South Carolina Electric & Gas Wateree Station and International Paper Eastover Mill - Request for use of AERMOD Non-guideline LOWWIND3 Option

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Executive Summary

This document provides a site-specific justification for use of the LOWWIND3 model option in AERMOD. The document discusses the application background, the source setting, and the overall modeling methodology used. The alternative model justification is then provided to address the conditions in EPA's Appendix W, (40 CFR 51) Section 3.2.2 with some additional considerations.

The South Carolina Department of Health & Environmental Control (DHEC) Bureau of Air Quality (BAQ) has identified the South Carolina Electric & Gas (SCE&G) Wateree Station (Wateree) and the International Paper (IP) Eastover Mill (Eastover) as sources subject to the requirements in United States Environmental Protection Agency's (EPA) August 2015 SO_2 Data Requirements Rule (DRR) (Subpart BB of 40 CFR 51). Since both sources are located in close proximity to each other in Richland County, South Carolina, DHEC requested the sources work together on an analysis to characterize SO_2 air quality in the vicinity of both sources. Under the DRR, both sources have elected to characterize air quality based on a modeling approach.

The modeling protocol submitted to DHEC/EPA outlined the modeling methodology that would be used, including use of the LOWWIND3 option in AERMOD. The protocol states that if LOWWIND3 was not a regulatory default option (as it was proposed to be in EPA's proposed changes to its modeling guideline; 40 CFR Part 51, Appendix W; see 80 FR 45339), then additional justification would be provided in the modeling submittal. This document provides the additional justification and requests formal approval to use LOWWIND3 for this modeling exercise in accordance with the requirements outlined in Section 3.2.2 of EPA's Appendix W.

The justification was prepared in a similar manner to those submitted for recent EPA Model Clearinghouse approvals for the ADJ_U* option in that a similar model evaluation database was utilized to draw conclusions regarding the model performance with the LOWWIND3 option for the Wateree and Eastover sites since a site specific model evaluation database is not available for Wateree and Eastover.

The analysis and research performed as part of this technical justification satisfy the requirements found in Appendix W Section 3.2.2(b) condition 2 for a non-guideline model approval. Even though this largely addresses condition 2 approval requirements, we point out that certain aspects of condition 3 are also satisfied.

For Section 3.2.2(b)(2) as documented below;

The predicted reduction in concentrations between AERMOD with default options vs. LOWWIND3 for Wateree and Eastover was similar to the difference shown by the comparison of a site-specific model evaluation database to monitored values at a similar site for monitors not affected by building downwash.

The percent reduction from using AERMOD with default to LOWWIND3 was about 15-16% for Wateree and Eastover and for the site-specific model evaluation database using a full receptor grid. The corresponding reduction at the top 10 receptors ranged from 15 – 22%.

The location of the maximum impact remained in the same general wind sector using default and LOWWIND3.

For Section 3.2.2(b)(3) as documented below;

The model has received sufficient scientific peer review, the model can be demonstrated to be applicable to the problem on a theoretical basis, and the appropriate performance evaluations of the model have shown that the model is not biased toward underestimates.

This analysis, a discussion of source similarities, and a model sensitivity comparison are provided to EPA as documentation in support of the request to use the LOWWIND3 non-default model option to more accurately handle light wind conditions in AERMOD in the 1-hour SO_2 DRR modeling of WATEO. We feel this analysis fulfills the requirements of Section 3.2.2(b)(2) of Appendix W. The analysis was prepared in a similar manner to others for which EPA has approved the use of ADJ_U* (with similar conclusions) and accordingly that the use of LOWWIND3 should be approved for use in the WATEO modeling.

Background

Based on recent annual SO_2 emissions levels, DHEC has requested that Wateree and Eastover, both located in Eastover in Richland County, South Carolina, characterize SO_2 air quality in the vicinity of both sources based on requirements in United States Environmental Protection Agency's (EPA) August 2015 SO_2 Data Requirements Rule (DRR). The DRR allows sources to characterize SO_2 air quality using either a modeling or monitoring approach. In anticipation of the DRR, EPA issued two critical draft guidance documents (1) "SO_2 NAAQS Designations Modeling Technical Assistance Document"[1] and (2) "SO_2 NAAQS Designations Source-Oriented Monitoring Technical Assistance Document"[2]. The latest versions of these draft TADs were issued in August 2016 and February 2016, respectively.

Given that the sources mentioned above are located in close proximity to each other with a potential for overlapping impacts, DHEC requested the sources work together and prepare one attainment area designation modeling analysis that includes both sources. The combined "source" (both the IP Eastover Mill and the Wateree Station) and the team addressing the SO_2 DRR requirements is herein referred to as "WATEO".

The WATEO source has elected to pursue the modeling pathway. The WATEO team submitted a dispersion modeling protocol on October 23, 2015 to DHEC. DHEC provided written comments on April 29, 2016. A revised protocol was submitted to DHEC on June 2, 2016. EPA provided comments on the protocol on September 1, 2016.

As part of the modeling protocol submitted to DHEC/EPA, the WATEO source stipulated in Section 2 of the protocol that the AERMOD beta-option LOWWIND3 would be utilized for the attainment designation modeling. Section 2 also stated, that if LOWWIND3 was not a regulatory default option (as it was proposed to be in EPA's proposed changes to its modeling guidelines; 40 CFR Part 51, Appendix W; see 80 FR 45340) by the time that the modeling analysis was submitted, that additional

[1] Available at: https://www.epa.gov/sites/production/files/2016-06/documents/so2modelingtad.pdf.

[2] Available at: https://www.epa.gov/sites/production/files/2016-06/documents/so2monitoringtad.pdf.

justification would be provided in the modeling submittal. WATEO was informed in August 2016 that that LOWWIND3 likely would not be a regulatory default option in the updated Appendix W. Therefore, this document has been prepared to provide the requisite support needed for approval of a non-default model option.

Source Setting

The WATEO source is located in Eastover, Richland County, South Carolina. The two facilities are located just west of the Wateree River, which forms the boundary between Richland County and Sumter County, and to the east of McCords Ferry Road, also referred to as Route 601.

The facilities are situated in generally remote, rural areas with surroundings characterized by woods and fields with no nearby residences. Terrain in this area can be characterized as rolling with some nearby hills, but with no significant terrain features.

Figure 1 shows the terrain in the area surrounding the two facilities. **Figure 2** shows the land use in the area. **Figure 3** shows the area surrounding both facilities. A circle with a radius of 10 km centered on a point midway between the two facilities is plotted on **Figure 2** and **Figure 3** to help establish scale. The distance between Wateree and Eastover is about 7 km.

Modeling Methodology

The use of AERMOD (the current version as of mid-December 2016 is 15181) was proposed for modeling that will be used to characterize SO_2 concentrations in the vicinity of the WATEO source. AERMOD is the EPA guideline model for short-range transport and has the ability to account for the source types and dispersion environment located at, and surrounding, the WATEO source. AERMOD is appropriate for use in many different types of dispersion environments including sources subject to building downwash and sources located in flat or elevated terrain.

In concert with a proposed rulemaking published in the July 29, 2015 Federal Register (80 FR 45340), the EPA released a revised version of AERMOD (Version 15181), which replaced the previous version of AERMOD (Version 14134). EPA proposed refinements to AERMOD, its preferred short-range model, involving low wind conditions. These refinements involve an adjustment to the computation of the friction velocity ("ADJ_U*") in the AERMET meteorological pre-processor and a higher minimum lateral wind speed standard deviation, sigma-v (σ_v), as incorporated into the AERMOD "LOWWIND3" option. The EPA proposal indicates that "the LOWWIND3 beta option increases the minimum value of sigma-v from 0.2 to 0.3 m/s, uses the FASTALL approach to replicate the centerline concentration accounting for horizontal meander, but utilizes an effective sigma-y and eliminates upwind dispersion".

For the application of AERMOD at WATEO, it is proposed that the regulatory default options for AERMOD and AERMET be used except that AERMOD should be run using the EPA-proposed LOWWIND3 option, with its default settings[3] that use a minimum sigma-v value of 0.3 m/s and an upper limit of 0.95 applied to the horizontal meander algorithm.

The proposed modeling will utilize three recent years (2012-2014) of surface meteorological data from Columbia Metropolitan Airport along with concurrent upper air observations from Greensboro, North Carolina's Piedmont Triad International Airport. These data were processed by DHEC using AERMET (Version 15181) and provided in a model-ready format. Section 5 of the modeling report includes a more detailed justification on the selection of the meteorological data used for this modeling.

[3] All references to "LOWWIND3" in this application assume these default settings for this model option.

Because the LOWWIND3 option is still a non-default model option, additional technical support for the use of this option must be provided in the form of an alternative model justification in accordance with Appendix W.

