UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF:

MEMORANDUM

Subject: Concurrence Request for Approval of a Stack-Specific Approach for Applying Downwash in AERMOD for Ahlstrom-Munksjo in Rhinelander, Wisconsin

From: Randy Robinson, Regional Meteorologist
Control Strategies Section, Air Programs Branch

RANDALL ROBINSON Digitally signed by RANDALL ROBINSON Date: 2021.04.23 11:35:52 -05'00'

Thru: John Mooney, Director
Air and Radiation Division

JOHN MOONEY Digitally signed by JOHN MOONEY Date: 2021.04.28 12:44:30 -05'00'

To: George Bridgers, Director of Model Clearinghouse
Air Quality Modeling Group, Office of Air Quality Planning and Standards

SUMMARY

EPA Region 5 seeks concurrence with EPA's Model Clearinghouse (MCH) on approval of the use of a stack-specific approach for modeling building downwash of sulfur dioxide (SO_2) emissions from exhaust stack S09 at Ahlstrom-Munskjo, which is a pulp and paper mill located in Rhinelander, Wisconsin. (Site map shown in Attachment 1.) In this approach, downwash increases with increasing wind speed and, with declining wind speeds, diminishes to negligible impacts at wind speeds below 2 m/s. This is implemented in AERMOD by increasing hourly emissions based on ambient wind speed to account for the increasing influence of downwash on surface concentrations. Based on improved model performance as demonstrated through a case-specific model to monitor comparison, Region 5 considers Wisconsin's use of a stack-specific approach to applying downwash in AERMOD to be an acceptable alternative modeling technique.

BACKGROUND

This mill was previously owned by Expera. Routine air quality modeling for this facility, including downwash in AERMOD, has been shown to underpredict SO_2 concentrations when compared to nearby air quality monitoring data, at least partially due to corner vortex downwash as explained in more detail later in this memorandum. Ahlstrom-Munskjo (Mill) is located in an area consisting of the City of Rhinelander and four townships including Crescent Town, Newbold Town, Pine Lake Town, and Pelican Town (Oneida County area), which is designated nonattainment under the 2010 SO_2 National Ambient Air Quality Standard (NAAQS). The Mill's coal-fired boiler B26 exhausting to stack S09 is the primary emission unit contributing to nonattainment of the 2010 SO_2 NAAQS in the Oneida County area. As part of its draft attainment plan for the Oneida County area, Wisconsin used wind tunnel studies to evaluate the impact of building downwash and to justify increases to the height of stack S09. Since AERMOD was underpredicting downwash impacts from stack S09, Wisconsin incorporated a stack-specific approach for representing building downwash associated with emissions from stack S09 into its air quality modeling demonstration to show modeled attainment for the Oneida County area. The other stack in the modeled attainment demonstration (S08) is well represented with the existing downwash algorithms in AERMOD and applies these algorithms unmodified in AERMOD.

EPA's Guideline on Air Quality Models (40 CFR Part 51 Appendix W) indicates that determination of acceptability of a model is a Regional Office responsibility with concurrence sought from EPA's Model Clearinghouse. When an alternative model is found to be more appropriate than a preferred model, that model may be used subject to the recommendations of 3.2.2 of Appendix W. In this case, the preferred air quality modeling technique of applying downwash in AERMOD is not appropriate for the particular application, since it has been shown to significantly underpredict when compared to monitored SO_2 impacts. Region 5 finds Wisconsin's stack-specific approach for representing downwash at stack S09 to be a suitable alternative, as described in more detail below. Region 5 is requesting MCH concurrence with Region 5's views in support of approving Wisconsin's stack-specific downwash approach.

<u>ISSUE AND PROPOSED RESOLUTION</u>

On August 5, 2013, (78 FR 47191) the Oneida County area was designated nonattainment of the 2010 SO_2 NAAQS based on monitored concentrations of SO_2 collected at the Rhinelander municipal water tower monitoring site (AQS site ID 55-085-0996) located about 600 meters (m) north of the Mill. Previous efforts to model SO_2 impacts from the Mill have shown that the EPA regulatory models (first ISCST and then AERMOD) have significantly underpredicted SO_2 impacts at the water tower monitor location. Evidence from a wind tunnel study suggests that the monitor is located in the area of expected peak concentrations. An evaluation of the issue has indicated that an aspect of building downwash, referred to as a corner vortex, is responsible for the inability of these models to replicate monitored values. The corner knifes through the approaching wind creating a pair of counter-rotating vortices that act to enhance the descending air on the lee side. This leads to higher pollutant concentrations downwind of the building than when the wind is blowing perpendicular to the building. To evaluate and address this problem, the prior owners of the Mill (Expera) contracted with CPP Inc. to conduct a wind tunnel study of dispersion conditions near this facility.

