SO_2 Characterization Modeling Analysis for the H.A. Wagner and Brandon Shores Power Plants

Prepared for:
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1 Introduction

1.1 Background

The United States Environmental Protection Agency (EPA) promulgated a 1-hour National Ambient Air Quality Standard (NAAQS) for SO_2 in 2010. The 1-hour SO_2 NAAQS has a level set at 75 ppb and the form of the standard is the average of the 99th percentile of the daily maximum 1-hour average concentrations realized in each of three consecutive calendar years (the "design value," or DV).

The EPA is implementing the 2010 1-hour SO_2 National Ambient Air Quality Standard (NAAQS) in an approach that involves either a dispersion modeling or monitoring approach to characterize local SO_2 concentrations near isolated emission sources. On March 20, 2015, EPA informed affected states that certain emission sources within their states will be addressed in an expedited round of designations under the 1-hour SO_2 NAAQS due to terms of the SO_2 Consent Decree negotiated between the Sierra Club and EPA.[1] The EPA intends to designate the affected areas as either "attainment" (same as "unclassifiable/attainment"), "nonattainment," or "unclassifiable" by July 2, 2016 after a review of available modeling or monitoring data to support the SO_2 concentration characterizations.

One of the affected sources evaluated in this Consent Decree analysis is the H. A. Wagner Generating Station ("Wagner"). Due to its proximity to Wagner, the Brandon Shores Generating Station is also part of the SO_2 characterization process.

The Maryland Department of the Environment (MDE or the Department) has been working with Raven Power, owner of Wagner and Brandon Shores, with Raven Power's consultant AECOM, and with EPA Region 3 to ensure the area around Wagner is characterized appropriately. In addition, the Crane Generating Station (Crane) and another minor source in the vicinity of the Wagner area were included in the modeling analysis.

This modeling analysis was completed in consultation with EPA Region 3, to demonstrate that the size of the 1-hour SO_2 nonattainment area proposed by EPA in their March 1, 2016 Draft Technical Support Document entitled "Area Designations for the 2010 SO_2 Primary Ambient Air Quality Standard"[2] should be reduced in size to the immediate area surrounding Wagner. This modeling analysis will use updated modeling procedures and the dispersion modeling results that are summarized in this appendix, to characterize SO_2 concentrations in the area surrounding Wagner.

[1] See Case No.: 3:13-cv-3953-SI, in the United States District Court for the Northern District of California, San Francisco Division, filed March 2, 2015, available at http://www.4cleanair.org/sites/default/files/resources/Litigation-SO2-Designations_Deadline_Suit-Final_CD-030215.pdf.

[2] https://www3.epa.gov/so2designations/round2/03_MD_tsd.pdf

2 Modeling Procedures and Results

2.1 Dispersion Model Selection

This modeling analysis utilized the most recent version of the AERMOD dispersion model[3] (Version 15181) to evaluate air quality impacts from the emission sources of interest. The AERMOD modeling system consists of two preprocessors and the dispersion model. AERMET is the meteorological preprocessor component and AERMAP is the terrain pre-processor component that characterizes the terrain and generates receptor elevations along with critical hill heights for receptors.

2.2 Emissions Data and Source Characterization

The most recent three years (2013-2015) of actual emissions data for Crane, Brandon Shores, and Wagner, data that Raven Power's consultant AECOM submitted to MDE, were used in the 1-hour SO_2 source characterization modeling analysis as per the guidance in EPA's SO_2 NAAQS Designations Modeling Technical Assistance Document (TAD)[4]. Also, one additional source, Wheelabrator, was included in the modeling analysis. Actual emissions for the Wheelabrator source were not available, so the allowable emissions rate was used. Figure 2-1 (see the figures at the end of this appendix) shows the sources located in the Baltimore area. Table 2-1, on the next page, lists the sources and parameters modeled. Brandon Shores Units 1 and 2 exhaust to a common stack with height and internal exit diameter as reported in Table 2-1. When both units were operating, the combined emission rate, average flow rate and weighted average temperature were used in AERMOD, consistent with EPA Model Clearinghouse Memo 91-II-01. When Unit 1 or 2 operated alone, the single flue diameter was used. AECOM updated the flue gas temperature and exit velocity data in the hourly emissions file. These data were derived via examination of 2013-2015 data collected using the certified flue gas flow monitors (CEMs data) installed in the Brandon Shores, Wagner, and Crane stacks.