Figure 1 Terrain Surrounding SCE&G Wateree Station and IP Eastover Mill

Figure 2 Land Use Surrounding Wateree and Eastover Mill with 10 km Radius Circle

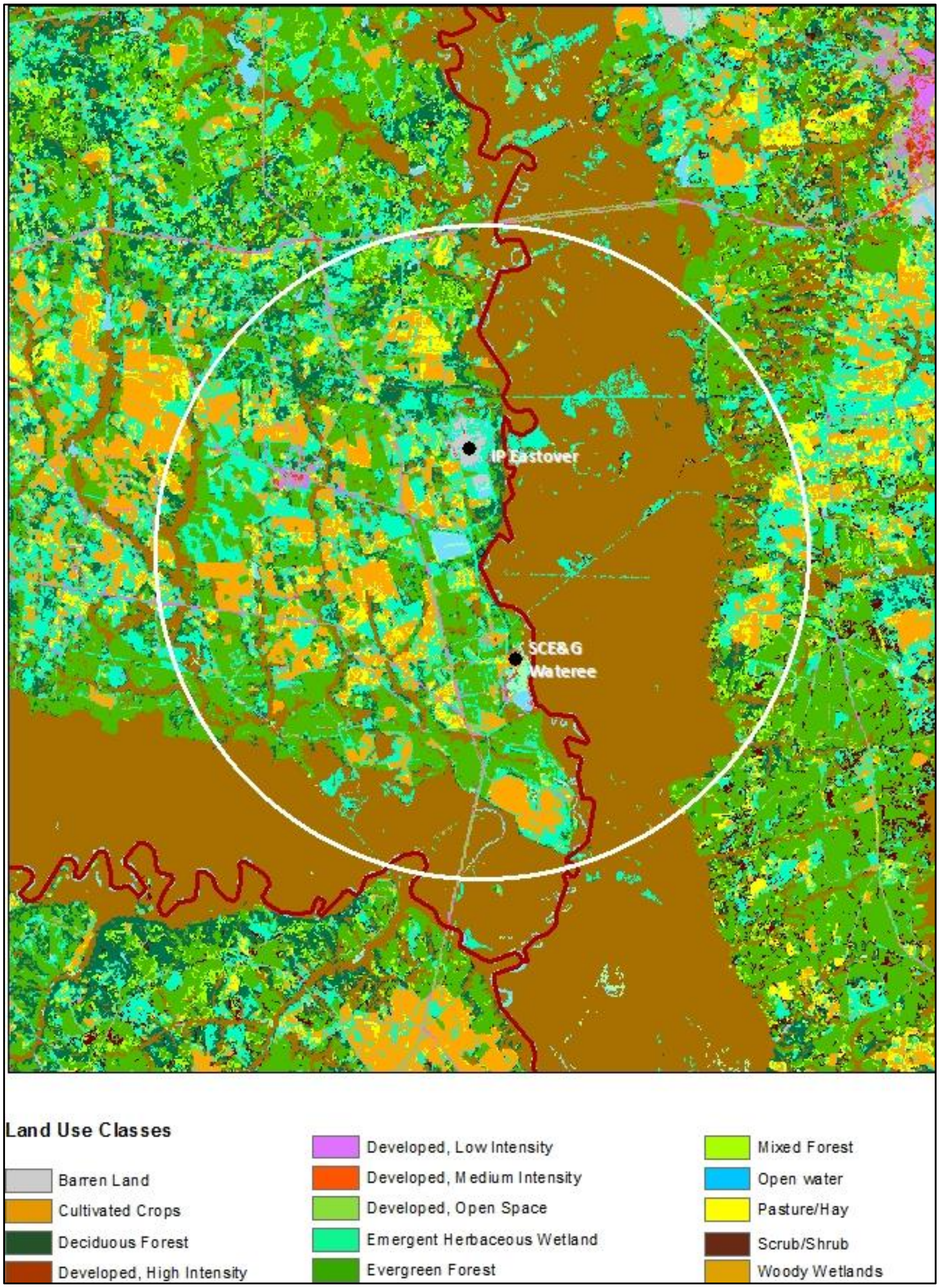
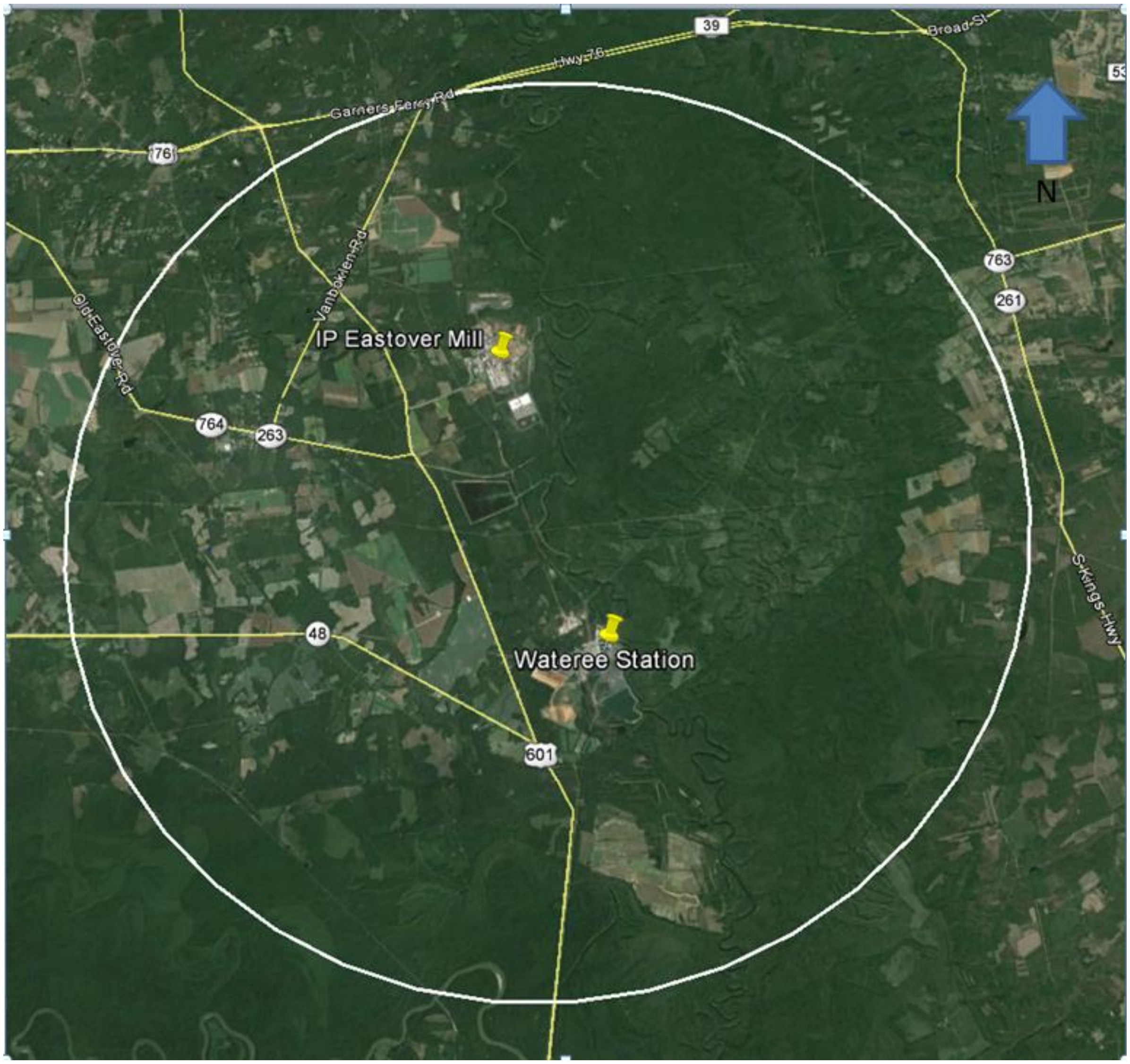


Figure 3 Area Surrounding Wateree and Eastover with 10 km Radius Circle



Alternative Model Justification

Appendix W in the GAQM, Section 3.2.2(b) provides an approach for approval of an alternative model to determine whether it is more appropriate for a given application. Section 3.2.2(b) states that the request for an alternative approach must meet one of the following 3 conditions:

(1) If a demonstration can be made that the model produces concentration estimates equivalent to the estimates obtained using a preferred model;

(2) If a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model; or

(3) If the preferred model is less appropriate for the specific application, or there is no preferred model.

WATEO's request to use LOWWIND3 falls generally under the second of these conditions, Section 3.2.2(b)(2), similar to that for several EPA Model Clearinghouse approvals[4,5,6,7] of the ADJ_U* option. Appendix W, Section 3.2.2(d) stipulates that to satisfy condition (2) in paragraph (b) of this subsection, one must follow established procedures and techniques[8,9] for determining the acceptability of a model for an individual case based on superior performance, as appropriate. Preparation and implementation of an evaluation protocol which is acceptable to control agencies and regulated industry are important elements in such an evaluation.

In addition to fulfilling requirements of condition 2 in Section 3.2.2(b) in Appendix W, we feel there are certain aspects of condition 3 in Section 3.2.2(b) that are fulfilled, including the following associated elements from Section 3.2.2(e): (i) the model has received a scientific peer review; (ii) the model can be demonstrated to be applicable to the problem on a theoretical basis; and (iii) the data bases which are necessary to perform the analysis are available and adequate.

The requirements to satisfy Appendix W condition 2 for a non-guideline model approval are found in Section 3.2.2(d)) and are addressed below. The relevant requirements to satisfy Appendix W condition 3 are found in Section 3.2.2(e) are also addressed below. Condition 3 is discussed first, followed by condition 2.

The model selected for this application is based on the EPA-proposed updates to the AERMOD modeling system version 15181, including the AERMOD LOWWIND3 option. EPA has indicated support for these changes in the Appendix W proposal and in the EPA presentation made at the 11th Modeling Conference on August 12, 2015[10].

Appendix W Condition 3

As stated, in addition to fulfilling requirements of condition 2 in Section 3.2.2(b) in Appendix W, we feel there are certain aspects of condition 3 in Section 3.2.2(b) that are fulfilled including the following associated elements from Section 3.2.2(e): (i) the model has received a scientific peer review; (ii) the

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[4] The approval of the ADJ_U* beta option for the Heskett Station in EPA Region 8 is documented at https://cfpub.epa.gov/oarweb/MCHISRS/index.cfm?fuseaction=main.resultdetails&recnum=16-VIII-01.

[5] The approval of the ADJ_U* beta option for the Schiller Station in EPA Region 1 is documented at https://www3.epa.gov/ttn/scram/guidance/mch/new_mch/16-I-01_MCResponse_Region1_Schiller-04292016.pdf.

[6] The approval of the ADJ_U* beta option for the Wagner Station in EPA Region 3 is documented at https://www3.epa.gov/ttn/scram/guidance/mch/new_mch/16-III-01_MCResponse_Region3_Wagner-06202016.pdf.

[7] The approval of the ADJ_U* beta option for the Donlin Mine in EPA Region 10 is documented at https://www3.epa.gov/ttn/scram/guidance/mch/new_mch/16-X-01_MCResponse_Region10_Donlin-02102016.pdf.

[8] Environmental Protection Agency, 1992. Protocol for Determining the Best Performing Model. Publication No. EPA–454/ R–92–025. Office of Air Quality Planning & Standards, Research Triangle Park, NC. (NTIS No. PB 93–226082)

[9] ASTM D6589: Standard Guide for Statistical Evaluation of Atmospheric Dispersion Model Performance. (2000)

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

model can be demonstrated to be applicable to the problem on a theoretical basis; and (iv) appropriate performance evaluations of the model have shown that the model is not biased toward underestimates. Each of these elements s discussed below.