Wisconsin's initial attainment plan for this area, submitted January 22, 2016, relied on this wind tunnel study for two purposes: 1) to justify credit for a stack height that is greater than is computed with the formula in 40 CFR 51.100(ii)(2)(ii) ("formula GEP stack height"), and 2) to support an alternative means of quantifying the downwash caused in part by corner vortices. In subsequent discussions, EPA questioned whether Wisconsin had fully met the requirements for justifying credit for an above formula GEP stack height, originally proposed to be 90 m. In particular, EPA questioned whether the facility could be considered to have excessive concentrations as defined in 40 CFR 51.100(kk)(1), which stipulates application of a defined level of emission control. Pursuant to these discussions, Wisconsin has revised its plan, which it submitted in proposed form on February 19, 2021 and in final form on March 29, 2021. In this revised plan, while the actual S09 stack height is 90 m, Wisconsin now relies on credit only for formula GEP stack height, which is 75 m. However, the effects of corner vortices on downwash near this facility, and the inability of AERMOD to quantify these effects properly, remains a concern that Wisconsin and Region 5 share. Thus, Wisconsin's revised plan continues to rely on an alternate means of quantifying downwash near this facility, using information developed from the wind tunnel study. This alternate means of quantifying downwash is the focus of this request for concurrence on use of an alternate modeling procedure.

The pertinent wind tunnel studies are documented in a pair of reports.[1,2] These studies were conducted using EPA technical guidance[3,4] and in consultation with EPA Region 5, EPA's Office of Air Quality Planning and Standards, and EPA's Office of Research and Development.

In its revised submittal, Wisconsin used PRIME, the AERMOD component for addressing downwash, for all stacks excluding stack S09, i.e. for modeling the other comparatively minor source at the Ahlstrom-Munksjo's facility and nearby sources. In lieu of using BPIPPRIME for stack S09, Wisconsin modeled the effect of building downwash for stack S09 with a higher emission rate that varies with wind speed.

In accordance with EPA guidance,[3,4] the GEP stack height wind tunnel studies were conducted using wind speeds that are less than the 2% wind speed (i.e., wind speed that is exceeded less than 2% of the time). The 2% wind speed for the study was 7.9 m/s based on 1998-2010 meteorological observations from the nearby Rhinelander-Oneida County Airport. The maximum influence of the Mill building on downwash was determined at a wind speed of 7.56 m/s. At this wind speed, in a wind tunnel simulation simulating a 90 m stack, for the worst-case wind direction, the observed ratio of the maximum ground-level concentration of SO_2 with and without downwash was 1.46. However, the wind tunnel study results indicated that the corner vortex downwash effects are not present for all wind speed conditions. Therefore, Wisconsin, in its AERMOD attainment demonstration analysis, using the relationship between wind speed and the impact of downwash based on data from the wind tunnel study, estimated hourly downwash adjustment ratios and applied these adjustment ratios to estimate concentrations that more appropriately reflected the impact of downwash at this facility. (See Attachments below.) This analysis utilized each hour in the National Weather Service (NWS) 5-year 2011-2015 meteorological data to account for the variation in wind speed and the associated variation in downwash, based on EPA's SO_2 nonattainment guidance that states that as per section 8.3.1.2, Appendix W, 5 years of NWS meteorological data or at least 1 year of site-

[1] Peterson, R. L. and A. Beyer-Lout, Fluid Modeling Good Engineering Practice Stack Height Determination for the Rhinelander Mill Stack S09, CPP Report 7935, October 2014.
[2] Peterson, R. L. and A. Beyer-Lout, Wind Tunnel Modeling to Show Compliance for Expera Rhinelander Mill Stack S09, CPP Report 7835, December 2014.
[3] Guideline for Fluid Modeling of Atmospheric Diffusion, United States Environmental Protection Agency, Environmental Sciences Research Laboratory, Research Triangle Park, North Carolina. EPA-600/8-81-009. April 1981.
[4] Guideline for Use of Fluid Modeling to Determine Good Engineering Practice Stack Height, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-450/4-81-003. July 1981.

specific data should be used.[5] These adjustments are designed for the wind direction with the greatest degree of downwash, reflecting the greatest impact of corner vortices, but applied in AERMOD in all wind directions, an approach that is conservative insofar as other wind directions experience less increase in concentrations, when the corner vortices are not causing downwash.

