SO_2 air quality around SO_2 emission sources emitting 2,000 or more tons per year of SO_2. ADEQ identified five sources that needed to be addressed for the SO_2 DRR. Those sources include two copper smelters and three coal-fired power plants. EPA has designated the two copper smelters areas (Hayden and Miami) as nonattainment areas in the first round of designations. The three coal-fired power plants include the Tucson Electric Power Springerville Generating Station (TEP-Springerville), the Arizona Public Service Cholla Generating Station (APS-Cholla), and the Arizona Electric Power Cooperatives Apache Generating Station (AEPCO-Apache). As required, ADEQ must characterize air quality in the areas impacted by the three power plants and EPA expects to use this data to designate the areas as meeting or not meeting the 2010 SO_2 standard.

This SO_2 DRR provides air agencies the flexibility to characterize air quality using either modeling of actual source emissions or using appropriately sited ambient air quality monitors. ADEQ decided to evaluate air quality using air dispersion modeling for the three coal-fired power plants. Specifically, ADEQ characterized ambient air quality in areas proximate to the three sources by using actual hourly emissions and meteorology for the most recent 3 years (2012, 2013 and 2014). As required by DRR, for source areas that an air agency decides to evaluate through air quality modeling, the air agency must provide a modeling protocol and a modeling analysis to the EPA Regional Administrator by July 1, 2016 and January 13, 2017, respectively. ADEQ submitted a modeling protocol to EPA Region 9 for review on July 1, 2016 and the protocol was approved by email on December 05, 2016. This modeling report presents the results of the modeling conducted in accordance with the approved protocol for areas around the AEPCO facility. For the other two sources, please see separate modeling reports.

As described in the approved protocol, the modeling work performed in accordance with the EPA's SO_2 NAAQS Designations Modeling Technical Assistance Document (hereafter, "EPA's Designation Modeling TAD", U.S. EPA, 2016a). The modeling report is organized as follows:

- Section 2 provides general description of AEPCO power plant including processes, topography and climate;
- Section 3 provides a discussion on the determination of the modeling domain, sources to explicitly model and the receptor grid;
- Section 4 provides a discussion on the model selection;

- Section 5 provides detailed source inputs, including source configuration, source emissions, source release parameters, and urban/rural determination;
- Section 6 provides a discussion on the selection and processing of meteorological data;
- Section 7 provides a discussion on the determination of background concentrations; and
- Section 8 provides a summary of model results.

2.0 General Description of AEPCO

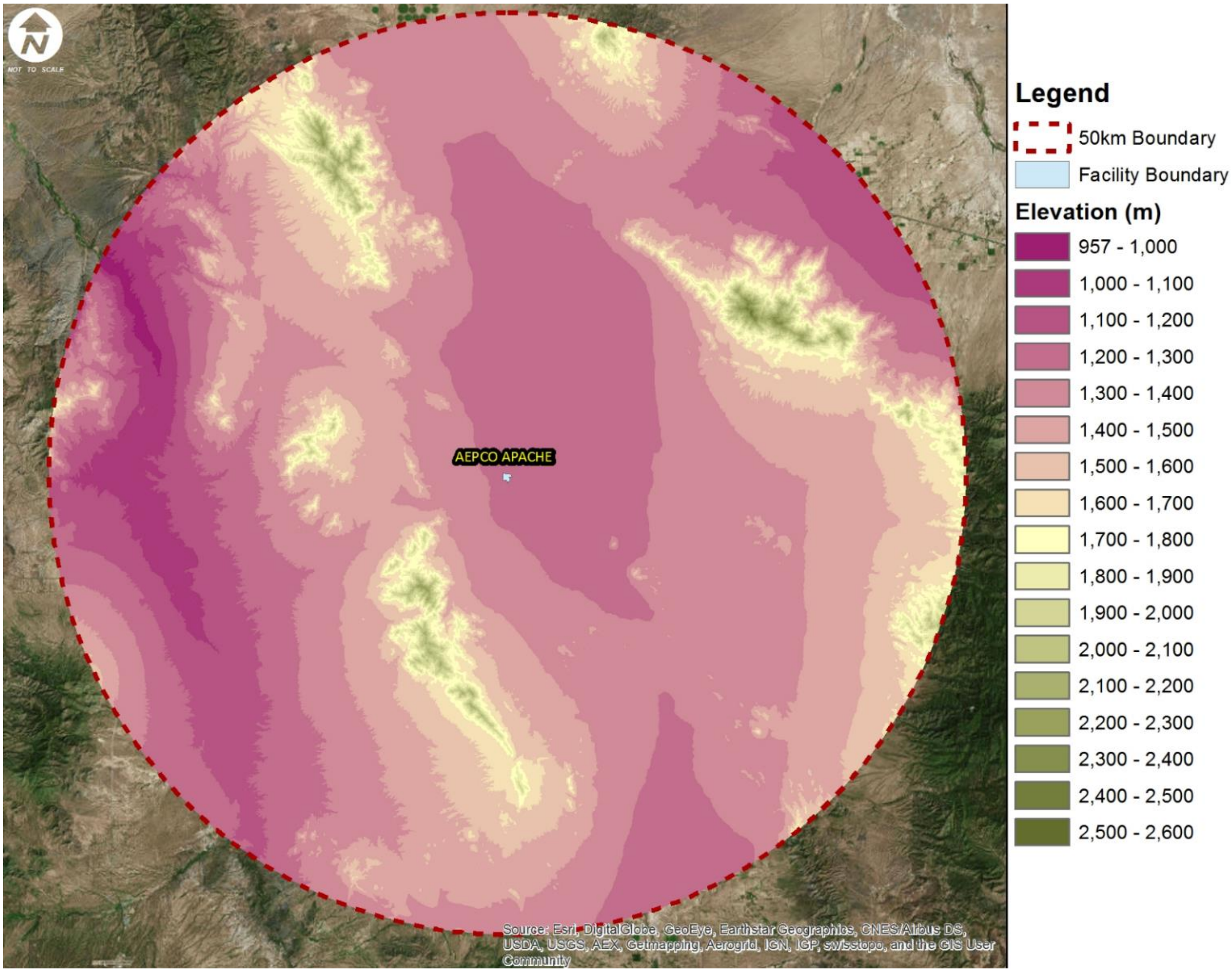
The Arizona Electric Power Cooperative (AEPCO) Apache Generating Station is located approximately 3 miles south of the town of Cochise, Cochise County, Arizona. The Apache Generating Station consists of seven electric generating units: two coal/natural gas fired steam electric units (Unit 2 and Unit 3), a natural gas/fuel oil-fired steam electric, combined cycle unit (Unit 1), and four natural gas/fuel oil-fired turbines with a total generating capacity of 560 megawatts (MW).

ADEQ issued a Significant Permit Revision to Air Quality Control Permit in May 2014 to authorize AEPCO for its Apache Generating Station to change for Steam Unit 2 (ST2) from coal to combusting pipeline natural gas, and to authorize a change in air pollution control for Steam Unit 3 (ST3) to selective non-catalytic reduction (SNCR) and the use of low NOx burners. EPA approved Best Available Retrofit Technology limits for Steam Unit 2 and Unit 3 requiring that effective December 5, 2016, Steam Unit 2 and Unit 3 shall not emit SO_2 in excess of 0.15 lb/MMBtu heat input, averaged over 30 boiler operating days (79 FR 56322).

AEPCO is located in an area which is warm during summer and cold during winter. The warmest month of the year is June with an average maximum temperature of 95.5 degrees Fahrenheit, while the coldest month of the year is December with an average minimum temperature of 27.2 degrees Fahrenheit. The annual average precipitation is 13.4 Inches. The wettest month of the year is August with an average rainfall of 2.6 Inches.

There are no elevated terrain features in immediate vicinity of the AEPCO facility. Dragoon Mountains are located about 8 kilometers (km) south-west of the facility. The Dragoon Mountains are a range of mountains located in Cochise County, Arizona. The range is about 40 km long, running on an axis extending south-south east through Willcox, AZ. Mount Glenn (7,520 ft/2,292 m) is the highest point in the range. Winchester Mountains and Galiuro Mountains are located about 35 km North West of the facility, running on an axis extending south-south east. Pinaleno Mountains are located about 40 km north of the facility. The highest point of the mountains is Mount Graham at 10,720 feet (3,267 m). The mountains cover 300 square miles (780 km^2) and are part of the Coronado National Forest, Safford ranger district. The terrains within 50 km east and south of the facility are mostly flat. The topography of the local area is depicted in Figure 2-1.

Figure 2-1 Topography of the Area Surrounding AEPCO



3.0 Modeling Domain

Selection of the modeling domain is dependent on the number of sources to explicitly model and size of the receptor network in order to account for the areas of impact (U.S. EPA, 2016a). The modeling domain should at a minimum include the sources that are most likely to cause or contribute to NAAQS violations in the area. In the modeling exercise, all modeled receptors should exhibit modeled attainment of the NAAQS.

In this modeling analysis, the modeling domain is centered at the facility and extended for 50 km from the facility fence line.

3.1 Determining Sources to model

Per EPA's SO_2 NAAQS Designations Modeling TAD (U.S. EPA, 2016a), the determination of modeling domains and number of sources to consider for modeling should begin with analyzing the spatial distributions of sources that meet or exceed the emissions threshold established in the data requirements rule. The modeling domains could be centered over these sources.

ADEQ has identified SO_2 sources within the 50 km modeling domain for AEPCO. Figure 3-1 is a geographical representation of these sources. Table 3-1 is an inventory of the individual sources within the 50 km modeling domain for this facility. As table 3-1 shown, the SO_2 emissions from AEPCO represent more than 99% of actual SO_2 emissions during 2012-2014. Excluding this source, there are no sources that emitted more than 1.13 tons per year of SO_2 in AEPCO modeling domain during 2012-2014. Due to their insignificant emissions, it is very unlikely that these minor sources could cause or contribute to a NAAQS violation in the area. Therefore, ADEQ only modeled AEPCO for this designation modeling.

Figure 3-1 Point Sources within 50 km Modeling Domain of AEPCO

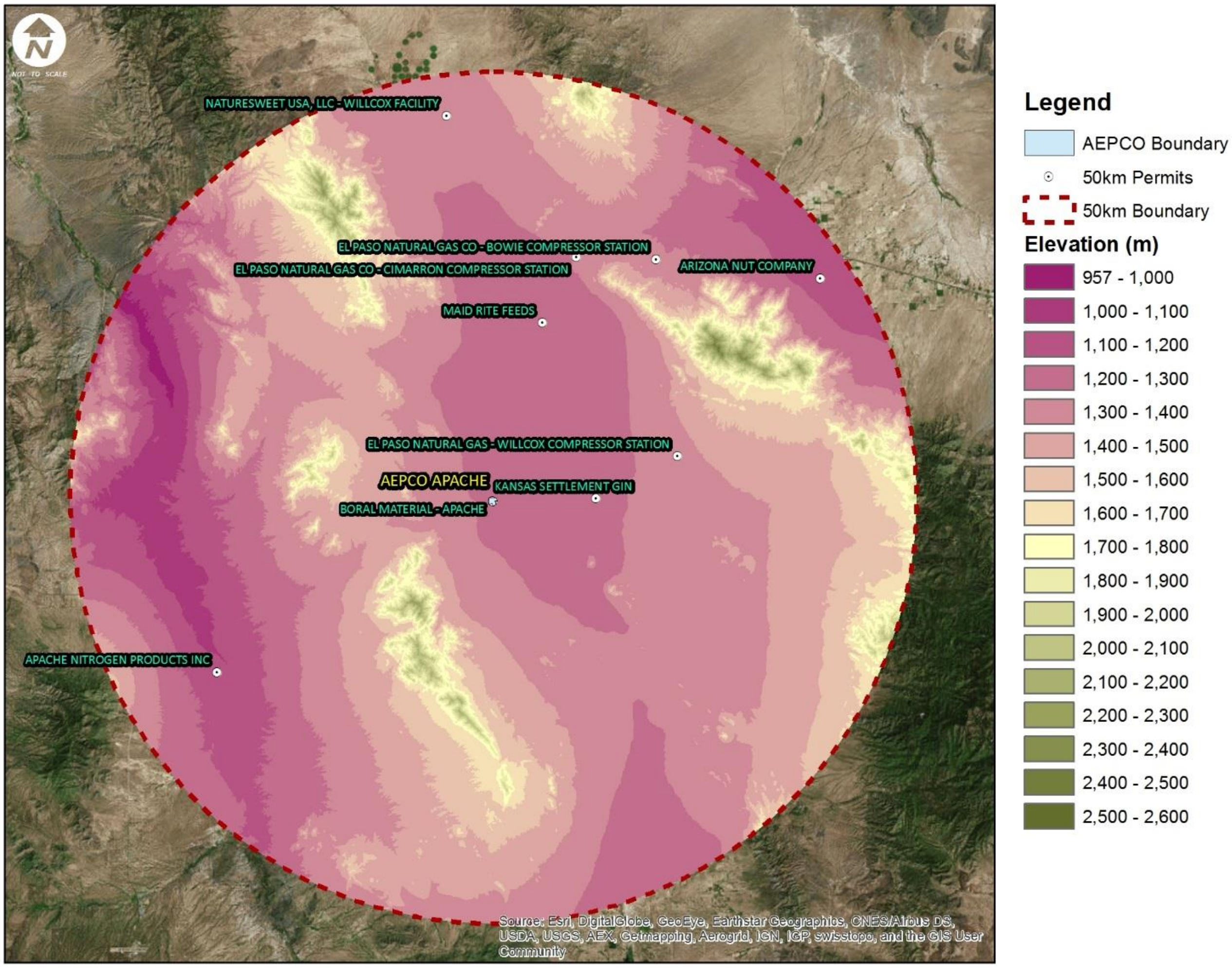


Table 3-1 Point Sources within 50 km Modeling Domain of AEPCO (Permitted Sources)

County	Site Name	Facility Type	Latitude	Longitude	2012 SO_2 (TPY)	2013 SO_2 (TPY)	2014 SO_2 (TPY)
Cochise	Boral Material- Apache	Chemicals and Allied Products	32.061	-109.894	0	0	0
Cochise	Kansas Settlement Gin	Cotton Gins Agricultural Equipment and Supplies	32.064	-109.764	0	0	0
Cochise	El Paso Natural Gas- Willcox Compressor Station	Gas Production and Distribution	32.108	-109.662	0.000063	0.585	0.821
Cochise	Apache Nitrogen Products Inc.	Manufacturer of Ammonium Nitrate-based Products	31.879	-110.238	0.141	0.139	0.154
Cochise	Apache Generating Station	Power Plant	32.064	-109.893	2090.35	3744.31	4811.87
Cochise	El Paso Natural Gas Co.- Bowie Compressor Station	Gas Production and Distribution	32.317	-109.689	0.174	0.304	0.402
Cochise	Nature Sweet USA, LLC- Willcox Facility	Hydroponic Tomatoes and Cucumbers Production	32.468	-109.951	1.13	0.659	0.239
Cochise	El Paso Natural Gas- Cimarron Compressor Station	Gas Production and Distribution	32.319	-109.789	0.256	0.558	1.007
Cochise	Arizona Nut Company	Nuts Production	32.296	-109.484	0	0	0
Cochise	Maid Rite Feeds	Farm, Ranch, and Pet Supplies	32.249	-109.831	0	0	0

3.2 Receptor Grid

ADEQ chose a modeling domain centered on AEPCO facility and extended that to 50 km from the facility fence line to make sure that the high model concentrations are captured. A total of 11505 receptors are placed in approximately 104 km by 112 km modeling domain.

ADEQ used the following receptor spacing to determine areas of maximum predicted concentrations:

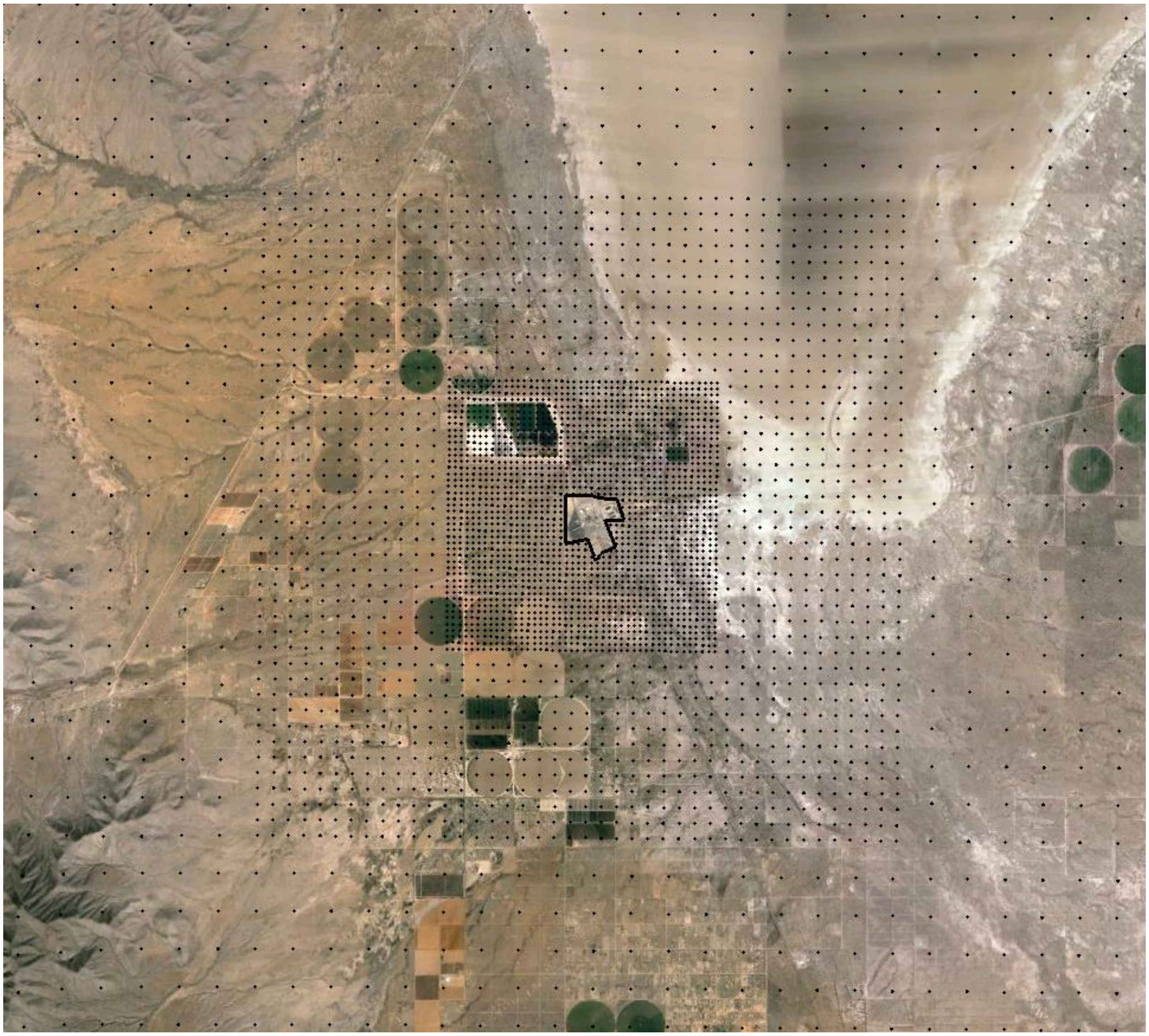
- Receptors along ambient air boundary (AAB) at a spacing of 25 m;
- Receptors from AAB to 1 km at a spacing of 100 m;
- Receptors from 1 km to 5 km away from AAB at a spacing of 200-500 m;
- Receptors from 5 km to 20 km away from AAB at a spacing of 500-1,000 m;
- Receptors from 20 km to 50 km away from AAB at a spacing of 1,000-2,500 m.