The stack temperature data includes several periods of erroneous temperature data for Wagner Unit 3. Four hours erroneously reported a temperature of 0 degrees F (March 21, 2013 Hour 8, June 12, 2013 Hour 9, August 8, 2013 Hour 19, and September 3, 2013 Hour 13). These values were replaced with the temperatures in the Department's emissions inventory files (289.99 degrees F / 416.48 K).

Intermittent sources and transient conditions such as emergency generators, auxiliary boilers, and startup/shutdown operations were not modeled as explained in the March 2011 EPA guidance document[5] for modeling 1-hour NO_2 and SO_2. These emission sources are of insufficient duration and frequency to affect NAAQS compliance.

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[3] Available at http://www.epa.gov/ttn/scram/11thmodconf/presentations/1-5_Proposed_Updates_AERMOD_System.pdf.

[4] http://www3.epa.gov/airquality/sulfurdioxide/pdfs/SO2ModelingTAD.pdf

[5] http://www3.epa.gov/scram001/guidance/clarification/Additional_Clarifications_AppendixW_Hourly-NO2-NAAQS_FINAL_03-01-2011.pdf

Table 2-1: Emissions and Stack Parameters for Input to AERMOD

Stack	SO_2 Emissions (g/s)	Stack Height (m)	Exit Diameter (m)	Exit Temperature (K)	Exit Velocity (m/s)
Crane Unit 1	Variable[a]	107.59	3.328	Variable[a]	Variable[a]
Crane Unit 2	Variable[a]	107.59	3.330	Variable[a]	Variable[a]
Brandon Shores Unit 1	Variable[a]	121.92	9.50	Variable[a]	Variable[a]
Brandon Shores Unit 2	Variable[a]	121.92	9.50	Variable[a]	Variable[a]
Brandon Shores Merged Stack	Variable[a]	121.92	13.435	Variable[a]	Variable[a]
Wagner Unit 1	Variable[a]	87.48	3.099	330.00	30.48
Wagner Unit 2	Variable[a,c]	87.48	3.100	Variable[a]	Variable[a]
Wagner Unit 3	Variable[a]	105.46	4.215	Variable[a]	Variable[a]
Wagner Unit 4	Variable[a]	104.24	5.334	610.93	35.357
Wheelabrator	12.6	96.01	2.130	485.93	22.55

[a] Actual hourly monitor values were used in the modeling, as provided by Raven Power
[b] Wagner Units 1 and 4 are not equipped with stack flow meters.
[c] Wagner Unit 2 emission rate was capped at 1.0 lb/MMBTU to represent future operations.

In April 2015, Raven Power reduced SO_2 emissions at Wagner Unit 2 by changing to Colorado coal, a lower chlorine and lower sulfur bituminous coal that will comply with the Mercury and Air Toxics Standards (MATS) Rule. Figure 2-2 shows the comparison of megawatt (MW) output to SO_2 emissions for January 1 – September 30, 2015. Maximum SO_2 emissions before the change were on the order of 2,500 lb/hr and after the maximum emission rate has been less than 1,500 lb/hr or less than 1.0 lb/MMBTU (~40% reduction in SO_2 emissions) at the same MW output. Raven Power plans to continue burning this or similar coal in Wagner Unit 2 in order to meet MATS. For this modeling analysis no changes were made to the actual emissions for the Wagner, Brandon Shores and Crane sources.

2.3 Good Engineering Practice (GEP) Analysis

Federal stack height regulations limit the stack height used in performing dispersion modeling to predict the air quality impact of a source. Sources must be modeled at the actual physical stack height unless that height exceeds the Good Engineering Practice (GEP) formula stack height. If the physical stack height is less than the formula GEP height, the potential for the source's plume to be affected by aerodynamic wakes created by the building(s) must be evaluated in the dispersion modeling analysis.

A GEP formula stack height analysis has been performed for sources of interest located at Brandon Shores, Wagner, and Crane in accordance with the EPA's "Guideline for Determination of Good Engineering Practice Stack Height" (EPA, 1985)[6]. A GEP stack

[6] Available at http://www.epa.gov/scram001/guidance/guide/gep.pdf.

height is defined as the greater of 65 meters (213 feet), measured from the ground elevation of the stack, or the formula height (Hg), as determined from the following equation:

$$Hg = H + 1.5 L$$

Where,

H is the height of the nearby structure which maximizes Hg, and
L is the lesser dimension (height or projected width) of the building.