Wisconsin used Equation 1 to determine the relationship between wind speed and the emissions multiplier, R, which is the ratio of pollutant concentration with and without building downwash. The equation development is discussed in Appendix A of the SO_2 NAAQS Compliance Report for the Rhinelander Mill submitted by the facility.[6] In equation 1, R approaches 1 as wind speed decreases and R approaches a constant value at high wind speeds where downwash impacts are expected to remain relatively constant. $U_{airport}$ is the Rhinelander-Oneida County airport wind speed, U_{max} is assigned as 10.8 m/s, which is the 1% wind speed, and A and B are best-fit constants.

$$R = A \exp\left[-\frac{\left(\frac{1}{Uairport}-\frac{1}{Umax}\right)^2}{B^2}\right] + 1.0 \qquad \textit{Equation 1}$$

While the amount of wind speed and downwash information from the wind tunnel studies was limited, there was sufficient data available to determine equation 1 and the values for A and B. Three wind speeds were evaluated at the 85 m stack height and one wind speed was evaluated at the 90 m stack height. Because the 85 m height had more data, best-fit constants were initially determined for the 85 m stack (A = 0.674, B = 0.174).

The A coefficient (0.674) + 1 represents the maximum downwash multiplier that can be calculated for an 85 m stack using Equation 1. The facility operates an actual stack of 90 m, however, the modeled attainment demonstration can only use the creditable height of 75 m. Consequently, the A coefficient was proportionally adjusted for the 75 m stack using an observed R value for the 85 m stack study and a predicted R value for the 75 m stack, at the 7.56 m/s wind speed, which was determined to be the worst-case wind speed for the purposes of the wind tunnel studies.[6] Attachment 4 shows the equation used to determine the R value for a 75 m stack. Attachments 2, 3, and 5 show specific results from the wind tunnel studies including observed and predicted concentration ratio information for various stack heights. Using the approach above resulted in a 75 m stack A value of 0.826. Equation 2 below shows how the value of A for the 75 m stack was calculated.[6]

$$\frac{A_{75}}{A_{85}} = \frac{(R_{75}-1)}{(R_{85}-1)} \qquad \textit{Equation 2}$$

---

[5] Memorandum from Stephen D. Page, EPA OAQPS, to EPA Air Division Directors, "Guidance for 1-Hour SO_2 Nonattainment Area SIP Submissions," April 23, 2014.

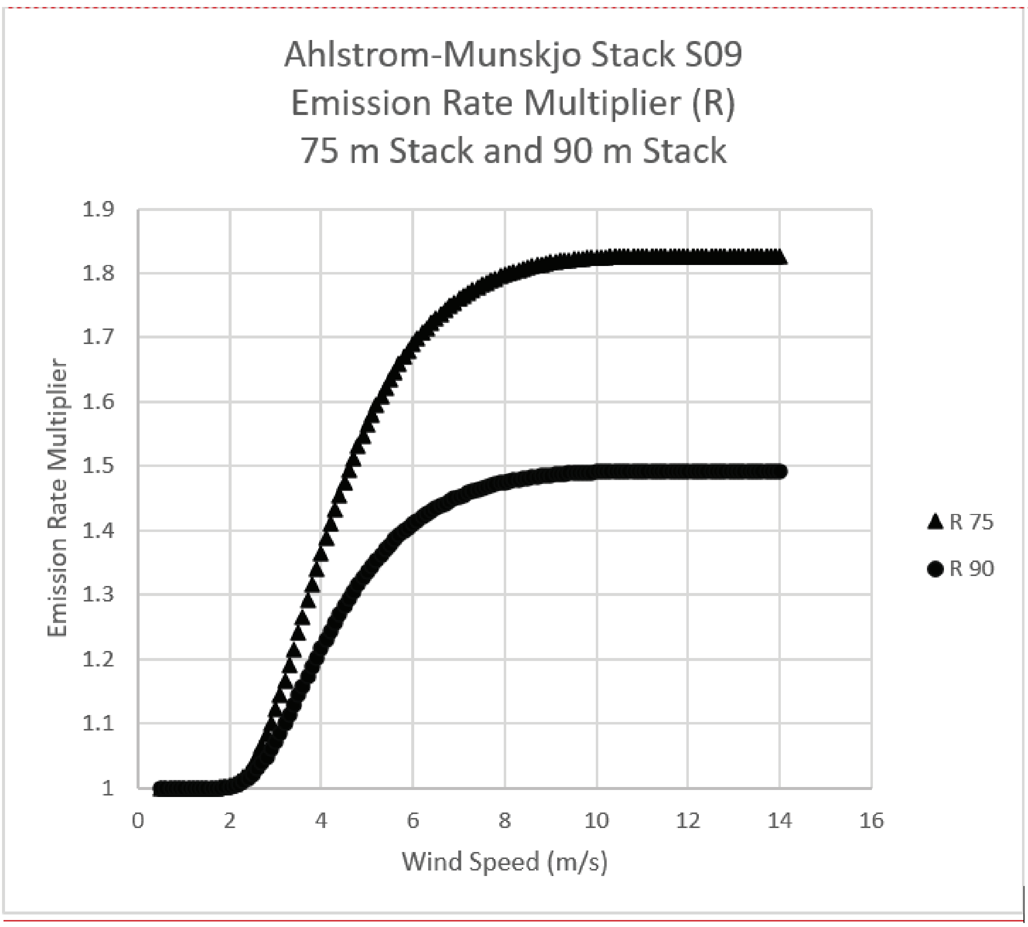
[6] SO2 NAAQS Compliance Report for the Rhinelander Mill; Appendix A; AECOM, October 2020