ADEQ used the EPA's AERMAP software tool (version 11103; U.S. EPA, 2011b) to estimate receptor elevations and hill heights. AERMAP is the terrain preprocessor for AERMOD (discussed in Section 4) and uses the following procedure to assign elevations to a receptor:

- For each receptor, the program searches through the U.S. Geological Survey (USGS) input files to determine the two profiles (longitude or easting) that straddle this receptor;
- For each of these two profiles, the program then searches through the nodes in the USGS input files to determine which two rows (latitudes or northings) straddle the receptor;
- The program then calculates the coordinates of these four points and reads the elevations for these four points;
- A 2-dimensional distance-weighted interpolation is used to determine the elevation at the receptor location based on the elevations at the four nodes determined above.

ADEQ used 10 meter USGS National Elevation Dataset (NED) data as inputs to AERMAP. The NED data are produced from digitized map contours or from manual or automated scanning of aerial photographs. A 1/3 arc-second NED data file consists of a regular array of elevations referenced horizontally in the UTM coordinate system, with a uniform horizontal spacing of approximately 10 meters. The NED data used for this analysis are based on the 1983 North American Datum (NAD83).The modeled receptors for AEPCO are depicted in Figure 3-2.

Figure 3-2 Modeled Receptors for AEPCO



4.0 Model Selection

In 2005, the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was promulgated as the EPA's preferred near-field dispersion modeling for a wide range of regulatory applications in all types of terrain based on extensive developmental and performance evaluation (40 CFR 51, Appendix W) (U.S. EPA, 2005). AERMOD is EPA's preferred model for area designations under the 1-hour SO_2 primary NAAQS.

ADEQ used AERMOD (version 15181; U.S. EPA, 2014a) to predict ambient concentrations in simple, complex and intermediate terrain. ADEQ is aware that EPA just released AERMOD and AERMET Models Version 16216 on December 20, 2016 (U.S. EPA, 2016b). In the new version 16126, some beta options become regulatory default options. For the example, the adjusted u-star option (ADJ_U*) when measured turbulence data are not included is no longer flagged as a beta option. As will be discussed in Section 6.2, ADEQ used the ADJ_U* option without including any turbulence data when processing the meteorological data with AERMET version 15181. Therefore, it is expected that the changes made in the new version will not affect the AEPCO designation modeling.

There are two input data processors that are regulatory components of the AERMOD modeling system: AERMET (version 15181; U.S. EPA, 2015), a meteorological data preprocessor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP (version 11103; U.S. EPA, 2011), a terrain data preprocessor that incorporates complex terrain using USGS Digital Elevation Data. Other non-regulatory components of this system include: AERSURFACE (Version 13016; U.S. EPA, 2013), a surface characteristics preprocessor, and BPIPPRIM, a multi-building dimensions program incorporating the Good Engineering Practice technical procedures for PRIME applications (U.S. EPA, 2004).

ADEQ used the regulatory default option. This option commands AERMOD to:

- Use the elevated terrain algorithms requiring input of terrain height data for receptors and emission sources;
- Use stack tip downwash (building downwash automatically overrides);
- Use the calms processing routines;
- Use buoyancy-induced dispersion;
- Use the missing meteorological data processing routines.

5.0 Source Inputs

This section discusses source characterization to develop appropriate source inputs for dispersion modeling with AERMOD modeling system. SO_2 emissions are released to the atmosphere from two stacks at AEPCO power plant, which are shown in Figure 5-1.

Figure 5-1 Modeled Emission Sources in AEPCO

5.1 Source Inputs for AEPCO

5.1.1 Emission Data

In AERMOD SO_2 modeling, the real-time 2012-2014 SO_2 emissions and stack parameter data measured by continuous emission monitoring system (CEMS) are applied to obtain accurate modeling results. The hourly SO_2 emissions data being modeled are consistent with those reported from EPA Air Market database (https://ampd.epa.gov/ampd/). As discussed in EPA Designation Modeling TAD (U.S. EPA, 2016a),hourly SO_2 emissions data are input into AERMOD using the HOUREMIS keyword in the source pathway of the AERMOD control file (AERMOD.INP).

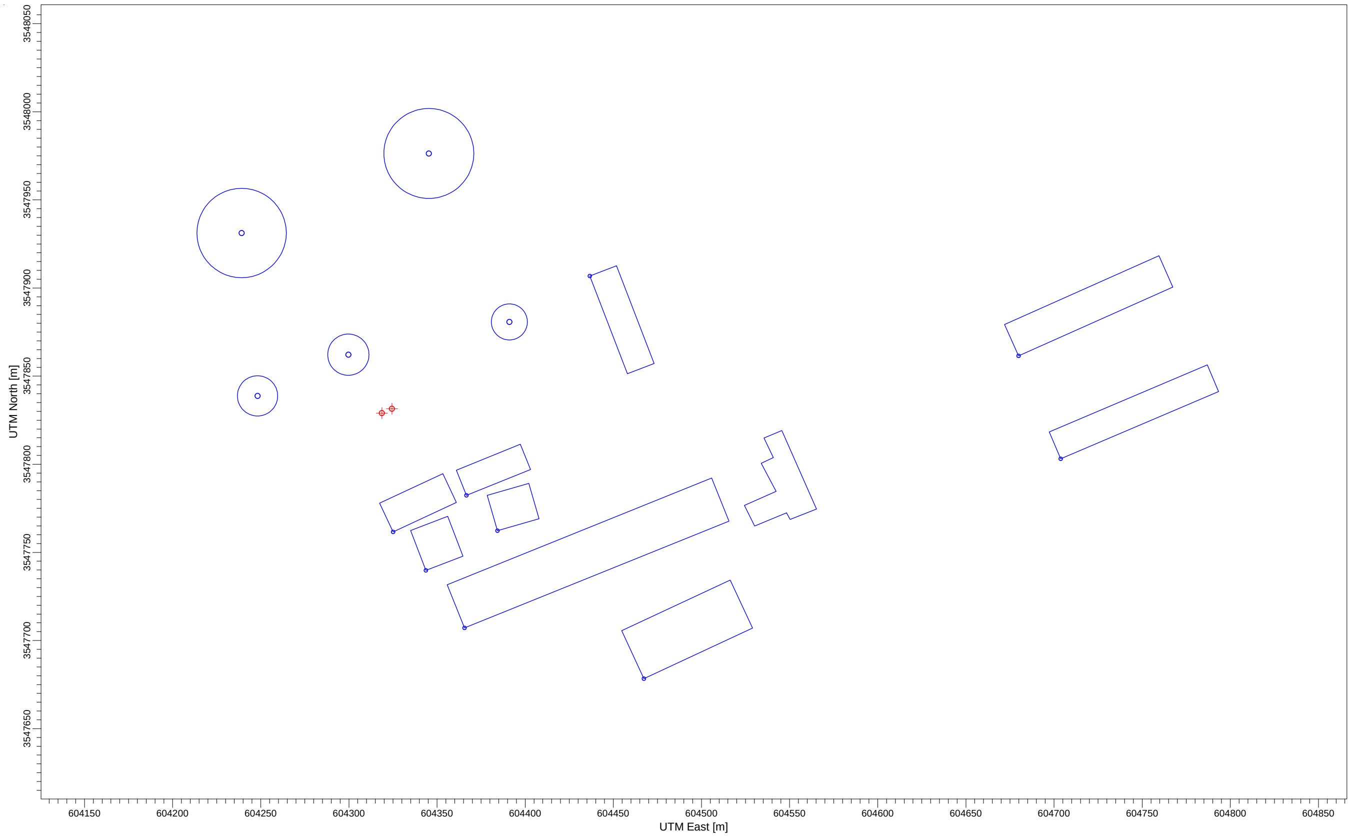
ADEQ obtained the CEMS data from AEPCO. After carefully reviewing the data, ADEQ identified some missing hours. For data substitution, ADEQ obtained the information on shutdown/maintenance periods from the facility and considered those hours as zero emission data. For the rest of missing hours, ADEQ averaged the data from immediate before and after hours and substituted the missing hours with those values.

5.1.2 Emission Release Parameters

For the purposes of modeling with actual emissions to characterize air quality, ADEQ followed the EPA recommendation and used actual stack heights, instead of calculating Good Engineering Practice (GEP) stack height. In addition, hourly emissions parameters measured by CEMS (including exhaust temperature, exit velocity and exit flow rate) were used as source inputs, which most closely represent the facility actual emission conditions.

Downwash effects were considered for AEPCO modeling by using BPIPPRM. BPIPPRM requires a digitized footprint of the facility's buildings and stacks. The source must evaluate the position and height of buildings relative to the stack position in the building wake effects analysis. The information of actual heights of existing structures were provided by the AEPCO facility. The simplified layout used in modeling for AEPCO is shown in Figures 5-2.

Figure 5-2 Simplified Facility Layout for AEPCO



ADEQ identified coordinates for the stacks by mapping the site buildings to rectified aerial photographs of the site and projected UTM coordinates of each stack to UTM Zone 12. These coordinates are based on the NAD83.

Table 5-1 presents the modeling parameters for the stacks.

Table 5-1 Modeling Parameters for AEPCO Stacks

Stack	UTM Easting (m)	UTM Northing (m)	Base Elevation (m)	Stack Height (m)	Exit Diameter (m)	Exit Velocity (m/s)	Exhaust Temp. (ºK)	Exit Flow Rate
Stack 2	604324.41	3547831.47	1279.04	121.92	5.06	Variable	Variable	Variable
Stack 3	604318.68	3547828.97	1279.10	121.92	5.06	Variable	Variable	Variable

5.2 Urban/Rural Determination

Dispersion coefficients for air quality modeling were selected based on the land use classification technique suggested by Auer (Auer, 1978), which is EPA's preferred method. The classification determination involved assessing land use by Auer's categories within a 3 km radius of the proposed site. A source selected urban dispersion coefficients if greater than 50 percent of the area consists of urban land use types; otherwise, rural coefficients apply.

ADEQ classified the land use of the area using the land-use procedure set forth in EPA's "Guideline on Air Quality Models" (GAQM) (U.S. EPA, 2005). This approach requires determining the amount of specific types of land use categories within a 3 km radius circle centered on the source; if the total land use (as defined by Auer) is classified as 50% or more "urban" then the area is designated as urban; otherwise it is designated as rural.

Land use (taken from the U.S. Geological Survey (USGS) National Land Cover Data (NLCD) 1992 archives) was examined for the 3 km radius circle, and totals of each land use category were calculated. These land use categories were then correlated to the categories as established by Auer (Auer, 1978), and the amount of urban and rural land use within 3 km of each facility was calculated. The area near AEPCO that was examined is depicted in Figure 5-3, while the results of the analysis are presented in Table 5-2.

Figure 5-3 Land Use near AEPCO

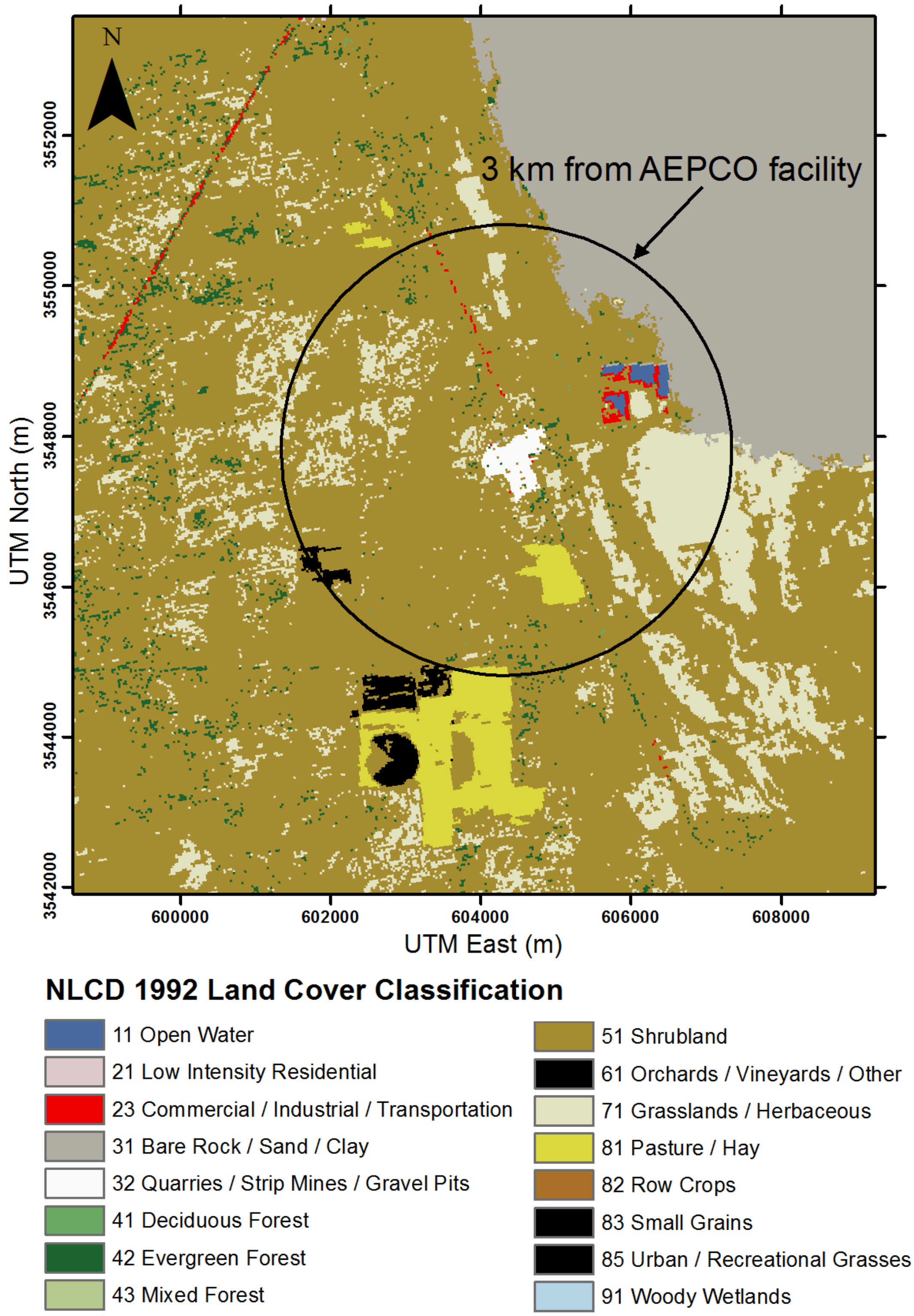


Table 5-2 Land Use Analysis within 3 km of AEPCO

1992 NLCD Land Use Category		% of Total Land Use within 3 km of AEPCO	Auer Land Use Category		
Code	Description		Code	Description	Rural/Urban
11	Open Water	0	A5	Water Surfaces	Rural
12	Perennial Ice/Snow	0	A5	Water Surfaces	Rural
21	Low Intensity Residential	1.3	R1 / R4	Common/Estate Residential	Rural
22	High Intensity Residential	0	R2 / R3	Compact Residential	Urban
23	Commercial / Industrial / Transportation	17.4	C1 / I1 / I2	Commercial/Heavy Industrial/Light-Moderate Industrial	Urban
31	Bare Rock / Sand / Clay	0.5	A	N/A	Rural
32	Quarries / Strip Mines / Gravel Pits	0	A	N/A	Rural
33	Transitional	0	A	N/A	Rural
41	Deciduous Forest	0	A4	Undeveloped Rural	Rural
42	Evergreen Forest	0	A4	Undeveloped Rural	Rural
43	Mixed Forest	0	A4	Undeveloped Rural	Rural
51	Shrubland	60.2	A3	Undeveloped	Rural
61	Orchards / Vineyards / Other	0	A2 / A3 / A4	Agricultural Rural / Undeveloped / Undeveloped Rural	Rural
71	Grasslands / Herbaceous	13.0	A3	Undeveloped	Rural
81	Pasture / Hay	0	A2	Agricultural Rural	Rural
82	Row Crops	0	A2	Agricultural Rural	Rural
83	Small Grains	0	A2	Agricultural Rural	Rural
84	Fallow	0	A2	Agricultural Rural	Rural
85	Urban / Recreational Grasses	7.6	A1	Metropolitan Natural	Rural
91	Woody Wetlands	0	A3 / A4 / A5	Undeveloped / Undeveloped Rural / Water Surfaces	Rural
92	Emergent Herbaceous Wetlands	0	A3 / A5	Undeveloped / Water Surfaces	Rural

Over 60% of the land use within 3 km of AEPCO is "shrubland" according to the NLCD92 classification scheme. Under the Auer scheme the sum of the percentage of land use categories classified as urban (R2, R3, C1, I1, and I2) is 17.4%. Accordingly, the sum of the rural categories is 82.6%. Therefore, the area around AEPCO is defined as "rural" and identified as such in the AERMOD input.

6.0 Meteorological Data

The AERMOD model used AERMET to process the meteorological data and create the data files for AERMOD.

6.1 Meteorological Data Selection

As stated in SO_2 designation modeling TAD (U.S. EPA, 2016a), for the purposes of modeling to characterize air quality for use in SO_2 designations, the EPA recommends using the most recent 3 years of meteorological data to allow the modeling to simulate what a monitor would observe.

AEPCO provided 2012-2014 site-specific meteorological data collected from a 10-m meteorological tower. However, these data have not gone through quality assurance. AEPCO provided additional 2008-2011 meteorological data collected from a 10-m meteorological tower. ADEQ's records indicate that the 2008-2011 data were subject to a quality assurance audit and met EPA Prevention of Significant Deterioration (PSD) quality assurance requirements. ADEQ reviewed the 2008-2014 data and found that the meteorological data were consistent from year to year (see Appendix A).

ADEQ also reviewed the meteorological data collected at the nearest National Weather Service (NWS) Automated Surface Observing System (ASOS) stations, Tucson International Airport and Safford Regional Airport, both of which are located about 60 miles from the AEPCO facility (Figure 6-1). ADEQ determined that neither of the two sites provides the representative meteorological data for evaluating the dispersion of emissions from the AEPCO facility due to different topography and terrain characteristics. The comparisons of the wind rose plots for Tucson, Safford and the on-site monitor clearly demonstrate that the wind patterns in the area of the project site significantly differ from those in Tucson or Safford (See Appendix A).