(i) The model has received a scientific peer review

A scientific justification for the related "LOWWIND2" option has been published in a scientific peer-reviewed technical journal by Paine et al. (2015)[11], and LOWWIND3 was thoroughly discussed in a peer-reviewed conference paper delivered at the 2016 annual meeting of the Air & Waste Management Association by Paine et al. (2016) [12]. EPA also provided[13] evaluation results for LOWWIND3 at the 11th modeling conference. Since the LOWWIND2 and LOWWIND3 formulations and the resulting predicted impacts from their use are very similar, we feel that these publications satisfy the requirement of Section 3.2.2.b(3) for an Appendix W non-guideline approval under Section 3.2.2(e)(i). Comparisons of LOWWIND2 and LOWWIND3 are provided below as part of the Appendix W requirement under Section 3.2.2(e)(ii) discussed in the next section.

(ii) The model can be demonstrated to be applicable to the problem on a theoretical basis.

During low wind speed (LWS) conditions, the dispersion of pollutants is limited by diminished fresh air dilution. Paine et al. (2015) discuss challenges and modeling approaches for steady-state plume model formulation approaches that are summarized here. Anfossi et al. (2005)[14] noted that in LWS conditions, dispersion is characterized by meandering horizontal wind oscillations. They reported that as the wind speed decreases, the standard deviation of the wind direction increases, making it more difficult to define a mean plume direction. Sagendorf and Dickson (1974)[15] and Wilson et al. (1976)[16] found that under LWS conditions, horizontal diffusion was enhanced because of the meander, and the resulting ground-level concentrations could be much lower than those predicted by steady-state Gaussian plume models that did not account for the meander effect.

A parameter that is used as part of the computation of the horizontal plume spreading in the EPA's preferred model, AERMOD (Cimorelli et al., 2005)[17], is the standard deviation of the crosswind component, σ_v, which, in the absence of direct measurements, can be parameterized as being proportional to the friction velocity, u_* (Smedman, 1988[18]; Mahrt, 1998[19]). These investigators found that there was a minimum, non-zero value of σ_v that can be attributed to wind meandering over the course of a given hour. While, small-scale turbulence is the main source of variance at higher wind

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[11] Paine, R., O. Samani, M. Kaplan, E. Knipping, N. Kumar. 2015. Evaluation of low wind modeling approaches for two tall-stack databases, Journal of the Air & Waste Management Association, 65:11, 1341-1353, DOI:10.1080/10962247.2015.1085924 http://www.tandfonline.com/doi/full/10.1080/10962247.2015.1085924#.VsYzz-baQp4 (Accessed January 18, 2016).

[12] Paine, R., C. Warren, and O. Samani, 2016. AERMOD Low Wind Speed Improvements: Status Report and New Evaluations. Paper #935, presented at the 109th Annual Conference, Air & Waste Management Association, New Orleans, LA.

[13] Available at https://www3.epa.gov/ttn/scram/11thmodconf/presentations/1-5_Proposed_Updates_AERMOD_System.pdf. Written documentation is provided by EPA in Appendix F of the AERMOD user guide addendum for version 15181, available at https://www3.epa.gov/ttn/scram/11thmodconf.htm.

[14] Anfossi, D., D. Oettl, G. Degrazia, A. Goulart. 2005. An analysis of sonic anemometer observations in low wind speed conditions. *Boundary Layer Meteorology* 114, 179–203.

[15] LA.Sagendorf, J. F. and Dickson, C. R. 1974. Diffusion under Low Windspeed, Inversion Conditions. *NOAA Technical Memorandum* 52, 89 pp. http://www.arl.noaa.gov/documents/reports/ARL-52.pdf (Accessed September 9, 2015).

[16] Wilson, R. B., Start, G. E., Dickson, C. R., and Ricks, N. R. 1976. Diffusion under low wind speed conditions near Oak Ridge, Tennessee, *NOAA Technical Memorandum* ERL ARL-61, 83 pp. http://www.arl.noaa.gov/documents/reports/ARL-61.pdf (Accessed September 9, 2015).

[17] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee, W.D. Peters, and R.W. Brode. 2005. AERMOD: A Dispersion Model for Industrial Source Applications. Part I: General Model Formulation and Boundary Layer Characterization. *Journal of Applied Meteorology* 44, 682-693.

[18] Smedman, A. S. 1988. Observations of a Multi-Level Turbulence Structure in a Very Stable Atmospheric Boundary Layer. *Boundary Layer Meteorology* 66, 105–126.

[19] Mahrt, L. 1998. Stratified Atmospheric Boundary Layers and Breakdown of Models. *Theor. Comput. Fluid Dyn*. 11, 263–279.

speeds, longer-scale sub-hourly lateral meandering motions appear to exist in all conditions. Hanna (1990)[20] found that the hourly-averaged σ_v has a non-zero minimum value of about 0.5 ms^{-1} as the wind speed approaches zero. Chowdhury et al. (2014)[21] noted that a minimum σ_v of 0.5 ms^{-1} is a part of the formulation for the advanced puff model SCICHEM. Anfossi (2005) noted that meandering exists under all meteorological conditions regardless of the stability or wind speed, and this phenomenon sets a lower limit for the hourly averaged horizontal wind component variances as noted by Hanna (1990) over all types of terrain. The use of a "floor" for the σ_v values input to hourly steady-state plume models like AERMOD is important not only for parameterizations that could result in very low computed σ_v values, but also for measurement systems that have starting speeds above the minimum σ_v values for calm conditions.

Thus, the simulation of pollutant dispersion in LWS conditions is challenging. These conditions are addressed by AERMOD in a unique manner. As stated in the AERMOD formulation document (EPA, 2004)[22], "AERMOD accounts for meander by interpolating between two concentration limits: the coherent plume limit (which assumes that the wind direction is distributed about a well-defined mean direction with variations due solely to lateral turbulence) and the random plume limit (which assumes an equal probability of any wind direction)."

The computation of the AERMOD coherent plume dispersion and the relative weighting of the coherent and random plumes in stable conditions are strongly related to the magnitude of σ_v, which is parameterized as being directly proportional to the magnitude of the friction velocity unless there are direct turbulence measurements. Therefore, the formulation of the friction velocity calculation and the specification of a minimum σ_v value were also considered by Paine et al. (2015). It is noted that the friction velocity also affects the internally-calculated vertical temperature gradient, which affects plume rise and plume-terrain interactions, and these are especially important in elevated terrain situations. The formulation of the friction velocity has been separately researched by Qian and Venkatram (2011)[23]. This research led to an adjustment of friction velocity computation in AERMET as proposed by EPA. However, Paine et al. (2016) focused upon the updated treatment in AERMOD of the specification of the minimum σ_v ("LOWWIND3") as well as how the meander weighted component is determined in AERMOD.

Paine et al. (2015) conducted an evaluation with two tall-stack databases with the AERMOD "LOWWIND2" option. Since that time, EPA proposed an updated option referred to as "LOWWIND3." Both options are similar, but certain aspects of LOWWIND3 include additional changes that EPA has proposed. Both options adopt a minimum σ_v of 0.3 ms^{-1}, which is an increase from the current default value of 0.2 ms^{-1} but still less than the above-referenced 0.5 ms^{-1}. The differences between LOWWIND2 and LOWWIND3 are as follows:

- The LOWWIND2 option reduced the time scale for the meander component from the original AERMOD formulation specification of 24 hours to 12 hours, but LOWWIND3 has restored the meander time scale to 24 hours.
- The LOWWIND3 option eliminated the computation of upwind concentrations that the meander component allowed under other options. This is more typical of the behavior of most steady-state Gaussian models.
- The LOWWIND3 option assumes a travel time to the model receptor based on the actual wind direction, while the LOWWIND2 option assumes a travel time based on a wind blowing

[20] Hanna, S. R. 1990. Lateral Dispersion in Light-Wind Stable Conditions, *Nuovo Cimento* 13, 889–894.

[21] Chowdhury, B., R. I. Sykes, D. Henn, P. Karamchandani. 2014. SCICHEM Version 3.0 (Beta 2) Technical Documentation. Available at http://sourceforge.net/projects/epri-dispersion/files/SCICHEM/SCICHEM3.0b2.zip/download

[22] U.S. Environmental Protection Agency. 2004. AERMOD: Description of Model Formulation. EPA-454/R-03-004. http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_mfd.pdf. (accessed June 10, 2015).

[23] Qian, W. and A. Venkatram. 2011. Performance of steady-state dispersion models under low wind-speed conditions. *Boundary Layer Meteorology,* 138, pp 475-491.

directly toward the receptor. The LOWWIND3 treatment is more consistent with typical steady-state plume model formulations.

In essence, the LOWWIND3 option has restored certain features of the original AERMOD formulation that were altered by the LOWWIND2 option while improving other features of the model's treatment of dispersion under low wind conditions. However, since both LOWWIND2 and LOWWIND3 options limit the minimum σ_v value to 0.3 ms^{-1}, the differences in model predictions using the two model options are expected and generally found to be small, as noted below.

The Sierra Club initially expressed its concerns about the AERMOD low wind options in a presentation[24] by Camille Sears at the 2013 EPA Modeling Workshop. The Sierra Club also expressed its concerns about the AERMOD low wind options as part of their comments on the proposed EPA changes to AERMOD presented in 2015. Paine et al. (2016) noted that the Sierra Club evaluations methods when using AERMOD evaluation databases posted by EPA[25] were based on somewhat dated techniques that are not appropriate for a probabilistic NAAQS that focuses upon a 99th percentile rather than a maximum value. Paine et al. (2016) stated that it is more appropriate to conduct the model evaluations relative to the current form of the newer probabilistic NAAQS given the high importance put on these new standards.

We feel this theoretical rationale supports LOWWIND3 as a better model option and fulfills the requirement of Section 3.2.2.b(3) for an Appendix W non-guideline approval under Section 3.2.2(e)(ii).

(iv) Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates.