For a squat structure, i.e., height less than projected width, the formula reduces to:

$$Hg = 2.5H$$

In the absence of influencing structures, a “default” GEP stack height is credited up to 65 meters (213 feet). Both the height and the width of the building are determined through a vertical cross-section perpendicular to the wind direction. In all instances, the GEP formula height is based upon the highest value of Hg as determined from H and L over all nearby buildings over the entire range of possible wind directions. For the purposes of determining the GEP formula height, only buildings within 5L of the source of interest are considered.

The GEP analyses were conducted with the latest version of the US EPA’s Building Profile Input Program software (BPIP-PRIME version 04274).

2.4 Meteorological Data Processing

The meteorological data required for input to AERMOD were created with the latest version of AERMET (15181) using the adjusted u* option. This option is currently a beta non-guideline option; justification for its use is discussed below. Hourly surface observations from Baltimore-Washington International Thurgood Marshall Airport (BWI), MD along with concurrent upper air data from Sterling, VA were used as input to AERMET. The surface data (wind direction, wind speed, temperature, sky cover, and relative humidity) are measured 10 m above ground level. A wind rose for 2013-2015 is shown in Figure 2-3.

AERMET requires specification of site characteristics including surface roughness (zo), albedo (r), and Bowen ratio (Bo). These parameters were developed according to the guidance provided by US EPA in the recently revised AERMOD Implementation Guide[7] (AIG).

The AIG provides the following recommendations for determining the site characteristics:

1. The determination of the surface roughness length should be based on an inverse distance weighted geometric mean for a default upwind distance of 1 kilometer relative to the measurement site. Surface roughness length may be varied by sector

[7] Available at http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_19March2009.pdf.

to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.

2. The determination of the Bowen ratio should be based on a simple un-weighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 10-km by 10-km region centered on the measurement site.
3. The determination of the albedo should be based on a simple un-weighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for Bowen ratio, with a default domain defined by a 10-km by 10-km region centered on the measurement site.

The AIG recommends that the surface characteristics be determined based on digitized land cover data. EPA has developed a tool called AERSURFACE that can be used to determine the site characteristics based on digitized land cover data in accordance with the recommendations from the AIG discussed above. Aersurface[8] incorporates look-up tables of representative surface characteristic values by land cover category and seasonal category. AERSURFACE was applied with the instructions provided in the AERSURFACE User's Guide.

The current version of AERSURFACE (Version 13016) supports the use of land cover data from the USGS National Land Cover Data 1992 archives[9] (NLCD92). The NLCD92 archive provides data at a spatial resolution of 30 meters based upon a 21-category classification scheme applied over the continental United States. The AIG recommends that the surface characteristics be determined based on the land use surrounding the site where the surface meteorological data were collected.

As recommended in the AIG for surface roughness, the 1-km radius circular area centered at the meteorological station site can be divided into sectors for the analysis; the default 12 sectors was used for this analysis.

In AERSURFACE, the various land cover categories are linked to a set of seasonal surface characteristics. As such, AERSURFACE requires specification of the seasonal category for each month of the year. The following five seasonal categories are supported by AERSURFACE, with the applicable months of the year specified for this site.

1. Midsummer with lush vegetation (June-August).
2. Autumn with un-harvested cropland (September- November).
3. Late autumn after frost and harvest, or winter with no snow (December - February)
4. Winter with continuous snow on ground (none).
5. Transitional spring with partial green coverage or short annuals (March - May).

[8] Documentation available at http://www.epa.gov/ttn/scram/dispersion_related.htm#aersurface.

[9] See additional information at http://landcover.usgs.gov/natllandcover.php.

For Bowen ratio, the land use values are linked to three categories of surface moisture corresponding with average, wet, and dry conditions. The surface moisture condition for the site may vary depending on the meteorological data period for which the surface characteristics should be applied. AERSURFACE applies the surface moisture condition for the entire data period. Therefore, if the surface moisture condition varies significantly across the data period, then AERSURFACE can be applied multiple times to account for those variations.

As such, the surface moisture condition for each season was determined by comparing precipitation for the period of data to be processed to the 30-year climatological record, selecting “wet” conditions if precipitation was in the upper 30th-percentile, “dry” conditions if precipitation was in the lower 30th - percentile, and “average” conditions if precipitation was in the middle 40th -percentile. The 30-year precipitation data set to be used in this modeling was taken from the National Climatic Data Center[10].