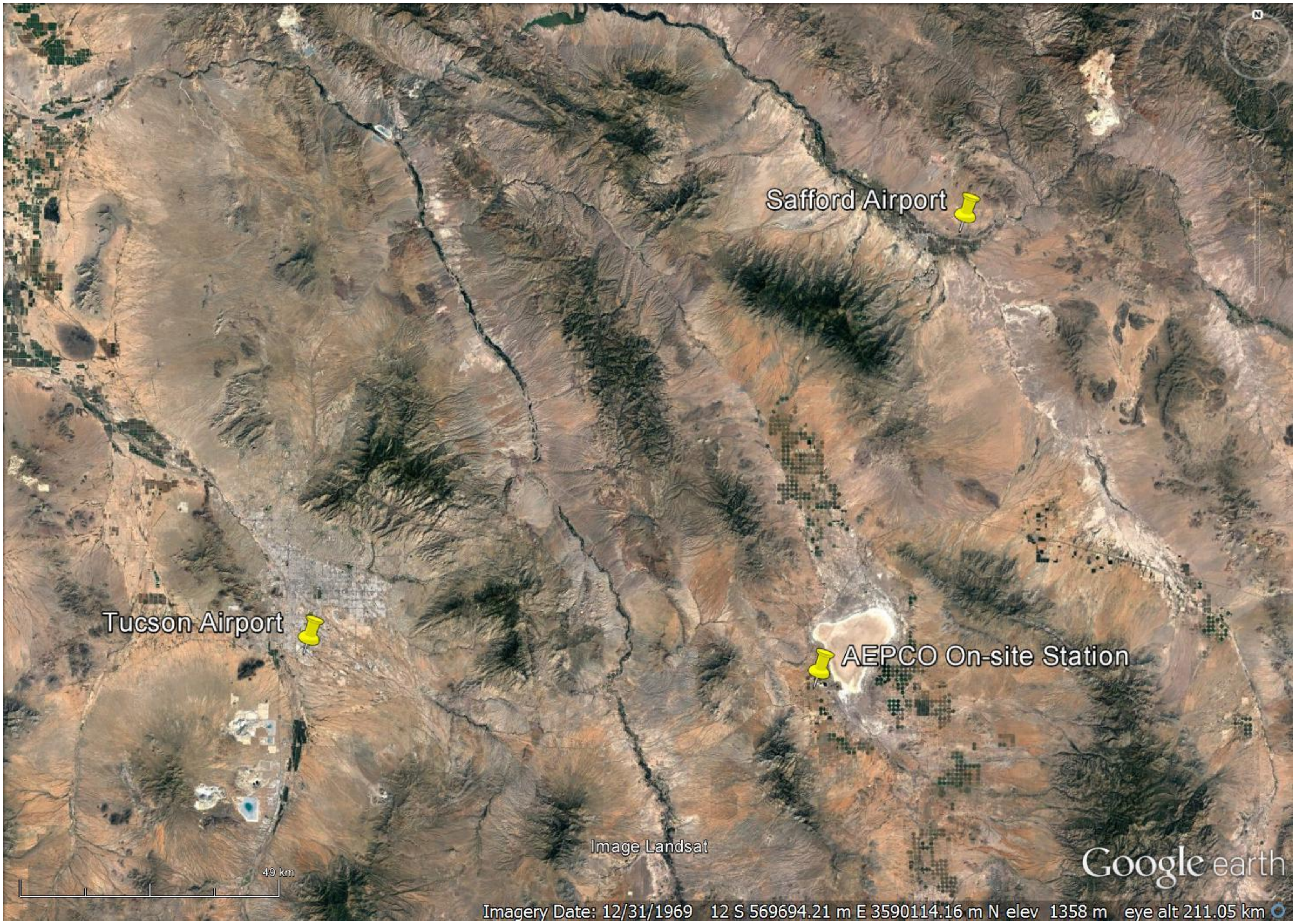
It is stated in EPA Designation Modeling TAD (U.S. EPA, 2016a):

> *"In some instances, representative meteorological data from the most recent three years may not be available, especially if the most representative data is older site-specific data. In such cases, it may be feasible to use older meteorological data (either site specific or NWS) that has been used in past regulatory applications for the area containing the threshold exceeding source, if these datasets are still considered representative of the most recent three years of meteorological conditions".*

ADEQ determined that the meteorological data collected during 2009-2011 were representative of the most recent three years (2012-2014) of meteorological conditions. Therefore, ADEQ decided to use the 2009-2011 site-specific data for AEPCO designation modeling.

Appendix A presents the wind rose plots for the years 2008-2014 for on-site monitor, the years 2012-2014 for Tucson NWS station, and the years 2012-2014 for Safford NWS station.

Figure 6-1 Locations of On-site Meteorological Station, Tucson NWS Station and Safford NWS Station



6.1.1 Compliance of the On-site Meteorological Station with Siting Criteria Requirements

EPA's Meteorological Monitoring Guidance for Regulatory Modeling Applications (U.S. EPA, 2000) lists criteria for siting of meteorological instruments. A listing of these criteria and the compliance status of the AEPCO 10-meter meteorological tower with such criteria are presented below:

Wind Instruments: The standard exposure height of wind instruments over level, open terrain should be 10 meters above the ground. Open terrain is defined as an area where the distance between the instrument and any obstruction is at least 10 times the height of that obstruction. As shown in Figures 6-2 and 6-3, there are no such obstructions in the immediate vicinity of the AEPCO meteorological tower.

Temperature Sensors: Ambient temperature should be measured at 2 meters and the sensor should be located over an open area of at least 9 meters in diameter, and should be located at a distance of at least 4 times the height of any nearby obstruction. The surface should be covered by short grass, or, where grass does not grow, the natural earth surface. Instruments should be protected from thermal radiation (from the earth, sun, sky, and any surrounding objects) and adequately ventilated using aspirated shields. The location of the on-site ambient and differential temperature sensors meets these criteria.

Figure 6-2 Picture of the AEPCO 10-m Meteorological Tower

Figure 6-3 Aerial View of AEPCO 10-m Meteorological Tower Location

6.1.2 Compliance with Quality Assurance and Completeness Requirements

The monitoring program met the quality assurance audit requirements for 2008-2011 (see Table 6-1) as described in EPA's "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), 1987" and "Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. IV: Meteorological Measurements, Version 2.0 Final, March 2008". Independent audits were conducted every 6 months during 2008-2011 by Meteorological Solutions Inc.

Table 6-1 Recommended System Accuracies and Resolutions

Meteorological Variable	System Accuracy	Measurement Resolution
Wind Speed (Horizontal and vertical)	± (0.2 m/s + 5% of observed)	0.1 m/s
Wind Direction (azimuth and elevation)	± 5 degrees	1.0 degree
Ambient Temperature	± 0.5 ^oC	0.1 ^oC
Vertical Temperature Difference	± 0.1 ^oC	0.02 ^oC
Dew Point Temperature	± 1.5 ^oC or ± 7% RH	0.1 ^oC
Precipitation	± 10% of observed or± 0.5 mm	0.3mm
Pressure	± 3 mb (0.3 kPa)	0.5 mb
Solar Radiation	± 5% of observed	10 W/m2

6.1.3 Processed Data Completeness

According to EPA-454/R-99-005, "Meteorological Monitoring Guidance for Regulatory Modeling Applications" (U.S. EPA, 2000), meteorological data must be 90 percent complete in order to be acceptable for usage in regulatory dispersion modeling. The 2009-2011 site-specific data were evaluated quarter by quarter to assess compliance with the 90 percent completeness criteria. No data substitution was employed. The results are shown in Table 6-2. As shown in the table, the data meet the 90 percent requirement for each monitored parameter for each quarter.

Table 6-2 AEPCO On-site Data Completeness

Year	Quarter	Wind Speed	Wind Direction	Temp (10 m)
2009	Q1	99%	99%	99%
	Q2	99.8%	99.8%	99.8%
	Q3	100%	100%	100%
	Q4	100%	100%	100%
2010	Q1	91.8%	91.8%	91.8%
	Q2	100%	100%	100%
	Q3	99.7%	99.7%	99.7%
	Q4	100%	100%	100%
2011	Q1	100%	100%	100%
	Q2	100%	100%	100%
	Q3	100%	100%	100%
	Q4	99.9%	99.9%	99.9%

6.2 Meteorological Data Processing with AERMET

ADEQ used the EPA's AERMET tool (version 15181; U.S. EPA, 2014b) to process meteorological data for use with AERMOD. AERMET merges site-specific meteorological data and NWS surface observations with NWS upper air observation and performs calculation of boundary layer parameters required by AERMOD. In addition to the meteorological observations, AERMET further requires the inclusion of the characteristics of land use surfaces (routinely calculated using EPA's AERSURFACE tool).

EPA has proposed to designate some beta options as the default regulatory formulation in the proposed revisions to the Guideline on Air Quality Models (Proposed Rule, U.S. EPA, 2015). In the AEPCO SO_2 DRR modeling protocol submitted to EPA Region 9, ADEQ proposed to use the beta alternative formulation of surface friction velocity (u*) non regulatory default option (ADJ_U*) in AERMET version 15181 to process meteorological data for modeling with AERMOD (see Appendix B for detailed discussions). On December 20, 2016, EPA finalized the revisions to the Guideline on Air Quality Models and released AERMOD and AERMET Models Version 16216 (Final Rule, U.S. EPA, 2016b), in which the ADJ_U* option when site-specific turbulence data (sigma-theta and/or sigma-w) are not included is no longer flagged as a beta option. As stated in the Final Rule, using the ADJ_U* option is appropriate when standard National

Weather Service (NWS) airport meteorological data, site-specific meteorological data without turbulence parameters, or prognostic meteorological input data are used for the regulatory application (U.S.EPA, 2016b). EPA also determined that the ADJ_U* option should not be used in AERMET in combination with use of measured site-specific turbulence data since it may introduce a bias toward under-prediction of modeled concentrations (U.S. EPA, 2016b).

To process the site-specific meteorological data for AEPCO with the ADJ_U* option, ADEQ did not use any turbulence parameters. The ADEQ's records (the audit reports for AEPCO's meteorological monitoring station) did not explicitly indicate that AEPCO had measured site-specific turbulence data (sigma-theta and/or sigma-w). The raw meteorological data sets AEPCO submitted to ADEQ did not include any site-specific turbulence data as well. ADEQ is also aware that, for some cases that had site-specific turbulence data available, the EPA's Model Clearinghouse (MCH) approved the use of the ADJ_U* option when the site-specific turbulence data were excluded in the meteorological data processing (U.S.EPA, 2016c). For AEPCO, ADEQ used site-specific meteorological data without turbulence parameters in accordance with the requirements of the final rule (U.S. EPA, 2016b). For the above reasons, ADEQ believes that it is appropriate to use the ADJ_U* option for AEPCO.

It should be noted that using the previous default regulatory options (without using the ADJ_U* option) for this project shows maximum impact locations in the rugged terrain of the mountains located about 8-10 km from the facility. Installation of a monitor in the current maximum impact location is unreasonable due to accessibility issues associated with the location. Also, the maximum impact location is not populated and, would thus, not provide an adequate representation of impact on public health. This situation is very similar to a case in Utah, where the maximum model concentrations were observed in an unpopulated, mountainous area. In that case, EPA agreed (via email) that monitoring was not an option. Other similar documented case studies are described in Appendix B.

Additionally, the controls that will be implemented by AEPCO by the end of 2017, will result in SO_2 emissions lower than 2000 tons per year threshold identified by EPA for source consideration of either modeling or monitoring.

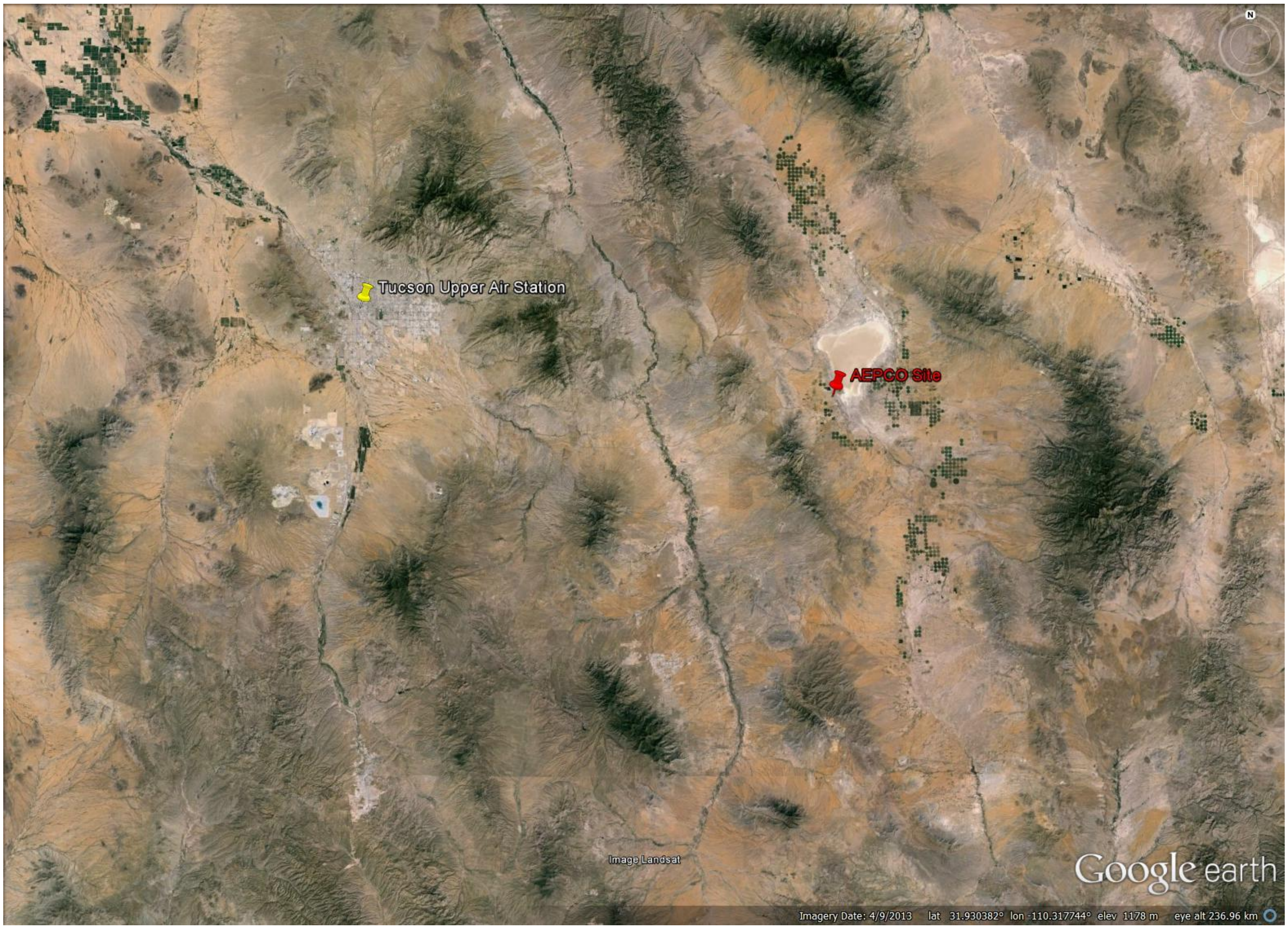
6.2.1 Surface Data

As discussed in Section 6.1, ADEQ used the 2009-2011 site-specific meteorological data for AEPCO designation modeling. Since hourly emissions for most recent three years (2012-2014) were modeled, the dates of the meteorological datasets were adjusted. Based on SO_2 designation modeling TAD (U.S. EPA, 2016a), ADEQ modified the years of the meteorological datasets to match the most recent three years of emissions (i.e., change 2009 to 2012, 2010 to 2013, and 2011 to 2014). Months, days, and hours remained unchanged. Since the year of 2012 contains emissions for February 29 but the meteorological data does not cover leap years, ADEQ substituted meteorological data collected on February 28 for February 29.

6.2.2 Upper Air Observations

Given the proximity of location, topography and climate as AEPCO power plant, ADEQ used the upper air data obtained from Tucson, AZ (Station ID:23160, Latitude/Longitude: 32.23 N/110.96 W), which is 101 km northwest away from AEPCO facility (see Figure 6-4).

Figure 6-4 Location of Tucson Upper Air Station and AEPCO Power Plant



6.2.3 AERSURFACE

ADEQ used EPA's AERSURFACE tool to calculate the surface roughness length, albedo and Bowen ratio inputs required by AERMET. EPA developed AERSURFACE to identify these parameters within a defined radius from a specified point. In this case, ADEQ inputted the UTM coordinates of the on-site meteorological station to AERSURFACE along with a 1 km radius per EPA guidance. ADEQ used 1992 USGS National Land Cover Data (NLCD) for the state of Arizona as inputs to AERSURFACE. ADEQ calculated the parameters for twelve compass sectors of 30 degrees each, and by month. Considering the climate characteristics in the AEPCO area, ADEQ assigned the seasonal categories for AEPCO as follows:

- Late autumn after frost and harvest, or winter with no snow: January, February, March, December;
- Winter with continuous snow on the ground: none;

- Transitional spring (partial green coverage, short annuals): April, May, June;
- Midsummer with lush vegetation: July, August, September;
- Autumn with un-harvested cropland: October, November.

The surface moisture condition were determined by comparing precipitation for the period of data to be processed to the 30-year climatological record, selecting “wet” conditions if precipitation is in the upper 30th-percentile, “dry” conditions if precipitation is in the lower 30th-percentile, and “average” conditions if precipitation is in the middle 40th-percentile.ADEQ choose “average” conditions for AEPCO case.

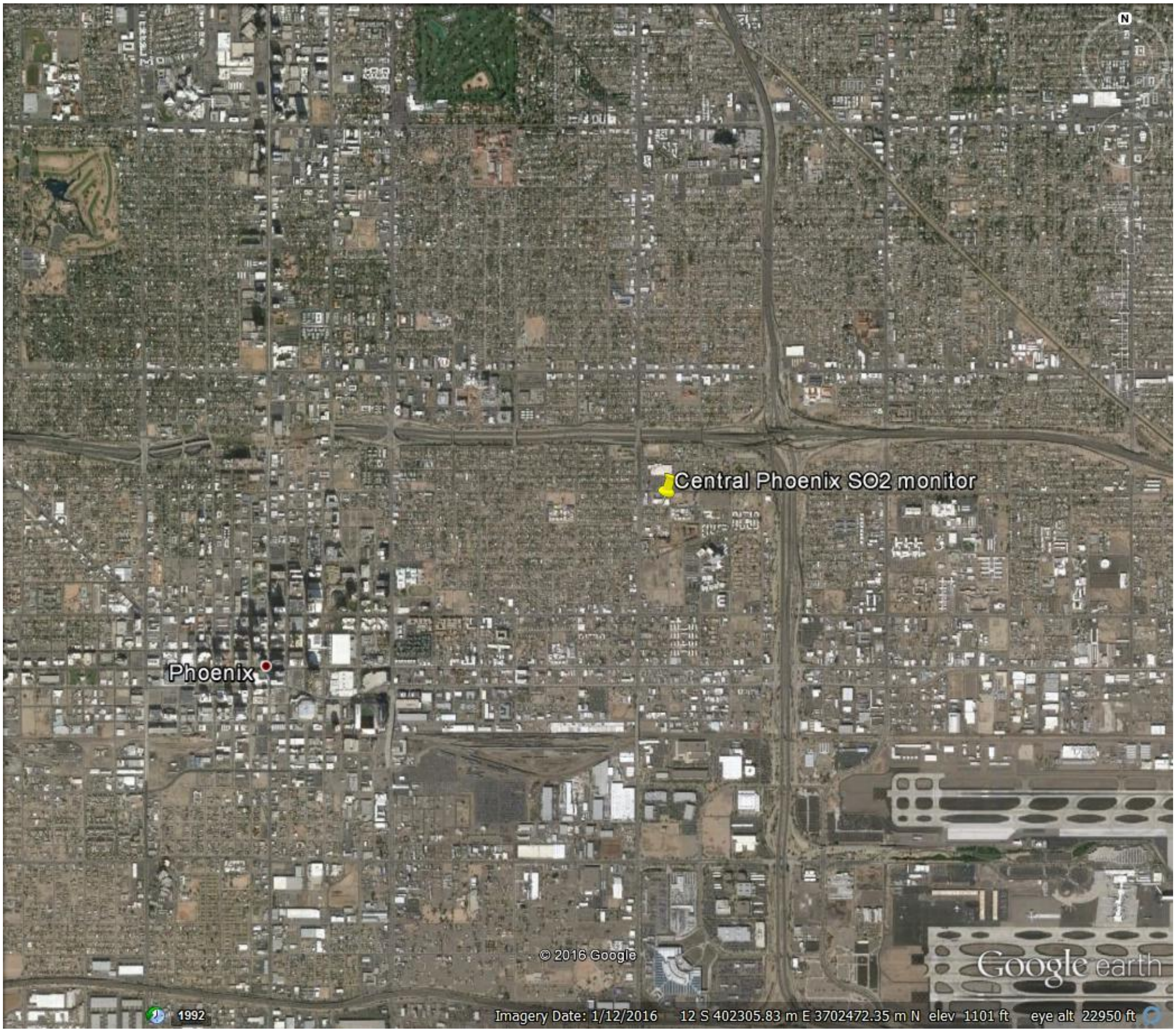
7.0 Background Air Quality

EPA requires background air quality estimates be added to modeling results for comparison to the NAAQS.