Equation 2 is solved for A_{75} as shown below.

$$A_{75} = 0.674\frac{(1.772-1)}{(1.630-1)} = 0.826 \qquad \textit{Equation 3}$$

The impact of Equation 1 is that the downwash ratio multiplier, R, varies with wind speed. As the airport wind speed approaches zero, R approaches 1, meaning no downwash contribution. As the airport wind speed approaches U_{max}, R equals A+1, which is theoretically the maximum value of R. However, for wind speeds in excess of U_{max} (10.8 m/s), Equation 1 results in a slight reduction of R. Therefore, Wisconsin assumed the maximum value of R (1.826) persists for higher wind speeds and set the value of R to 1.826 for wind speeds above 10.8 m/s. This is a conservative approach for applying downwash at the higher wind speeds. The values of the downwash ratio multiplier, R, versus wind speed as applied from Equation 1 at the 75 m and 90 m stack heights are shown below.

Figure 1: Emission Rate Multiplier Versus Wind Speed for 75 m and 90 m Stacks



The downwash ratio adjustment factor, R, was applied in Wisconsin's AERMOD attainment demonstration modeling by multiplying the hourly emission rate, based on the emission limitation on the coal-fired boiler exhausting to the Mill's stack S09, by the hourly value of R determined at the corresponding wind speed in the 2011-2015 meteorological data. The R-adjusted emission rate for stack S09 for each hour from 2011-2015 was then used with the HOUREMIS keyword in AERMOD.

RECOMMENDATION

The downwash at the Mill is such that measured SO_2 concentrations and subsequent wind tunnel simulations indicate that corner vortices, caused by the proximity and orientation of a nearby significant building to stack S09, are resulting in observed concentrations of SO_2 larger than those simulated by the downwash algorithms in the PRIME component of AERMOD.

Wisconsin's methodology uses the wind tunnel study results, consistent with general principles of building downwash, to determine a site-specific relationship between wind speed and the degree of concentration enhancement due to building downwash. In this methodology, downwash increases with increasing wind speed and, with declining wind speeds, diminishes to negligible impacts at wind speeds below 2 m/s. Further, the wind tunnel studies, which were the basis upon which this stack-specific downwash modeling technique was developed, were conducted using EPA technical guidance on wind tunnel studies. (See citations above.) Wisconsin uses this relationship, expressed in a formula identified above, to determine hourly adjustment factors expressing the degree of concentration enhancement attributable to downwash based on the hourly wind speed. As described above, these adjustment factors are applied to the modeled emission rate. Thus, instead of modeling a constant emission rate (a critical emission value) and relying on AERMOD to estimate the concentration enhancement due to downwash, Wisconsin used AERMOD with an HOUREMIS file in which each hour's emissions value equaled the critical emission value times the hour-specific (wind speed dependent) downwash adjustment factor, while running AERMOD with no buildings for Stack S09 and thus no AERMOD-estimated downwash.

Region 5 is recommending approval of Wisconsin's stack-specific approach for representing downwash of SO_2 emissions from the Mill's stack S09 with the Equation 1 multiplier, R, and is requesting concurrence for this recommendation from the MCH. Section 3.2.2.b.2 states that an alternative model may be approved, on a theoretical and performance basis, if a statistical evaluation shows the model to perform better than the comparable model in Appendix A. The accompanying Technical Support Document (TSD) details a case-specific statistical model-to-monitor analysis conducted for this alternative model application. It clearly shows improved model performance compared to the recommended Appendix A model, AERMOD, and further demonstrates that the alternative model approach does not have a general bias toward model underprediction. The alternative approach is based on data acquired from wind tunnel studies for this specific site, conducted in accordance with EPA guidance. The approach is also consistent with downwash principles regarding increased downwash impacts with increasing wind speeds.