The monthly designations of surface moisture that were input to AERSURFACE are summarized in Table 2-2.

Table 2-2: AERSURFACE Bowen Ratio Condition Designations

Month	Bowen Ratio Category		
	2013	2014	2015
January	Wet	Average	Wet
February	Dry	Wet	Average
March	Average	Average	Average
April	Dry	Wet	Wet
May	Average	Average	Dry
June	Wet	Wet	Wet
July	Average	Average	Average
August	Dry	Wet	Wet
September	Dry	Average	Average
October	Wet	Average	Average
November	Average	Average	Average
December	Wet	Average	Wet

[10] http://www.ncdc.noaa.gov/cdo-web/

2.5 Receptors to be Modeled

Receptors were placed in nested Cartesian grids centered on the Fort Smallwood Complex and Crane with the following spacing:

- Every 25 meters along the property boundary
- Every 100 meters out to a distance of 2 km
- Every 250 meters between 2 and 5 km, and
- Every 500 meters between 5 and 10 km.

Additional receptors were placed at the outer edges to the northwest of Wagner in order to make sure that the maximum 1-hour SO_2 concentrations were accurately modeled.

The original 10,600 receptors were included in the modeling grid. After the initial modeling showed high 1-hour SO_2 concentrations to the northwest close to the modeling domain boundary, an additional 6,600 receptors were located there to assure the maximum 1-hour SO_2 concentrations were modeled. This brought the total number of receptors used in this analysis to 17,000.

The current version of AERMAP has the ability to process USGS National Elevation Dataset (NED) data in place of Digital Elevation Model files. The appropriate file for 1-arc-second, or 30-m, NED data were obtained from the Multi-Resolution Land Characteristics Consortium (MRLC) link at http://www.mrlc.gov/viewerjs/.

Per EPA's SO_2 Technical Assistance Document for modeling[11], receptors in inaccessible areas such as over water and on Aberdeen Proving Ground were removed for this modeling analysis as shown in Figure 2-4.

2.6 Model Configurations and Options

AERMET and AERMOD (Versions 15181) were run with the default options and the Adjust U* (ADJ_U*) option in AERMET. In accordance with Appendix W, Section 3.2.2, the Department has submitted a request to the EPA Region 3 Regional Administrator to be given approval to use the non-regulatory default ADJ_U* option in this modeling analysis.[12]

2.7 Background Concentrations

The Beltsville, MD monitor (Site #24-033-0030), which is located about 33 km to the southwest of the Fort Smallwood Complex, was used to determine the uniform regional background

[11] https://www3.epa.gov/airquality/sulfurdioxide/pdfs/SO2ModelingTAD.pdf

[12] Letter from Mr. Ben Grumbles (MDE Secretary) to Regional Administrator Mr. Shawn Garvin, April 14, 2016. See Appendix C of the document, "MDE Technical Support Document Regarding the Designation of the Area of the Herbert A. Wagner Generating Plant for 1-Hour Sulfur Dioxide."

component for the NAAQS SO_2 modeling. EPA's March 2011 clarification memo[13] regarding 1-hour SO_2 NAAQS modeling allows for an approach using the 99th percentile monitored values whereby the background values vary by season and by hour of the day. MDE used the AECOM approach and applied it to the modeling, using data from the 3-year period of 2013 – 2015. The SO_2 concentrations that were used are listed in Table 2-3. According to the EPA's "Table 5c. Monitoring Site Listing for Sulfur Dioxide 1-Hour NAAQS",[14] the completeness criteria for 2013 and 2014 (Column W) are satisfied, therefore, the Beltsville 1-hour SO_2 monitoring data is complete and is acceptable to use in the modeling. For 2015, the Beltsville monitor recorded data for 8,334 hours (95% complete).

[13] Available at http://www.epa.gov/ttn/scram/guidance/clarification/Additional_Clarifications_AppendixW_Hourly-NO2-NAAQS_FINAL_03-01-2011.pdf.

[14] See http://www3.epa.gov/airtrends/pdfs/SO2_DesignValues_20122014_FINAL_8_3_15.xlsx.