There are limited SO_2 monitoring sites in Arizona and the monitoring sites are located in the Phoenix/Tucson metropolitan area or close to copper smelters. ADEQ used the ambient monitoring data collected from Central Phoenix (1645 E Roosevelt St, ID: 40133002, Figure 7-1) as 1-hour SO_2 background concentration. This site is located in an urban area and surrounded by various anthropogenic sources. The AEPCO power plant is located in a rural area without significant human activities. Therefore, the monitoring concentration at central Phoenix monitor is expected to be higher than the background concentration in the AEPCO modeling domain. Thus this method is considered conservative.

The 99th percentile SO_2 1-hour concentrations at the Central Phoenix Monitoring Site was calculated for each year in the 2010-2014 dataset, which were retrieved from U.S. EPA's Air Quality System (https://www3.epa.gov/airdata/). The 3 year (2012-2014) design values were 8ppb, 8ppb and 7ppb, respectively. Following the EPA Designation Modeling TSD, the SO_2 background concentration for the AEPCO power plant was determined to be 7.7 ppb (20.18 µg/m3) as the average of 3-year 99th percentile SO_2 1-hour concentrations.

Figure 7-1 Location of Central Phoenix SO_2 Monitor



8.0 Modeling Results and Discussions

Demonstration of protection of the NAAQS was accomplished by comparison of the modeled design value to the applicable standard. The modeled design value for 1-hour SO_2 is defined as the sum of the 4th highest modeled hourly concentration and the 99th percentile background concentration. The results for AEPCO power plant are discussed in this section.

The predicted highest 4th high 1-hour SO_2 concentrations using the site-specific meteorological data with the ADJ_U* Beta option was 140.91 µg/m^3.This predicted concentration was added to the 1-hour SO_2 background concentration of 20.18 µg/m^3 and provided the ambient concentration of 161.09 µg/m^3. This concentration is less than the applicable 1-hour SO_2 NAAQS of 196 µg/m^3. Table 8-1 summarizes the modeling results.

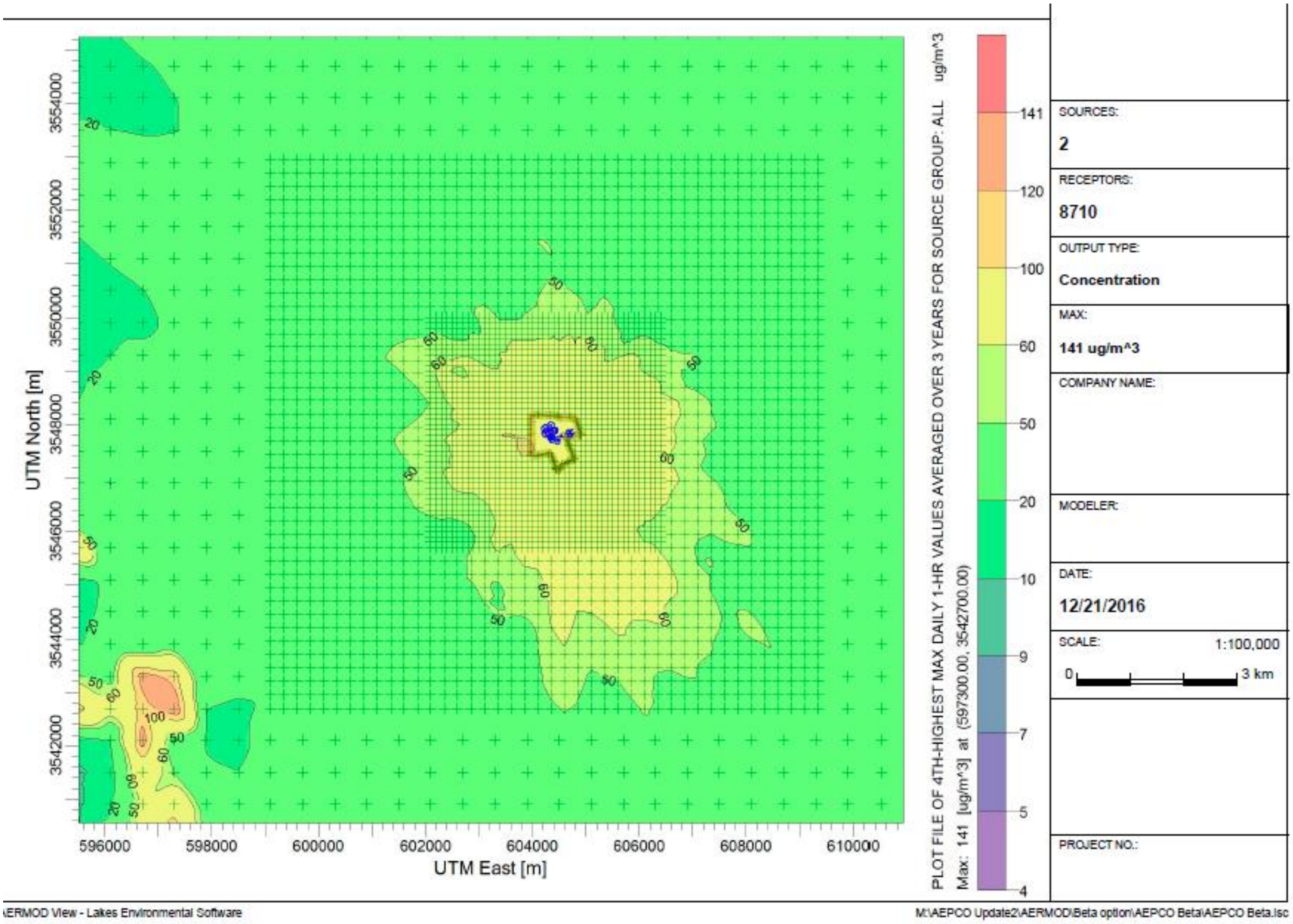
Table 8-1: Summary of Modeling Results

Model Predicted Concentration (Highest 4th High) µg/m^3	Background Concentration (99th Percentile) µg/m^3	Total Concentration µg/m^3	NAAQS µg/m^3
140.91	20.18	161.09	196
4th highest maximum daily 1-hour SO_2 concentration predicted to occur at 597300.00m E and 3542700.00m N			

Based on the spatial concentration of contour plot (Figure 8-1), the highest concentrations of 1-hour SO_2 around AEPCO power plant were located in the southwest area, which is about 8.6 km away from the facility.

ADEQ submitted all applicable electronic modeling files including model input files, model output files, building downwash files, terrain files, and meteorological data files along with this modeling report.

Figure 8-1 Spatial distributions of SO_2 concentration modeled by AERMOD near APECO



9.0 References

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Appendix A: Wind Rose Plots for AEPCO On-site Meteorological Monitor, Tucson NWS Station and Safford NWS Station

Table A-1 The information of meteorological site location

Meteorological Data Sources	Sampling Period	Latitude	Longitude
On-site 10-m meteorological tower	2012-2014	32.068 N	109.926 W
Tucson International Airport	2012-2014	32.133 N	110.933 W
Safford Regional Airport	2012-2014	32.855 N	109.630 W

2008-2014 Year to Year Analysis

Figure A-1 2008 On-site MET Data

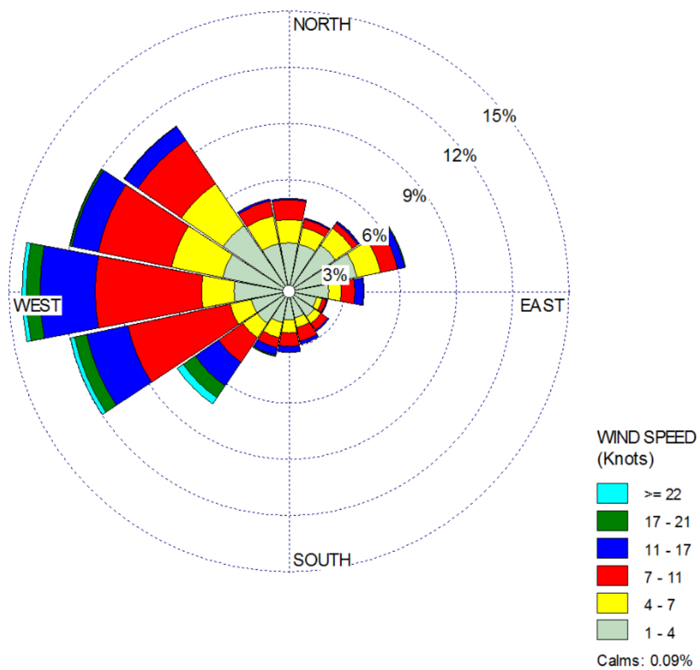


Figure A-2 2009 On-site MET Data

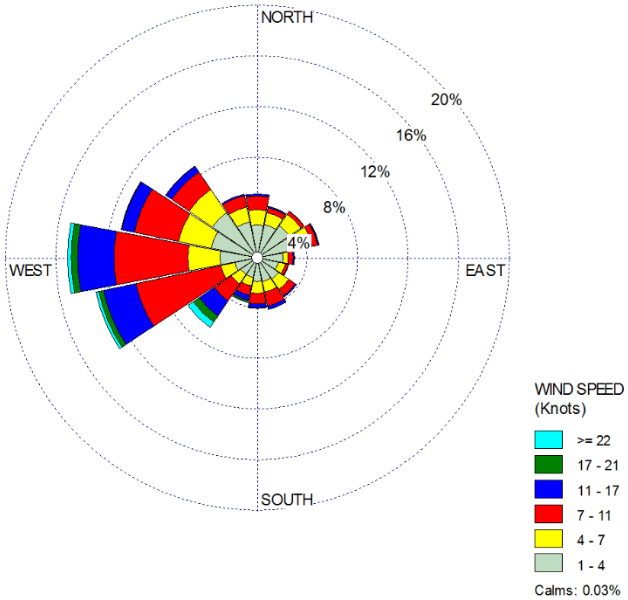


Figure A-3 2010 On-site MET Data

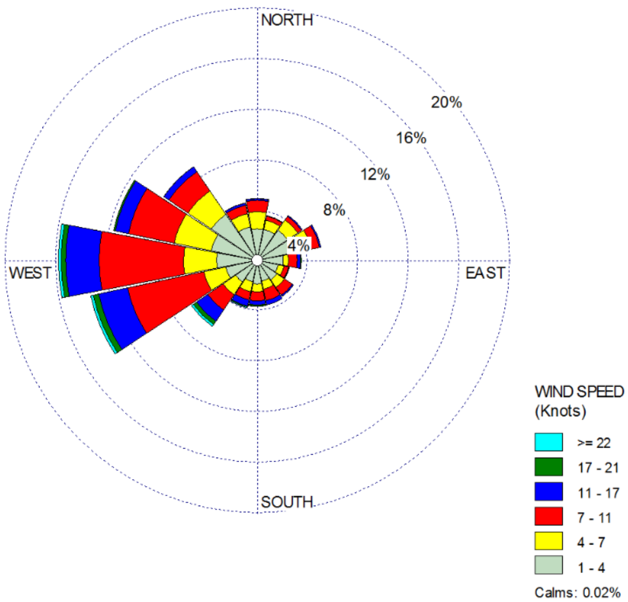


Figure A-4 2011 On-site MET Data

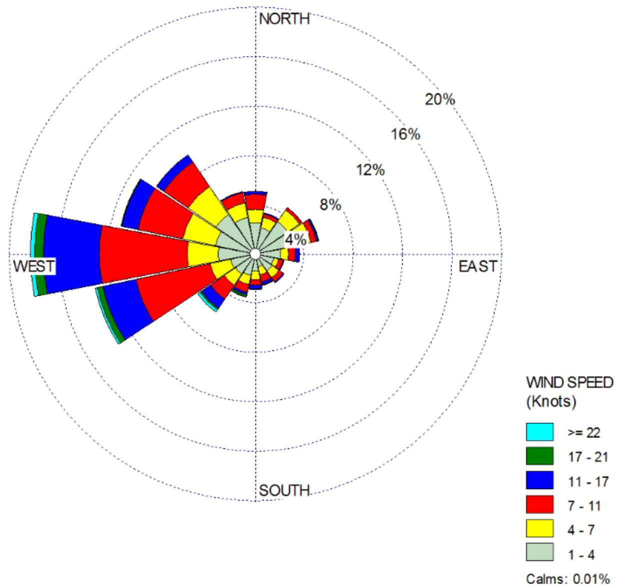


Figure A-5 2012 On-site MET Data

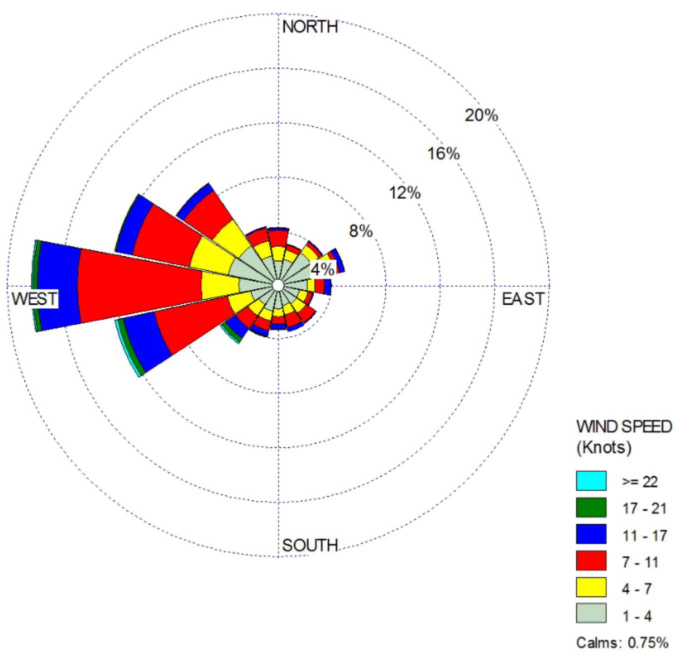


Figure A-6 2013 On-site MET Data

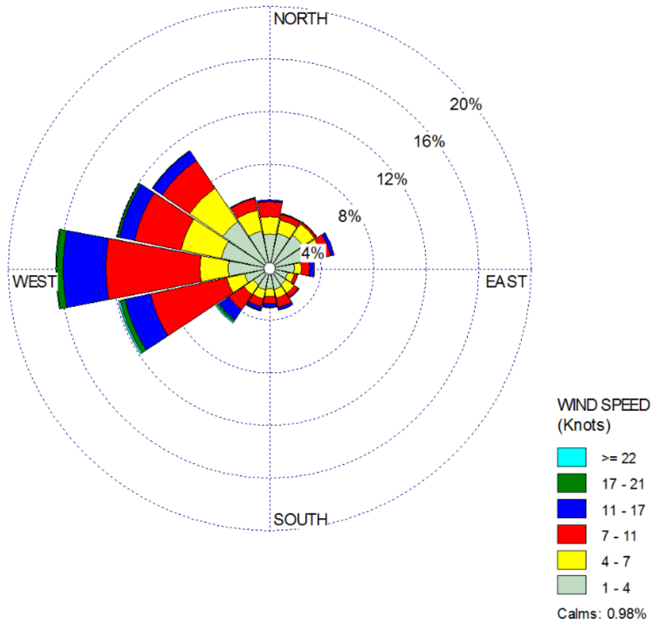
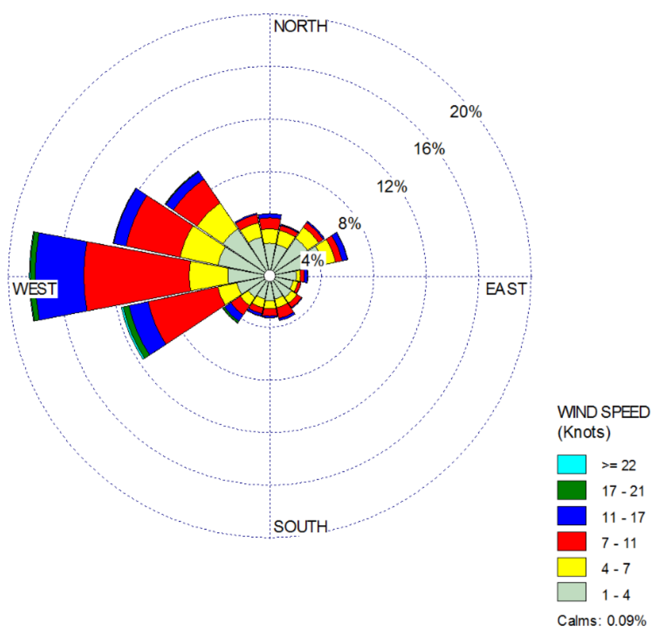