If a site-specific field database is not available for a specific site (such as WATEO), EPA has, in the case of several ADJ_U* requests, accepted a comparison and sensitivity study that shows modeled results and trends for the application site similar to those from a similar site with a site-specific field study evaluation against monitored data. This is referred to by EPA as an "apples-to-apples" comparison. A similar approach is used here for a request to use LOWWIND3 for WATEO since a site-specific study for WATEO is not available in this case.

We have found a similar site with a model performance evaluation: the Gibson Generating Station owned by Duke Energy. An evaluation database for this site exists and has been peer-reviewed and published for evaluation of low wind modeling approaches by Paine et al. (2015) in which LOWWIND2 was evaluated.

An available 3-year period of 2008-2010 was used for this evaluation. The Gibson Generating Station is located in southwestern Indiana, an area characterized by flat terrain. During this period, continuous measurements were taken at four SO_2 monitors within 6 km of the plant. The evaluation database is supplemented by representative airport hourly meteorological data (from Evansville, IN, 1-min data, located about 40 km south-southeast of the plant), and hourly emissions data from the Gibson Generating Station. The facility consists of five active boiler units; units 1 and 2 have separate flues within a common stack, while units 3, 4, and 5 exhaust through separate stacks. All four stacks are considered to be tall, with heights of 620 feet (units 1-3) and 500 feet (units 4 and 5) with nearby terrain being quite flat. **Table 1** summarizes the stack parameters for each of the sources modeled. Because there are no major SO_2 sources within at least 30 km of Gibson, only emissions from Gibson were included in the model evaluation study.

[24] Camille Sears presentation at the 2013 Regional State Local Air Quality Modeling Workshop, available at http://www.cleanairinfo.com/regionalstatelocalmodelingworkshop/archive/2013/Files/Presentations/Tuesday/107-Sears-Sierra_Club.pdf.

[25] EPA, AERMOD modeling system. Available at http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod.

Two of the monitors were located approximately 3 km north (Mt. Carmel) and north-northeast (East Mt. Carmel) of Gibson, placing them downwind of the most frequently observed wind direction relative to the facility. The other two monitors were located 2 km southeast (Gibson Tower) and 6 km to the west (Shrodt) of Gibson. A map showing the monitor sites relative to the Gibson Generating Station is provided in **Figure 5**. Coordinate locations and elevations for the monitors are listed in **Table 2**.

Table 1: Gibson Stack Parameters

Source ID	UTM East (m)	UTM North (m)	Base Elevation (m)	Stack Height (m)	SO_2 Emissions[C]	Exit Temperature (K)	Stack Diameter (m)
Unit 1	432999	4247189	119.0	189.0	Vary	327.2	7.6
Unit 2	432999	4247189	119.0	189.0	Vary	327.2	7.6
Units 1_2[A]	432999	4247189	119.0	189.0	Vary	327.2	10.78[B]
Unit 3	432923	4247251	118.5	189.0	Vary	327.2	7.6
Unit 4	432886	4247340	117.9	152.4	Vary	327.2	7.2
Unit 5	432831	4247423	116.3	152.4	Vary	327.2	7.2

[A] Denotes the merged flues from units 1 and 2 forming the common stack.
[B] Equivalent stack diameter due to merged flues.
[C] Hour-varying emissions were measured from continuous emissions monitoring systems (CEMS).

Figure 4: Map of Gibson Model Evaluation

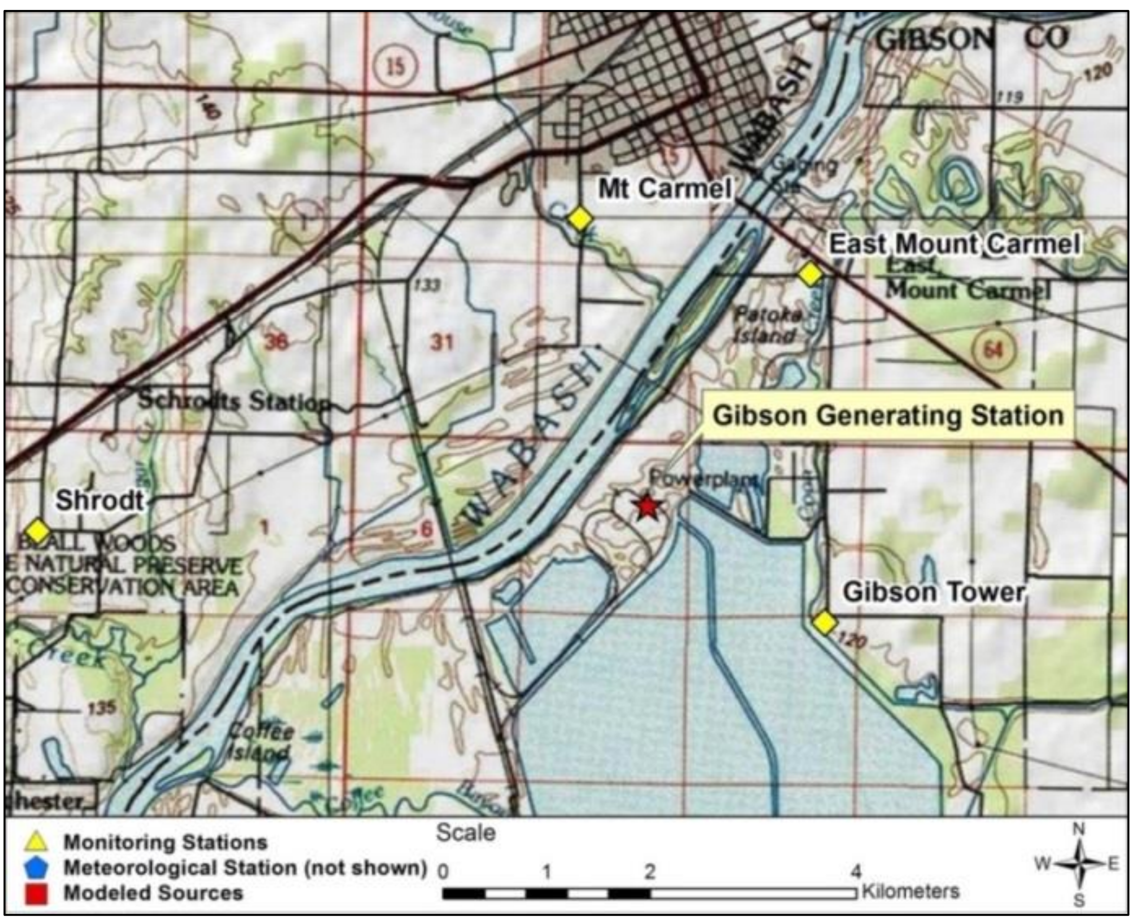


Table 2: Monitor Locations for the Gibson Database

Monitor	UTM East (m)	UTM North (m)	Monitor Elevation (m)
Mt. Carmel	432424.0	4250202.0	119.0
East Mt. Carmel	434654.0	4249666.0	119.3
Shrodt	427174.9	4247181.5	138.0
Gibson Tower	434791.6	4246296.0	119.0

The Gibson evaluation includes two monitors that are in areas in which measured and predicted impacts from Gibson are affected substantially by building downwash (Mt. Carmel and East Mt. Carmel). The evaluation includes two monitors (Shrodt and Gibson Tower) in areas in which predicted impacts from Gibson are not affected substantially by building downwash. The LOWWIND2 and LOWWIND3 options may have a small effect on receptors affected by building downwash, but the relative change is minimal because the highest downwash concentrations will occur under higher wind speed cases which really are not affected by low wind options such as LOWWIND2 and LOWWIND3.

This evaluation was performed both with and without building downwash to better understand the full impact of the LOWWIND options on Gibson. Essentially, this evaluation of Gibson expanded upon the Paine et al. (2015) and (2016) studies and provided evaluations for the following cases:

Case 1: AERMET (default) and AERMOD (default) with building downwash.

Case 2: AERMET (default) and AERMOD (default) without building downwash.

Case 3: AERMET (default) and AERMOD (LOWWIND2) with building downwash.

Case 4: AERMET (default) and AERMOD (LOWWIND2) without building downwash.

Case 5: AERMET (default) and AERMOD (LOWWIND3) with building downwash.

Case 6: AERMET (default) and AERMOD (LOWWIND3) without building downwash.

A regional background of 18 $\mu g/m^3$ determined from monitors with no plant impacts was added to the AERMOD modeled predictions. The background concentration is a small fraction of the modeled concentration and has little effect on the results.

A plot of the predicted-to-observed concentration ratios (with background concentrations included) is provided in **Figure 5**. The plot shows that these ratios are consistently greater than 1.0 for the monitors unaffected by downwash, Shrodt and Gibson Tower. When downwash is included, these ratios are also consistently greater than 1.0 for Mt. Carmel and East Mt. Carmel. As expected for the Mt. Carmel and East Mt. Carmel monitors, the exclusion of building downwash results in an under-prediction. The results for AERMOD with the LOWWIND3 option (Test Case 5 and 6) are within about 10% of the corresponding results for the LOWWIND2 option (Test Case 3 and 4) and thus are essentially equivalent due to the 10% tolerance allowed[26] by EPA in calibrations for SO_2 monitors. As in the case of the Mercer County, North Dakota study (Paine et al. 2016), the EPA-proposed LOWWIND3 low wind option (Test Case 5) provided modest improvements, ranging from 4 to 10% in performance relative to the default option (Test Case 1) for Gibson, while consistently showing an over-prediction tendency at each monitor. Specifically for the Shrodt and Gibson Tower monitors (and when building downwash was excluded from the Mt. Carmel and East Mt. Carmel monitors – Test

[26] 40 CFR Part 58 - Appendix A (Paragraph 2.3.1.5)