Table 2-3: 1-hr SO_2 Ambient Background Concentrations for Beltsville Monitor (2013-2015)

Hour	3-Year Averaged Hourly Values for Winter (μg/m³)	3-Year Averaged Hourly Values for Spring (μg/m³)	3-Year Averaged Hourly Values for Summer (μg/m³)	3-Year Averaged Hourly Values for Fall (μg/m³)
1	10.31	6.81	3.14	6.38
2	6.46	8.21	2.27	4.93
3	11.79	8.30	2.88	3.49
4	11.09	7.07	3.23	3.58
5	10.74	6.81	2.79	3.76
6	12.58	7.07	2.79	3.93
7	11.62	8.47	4.10	3.49
8	10.92	7.07	7.16	4.37
9	10.57	12.31	7.51	6.72
10	13.54	11.79	8.82	10.13
11	17.64	11.27	9.26	13.27
12	14.50	10.65	6.55	14.76
13	15.55	13.10	6.38	11.96
14	13.45	12.14	7.77	10.65
15	12.93	10.39	5.24	9.34
16	13.54	9.08	5.76	10.65
17	13.45	11.35	5.76	8.56
18	11.53	14.24	4.10	7.16
19	14.58	11.70	3.58	5.94
20	14.50	9.34	3.23	4.54
21	12.75	8.12	3.41	4.80
22	11.79	8.03	3.14	5.33
23	15.72	8.21	2.97	4.45
24	11.53	6.55	3.06	4.28

2.8 Results of SO_2 Characterization Analysis

The results of this SO_2 characterization analysis using modeling can inform the decision as to proper designation of the Wagner area for the 1-hour SO_2 NAAQS based on three years (2013-2015) of actual emissions for Wagner, Brandon Shores and Crane. This modeling process has some conservative features included, such as:

- Use of allowable emission rates for background sources (Wheelabrator).
- Use of actual emissions for Wagner Unit #2, 1-hour SO_2 emissions have been dramatically reduced by the use of low chlorine coal, with low sulfur content, for compliance with MATS.

Therefore, with these conservative assumptions, the modeling results show that the 99th percentile peak daily 1-hour maximum concentration around Wagner modeled to be 255.58 $\mu g/m^3$ (including background) which exceeds the 1-hour SO_2 NAAQS of 196.2 $\mu g/m^3$. However, also based on modeling, the 1-hour SO_2 nonattainment area should be limited to only the area immediately surrounding Wagner. Provided in Figure 2-5 is the area not demonstrating compliance with the 1-hour SO_2 NAAQS.