Figure A-7 2014 On-site MET Data



2012-2014 On-site and Airport Data

Figure A-8 2012-2014 On-site MET Data

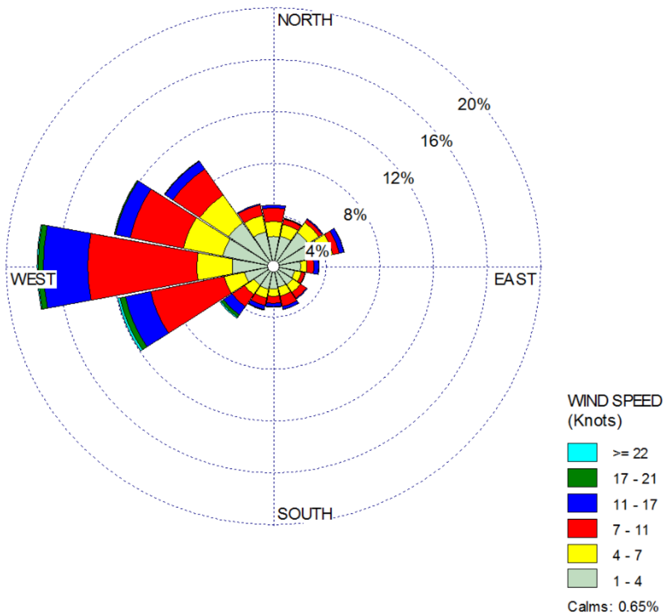


Figure A-9 2012-2014 Tucson Airport Data

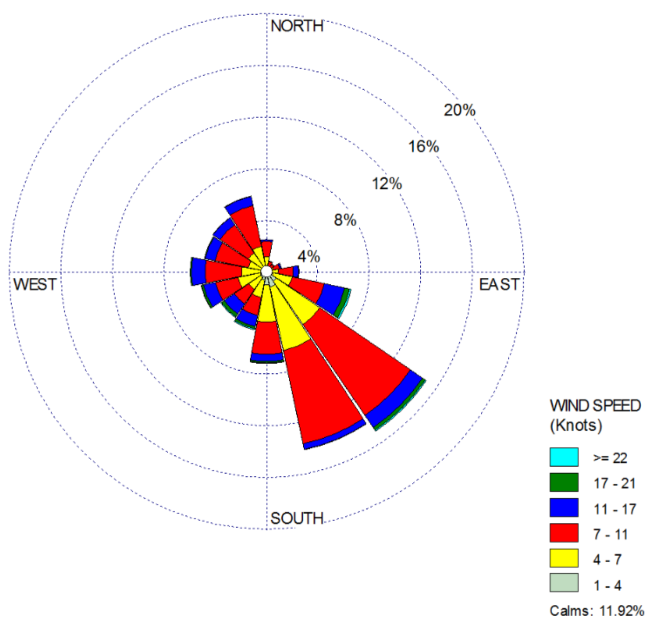
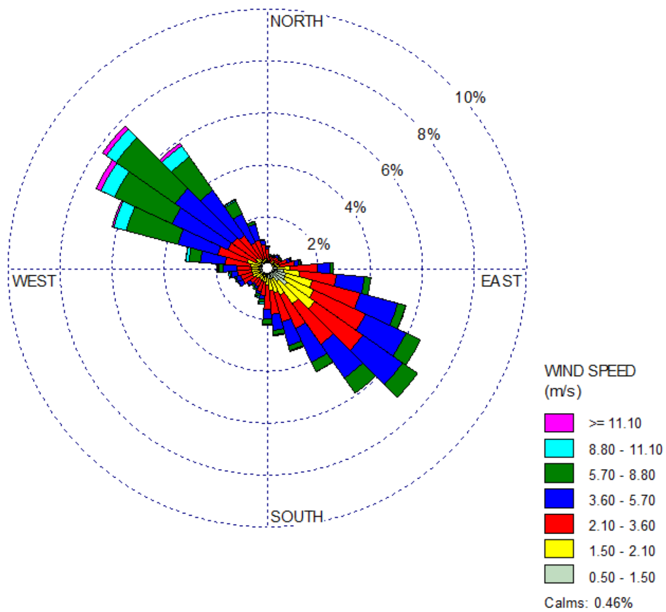


Figure A-10 2012-2014 Safford Airport Data



Appendix B: Using the ADJ_U* Option Formulation for Meteorological Data Processing for AEPCO

B.1 Introduction

The Arizona Department of Environmental Quality (ADEQ) is proposing the use of the beta adjusted surface friction velocity (ADJ_U*) modeling technique in the AERMET meteorological preprocessor (version 15181) in dispersion modeling of Apache Generating Station in Cochise, Arizona, owned and operated by Arizona Electric Power Cooperative (AEPCO). The modeling intends to demonstrate compliance with the 2010 1-hour sulfur dioxide (SO_2) National Ambient Air Quality Standards (NAAQS) for the Apache Generating Station under the 2010 1-hour NAAQS SO_2 Data Requirements Rule (DRR).

This technical report provides justification for the use of the ADJ_U* option in AERMET. Section 2 provide a brief description of the AEPCO Apache Generating Station. Section 3 reviews background of the development of the ADJ_U* option as well as the regulatory requirements of the application of this non-regulatory beta option. Section 4 performs a comprehensive review on published performance evaluations that compare the results of AERMOD with AERMET run with default options versus with the ADJ_U* option. Specifically, the review focuses on the circumstances associated with tall stacks with buoyant releases in complex terrain, which is an accurate emissions characterization of the Apache Generating Station. Section 5 presents a site-specific analysis for the Apache Generating Station, comparing the results of AERMOD with AERMET run with default options versus with the ADJ_U* option. ADEQ may further conduct additional analysis based on the EPA's comments and suggestions.

B.2 Source Overview

The Apache Generating Station is located approximately 3 miles south of the town of Cochise, Cochise County, Arizona. The Apache Generating Station consists of seven electric generating units: two coal/natural gas fired steam electric units (Unit 2 and Unit 3), a natural gas/fuel oil-fired steam electric, combined cycle unit (Unit 1), and four natural gas/fuel oil-fired turbines with a total generating capacity of 560 megawatts (MW). The Apache Generating Station has two tall stacks with a height of 122 m at a base elevation of 1279 m (the stack top height is around 1400 m).

Terrain within 8-10 km surrounding the facility is simple with flat or gently rolling features. Beyond this distance, the complex terrain (i.e., features with elevations above the height of the stack) begin. The Dragoon Mountains are located about 8 km south-west of the facility in Cochise County, Arizona. The range is about 40 km long, running on an axis extending south-south-east through Willcox, Arizona. Winchester Mountains and Galiuro Mountains are located about 35 km northwest of the facility, running on an axis extending south-south-east. Pinaleno Mountains are located about 40 km north of the facility, which cover 300 square miles (780 km^2) and are part of the Coronado National Forest, Safford ranger district. The terrains within 50 km east and south of the facility are mostly flat. The topography of the local area is depicted in Figure B-1.

The nearest complex terrain features are the Dragoon Mountains located about 8 km south-west of the facility and Gunnison Hills located about 10 km west of the facility. The two terrain features are of great interests to ADEQ, as preliminary AERMOD modeling with AERMET default options indicated that the controlling concentrations occurred in these areas. Figure B-2 illustrates the elevation profile from Gunnison Hills/Dragoon Mountains to the facility. As discussed, the setting of the Apache Generating Station can be characterized as tall stacks with buoyant releases in complex terrain.

Figure B-1 Terrain within 50 km of AEPCO Facility

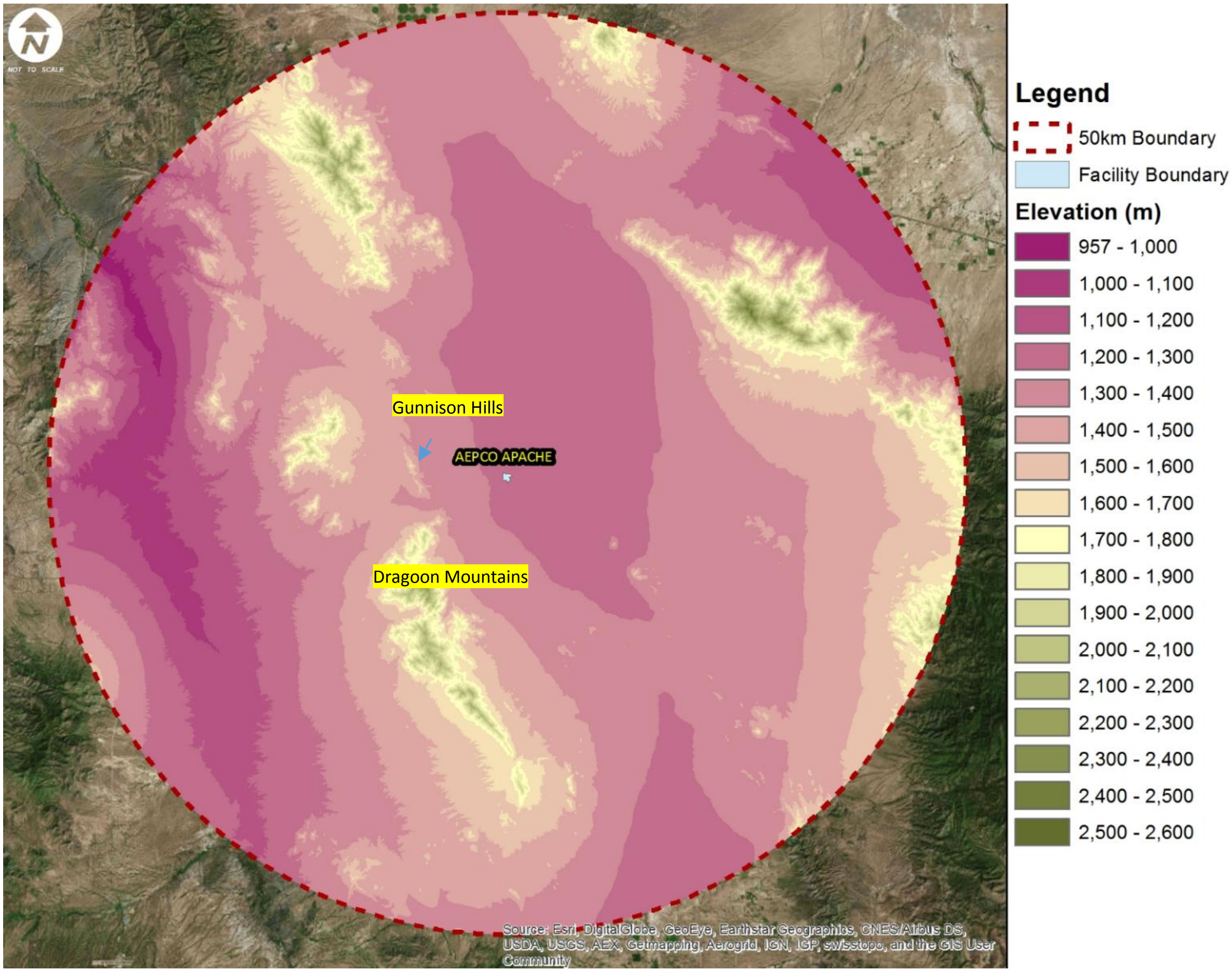


Figure B-2a Elevation Profile from Gunnison Hills Hill to AEPCO

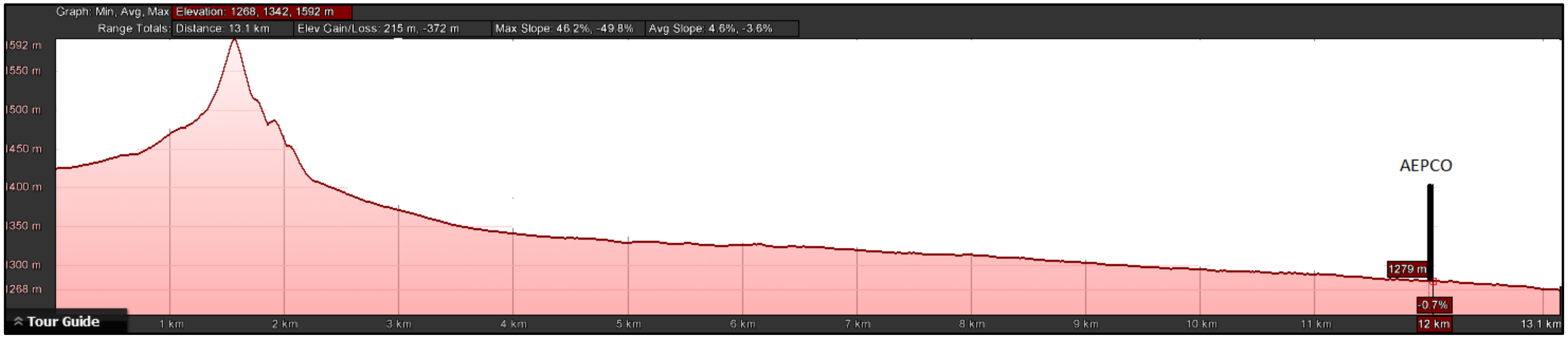
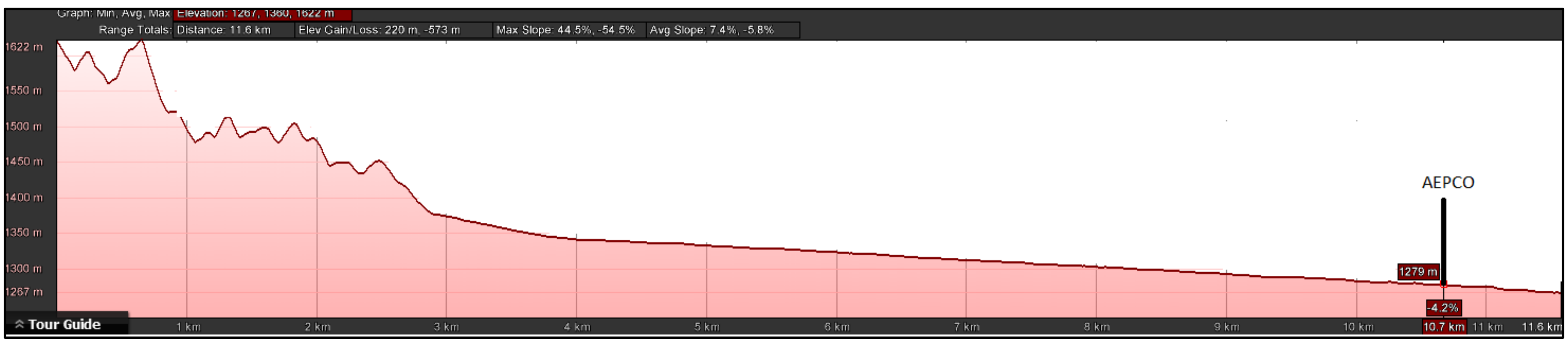


Figure B-2b Elevation Profile from Dragoon Mountains to AEPCO



B.3 Regulatory Background of the ADJ_U* Option

EPA has long known that AERMOD intended to over-predict ambient concentrations during stable boundary layer conditions under low wind speeds (Robinson and Brode, 2007). This over-prediction tendency has partially resulted from the underestimation of surface friction velocity (u*) in the AERMET meteorological processor. Several studies have demonstrated that AERMET with default options tend to significantly underestimate surface friction velocity (u*) for low wind speed conditions (Luhar and Rayner, 2009; Qian and Venkatram, 2010; Paine et al., 2015). For example, Luhar and Rayner (2009) compared u* estimates by AERMOD/AERMET with boundary-layer observations during field experiments and found that at very low wind speeds, u* was being underestimated by AERMET by as much as a factor of 2. As u* is a key parameter being used to estimate wind profiles, turbulence, and mixing depths, the underestimation of u* results in the underestimation of turbulence and mixing height in AERMOD for stable conditions. This underestimation reduces dispersion and leads to over-predicted concentrations (Hanna and Chowdhury, 2013).

In an effort to address AERMOD's propensity to overestimate concentration estimates during low wind speed stable conditions, EPA has introduced a beta adjust u* option (ADJ_U*) in Version 12345 of the AERMET meteorological processor (U.S. EPA, 2012), based on peer-reviewed work by Qian and Venkatram (2011) and Luhar and Rayner (2009). This option was subsequently updated in Versions 13350(U.S. EPA, 2013), 14134 (U.S. EPA, 2014a) and 15181 (U.S. EPA, 2015a).

EPA has conducted model performance evaluations of the ADJ_U* option and the current regulatory default AERMOD system (U.S. EPA, 2015b). The evaluations were performed against results from monitoring field studies to investigate diffusion under low wind speed conditions, and against results from a field study with a tall stack in complex terrain where stable and low wind speed conditions can also be important. The results of these evaluations indicated significant over-prediction using the regulatory default AERMET/AERMOD, and better performance - though still somewhat over-predicting - using the ADJ_U* option. Based in part on the results of these evaluations, EPA has proposed to designate the ADJ_U* option as the default regulatory formulation in AERMET for estimating u* under stable conditions with low wind speeds in the proposed revision to Appendix W (U.S. EPA, 2015c)

While it is very clear that EPA intends to incorporate the ADJ_U* option in AERMET into the regulatory version of the model, the ADJ_U* option is still a non-regulatory beta option at this stage. In December 2015, EPA issued a memorandum that clarified the approval process for non-regulatory beta options in AERMOD that have been proposed as regulatory options in the proposed revision to Appendix W (U.S. EPA, 2015d). This memorandum confirmed that the use of all non-default beta options, including the ADJ_U* option, in regulatory modeling requires formal approval from EPA Regional Office and is subject to the requirements of Section 3.2 of the current 2005 version of Appendix W.

Appendix W Section 3.2.2 provides three different conditions for which an alternative model is approvable (U.S. EPA, 2005). These three conditions are briefly summarized as:

- The alternative and preferred model provide equivalent estimates (Condition 1);
- The alternative model outperforms the preferred model when comparing the results to actual air quality data (Condition 2); or
- The preferred model is less appropriate or there is no preferred model for the given scenario (Condition 3).

ADEQ relies on Condition 2 for the basis of this alternative model approval. As will be presented in the following sections, field studies using measured air quality data have clearly demonstrated that the current regulatory default AERMOD system significantly over-predicts ambient concentrations during stable boundary layer conditions under low wind speeds. Comparatively, the use of AERMET version 15181 with the ADJ_U* option improves model performance for AERMOD.

B.4 Performance Evaluations on the ADJ_U* Option vs. Default Option

In the past several years, there has been increased study on the performance of AERMOD low wind beta options (including the ADJ_U* option) for low-wind stable conditions. The available studies include:

<u>EPA's evaluations on the ADJ_U* option:</u>

- Oak Ridge (low-level, non-buoyant release, complex terrain) (U.S. EPA, 2015b);
- Idaho Falls (low-level, non-buoyant release, complex terrain) (U.S. EPA, 2015b);
- Lovett (tall stacks, complex terrain) (U.S. EPA, 2015b); and
- Cordero Rojo (low-level, non-buoyant fugitive release, simple terrain) (U.S. EPA, 2014b).

<u>Peer-reviewed work on the ADJ_U* option by Paine et al., 2015:</u>

- Mercer County, North Dakota (tall stacks, both simple and complex terrain); and

- Gibson (tall stacks, simple terrain).

<u>EPA's Model Clearinghouse concurrence memorandum regarding the use of the ADJ_U* option as an alternative model:</u>

- DGLLC, EPA Region 10 (low-level, non-buoyant fugitive release/tall stacks, complex terrain) (U.S. EPA, 2016a);
- Schiller, EPA Region 1 (tall stacks, complex terrain) (U.S. EPA, 2016b);
- Wagner, EPA Region 3 (tall stacks, complex terrain) (U.S. EPA, 2016c); and
- Heskett, EPA Region 8 (tall stacks, complex terrain) (U.S. EPA, 2016d)

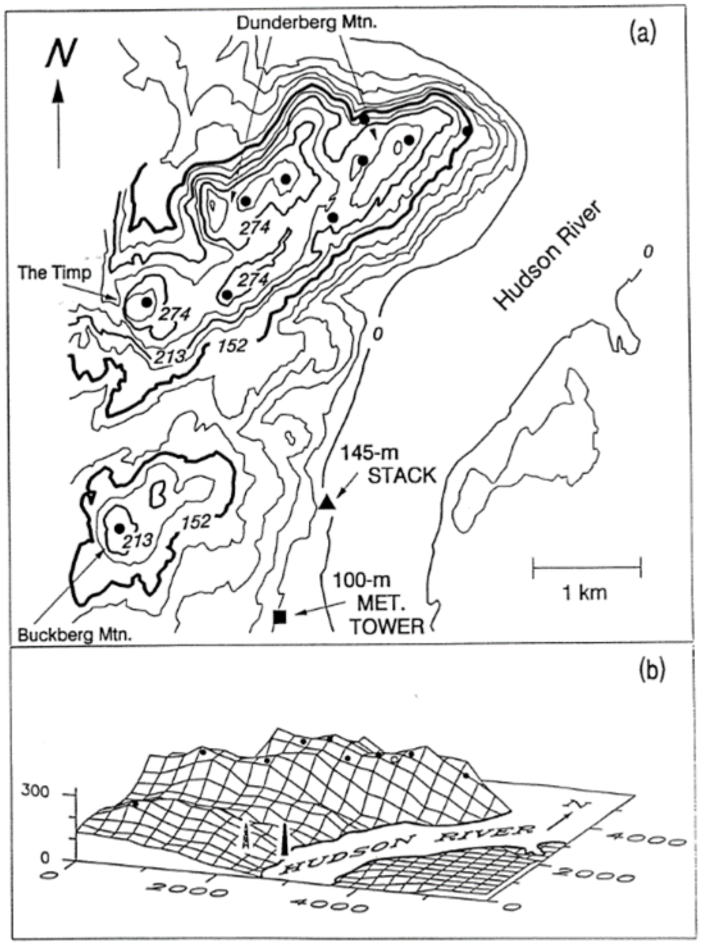
The Oak Ridge, Idaho Falls, and Cordero Rojo studies are less directly applicable to AEPCO because the release heights from those studies are low-level, whereas AEPCO release buoyant plumes from tall stacks. The Gibson study is also limited in relevance to AEPCO because of the simple terrain of the area around Gibson. Although the DGLLC project includes tall stacks, its primary ambient air impact issues are related to particulate concentrations from low-release fugitive emission sources, which are irrelevant to AEPCO.