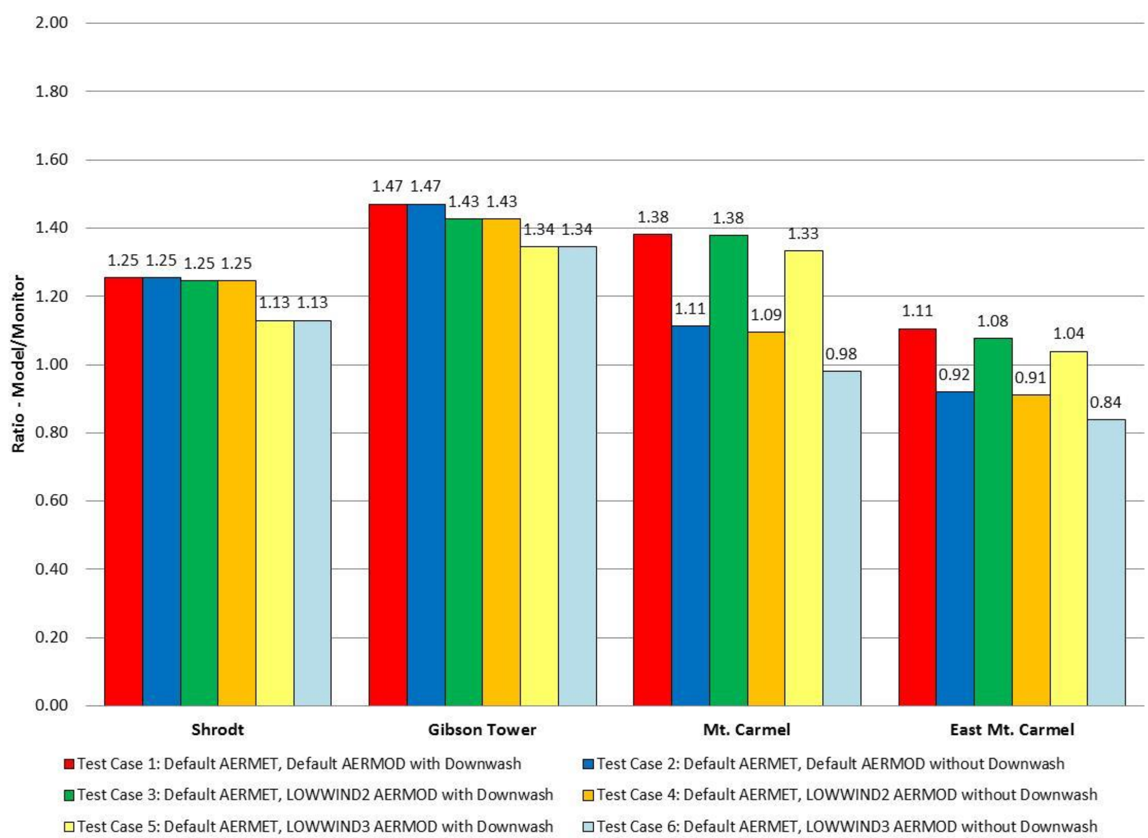
Case 2 vs Test Case 6), this percent change from default to LOWWIND3 (Test Cases 1/2 vs. Test Cases 5/6) was approximately 10%.

The overall evaluation results for Gibson indicated the following:

- The highest modeled design concentration from all monitor sites for both default and low wind options with downwash are higher than observed.
- The AERMOD v15181 default highest design concentration from all monitor sites is greater than that for the low wind options.
- The ratios of the modeled to monitored concentrations at each monitor are greater than 1.0 with downwash. With downwash, the default option over-predicts by about 11-47% (red bar). The low wind options with downwash reduce the over-predictions to 4-34% at the four monitors (green and pale yellow).

The model evaluation of the Gibson data presented herein satisfies the requirement of Section 3.2.2.b(3) for an Appendix W non-guideline approval under Section 3.2.2(e)(iv) in that the use of LOWWIND3 for the Gibson database improves the AERMOD performance and still results in a model over-prediction. Due to the obscuring effect of downwash on low wind option effects, an "apples-to-apples" evaluation was performed using no downwash for both the Gibson and WATEO sites.

Figure 5 Ratio of Model/Monitored Concentrations for Four Gibson Monitors



Appendix W Condition 2

As stated above, the WATEO request to use LOWWIND3 generally falls under Section 3.2.2(b)(2) of Appendix W. The following technical discussion fulfills the associated requirements under Section 3.2.2(d) of Appendix W in a manner to similar to other requests to use the "ADJ_U*" beta option approach in AERMOD. An ideal alternative model demonstration would involve a site-specific field study at the WATEO site. This demonstration would involve a statistical performance evaluation using site-specific monitored data that shows no under-prediction tendency. However, since site-specific studies are usually not available, EPA has, in the case of ADJ_U* requests, accepted a sensitivity study that shows modeled results and trends when compared to those from a similar site with a site-specific evaluation against monitored data.

A similar approach is used here for Condition 2 since a site-specific study is not available in this case. As stated previously, since building downwash impacts are controlled by higher wind speed events, downwash was not included in the analysis contained herein that is designed to examine the impact of LOWWIND3 versus default AERMOD at Gibson and WATEO. Performing the analysis in this manner is the most logical due to the reasons noted below.

(1) The WATEO results are not controlled by receptors impacted by downwash (i.e. taking downwash out of the model does not change the location and value of the controlling design concentration).

(2) **Figure 5** (which shows the AERMOD evaluation for Gibson) indicates that the relative change in the design concentration when using the AERMOD default vs AERMOD with LOWWIND3 is relatively uniform when comparing the monitors not impacted by downwash. When downwash is included, the relative change using LOWWIND3 (for those monitors impacted by downwash) is lower than that using LOWWIND2. This is expected as modeled concentrations controlled by downwash will be associated with higher wind speeds.

(3) **Figure 5** indicates the model is still over-predicting the observed design concentrations for the monitors not affected by downwash (Shrodt and Gibson Tower) whether downwash is or is not removed from the modeling.

In order to have more of an "apples-to-apples" comparison between Gibson and WATEO for the LOWWIND3 comparison, there are several differences in how the Gibson modeling was performed for this analysis as compared to the Gibson model evaluation discussed previously. Those differences include:

(1) Gibson was run using a full Cartesian receptor grid with terrain elevation (described below) to determine if there is a change in the overall concentration pattern, location of maximum modeled design concentration, and relative change for all receptors using the LOWWIND3 option.

(2) Gibson was run using constant stack exhaust characteristics (velocity and temperature) for each Boiler along with normalized constant emission rates (described below).

The differences listed above from how the Gibson evaluation modeling was conducted provide more similarities with the WATEO modeling and allow for a more comparable evaluation of the performance of LOWWIND3.

Receptor Grids for Modeling

The top 10 modeled concentrations using a full receptor grid without downwash were examined to determine the overall relative change in modeled concentrations using LOWWIND3. This comparison was performed for Gibson as well as WATEO. For Gibson, a multi-tiered Cartesian grid with the following spacing was used:

- 100-m receptor spacing extending out 2 km from the grid center (located near the approximate mid-point of the facility);
- 250-m receptor spacing between 2 and 5 km from the grid center;
- 500-m receptor spacing between 5 and 10 km from the grid center; and
- 1000-m receptor spacing beyond 10 km (out to 15 km).

The modeling analysis for WATEO was conducted using the following Cartesian receptor grid design, matching that used in the SO_2 DRR modeling report.

- 25-m receptor spacing along the facility property boundaries;
- 100-m receptor spacing extending out to 1 km from the plant boundary;
- 250-m receptor spacing between 1 km to 5 km; and
- 500-m receptor spacing between 5 km to 10 km.

Stack Parameters for Modeling and Similarities between WATEO and Gibson

As discussed in the SO_2 DRR modeling report for WATEO, Wateree Station is a fossil fuel-fired electric generating plant with a rated capacity of approximately 685 megawatts (MW). The main SO_2-emitting sources at this station are two boilers (UB12) and an auxiliary boiler (AB1). The IP Eastover Mill is an integrated Kraft pulp and paper mill. At this facility, the main SO_2-emitting sources are a combined stack 381A/501A serving No. 1 Recovery Furnace (381A) and No. 1 Power Boiler (501A), a combined stack 382A/331A serving No. 2 Recovery Furnace (382A) and the NCG Incinerator (331A), and a stack 502A serving No. 2 Power Boiler. **Table 3** provides the stack parameters for these sources. More information on these sources as well as other smaller SO_2-emitting sources included in the modeling (generally insignificant contributors) can be found in the modeling report.

The stack parameters used for modeling Gibson are provided in **Table 1**. In addition to the data provided in **Table 1**, the emissions and stack velocities used for this modeling are provided in **Table 4**. The modeled emissions for Gibson are normalized based on the boiler with the maximum heat input, however the strength of each source is comparable to each source's permitted emission rate.

A comparison of the data in **Table 3** for WATEO and **Tables 1** and **4** for Gibson shows both sources have similar configurations of tall stacks with lots of buoyancy and momentum.

Table 3: WATEO Stack Parameters and Emissions [A]

Facility	Stack ID	Stack Height (m)	Exit Velocity (m/s)	Stack Diameter (m)	Stack Temperature (K)	Modeled Emission Rate (g/s)
Wateree	UB12	121.92	16.30	8.53	327.00	40.57
Eastover	381A/501A	86.11	17.19	4.11	459.26	8.77
Eastover	382A/331A	141.09	15.51	4.30	460.93	8.39
Eastover	502A	141.09	20.79	2.90	464.82	12.23

[A] Smaller sources with negligible impacts were also included in this analysis per the modeling report.