Figures 2-1 – 2-5

Figure 2-1. Locations of SO2 Sources Used in the Modeling Analysis

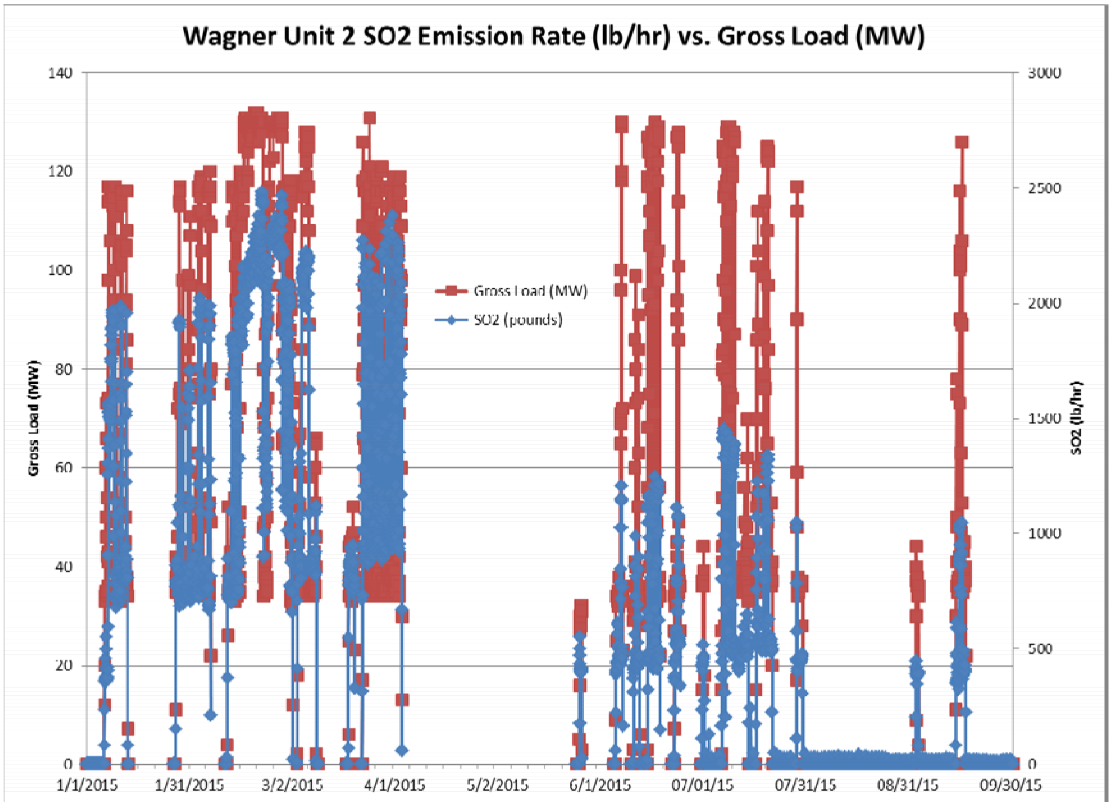