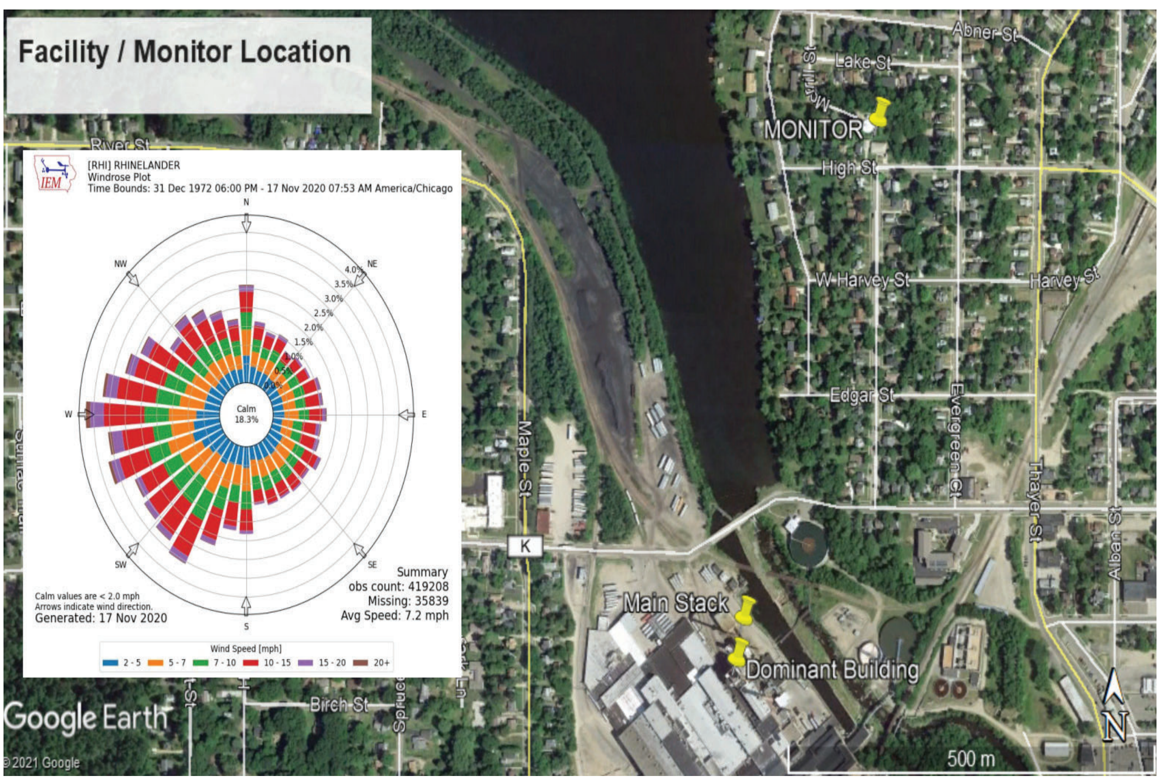
AERMOD has historically underestimated the significance of downwash from this source. The wind tunnel study demonstrated in fact that more downwash was occurring, and so the comparison described in the TSD gave the expected result that an approach that reflects the greater impact of downwash demonstrated in the wind tunnel study yields a better assessment of ambient concentrations than the standard application of AERMOD. Given the theoretical basis and the improved model performance, the alternative approach is recommended as acceptable for this specific application.

Note that approval of this approach only applies to the Mill's stack S09 for this specific State Implementation Plan attainment demonstration. Emissions from stack S09 represent over 95% of the SO_2 emissions from the Mill. Also, in the event downwash algorithms are enhanced in future AERMOD regulatory versions to appropriately consider the corner vortices issue, subsequent attainment demonstrations at this facility will need to utilize the current version of AERMOD rather than rely on the above approach. Lastly, and importantly, the air quality monitor that has been instrumental in identifying this corner vortex downwash issue, will continue to operate and thus provide a means for measuring real time impacts from emissions, including the actual concentration reductions achieved by the taller stack and lower SO_2 emission limit at the Mill as required by Wisconsin in its Oneida County area SO_2 attainment plan.

Please feel free to contact me at (312) 353-6713 if you have questions regarding this request.

Attachments

Attachment 1: Satellite Photos of Facility, Buildings, Monitor



Attachment 2*

Summary of Maximum Normalized Concentrations and Concentration Ratios

Run #	Source ID	Stack Height Above Base (m)	Anemometer Wind Speed (m/s)	Wind Direction (Deg.)	Maximum Normalized Concentrations* Buildings In (µg/m3 per g/s)	Buildings Out (µg/m3 per g/s)	Concentration Ratio $(C_{max})_{in}/(C_{max})_{out}$
Preliminary GEP Stack Height Tests							
worst wind direction tests							
101, 201	S09 max	85.0	7.9	185	3.92	2.55	1.54
102, 202	S09 max	85.0	7.9	190	3.95	2.43	1.63
103, 203	S09 max	85.0	7.9	195	3.81	3.12	1.22
104, 204	S09 max	85.0	7.9	200	3.91	2.52	1.55
105, 205	S09 max	85.0	7.9	205	3.70	2.54	1.45
worst wind speed tests							
111, 211	S09 max	85.0	6	190	4.58	2.94	1.56
112, 212	S09 max	85.0	5	190	4.61	3.24	1.42
worst load tests							
121, 221	S09 nom	85.0	7.9	190	2.54	1.77	1.43
122, 222	S09 min	85.0	7.9	190	2.44	1.52	1.61
stack height tests							
131, 231	S09 max	87.5	7.9	190	3.25	2.10	1.55
132, 232	S09 max	90.0	7.9	190	3.42	2.23	1.53
133, 233	S09 max	95.0	7.9	190	2.79	2.28	1.22
Final GEP Stack Height Tests							
documentation tests							
141, 241	S09 max	90.0	7.9	190	3.13	2.31	1.36
142, 242	S09 max	90.0	7.9	190	3.29	2.24	1.47
143, 243	S09 max	90.0	7.9	190	3.35	2.26	1.48
average	S09 max	90.0	7.9	190	3.31	2.27	1.46