The remaining studies (Lovett, Mercer County, Schiller, Wagner, and Heskett) are directly relevant to AEPCO due to similarities in terrain (complex) and emission characteristics (tall stacks with buoyant releases). Therefore, the following review focuses on these three studies.

B.4.1 Lovett Database

The Lovett database consists of 2,595 hours of ambient SO_2 monitoring data from 12 monitors near the Lovett Power Plant, located in a rural area with mountainous terrain along the Hudson River in New York. Most of the monitors had elevations above the release height of Lovett's 145 m stack, and at distances from the source of 1-3 km (Figure B-3). The Lovett database also includes a 100m meteorological tower with wind speed, wind direction, sigma-theta and temperature collected at the 10m, 50m, and 100m levels. In addition, sigma-w was also collected at the 10m and 100m levels.

Figure B-3 Monitoring Network Used for the Lovett Complex Terrain Model Evaluation Study (U.S. EPA, 2015b)



EPA conducted model performance evaluations of the ADJ_U* option and the current regulatory default AERMOD system with three different meteorological datasets (U.S. EPA, 2015b):

- Full site-specific meteorological data;
- Site-specific meteorological data without the temperature profile; and
- Site-specific meteorological data without the temperature profile and turbulence data.

EPA found that including the ADJ_U* option with full onsite meteorological data shows a slight improvement in model performance. In fact, the modeled concentrations with the ADJ_U* option are slightly higher than those with the regulatory default options. Therefore, it is likely that the modeled impacts at near-by elevated receptors (within a distance of several kilometers) would be higher using the ADJ_U* option.

Using site-specific meteorological data without the temperature profile /turbulence data, EPA found that the model with default options over-predicted ambient concentrations. The use of the ADJ_U* option significantly reduced the over-prediction bias resulted from the default options.

B.4.2 Mercer County, North Dakota Database

The Mercer County ND database consists of 4-years of hourly emission data from 13 tall stacks (> 60 m) as well as monitoring data from 5 monitors in the vicinity of the Dakota Gasification Company plant and the Antelope Valley Station power plant in an area of both simple and elevated terrain (Figure B-4). The elevation of the four monitors (DGC 12, DGC 14, DGC 16 and Beulah) ranges from 590 m to 630 m while the elevation of DGC 17 is as high as 710 m. Among the 13 tall stacks, 12 stacks have a stack top height above 650 m. In general, DGC17 is located in an elevated complex terrain setting while the other four monitors are located in a relatively flat and simple terrain setting.

Figure B-4 Terrain Features in the Mercer County ND Model Performance Study (Adapted from Paine et al, 2015)

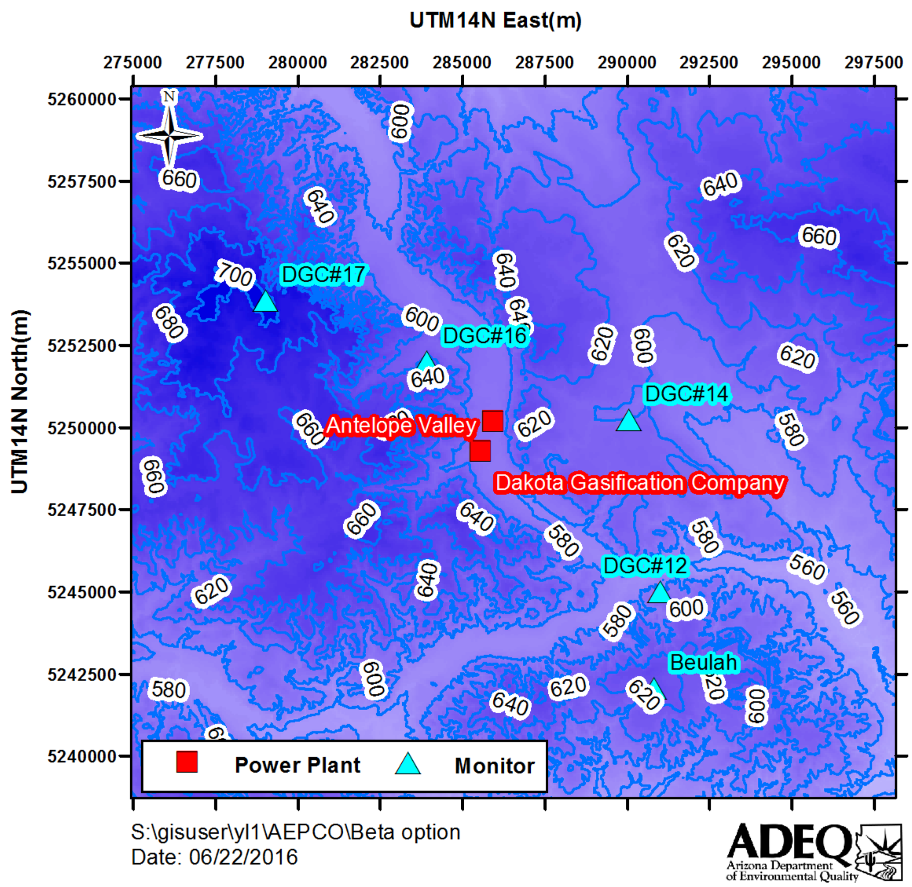
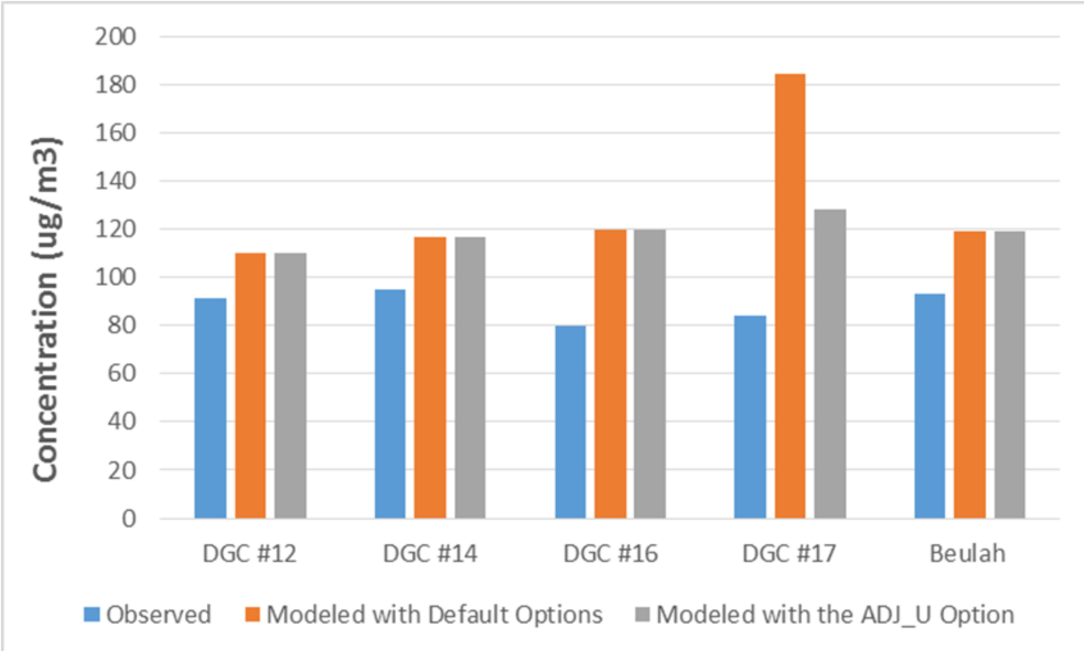


Figure B-5 presents the results of the model performance evaluation for Mercer County ND database. As indicated in Figure B-2, AERMOD over-predicted the ambient impacts regardless of whether the AERMET default options or the ADJ_U* option was used. In particular, AERMOD with AERMET default options significantly over-predicted the ambient impacts at DGC-17, as the modeled 99th percentile 1-hour monitoring concentration of 184.48 µg/m^3 is significantly higher than the observation concentration of 83.76 µg/m^3 by a factor of 2.2. The use of the ADJ_U* option in AERMET significantly improved model performance, while still remaining conservative, and reduced the over-prediction to a factor of 1.53 with a predicted concentration of 127.93 µg/m^3. In contrast, for the monitors in simple terrain (DGC 12, DGC 14, DGC 16 and Beulah), the modeled results with the ADJ_U* option were identical to those obtained from AERMET default options, indicating that the incorporation of the ADJ_U* in AERMET has virtually no effect on the predicted concentrations for receptors with lower elevations.

Figure B-5 Modeled vs. Monitoring Concentrations in Mercer County ND Model Performance Study (Adapted from Paine et al., 2015)



Paine et al. (2015) also found that the majority of peak modeled concentrations at DGC-17 with AERMET default options occurred during stable, light wind conditions. However, with the incorporation of the ADJ_U* option in AERMET, the majority of peak modeled concentrations were found to occur during daytime with light to moderate winds, which were more consistent with the meteorological conditions for actual peak observations.

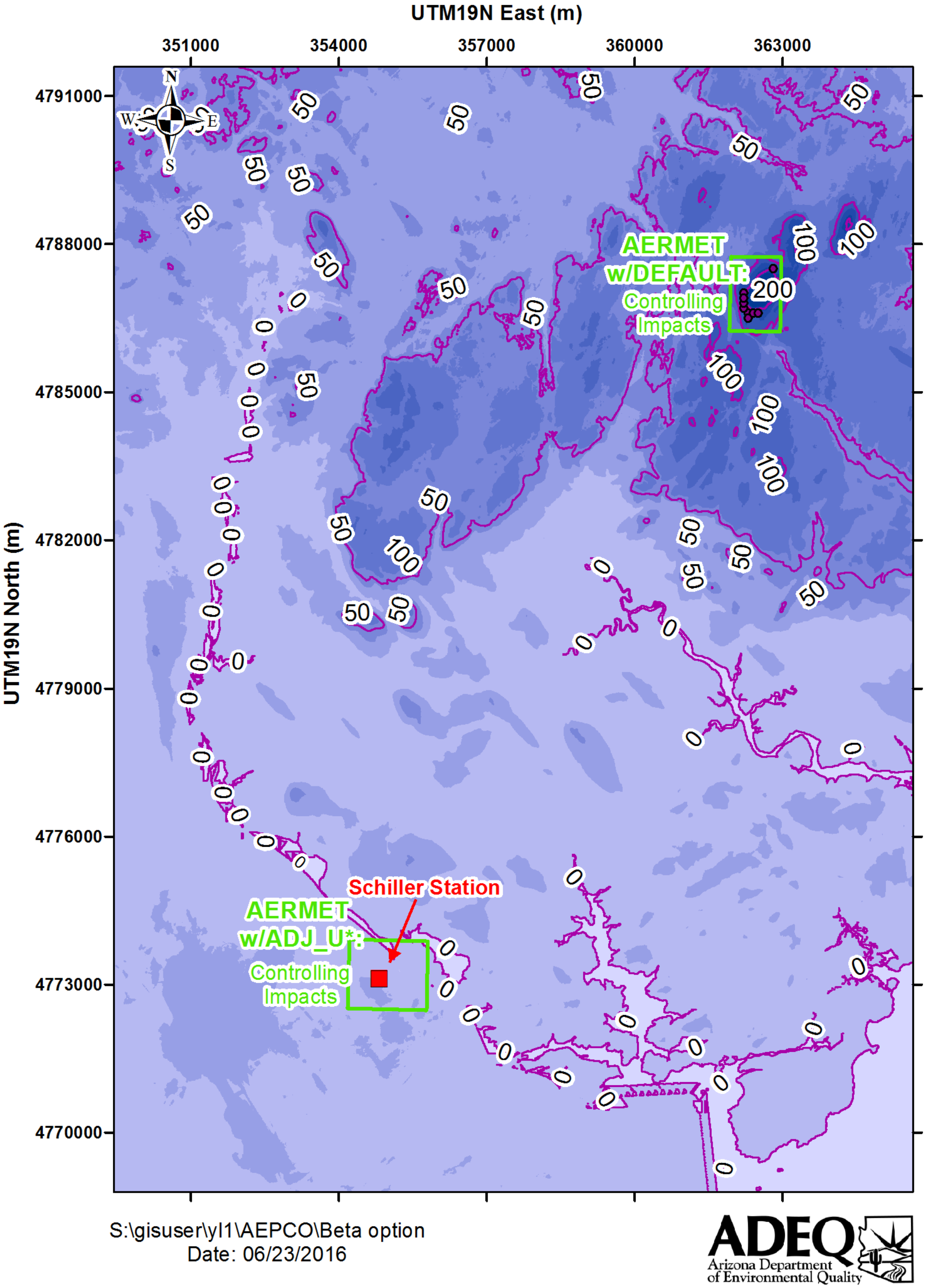
B.4.3 Schiller Study

On April 29, 2016, the EPA's Model Clearinghouse approved a request from EPA Region 1 for use of the ADJ_U* option in AERMET for modeling for the 2010 1-hour sulfur dioxide standard at Schiller Station in Portsmouth, New Hampshire (U.S. EPA, 2016b).

Schiller has three tall stacks ranging approximately 68-70 m in height at elevations of 6.4-7.3 m. Terrain within around 10 km around Schiller is simple with flat or gently rolling features; however, terrain becomes increasingly complex as an isolated terrain feature (Mt. Agamenticas), with a peak elevation about 200 m above the stack base, is located about 15km north-northeast from the Schiller Station (Figure B-6).

As reported in the model sensitivity analysis for Schiller (U.S. EPA R1, 2016e), using AERMOD with AERMET default options led to the controlling concentrations associated with receptors at a distance, in complex terrain. Specifically, the top ten 5-year average 4th highest maximum daily 1-hour impacts (herein, “top 10 impacts”) were predicted to occur near the peak of Mt. Agamenticus, at locations with elevations ranging from 129 m to 147 m. These top 10 impacts, located within distant terrain, were found to occur during low wind, stable conditions. The five-year average u* values corresponding to these top 10 impacts were substantially low, ranging from 0.057 m/s to 0.069 m/s. When the ADJ_U* option was used in AERMET, these u* values significantly increased by 62-96% (0.104-0.114 m/s). As a result of the increase in u* from the use of the ADJ_U*option, the 5-year average 4th highest maximum daily 1-hour impacts at these receptors on Mount Agamenticus dropped by 57-64%.

Figure B-6 Terrain Features Surrounding Shiller Generating Station (Adapted from U.S.EPA R1, 2016e)



Moreover, the application of the ADJ_U* option in AERMET shifted the controlling impact areas from remote Mt. Agamenticus to Eliot, Maine that is located within 1 km of Schiller. For the nearby controlling receptors, the top 10 impacts occurred at hours of relatively higher u* and these values were unchanged with the use of ADJ_U* option compared to AERMET run with default options.

The sensitivity analysis further revealed that the ADJ_U* option only had a significant impact on the model concentrations at receptors with elevations at or above the height of release (≥ 85 m), mainly due to the fact that stable conditions with low wind speeds were the controlling meteorological conditions for these receptors. In contrast, the use of ADJ_U* option had virtually no effect on the model concentrations at receptors below 85 m, indicating that stable conditions with low wind speeds are not controlling meteorological conditions at elevations below the release height.

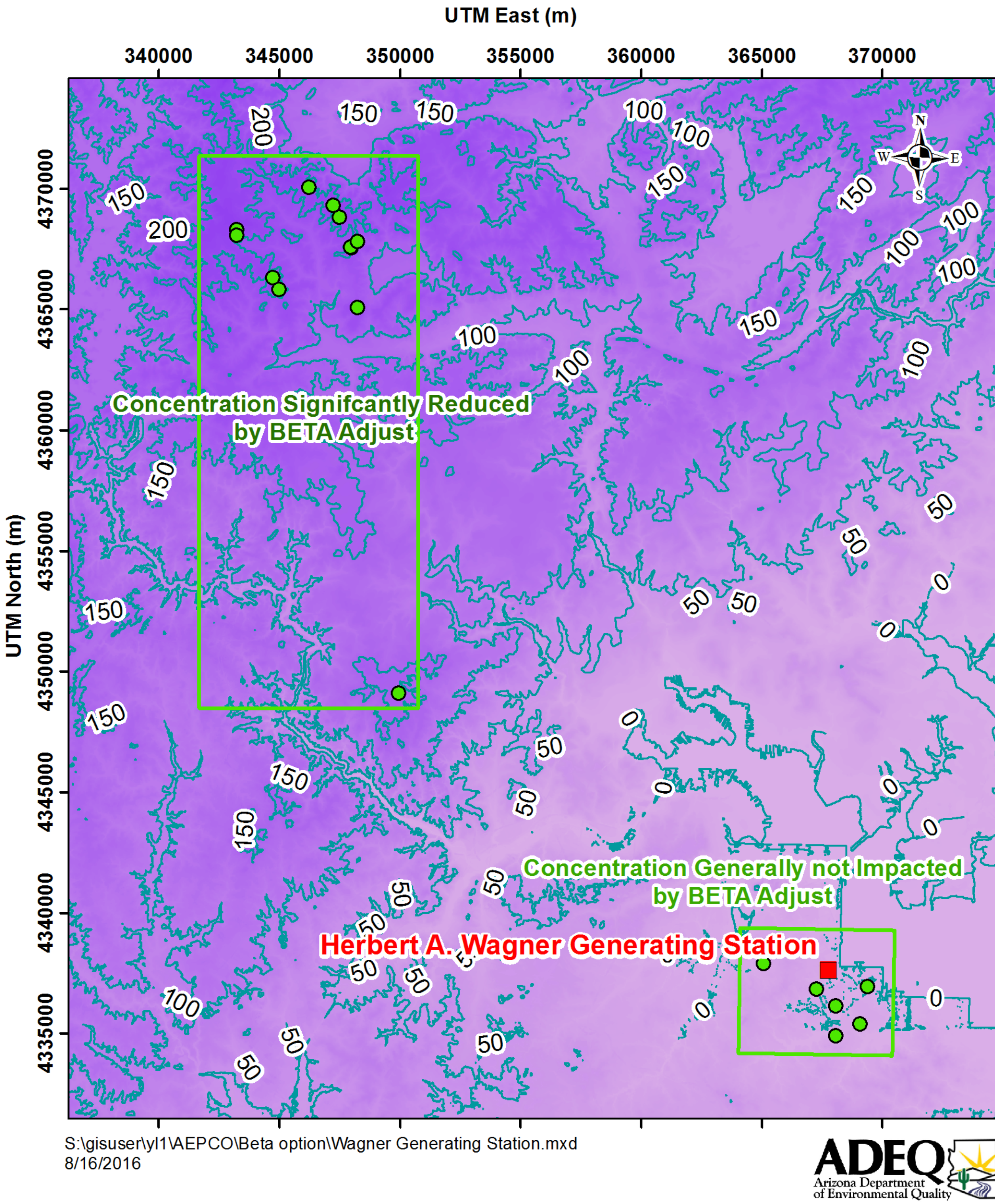
The sensitivity analysis also compared predicted concentrations vs. monitoring concentrations at two nearby SO_2 monitor that are located in simple terrain within 5 km of Schiller. However, due to the lack of monitoring data in complex terrain, this analysis did not provide direct evidence to demonstrate that AERMOD with AERMET default options over-predicts the ambient impacts at complex terrain and the use of the ADJ_U* option improves the model performance. Instead, the Schiller study still heavily relied upon the Lovett study (U.S. EPA, 2015b) as well as the Mercer County ND study (Paine et al., 2015) regarding the model performance for complex terrain.