Figure 2-2: Wagner Unit 2 Emission Reductions in 2015

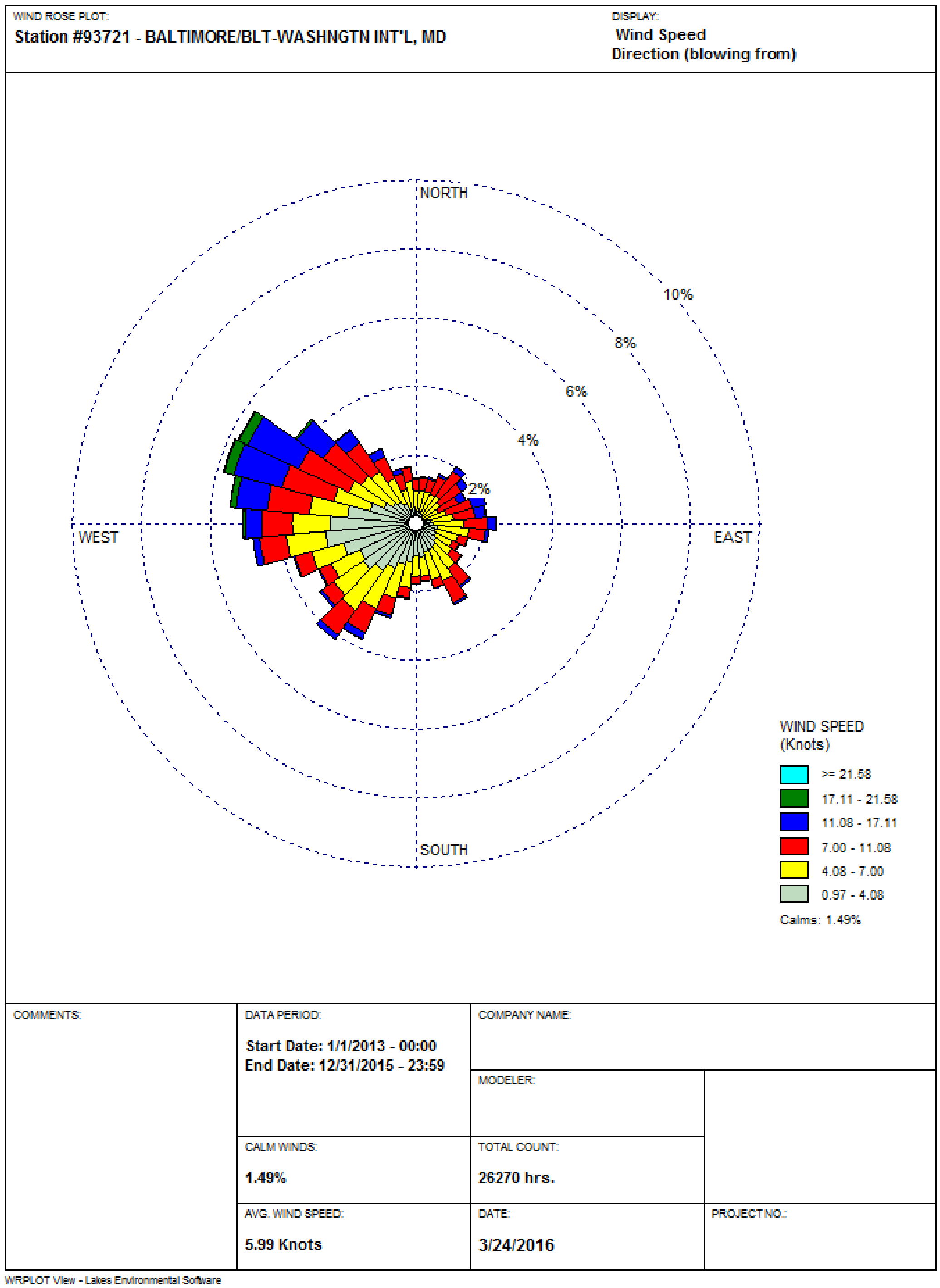

Figure 2-3. BWI Airport Wind Rose

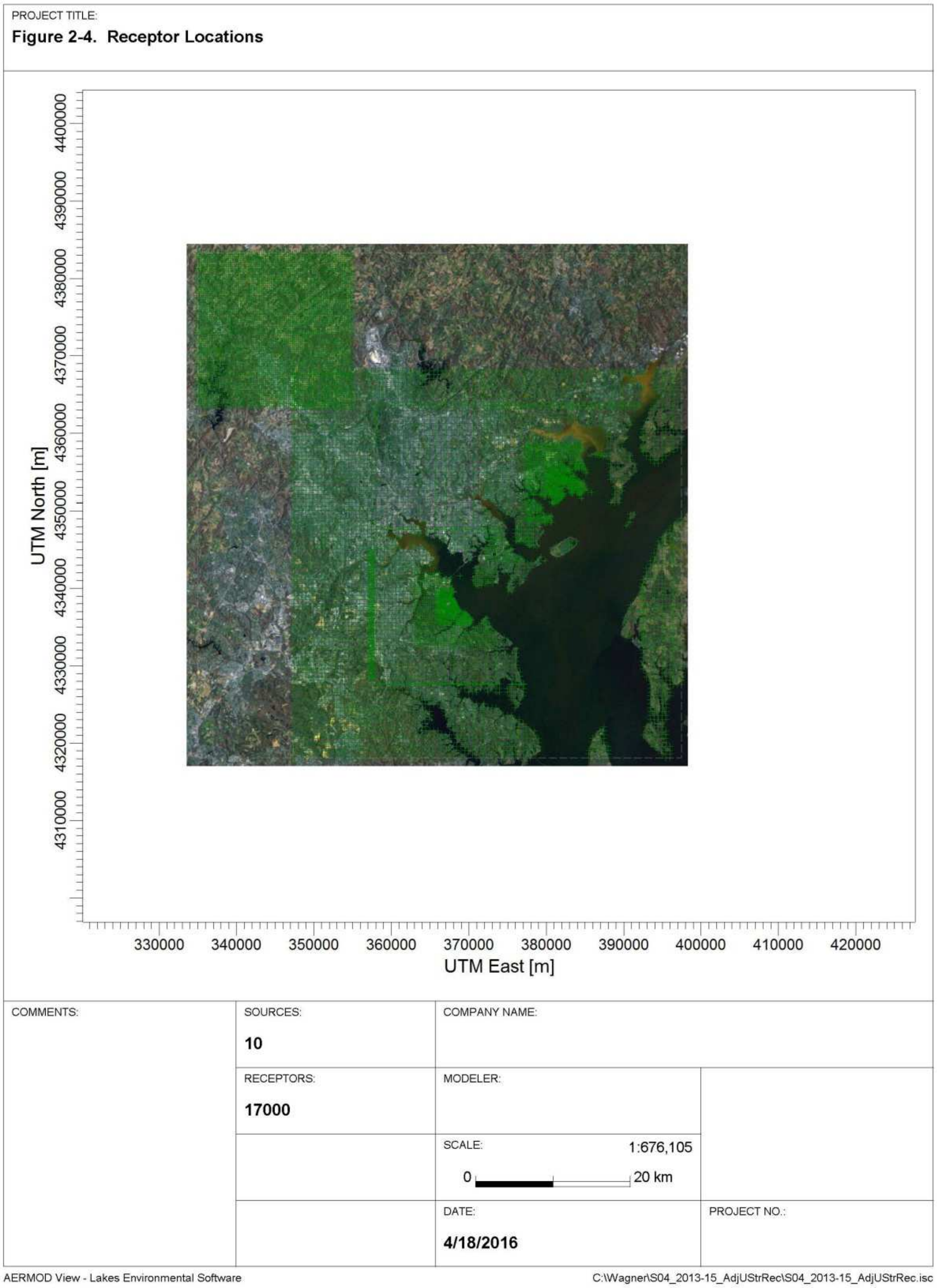