*) based on fit to wind tunnel data using a weighted least squares approach (See Section 3.4)

* Table 5 from Peterson, R. L. and A. Beyer-Lout, Fluid Modeling Good Engineering Practice Stack Height Determination for the Rhinelander Mill Stack S09, CPP Report 7935, October 2014.

This table shows the concentration ratio, R, of maximum concentration with the buildings present to that without the buildings present for various stack heights, operating scenarios, wind speeds, and wind directions.

Attachment 3*

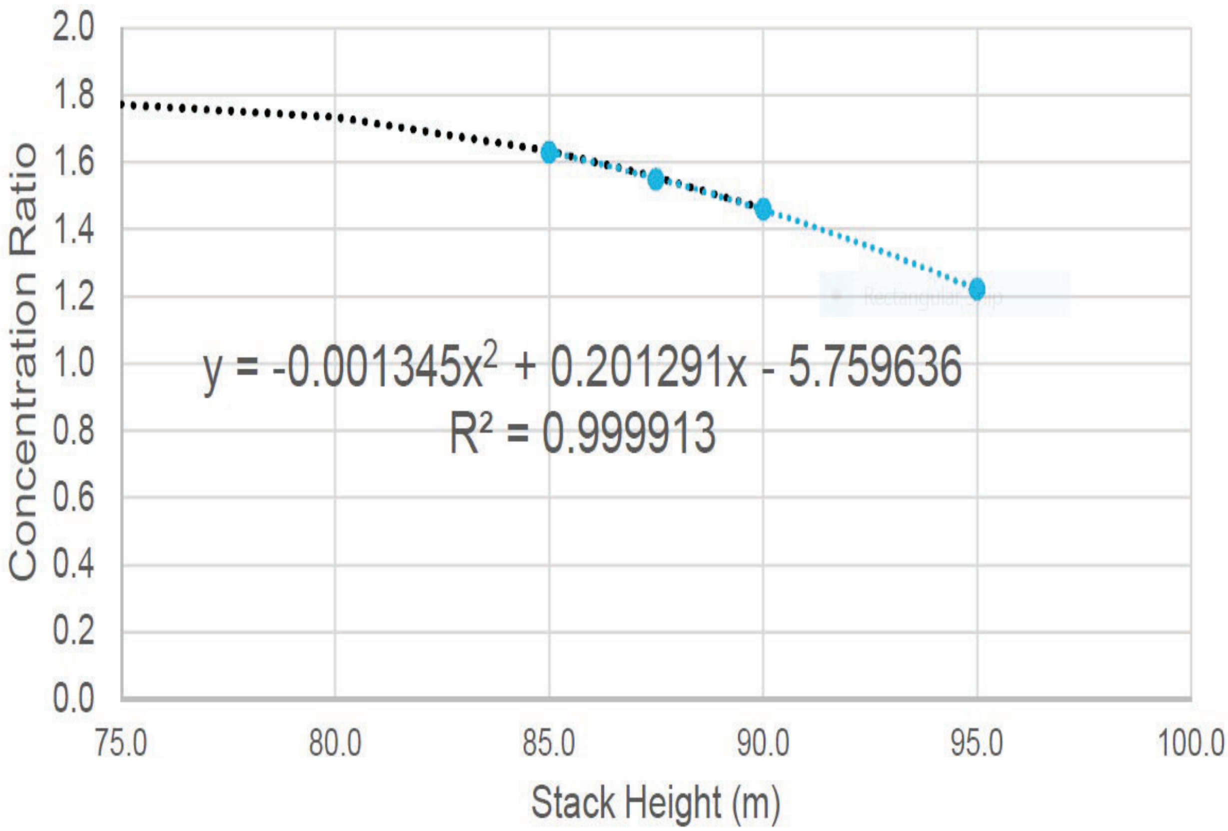
Observed and Predicted Concentration Ratios Versus Wind Speed and Stack Height