Table 4: Gibson Stack Parameters and Emissions

Facility	Stack ID	Exit Velocity (m/s)	Modeled Emission Rate (g/s)
Gibson	Units 1_2	21.49	15.80
Gibson	Unit 3	22.57	11.85
Gibson	Unit 4	21.98	4.74
Gibson	Unit 5	21.88	8.69

Results of Sensitivity Comparison Study

Four modeling scenarios were chosen to investigate the change in predicted concentrations for both Gibson and WATEO to support WATEO's request to use of the non-regulatory LOWWIND3 option. AERMET/AERMOD version 15181 was run using default options and AERMOD LOWWIND3 beta option for the following scenarios:

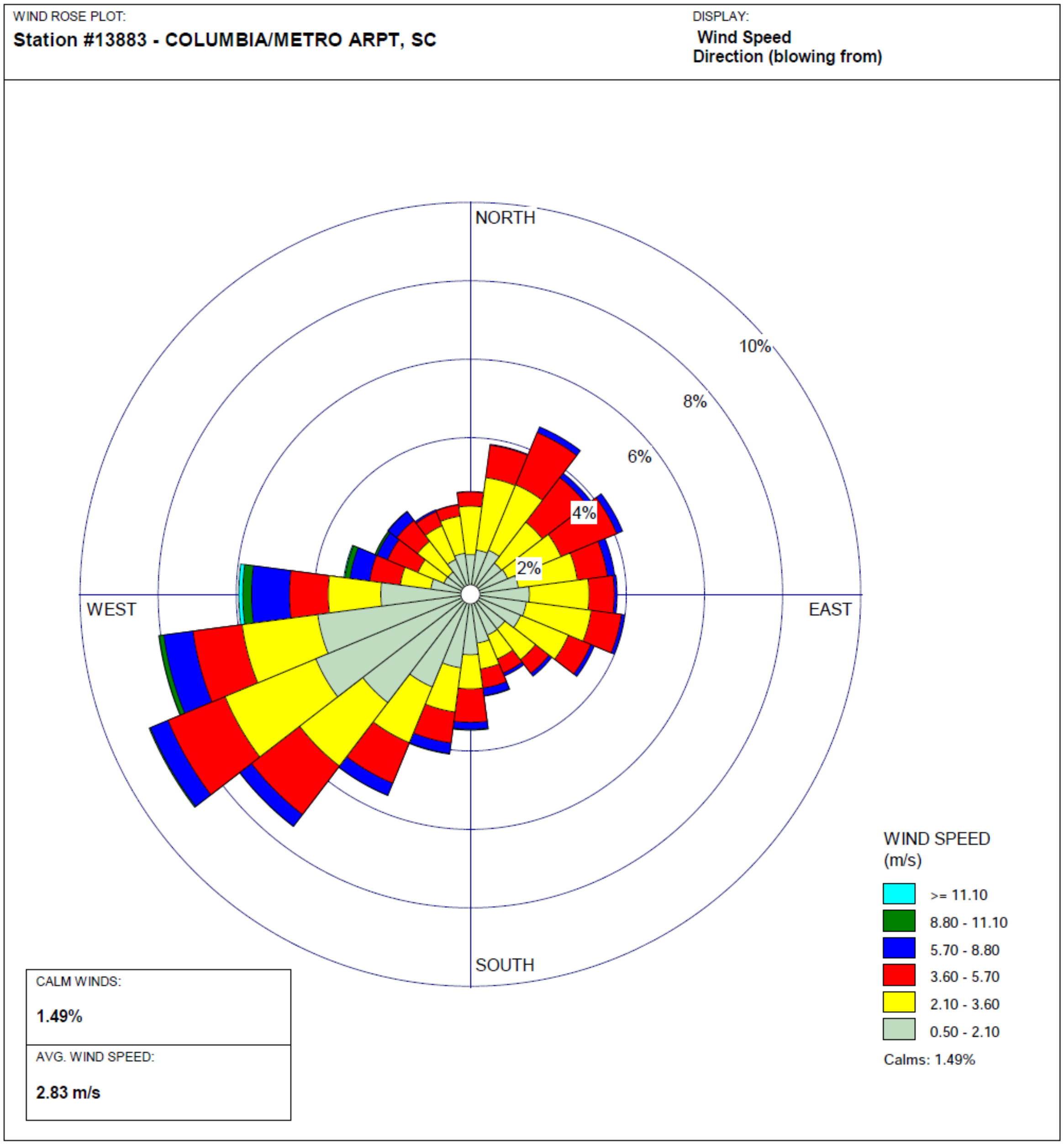
- AERMET default / AERMOD default without downwash at Gibson;
- AERMET default / AERMOD LOWWIND3 without downwash at Gibson;
- AERMET default / AERMOD default without downwash at WATEO; and
- AERMET default / AERMOD LOWWIND3 without downwash at WATEO.

As noted previously, no building downwash effects were modeled because WATEO is not affected by building downwash at the location of the controlling design concentration and modeling without downwash will illustrate the consistent trend in a comparison of LOWWIND3 results to the default model options. However, the final attainment demonstration shown in the modeling report includes building downwash effects.

The model input configuration (domain, meteorological data, etc.) used in this sensitivity comparison study is similar to that presented in the 1-hour SO_2 DRR modeling report for WATEO. These input configurations include:

- Modeling using 3-years (2012-2014) of representative meteorological data;
    - For WATEO, the Columbia Metropolitan Airport is used for surface meteorological data with concurrent upper air data from Greensboro, NC; wind rose from Columbia from 2012-2014 is shown in **Figure 7** which is based on the meteorological data used as input to AERMOD.
    - Turbulence is not used as it is not available from Columbia Metropolitan Airport.
- Multi-tiered Cartesian receptor grid, as described in the previous section.

Figure 6: Wind Rose for Columbia Metropolitan Airport (2012-2014)



Results of the 99th Percentile Concentrations

The 4th highest (99th percentile) daily 1-hour peak SO_2 concentrations for both WATEO and the Gibson study are summarized in **Table 5,** showing about a 15.5% concentration decrease from default to LOWWIND3. For this comparative modeling, no downwash effects were modeled in order to be consistent with the modeled impacts at the Shrodt and Gibson Tower monitor locations at Gibson which are unaffected by building downwash. Ambient background SO_2 concentrations were not included in the modeling comparison for either WATEO or the Gibson sensitivity studies.

Figures 7 and **8** show isopleth maps of the 4th highest daily 1-hour SO_2 modeled concentrations at each Gibson receptor using the AERMOD default and LOWWIND3 options, respectfully. **Figures 7** and **8** show a very similar concentration pattern irrespective of the model options used. Specifically, the location of the 4th highest daily 1-hour peak SO_2 concentration from Gibson is approximately 2 km from the plant when AERMOD is run either with default options or using the LOWWIND3 option.

The concentration pattern observed in the isopleth maps for WATEO using default AERMOD options (**Figure 9**) and the LOWWIND3 option (**Figure 10**) are also very similar. The location of the 4th highest daily 1-hour peak SO_2 concentration shifts slightly to the south to a location closer to Eastover when the LOWWIND3 option is used. When comparing **Figures 9** and **10**, only subtle differences are noted that include: slightly lower predicted impacts and, in general, a shift in the concentration pattern when LOWWIND3 is applied while the maximum concentration continues to be located in the same direction downwind of the source as the default run.

Comparison of Results of the Top 10 99th Percentile Concentrations for WATEO and Gibson

The top 10 3-year averaged 4th highest maximum daily 1-hour SO_2 concentrations for the LOWWIND3 modeling simulation are compared against the model simulation with default options. This comparison was performed for Gibson and WATEO.

The top 10 Gibson modeled concentrations for the default model (**Table 6**) indicate that LOWWIND3 reduces concentrations by approximately 15 – 20% from the default model. The hours for which these modeled concentrations occur are all in unstable conditions, just as the model to monitor comparison for Shrodt and Gibson Tower monitors showed. For the top 10 LOWWIND3 modeled concentrations (**Table 7**), LOWWIND3 decreased concentrations by a range of 7 – 17% from the default model.

The top 10 WATEO modeled concentrations for the default model (**Table 8**) indicate that LOWWIND3 reduces concentrations by approximately 19 – 22% from the default model. The hours for which these modeled concentrations occur are all in unstable conditions, just as the model to monitor comparison for Shrodt and Gibson Tower monitors showed. For the top 10 LOWWIND3 modeled concentrations (**Table 9**), LOWWIND3 decreased concentrations by a range of approximately 12 – 15% from the default model. These changes are similar to those noted in **Tables 6** and **7** for Gibson.

Table 5: 4th Highest Daily Peak 1-hour SO_2 Modeled Concentrations for WATEO and Gibson

Model Options	WATEO Daily 1-hour Highest 99th Percentile SO_2 Concentrations (µg/m³)[A]	Gibson Daily 1-hour Highest 99th Percentile SO_2 Concentrations (µg/m³)[A]
AERMOD Default, No Downwash	**22.4**	**10.4**
AERMOD LOWWIND3, No Downwash	**18.9**	**8.8**
Percent Change	**-15.6%**	**-15.4%**

[A] SO_2 predicted concentrations do not include any background contributions.

Table 6: **Gibson Modeled Concentrations with Default vs. LOWWIND3 at the Default Receptors Top 10 3-year Average 4th Highest Daily 1-hour Concentrations**

Rank	UTM East (m)	UTM North (m)	Ave Wind Speed (m/s)	3-Year Average Concentration Default (ug/m3)	3-Year Average Concentration LOWWIND3 (ug/m3)	Percent Change (%)
1st Highest	434900.0	4248500.0	1.71	10.405	8.718	-16.2%
2nd Highest	434900.0	4248400.0	1.69	10.325	8.803	-14.7%
3rd Highest	434800.0	4248400.0	1.90	10.294	8.632	-16.1%
4th Highest	434800.0	4248500.0	1.59	10.257	8.438	-17.7%
5th Highest	434900.0	4248600.0	1.75	10.253	8.497	-17.1%
6th Highest	434700.0	4248300.0	1.49	10.235	8.344	-18.5%
7th Highest	434800.0	4248300.0	1.65	10.195	8.324	-18.4%
8th Highest	434900.0	4248300.0	1.41	10.189	8.182	-19.7%
9th Highest	434600.0	4248300.0	1.62	10.187	8.246	-19.0%
10th Highest	434800.0	4248600.0	1.51	10.182	8.255	-18.9%

Table 7: **Gibson Modeled Concentrations with Default vs. LOWWIND3 at the LOWWIND3 Receptors Top 10 3-year Average 4th Highest Daily 1-hour Concentrations**

Rank	UTM East (m)	UTM North (m)	Ave Wind Speed (m/s)	3-Year Average Concentration Default (ug/m3)	3-Year Average Concentration LOWWIND3 (ug/m3)	Percent Change (%)
1st Highest	434900.0	4248400.0	1.65	10.325	8.803	-14.7%
2nd Highest	433900.0	4249950.0	1.98	9.382	8.751	-6.7%
3rd Highest	434900.0	4248500.0	1.52	10.405	8.718	-16.2%
4th Highest	433400.0	4250200.0	1.79	9.596	8.637	-10.0%
5th Highest	433900.0	4250450.0	1.93	9.438	8.634	-8.5%
6th Highest	434800.0	4248400.0	1.52	10.294	8.632	-16.1%
7th Highest	435150.0	4248450.0	1.81	10.077	8.614	-14.5%
8th Highest	433900.0	4250200.0	2.49	9.574	8.499	-11.2%
9th Highest	434900.0	4248600.0	1.79	10.253	8.497	-17.1%
10th Highest	435150.0	4248700.0	1.43	10.163	8.452	-16.8%