Figure 2-4. Receptor Locations

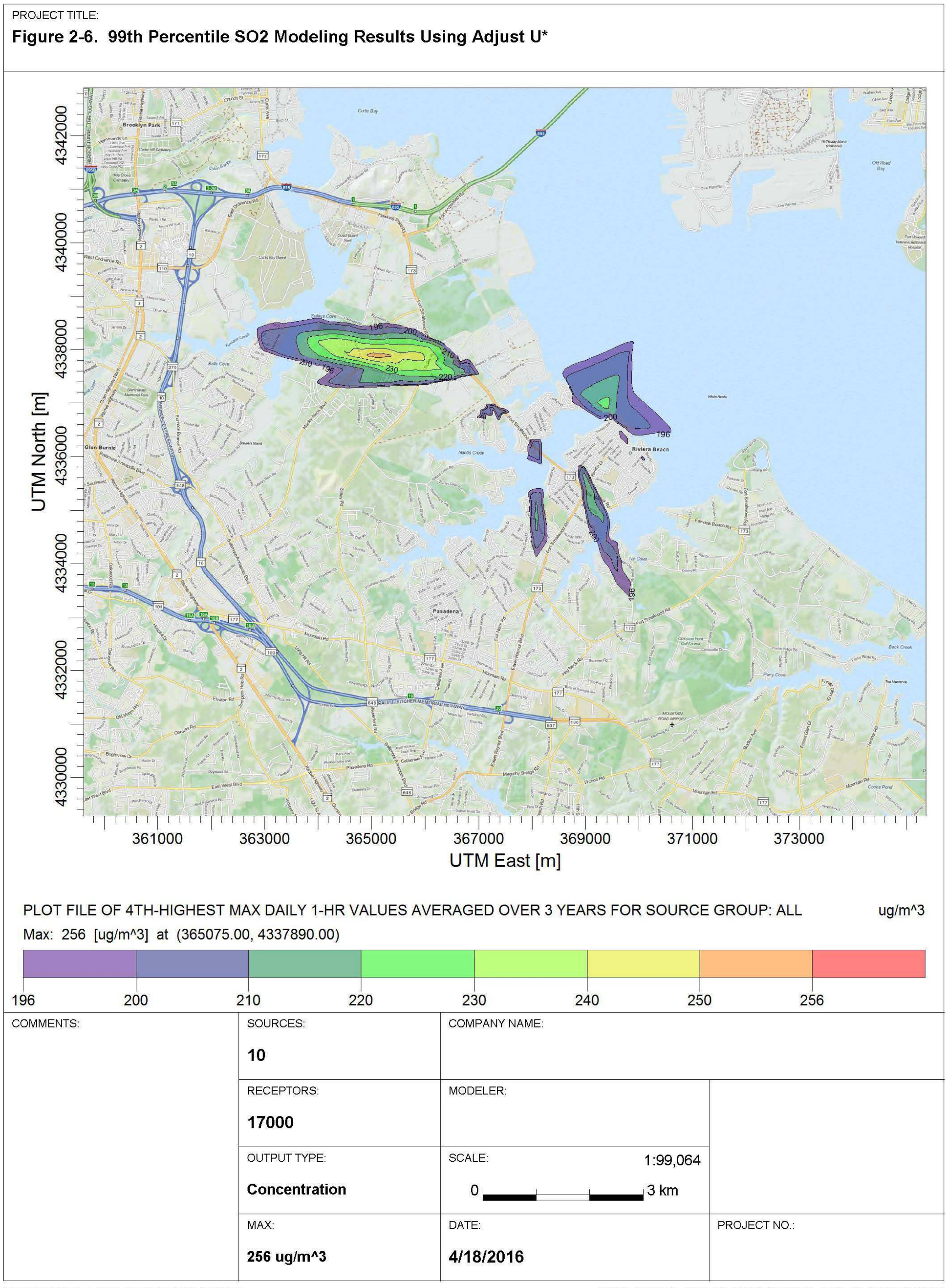

Figure 2-5. 99th Percentile SO2 Modeling Results Using Adjust U*