B.4.4 Wagner Study

On June 20, 2016, the EPA's Model Clearinghouse approved a request from EPA Region 3 for use of the ADJ_U* option in AERMET for modeling of the 2010 1-hour sulfur dioxide standard at the Herbert A. Wagner Generating Station (Wagner) located near the City of Baltimore (U.S. EPA, 2016c).

Wagner is located in northern Ann Arundel County, just outside Baltimore, Maryland. The sources in the Wager modeling analysis include four steam electric generating units (EGUs) at Wagner as well as other nearby EGUs. All modeled sources lie on the Atlantic Coastal Plane physiographic region and are less than 10 meters above mean sea level (AMSL). Stack heights for all sources are relatively tall ranging from 87 to 122 meters; the lowest effective stack elevation (stack + base height) is 93 meters. Distant terrain features are located at around 20 km and between 34 and 37 km northwest of the Wagner facility with a peak elevation approximately 200 meters above the stack base, with relatively flat or gradually sloping terrain between the source and those terrain features (Figure B-7).

Figure B-7 Terrain Features Surrounding Herbert A. Wagner Generating Station (Adapted from U.S. EPA R3, 2016f)



As reported in the model sensitivity analysis for Wager (U.S. EPA R3, 2016f), utilizing AERMOD with AERMET default options, violating receptor locations occurred in the immediate vicinity of Wagner and in several portions of Baltimore County west and northwest of the City of Baltimore. The nearby violating receptors are located in the areas within 5 km of Wagner at elevations between 0 and 10 m AMSL. For these nearby receptors, the highest concentrations occurred during daylight hours with unstable conditions. In contrast, the far-off violating receptors are generally located in terrain above the lowest effective stack height (93 m) and at distances ranging from approximately 20 km to 37 km from Wagner. For these far-off receptors, the highest model concentrations occurred during the overnight hours (with low wind speed, stable conditions).

The application of the ADJ_U* option eliminated all far-off violating receptors but nearby violating receptors were retained. When the ADJ_U* option was used in AERMET, the u* values associated with stable conditions for the far-off receptors significantly increased by 2-3 times (from 0.026-0.081 m/s to 0.094-0.150 m/s). Therefore, the modeled concentrations for these far-off receptors significantly dropped. In contrast, the use of the ADJ_U* option had virtually no effect on the u* values associated with unstable conditions. As a result, peak model concentrations for the nearby receptors were identical between the default and the ADJ_U* runs.

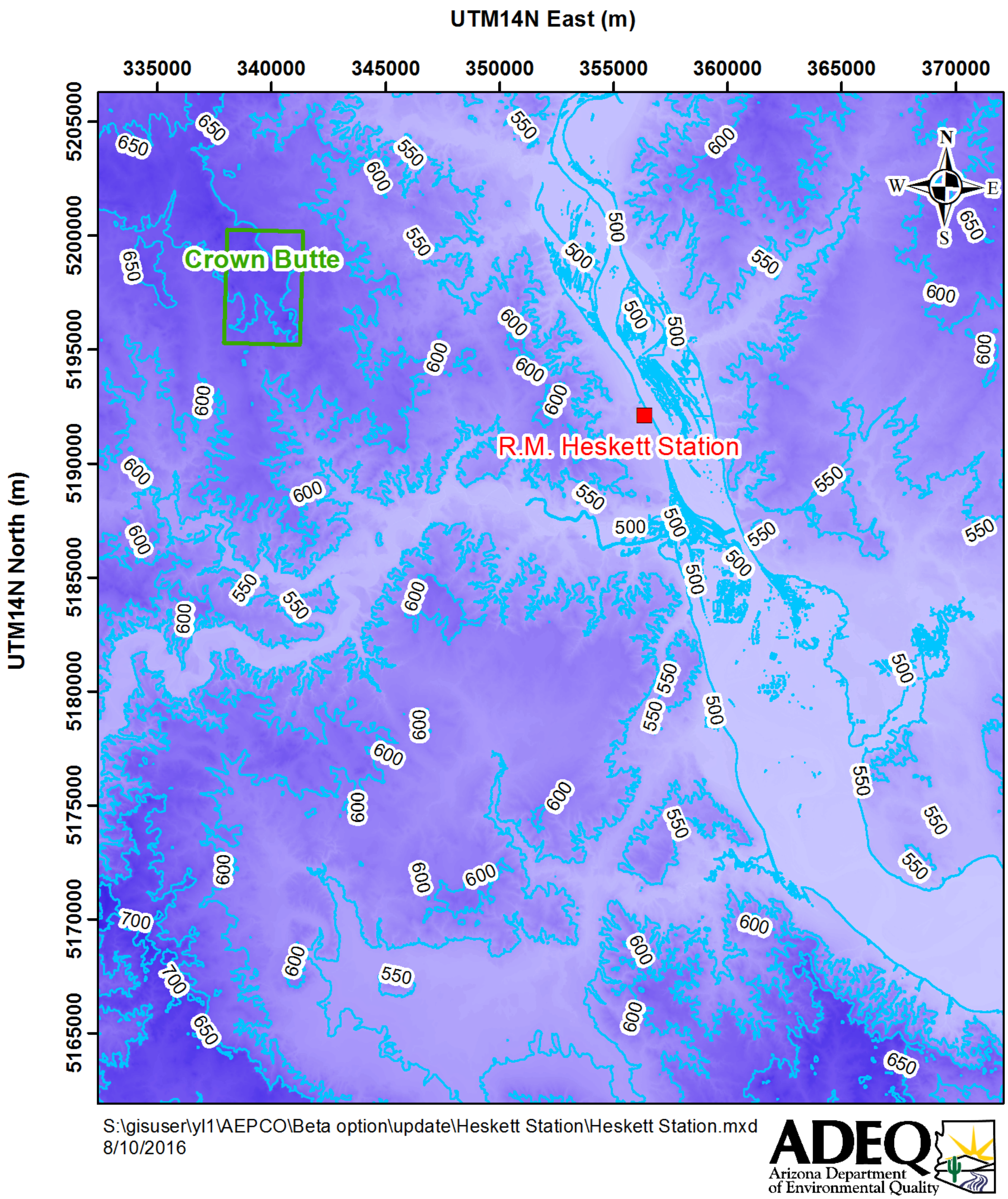
There is no evaluation database analysis for Wagner. Instead, the Wagner study heavily relied upon the Lovett study (U.S. EPA, 2015b) regarding the model performance for tall stacks in complex terrain.

B.4.5 Heskett Study

On August 1, 2016, the EPA's Model Clearinghouse approved a request from EPA Region 8 for use of the ADJ_U* option in AERMET for modeling of the 2010 1-hour sulfur dioxide standard at the Montana-Dakota Utilities Company's R.M. Heskett Station (Heskett), which is located about 10 km northwest of Bismarck, North Dakota (U.S. EPA, 2016d).

Heskett has two tall stacks with a height of 91 m at an elevation of 505 m. Heskett is situated along the west bank of the Missouri River where the topography is dominated by the Missouri Plateau. In general, the Missouri Plateau consists of rolling to hilly plains (Figure B-8). However, there is a prominent bluff approximately 15 km west-northwest of Heskett. The bluff, known as Crown Butte, peaks at approximately 707 m AMSL.

Figure B-8 Terrain Features Surrounding R.M. Heskett Station (Adapted from U.S. EPA R8, 2016g)



As reported in the model sensitivity analysis for Heskett (U.S. EPA, 2016g), using AERMOD with AERMET default options led to the controlling concentrations associated with receptors at a distance of approximately 15 km, in complex terrain. Specifically, the top ten 3-year average 4th highest maximum daily 1-hour impacts were predicted to occur at Crown Butte. These top 10 modeled impacts, located within distant terrain, were found to occur during low wind speed, stable conditions. The three-year average u* values corresponding to these top 10 impacts were substantially small, ranging from 0.029 m/s to 0.050 m/s. When the ADJ_U* option was used in AERMET, these u* values significantly increased with values ranging from 0.074 m/s to 0.105 m/s. As a result, the 3-year average 4th highest maximum daily 1-hour impacts at these receptors at Crown Butte dropped by 47-61%.

Using the AERMET ADJ_U* option and AERMOD default options, the locations of the receptors corresponding to the top 10 modeled impacts were split between those at Crown Butte (4 receptors) and within less than 1 km of Heskett (6 receptors). The four highest modeled impacts, occurring at Crown Butte, were still associated with low wind speed, stable conditions. In contrast, the six highest modeled impacts, occurring near Heskett, were associated with daylight hours with relatively higher u* (0.21-0.34 m/s). The design concentration across the modeling domain for Heskett still occurred at distant complex terrain but the design concentration significantly dropped compared to the default AERMET option.

The sensitivity analysis further revealed that the ADJ_U* option only had a significant impact on the model concentrations at receptors in complex terrain while it had virtually no effect on the model concentrations at receptors in flat terrain. These findings were consistent with those of the Schiller study.

There is no evaluation database analysis for Heskett. Instead, the Heskett study focused on the comparison with Mercer County, North Dakota evaluation database since significant similarities existed between the surrounding terrain of the Heskett facility and the Mercer County North Dakota evaluation study.

B.5 Model Sensitivity Analysis for AEPCO Apache Generating Station

To further demonstrate the appropriateness and applicability of the ADJ_U* option for the AEPCO case, ADEQ performed a model sensitivity analysis for AEPCO, similar to what the Schiller study and the Heskett study have done before.

B.5.1 Sensitivity of Model Controlling Concentrations to the ADJ_U* Option

Top 10 Model Impacts under AERMET Default Option

Using AERMOD with AERMET default options, ADEQ found that the controlling concentrations occurred on receptors within distant terrain. Specifically, the top ten 3-year average 4th highest maximum daily 1-hour impacts were predicted to occur at the receptors at Gunnison Hills and the Dragoon Mountains, around 8-10 km west or southwest of the facility (Figure B-9). The elevation of the top 10 receptors ranged from 1470 m to 1504 m, all above the stack top height of 1400 m at the Apache Generating Station. These top 10 model impacts within distant terrain were found to occur during low wind, stable conditions (Table B-1). As shown in Table 1, the u* values corresponding to these top 10 model impacts were extremely low, ranging from 0.023 m/s to 0.079 m/s. When the ADJ_U* option instead of default options was used in AERMET, the three-year average u* values corresponding the top 10 model impacts (under AERMET Default Options) significantly increased from 0.041-0.069 to 0.100-0.208 m/s (Table B-2). As a result of the increase in u* from the use of the ADJ_U*option, the three-year average 4th highest maximum daily 1-hour impacts at these distant receptors dropped by 58-75%.

Figure B-9 Locations of Top Ten Predicted 3-year Average 4th Highest Maximum Daily 1-hour Concentrations Using AERMOD V15181 and AERMET V15181 with Default Options

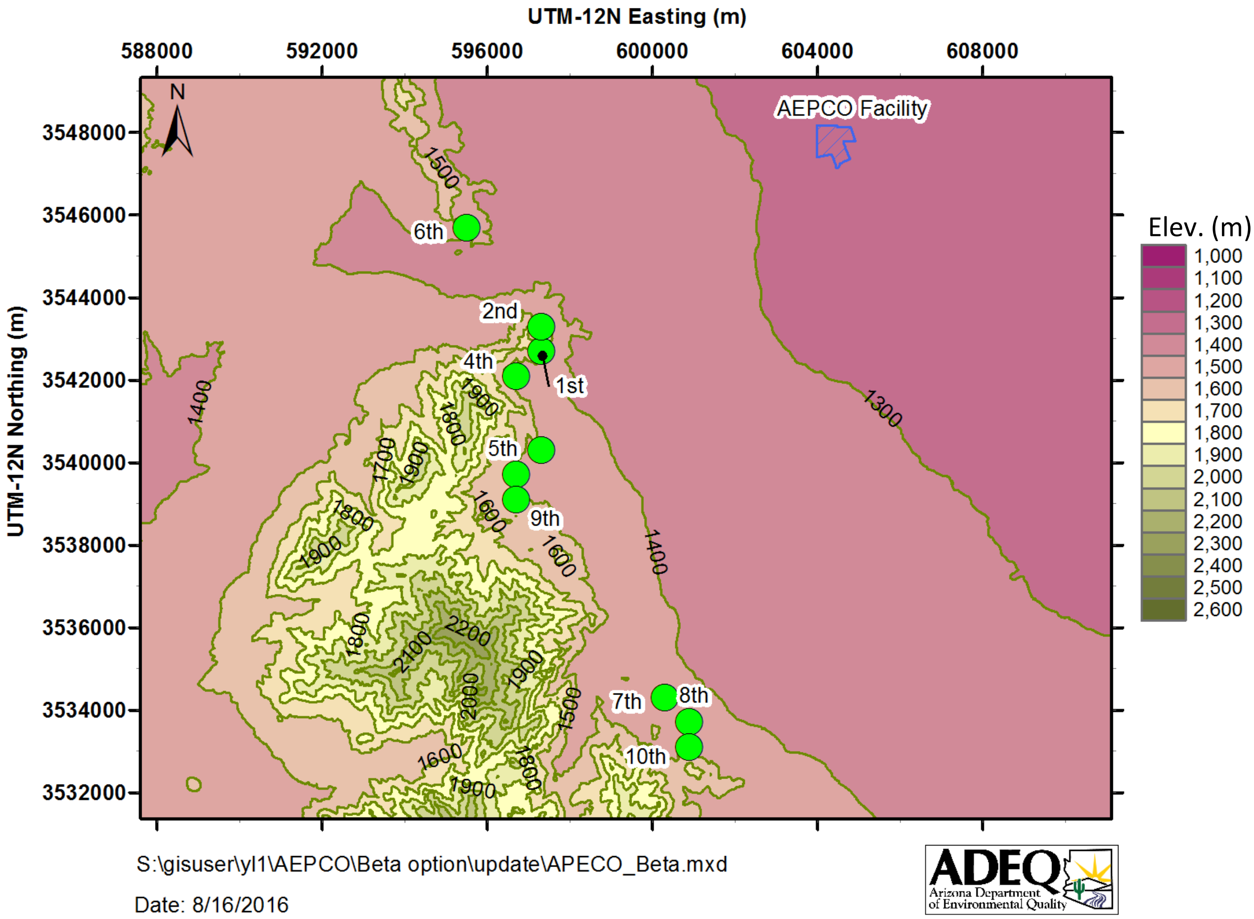


Table B-1 Top 10 Predicted 3-year Average 4th Highest Maximum Daily 1-hour SO_2 Concentrations Using AERMOD v15181 and AERMET v15181 Default Options

Rank	UTM-EAST (m)	UTM-North (m)	Year	4th Highest Max Daily 1-hour SO_2 Conc. ($\mu g/m^3$)	u* (m/s)	Hour Of Day	Wind Speed (m/s)	Monin-Obukhov length (m)
1st Highest	597300	3542700	2012*	145.12	0.044	17	1.1	5.8
			2013*	425.61	0.023	6	0.5	2.2
			2014*	522.73	0.055	6	1.2	5.4
2nd Highest	597300	3543300	2012*	203.33	0.032	2	0.7	3.3
			2013*	370.42	0.055	18	1.3	5.2
			2014*	479.33	0.055	19	1.2	5.5
3rd Highest	596700	3539700	2012*	118.36	0.036	17	0.9	4.8
			2013*	407.07	0.051	3	1.1	5.0
			2014*	448.06	0.040	5	1	3.5
4th Highest	596700	3542100	2012*	128.43	0.065	20	1.4	6.5
			2013*	311.61	0.079	19	1.7	7.7
			2014*	502.78	0.035	5	0.8	3.4
5th Highest	597300	3540300	2012*	144.03	0.065	23	1.4	6.3
			2013*	368.79	0.068	20	1.7	6.1
			2014*	419.77	0.075	1	1.9	6.7
6th Highest	595500	3545700	2012*	156.54	0.059	24	1.4	5.5
			2013*	352.34	0.056	1	1.2	5.5
			2014*	385.71	0.047	7	1	4.5
7th Highest	600300	3534300	2012*	89.51	0.045	5	1	4.4
			2013*	347.77	0.041	5	0.9	4.0
			2014*	444.92	0.036	6	0.8	3.5
8th Highest	600900	3533700	2012*	88.59	0.039	20	1.1	3.3
			2013*	367.55	0.042	6	1	4
			2014*	408.94	0.045	20	1	4.4
9th Highest	596700	3539100	2012*	87.89	0.051	5	1.1	5.0
			2013*	415.23	0.055	20	1.2	5.4
			2014*	353.80	0.042	4	0.9	4.0
10th Highest	600900	3533100	2012*	85.51	0.057	6	1.6	4.7
			2013*	363.63	0.042	6	1	4.0
			2014*	403.62	0.041	6	0.9	4.0

Note: As stated in Section 6.1.3, the meteorological data in 2012*, 2013* and 2014* were actually from 2009, 2010 and 2011, respectively.

Table B-2 Comparison of Predicted Concentrations with Default Options vs. ADJ_U* at Receptors with Top ten 3-year Average 4th Highest Maximum Daily 1-hour SO_2 Concentrations (Top 10 Concentrations were Based on Model Runs with AERMOD/AERMET Default Options)

Rank	UTM-EAST (m)	UTM-North (m)	Elev. (m)	3-Year Ave. Conc. AERMET W/Default (µg/m³)	3-Year Ave. Conc. AERMET W/ADJ_u* (µg/m³)	Decrease in Conc. (%)	3-year average u* AERMET w/ Default Options	3-year average u* AERMET w/ ADJ_u*
1st Highest	597300	3542700	1504	364.487	140.91	-61	0.041	0.121
2nd Highest	597300	3543300	1475	351.027	112.63	-68	0.047	0.109
3rd Highest	596700	3539700	1489	324.497	107.03	-67	0.042	0.115
4th Highest	596700	3542100	1486	314.273	132.89	-58	0.060	0.208
5th Highest	597300	3540300	1470	310.863	116.78	-62	0.069	0.122
6th Highest	595500	3545700	1474	298.197	92.85	-69	0.054	0.108
7th Highest	600300	3534300	1494	294.067	75.89	-74	0.041	0.111
8th Highest	600900	3533700	1481	288.360	71.73	-75	0.042	0.100
9th Highest	596700	3539100	1490	285.640	98.04	-66	0.049	0.112
10th Highest	600900	3533100	1480	284.253	69.69	-75	0.047	0.125

Top 10 Model Impacts under the ADJ_U* Option

Using the ADJ_U* option, ADEQ found that the top ten 3-year average of the 4th highest maximum daily 1-hour SO_2 impacts occurred at eight receptors at Dragoon Mountains and two receptors in the vicinity of the Apache Generating Station (Figure B-10 and Table B-3). ADEQ further investigated the locations of the top 50 receptors and found that 39 receptors among the top 50 receptors were located in the vicinity of the Apache Generating Station. This indicates that, with the ADJ_U* option, the locations of highest model impacts tend to shift from distant complex terrain to areas near the facility. This finding was consistent with the Schiller and Heskett studies discussed in section B 4.3 and B4.5, respectively.