Table 8: WATEO Modeled Concentrations with Default vs. LOWWIND3 at the Default Receptors Top 10 3-year Average 4th Highest Daily 1-hour Concentrations

Rank	UTM East (m)	UTM North (m)	Ave WS (m/s)	3-Year Average Concentration Default (ug/m3)	3-Year Average Concentration LOWWIND3 (ug/m3)	Percent Change (%)
1st Highest	532300.0	3753700.0	1.51	22.38544	17.66865	-21.1%
2nd Highest	532300.0	3753800.0	1.58	22.35302	17.58536	-21.3%
3rd Highest	532300.0	3753600.0	1.31	22.30277	17.76247	-20.4%
4th Highest	532300.0	3753900.0	1.58	22.26878	17.57124	-21.1%
5th Highest	532200.0	3754100.0	1.45	22.25238	17.34296	-22.1%
6th Highest	532200.0	3754000.0	1.45	22.22493	17.41817	-21.6%
7th Highest	532200.0	3754200.0	1.52	22.20828	17.37184	-21.8%
8th Highest	532200.0	3753900.0	1.45	22.17478	17.52889	-21.0%
9th Highest	532300.0	3754000.0	1.58	22.16145	17.53993	-20.9%
10th Highest	532300.0	3753500.0	1.31	22.14916	17.84115	-19.4%

Table 9: WATEO Modeled Concentrations with Default vs. LOWWIND3 at the LOWWIND3 Receptors Top 10 3-year Average 4th Highest Daily 1-hour Concentrations

Rank	UTM East (m)	UTM North (m)	Ave WS (m/s)	3-Year Average Concentration Default (ug/m3)	3-Year Average Concentration LOWWIND3 (ug/m3)	Percent Change (%)
1st Highest	532300.0	3751600.0	1.15	21.57432	18.85768	-12.6%
2nd Highest	532308.8	3751510.3	1.09	21.48746	18.83191	-12.4%
3rd Highest	532284.2	3751510.3	1.18	21.55689	18.80265	-12.8%
4th Highest	532333.3	3751510.3	1.09	21.40559	18.76988	-12.3%
5th Highest	532200.0	3751700.0	1.15	21.94006	18.71622	-14.7%
6th Highest	532357.9	3751510.3	1.09	21.30312	18.69432	-12.2%
7th Highest	532259.7	3751510.3	1.18	21.29675	18.62377	-12.6%
8th Highest	532200.0	3751600.0	1.25	21.34346	18.62053	-12.8%
9th Highest	532382.4	3751510.3	1.09	21.18591	18.60448	-12.2%
10th Highest	532300.0	3751700.0	1.15	21.52225	18.56412	-13.7%

Figure 7: Isopleths of the 99th Percentile SO_2 Concentrations using Default Options without Downwash for Gibson

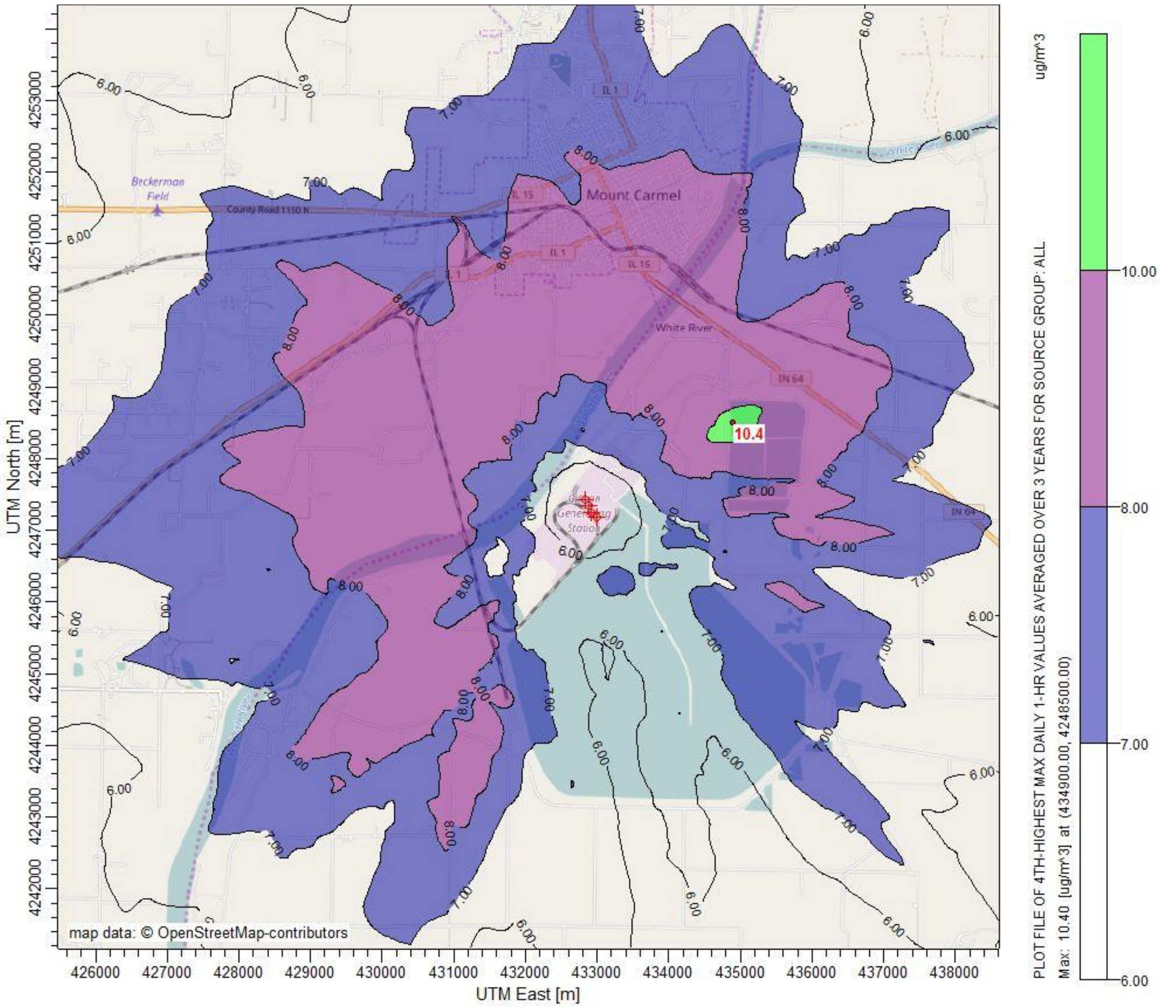


Figure 8: Isopleths of the 99th Percentile SO_2 Concentrations using the LOWWIND3 Option without Downwash for Gibson

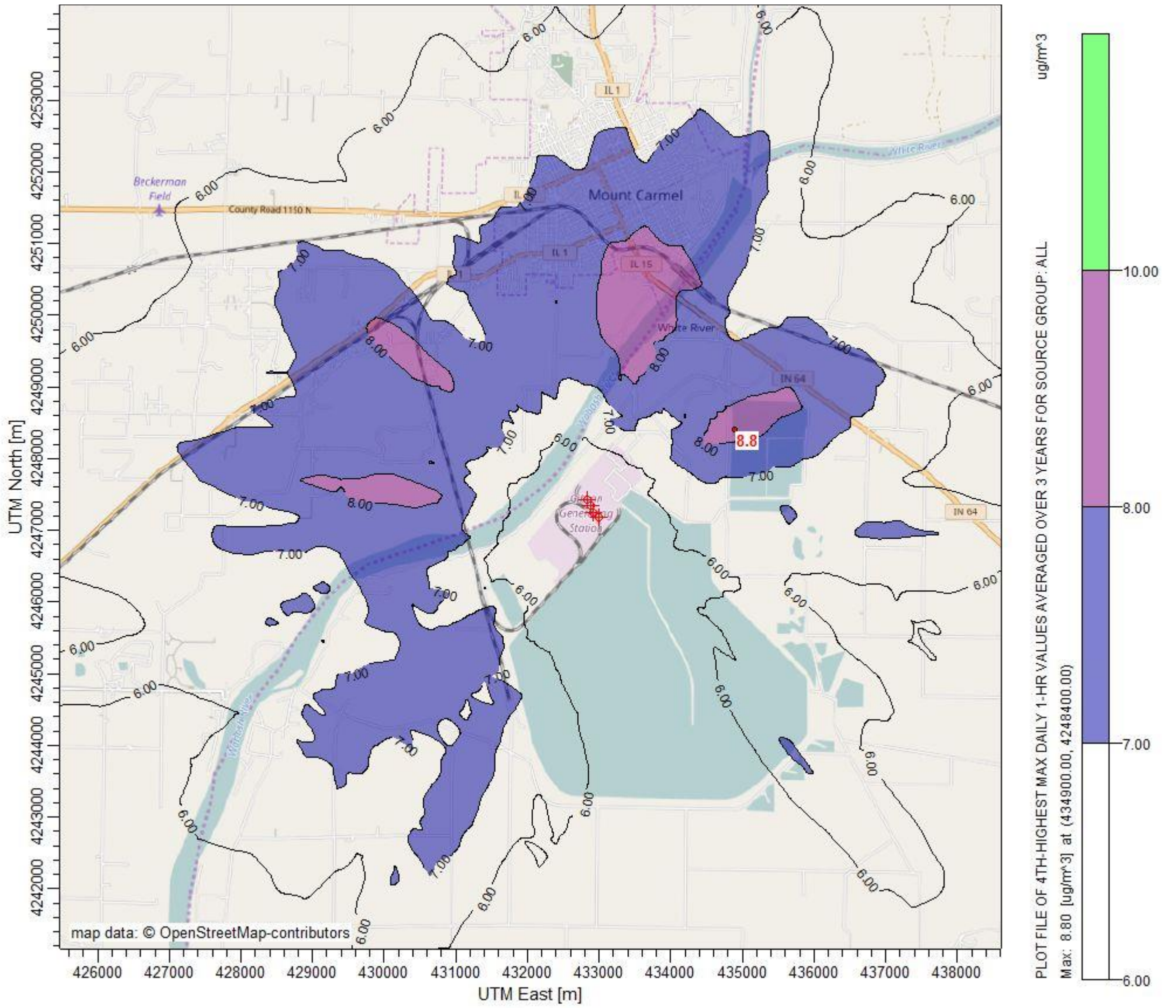


Figure 9: Isopleths of the 99th Percentile SO_2 Concentrations using Default Options without Downwash for WATEO