Hs (m)	$U_{airport}$ (10 m)	$U_{airport}$ (7.9 m)	Observed Ratio	Computed Ratio
85 m, Equation	11.49	11.00		1.67
85 m, WT data	7.90	7.56	1.63	1.64
85 m, WT data	6.00	5.74	1.56	1.54
85 m, WT data	5.00	4.78	1.42	1.43
85 m, Equation	3.66	3.50		1.20
85 m, Equation	2.61	2.50		1.03
85 m, Equation	2.09	2.00		1.00
90 m, Equation	11.49	11.00		1.49
90 m, WT data	7.90	7.56	1.46	1.47
90 m, Equation	6.00	5.74		1.39
90 m, Equation	5.00	4.78		1.31
90 m, Equation	3.66	3.50		1.14
90 m, Equation	2.61	2.50		1.02
90 m, Equation	2.09	2.00		1.00
	Wind tunnel data from Petersen and Beyer-Lout (2014)[2]			

*Table A-1 from Paine, R. (AECOM), R. Peterson (CPP), and T. Emond (Expera Specialty Solutions), Recommended Approach for SO_2 Nonattainment Modeling: Expera Specialty Solutions, Rhinelander, WI. June 4, 2015.

Attachment 4*

Concentration Ratio Versus Stack Height and Best-Fit Equation



* Figure A-2 from R. Peterson, Appendix A of SO2 NAAQS Compliance Modeling Report for the Rhinelander Mill (AECOM), October 2020.

Attachment 5*

Predicted and Observed Concentration Ratio versus Stack Height

Stack Height (m)	Concentration Ratio	
	Observed	Predicted
75.0	NA	1.772
80.0	NA	1.736
85.0	1.630	1.632
87.5	1.550	1.556
90.0	1.460	1.462
95.0	1.220	1.224

* Table A-2 from R. Peterson, Appendix A of SO2 NAAQS Compliance Modeling Report for the Rhinelander Mill (AECOM), October 2020.

The information above shows the observed pollutant concentration ratio with the buildings present to that without the buildings present for the three wind speeds tested at the 85-m stack height and the one wind speed tested at the 90-m stack height as well as the calculated ratios, R, using Equation 1 at other wind speeds with the corresponding best-fit values (A and B) for each stack height, including estimates for the creditable 75-m formula GEP stack height.

Technical Support for Concurrence Request Regarding Rhinelander Ahlstrom-Munskjo Paper Mill Use of Alternative Modeling Approach

The Wisconsin Department of Natural Resources (WDNR) has requested approval of an alternative modeling approach for the Ahlstrom-Munskjo Paper Mill (Mill), located in Rhinelander, Wisconsin. Preferred regulatory models have historically underpredicted ambient air concentrations in this area. The primary cause of the underprediction has been attributed to downwash influences, specifically corner vortices, that are not represented in AERMOD and previously, ISCST3. "When winds blow along a building corner, building corner vortices are generated that enhance building downwash."[1] The relationship between the buildings, the stack of interest (S09), and winds were investigated in wind tunnel studies conducted in 2014. These studies were done primarily to determine Good Engineering Practice (GEP) stack height. WDNR, in its assessment of downwash impacts from stack S09 for the attainment demonstration using AERMOD, applied the relationship between wind speed and the impact of downwash based on data from the wind tunnel study. Estimated hourly downwash adjustment ratios were applied as hourly adjustment ratios to the allowable emission limit. While the actual height of stack S09 is 90 m, the adjusted hourly emissions were modeled using the creditable GEP formula stack height of 75 m in the final attainment demonstration.

Section 3.2 of Appendix W contains the requirements for determining the acceptability of an alternative regulatory model. Subsection 3.2.2.b.2 discusses one of the three options for acceptability through the use of a statistical evaluation to indicate whether the alternative model performs better for a particular application than the preferred model, in this case AERMOD. Additionally, Section 3.2 contains language to ensure that the performance evaluation of the alternative model or technique is not inappropriately biased for regulatory application.

An air quality monitor has been located in the area of expected peak concentrations from the Mill for many years. Wind tunnel study results support this view as to where peak concentrations are expected.[1] Air quality data from this monitor is being used to assess whether the downwash approach described above performs better than the regulatory model, AERMOD. The stack at the mill was raised to 90 m in 2016. The previous stack height was 63 m. Additionally, the emissions-scaling approach to account for downwash proposed by the mill was developed based on wind tunnel test results with stack heights primarily at 85 m, with limited additional test data at 90 m. These results were initially scaled to 90 m and later to the GEP formula stack height of 75 m, which is the stack height used in Wisconsin's submittal.