For the eight receptors at Dragoon Mountains with the elevation of 1470-1564 m, the critical modeled impacts were still associated with low wind speed, stable conditions. On the contrary, for the two receptors in the vicinity of the source with an elevation of around 1285 m, the critical impacts occurred during daytime with light to moderate winds. Relatively higher u* values (0.21-0.24) corresponding to these hours indicated that stable conditions with low wind speeds are not controlling meteorological conditions for the nearby receptors that are not associated with the distant terrain features. As expected, the application of the ADJ_U* option resulted in significant increases in the u* values for receptors at Dragoon Mountains but had no effect on the u* values for receptors in close proximity to the facility (Table B-3).

Figure B-10 Locations of Top ten Predicted 3-year Average 4th Highest Maximum Daily 1-hour Concentration Using AERMOD V15181 and AERMET V15181 with ADJ_U*

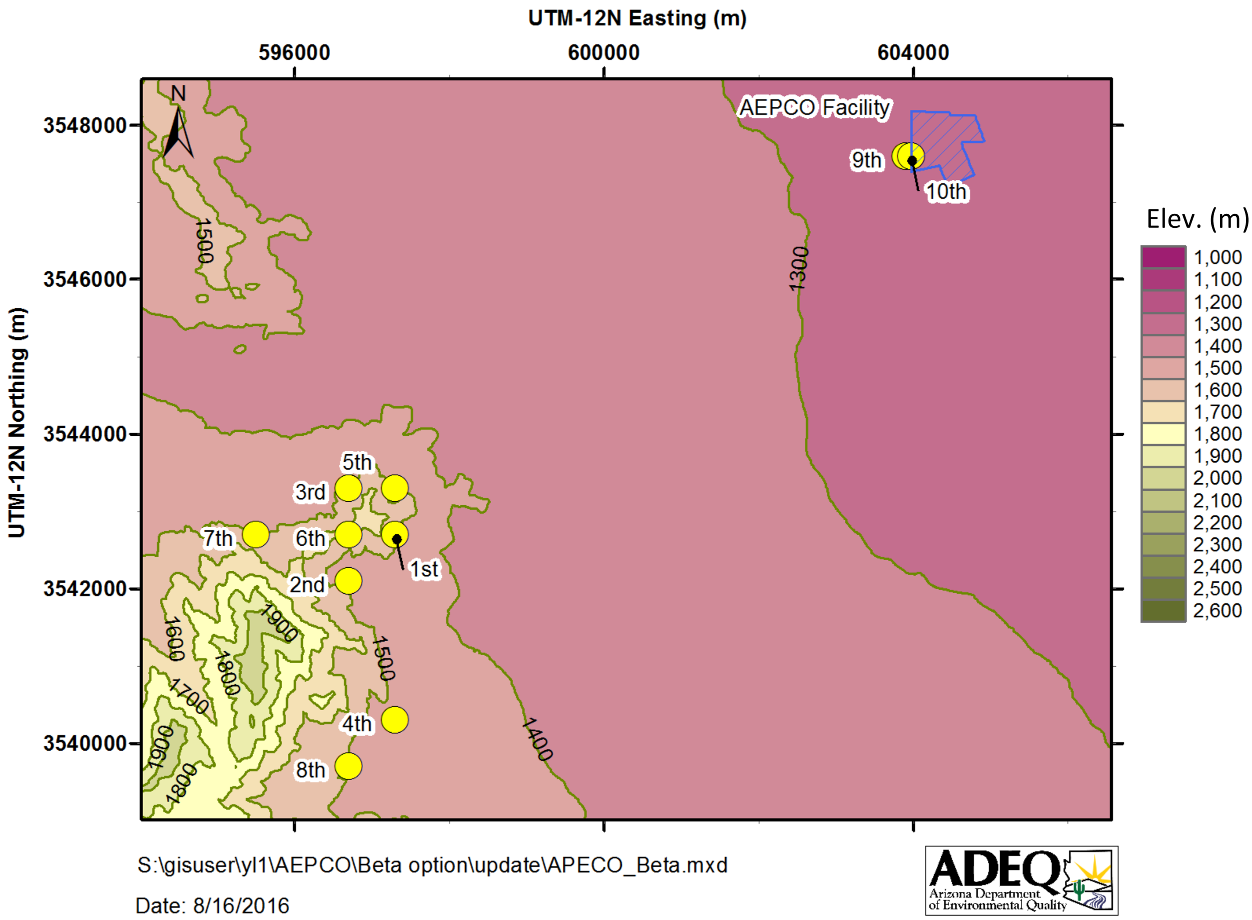


Table B-3 Comparison of Predicted Concentrations with Default Options vs. ADJ_U* at Receptors with Top Ten 3-year Average 4th Highest Maximum Daily 1-hour SO_2 Concentrations (Top Ten Concentrations were Based on Model Runs with AERMOD/AERMET ADJ_U* Option)

Rank	UTM-EAST (m)	UTM-North (m)	Elev. (m)	3-Year Ave. Conc. AERMET W/ADJ_U* (μg/m³)	3-year Ave. u* AERMET w/Default	3-year Ave. u* AERMET W/ADJ_u*
1st Highest	597300	3542700	1504	140.91	0.041	0.121
2nd Highest	596700	3542100	1486	132.89	0.06	0.125
3rd Highest	596700	3543300	1521	130.15	0.037	0.103
4th Highest	597300	3540300	1470	116.78	0.069	0.122
5th Highest	597300	3543300	1475	112.63	0.047	0.109
6th Highest	596700	3542700	1564	110.43	0.069	0.101
7th Highest	595500	3542700	1509	109.48	0.048	0.101
8th Highest	596700	3539700	1489	107.03	0.042	0.115
9th Highest	603900	3547600	1285	105.69	0.217	0.217
10thHighest	603977.52	3547599.05	1284	104.84	0.235	0.235

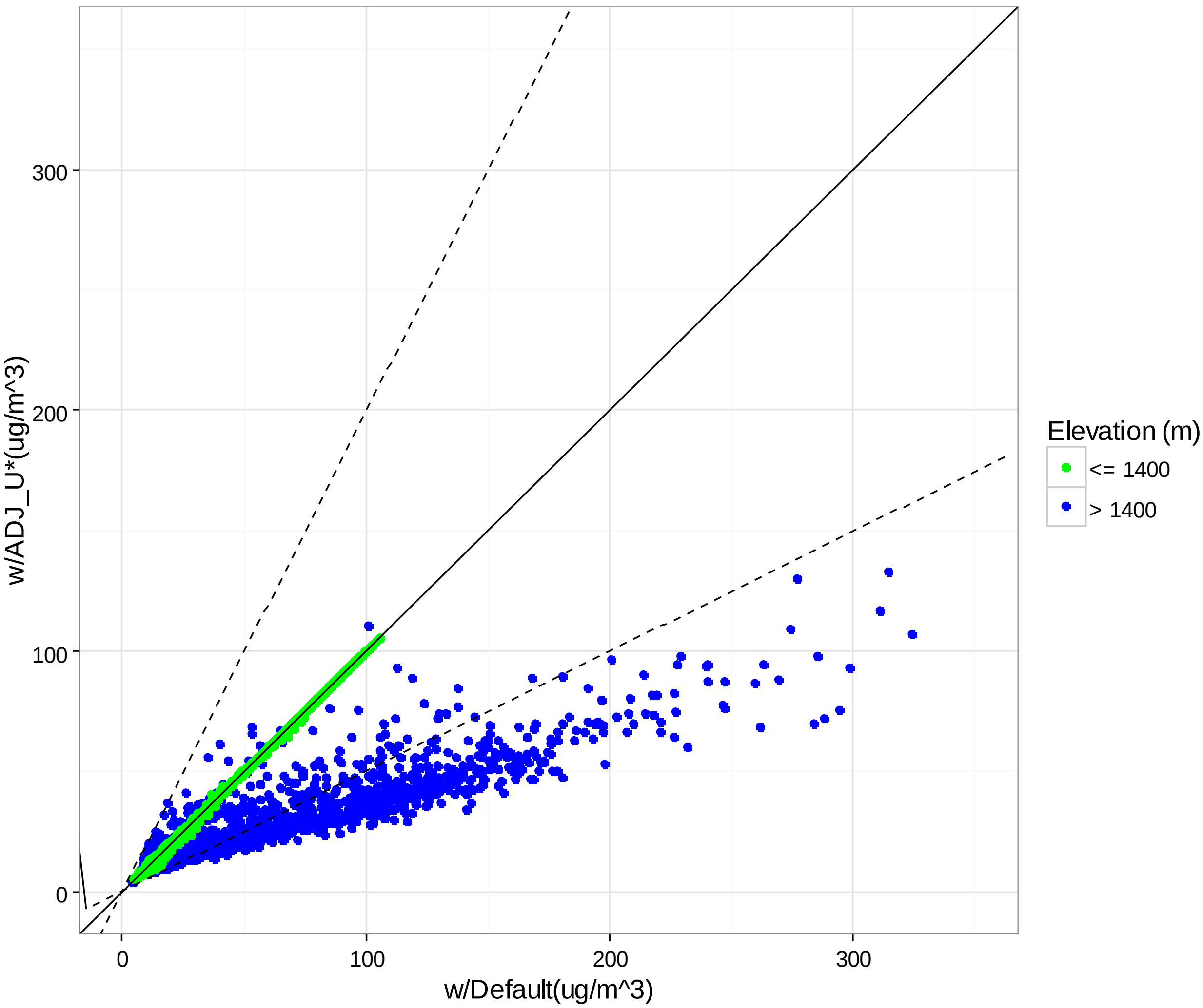
B.5.2 Sensitivity of Modeled Concentrations to Receptor Elevations with the Use of the ADJ_U* Option

ADEQ further investigated how the modeled concentrations at receptors with varied elevations responded to the use of ADJ_U* option. The receptors were simply classified into two groups: receptors with elevations above stack top height (> 1400 m) and receptors with elevations below stack top height (< 1400 m).

Figure B-11 compares the 3-year average 4th highest maximum predicted 1-hour concentrations with AERMET default options vs. with the ADJ_U* option for the two groups of receptors. As shown in Figure B-11, for receptors with elevations below stack top height, the modeled results with the ADJ_U* option were nearly identical to those obtained from AERMET default options (the plot is approximately a straight line with a slope of 1). In contrast, the use of the ADJ_U* option had a significant effect on the modeled concentrations at receptors with elevations above stack top height. Overall, the use of the ADJ_U* option reduced the modeled concentrations at these receptors by approximately a factor of two.

ADEQ also found that stable conditions with low wind speeds were the controlling meteorological conditions for the receptors located in a complex terrain under the AERMET default options. The use of the ADJ_U* option in AERMET reduced the underestimation bias of u*, resulting in lower modeled concentrations at these receptors.

Figure B-11 Comparison of Modeled Concentrations with Default Options vs. with ADJ_U* Option for Receptors with Elevations below 1400 m(green) and Receptors with Elevations above 1400 m (blue)



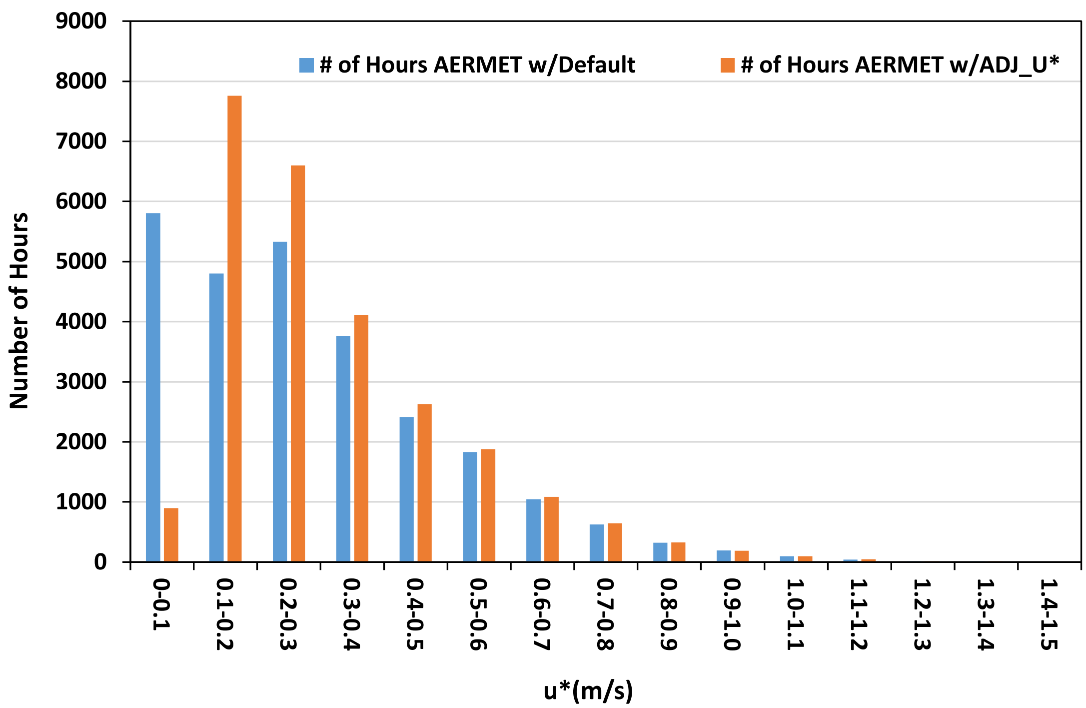
B.5.3 Sensitivity of Surface Friction Velocity Values (u*) to the Use of the ADJ_U* Option

ADEQ finally compared all u* values from AERMET default options against those from AERMET with the ADJ_U* option over the full three-year modeling period. The results are shown in Table B-4 and Figure B-12. Using the ADJ_U* option, the number of hours with extremely small u* values between 0.0-0.1 m/s dropped from 5805 (22.1%) to 896 (3.4%). As previously discussed, extremely low u* values results in the underestimation of turbulence and mixing height in AERMOD for stable conditions, leading to over-predicted concentrations. The use of the ADJ_U* option in AERMET raises the u* values and thus provides more realistic predicted concentrations for stable conditions.

Table B-4 Comparison of u* Values from AERMET Default Options vs. AERMET with the ADJ_U* Option over Three Model Years

u* (m/s)	# of Hours AERMET w/Default	# of Hours AERMET w/ADJ_U*	% Hours AERMET w/Default	% Hours AERMET w/ ADJ_U*
0-0.1	5805	896	22.09	3.41
0.1-0.2	4799	7758	18.26	29.52
0.2-0.3	5330	6601	20.28	25.12
0.3-0.4	3758	4107	14.30	15.63
0.4-0.5	2415	2625	9.19	9.99
0.5-0.6	1831	1878	6.97	7.15
0.6-0.7	1042	1086	3.97	4.13
0.7-0.8	625	644	2.38	2.45
0.8-0.9	322	327	1.23	1.24
0.9-1.0	191	188	0.73	0.72
1.0-1.1	94	98	0.36	0.37
1.1-1.2	40	43	0.15	0.16
1.2-1.3	15	15	0.06	0.06
1.3-1.4	11	12	0.04	0.05
1.4-1.5	1	1	0.004	0.004

Figure B-12 Histogram of u* Values from AERMET Default Options and AERMET with the ADJ_U* Option



B.6 Discussions

Both the Lovett study and the Mercer County ND study have clearly demonstrated that the use of AERMET version 15181 with the ADJ_U* option improves model performance for AERMOD modeling of tall stacks with buoyant releases in complex terrain.

In the Lovett study, elevated complex terrain features/elevated monitors are in proximity to the source, slightly differing from the AEPCO circumstances in which elevated complex terrain features are around 8-10 km away from the source. Comparatively, in the Mercer County ND study, the monitor located in an elevated complex terrain (DGC-17) is around 7.5 km away from the source, which matches the characteristics of the AEPCO case. Therefore, the Mercer County ND study provides a sufficient basis to evaluate the AEPCO case. The DGC-17 data have clearly demonstrated that AERMOD with AERMET default options significantly over-predict the ambient impacts at elevated complex terrain, and the use of the ADJ_U* option in AERMET significantly improves model performance. Moreover, the DGC-17 data have revealed that, although the use of the ADJ_U* option in AERMET reduces modeled concentrations at receptors in elevated complex terrain, the predicted modeled concentrations are still conservative when compared to the actual monitoring data. Based on the Mercer County ND study, ADEQ believes that the use of the ADJ_U* option in AERMET will provide more realistic, but still conservative, estimations of the impacts at Gunnison Hills/Dragoon Mountains in the AEPCO case.

ADEQ performed a model sensitivity analysis for AEPCO using the same approaches as presented in the studies for Schiller, Wagner and Heskett. ADEQ found that the findings resulted from the AEPCO study are very similar to those from these three studies. Peak modeled concentrations at receptors in complex terrain with AERMET default options occurred during stable, light wind conditions. The use of the ADJ_U* option in AERMET resulted in increases in the u* values, leading to lower modeled concentrations at these receptors. For the nearby controlling receptors not associated with the distant terrain features, peak modeled concentration occurred at times of much higher u* values, and these u* values were unchanged with the use of the ADJ_U* Beta option. Overall, the use of the ADJ_U* option in AERMET only had a significant impact on the model concentrations at receptors in complex terrain, while having virtually no effect on the model concentrations at receptors in simple terrain.

As discussed, circumstances (tall stacks in complex terrain) and model responses with the use of the ADJ_U* option for AEPCO, Schiller, Wagner and Heskett are nearly identical. Because the EPA model clearinghouse concurred with the use of the ADJ_U* Beta option for the Schiller, Wagner and Heskett demonstrations, ADEQ believes that it is also appropriate for the ADJ_U* Beta option in AERMET to be considered for the regulatory modeling demonstration at AEPCO.

B.7 Conclusions

Based on the EPA's model performance studies, peer-reviewed articles, as well as the AEPCO model sensitivity analysis, ADEQ believes that the use of the beta ADJ_U* option in AERMET for the AEPCO modeling under the Data Requirements Rule satisfies condition 2 of Appendix W, Section 3.2.2.b. Specifically ADEQ feels that "the alternative model performs better for the given application than a comparable model in Appendix A". Therefore, ADEQ is seeking the EPA's concurrence on the proposed use of the ADJ_ U* Beta option in AERMET for the AEPCO DRR modeling.

B.8 References

EPA. 2016a. Model Clearinghouse Review of the Use of the ADJ_U* Beta Option in the AERMET Meteorological Processor (Version 15181) for the Donlin Mine Compliance Demonstration. February 10, 2016.

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