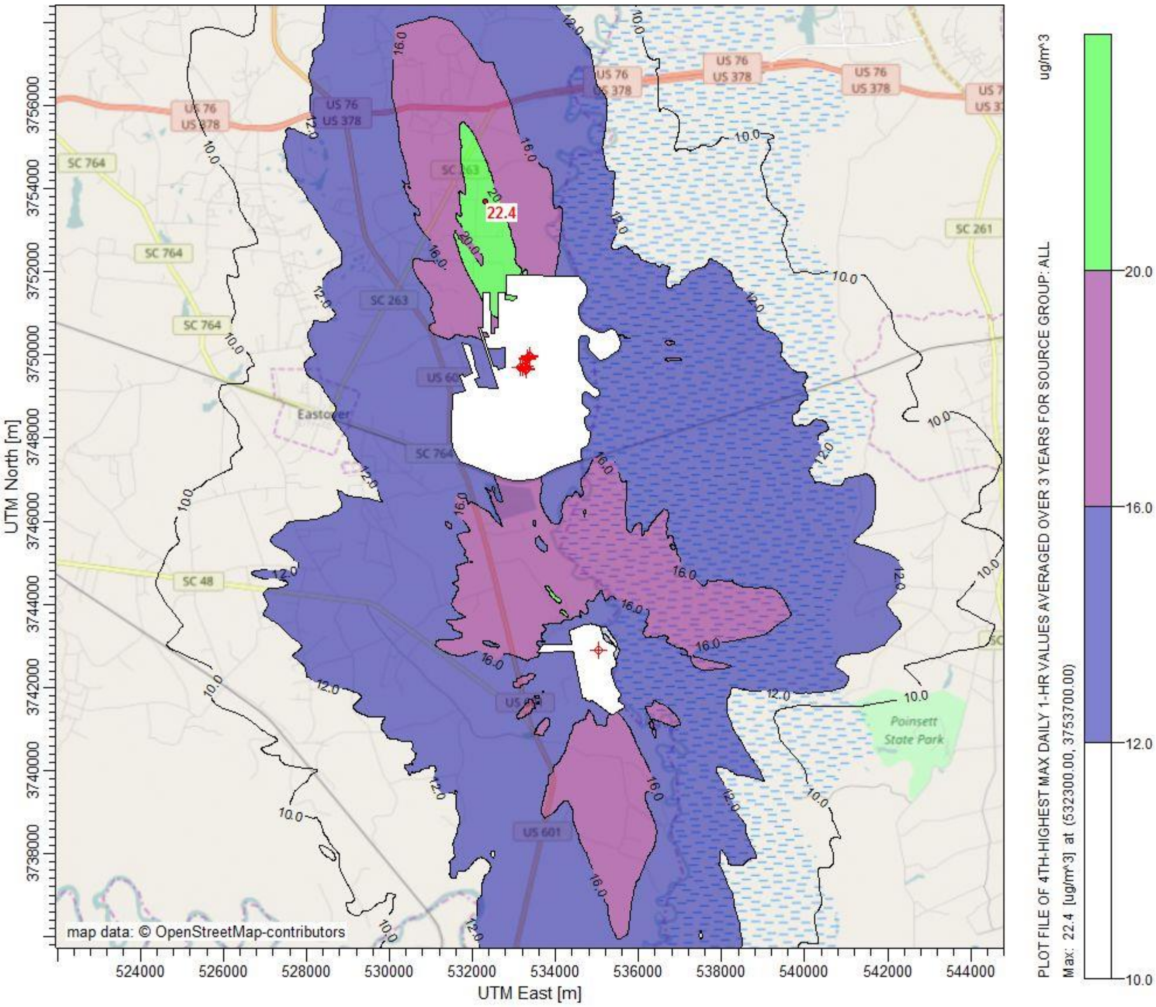
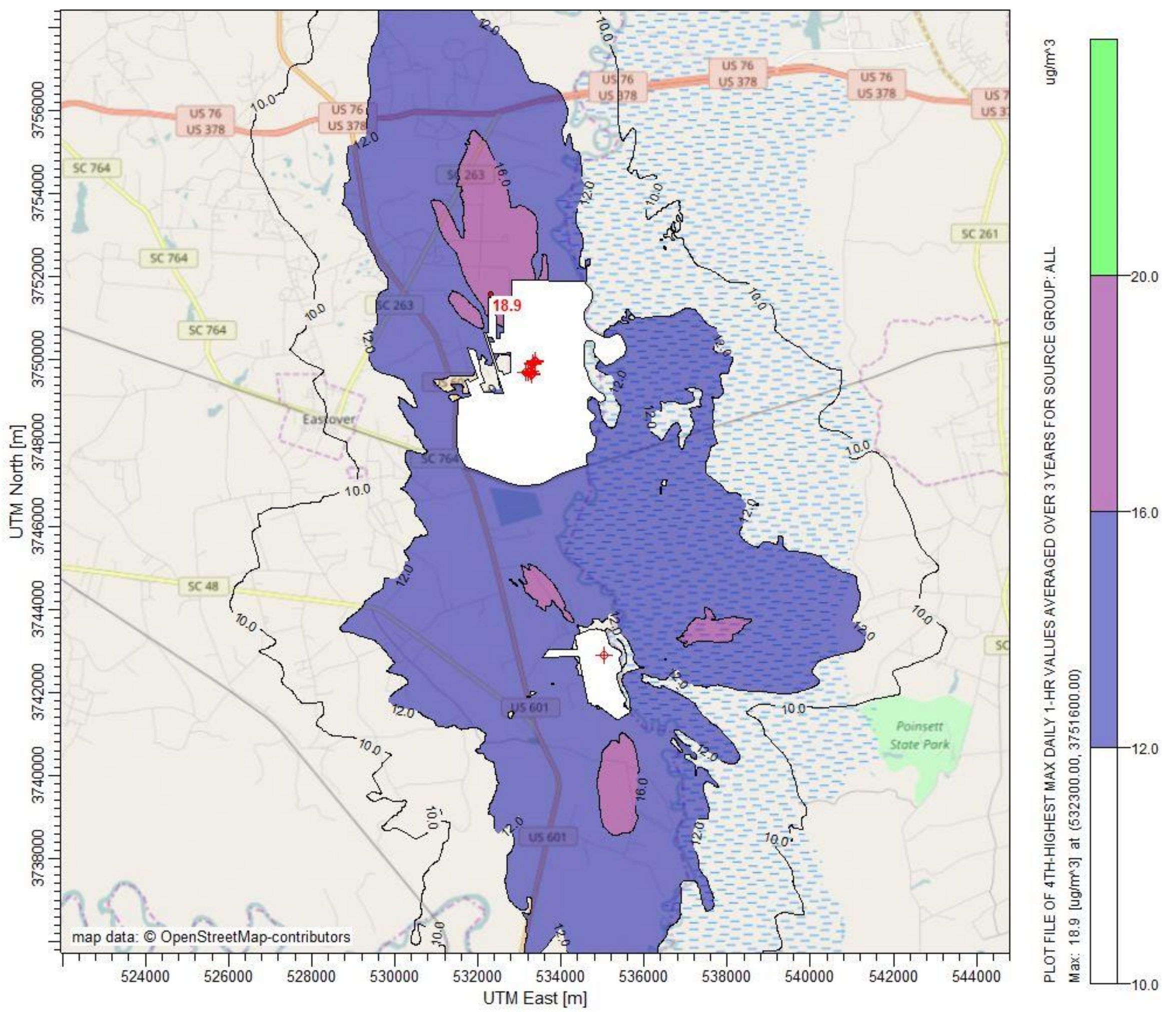


Figure 10: Isopleths of the 99th Percentile SO_2 Concentrations using the LOWWIND3 Option without Downwash for WATEO



Evaluation Comparison Conclusions

The model sensitivity comparison of LOWWIND3 was conducted to provide an “apples-to-apples” comparison between the WATEO application and the Gibson field study evaluation database on the impacts of 1-hour SO_2. Modeled impacts are based on the latest version of AERMET/AERMOD (v15181) for both of these tall-stack databases. The results from WATEO show very similar behavior to those identified in the Gibson evaluation study for the following reasons:

- The difference between concentrations predicted by default options vs. LOWWIND3 for WATEO was similar to that shown by the Gibson model to monitored comparison (about 10%) at monitors not affected by building downwash.

- The percent reduction in predicted impacts from using default options to LOWWIND3 was about 15% for both Gibson and WATEO using a full receptor grid, while the resulting percent reduction from impacts predicted using default options to LOWWIND3 ranged from 15 – 22% at the top 10 receptors.

- The location of the maximum predicted impact remained in the same general wind sector using default and LOWWIND3.

As described in the Gibson evaluation, the predicted-to-observed ratios of 99^{th} percentile SO_2 concentration using the LOWWIND3 option remained at or above 1.0 for monitors not affected by downwash, resulting in an over-prediction. This same result is expected with the use of LOWWIND3 for the WATEO modeling analysis.

This analysis, a discussion of source similarities, and a model sensitivity comparison are provided to EPA as documentation in support of the request to use the LOWWIND3 non-default model option to more accurately handle light wind conditions in AERMOD in the 1-hour SO_2 DRR modeling of WATEO. We feel this analysis fulfills the requirements of Section 3.2.2(b)(2) of Appendix W as well as many requirements of Section 3.2.2(b)(3). This demonstration provides a statistical performance evaluation using site-specific monitored data that shows no under-prediction tendency and is then used to draw a parallel conclusion for a very similar site as has been done with ADJ_U* non-guideline model approvals recently provided by EPA.