To simplify this assessment of the performance of the alternative approach, modeling runs were conducted to compare the predicted results versus monitored concentrations for a period with a constant stack height. Runs were conducted to examine the 1st High concentrations, top 26 concentrations, the fractional bias values, and the 99th percentile values for each monitored year (i.e, 2017, 2018, 2019). Meteorological data, processed for use in AERMOD, for the 3 recent years of monitoring was not available. Consequently, modeling runs were conducted using the 5 years of regulatory meteorological data for the years 2011-2015. Additionally, actual emissions were estimated for each of the three monitored years. The year 2018 had the highest emissions,

---

[1] Fluid Modeling Good Engineering Practice Stack Height Determination for the Rhinelander Mill, Stack S09, DRAFT; October 2014, Ronald L. Peterson, Anke Beyer-Lout, CPP Consulting

followed by 2019 and 2017. Annual emissions were totaled and then divided by the number of days the boiler venting through the S09 stack was operating. For each of 2017, 2018, and 2019, the year's actual total emissions were partitioned to represent days when the boiler was operating. Hourly emissions were constant during those operating days but zero on periods when the boiler was not operating. The operating day average emissions were: 2017 – 44.21 g/s; 2018 – 64.30 g/s; and 2019 – 55.18 g/s.

Modeling runs were performed both using the regulatory version of AERMOD (Version 19191, with normal consideration of downwash) and using the emissions-scaling alternative model approach proposed by WDNR. The runs were set up as follows:

Common Features of Default and Alternative Model Runs

- 90 m actual stack height (S09)
- 2017, 2018, 2019 annual actual emissions, on days when boiler was operating
- Nearby sources included
- Receptor grid (400m x 400m) focused on area to the north surrounding monitor
- Background concentrations included
- Use of meteorological data for the years 2011-2015.

Default Model Run

- Building dimensions for all sources, including S09

Alternative Model Run

- No building dimensions for S09. Incorporate downwash effects by using HOUREMIS inputs reflecting fixed emission rate multiplied by the hourly wind-speed based scalar.

<u>Results</u>

The results of the default and alternative modeling runs were compared to each other and to the monitored values. The results for each of the 3 years of monitoring represent actual emission estimates for that year and the 5 years of meteorology (2011-2015).

Table 1: High 1st High Concentrations – Average +/- Percentage Across Years; Default Model and Alternative Model Results Compared to Monitor (ug/m^3)

Year	Mon	Def.	Def %	Alt	Alt %
2017	111.8	90.9	-18.7 %	97.4	-12.9 %
2018	131.2	126.1	-3.9 %	135.5	3.3 %
2019	98.0	110.0	12.3 %	118.2	20.7 %
Average	**113.7**	**109.0**	**-3.4**	**117.0**	**3.7**

There was considerable variability in the estimated High 1st High concentrations across the 5 years of meteorology. Each year of emissions had years of underestimates and overestimates. The year 2017 was mostly characterized by underestimated High 1st High modeled values compared with the monitor. The 2019 and 2018 emission years both had multiple years of underestimates and significant overestimates. When the results are averaged, as shown above, the default model showed a net slight underestimate while the alternative model showed a net slight overestimate.

Table 2: Average of Top 26 Values - Model Compared to Monitor (ug/m^3)

	2017 Top 26 Ave	2018 Top 26 Ave	2019 Top 26 Ave	3-Yr Average
Default Model	63.1	87.0	76.1	75.4
Alternate Model	74.7	104.3	90.8	90.0
Monitor	83.3	98.4	79.3	87.0

Table 3: Top 26 Values - Average Model to Monitor Ratio

	2017 Top 26 Ave Ratio	2018 Top 26 Ave Ratio	2019 Top 26 Ave Ratio	3-Yr Average
Default Model	-23.1	-10.5	-3.2	-12.3
Alternate Model	-8.4	7.7	16.1	5.1

Table 2 shows the average of the top 26 modeled and monitored values. The variability among the years is a combination of emission changes and meteorological variability. The net 3-yr average shows the default model with an underestimate of the average top 26 values with the alternative model prediction slightly above the monitored average.

Table 3 shows the average of the model to monitor ratio for the top 26 values. As with Table 2, there is yearly variability in the results. The 3-yr average shows underestimates using the default model and slight overestimates using the alternative approach.

Table 4: Fractional Bias – Model Compared to Monitor

	2017 Ave	2018 Ave	2019 Ave	3-Yr Average
Default Model	0.28	0.12	0.04	0.15
Alternate Model	0.14	-.07	-.16	-.03

The fractional bias is a metric comparing modeled and monitored concentrations using the top 26 values. A fractional bias value of 0 represents a perfect model to monitor comparison. Negative values showing model overprediction and positive values show model underprediction. The default model shows a slight underestimate for the 3-yr average with the alternative model showing a slight overestimate. The results vary significantly from year to year with underestimates for both models in 2017 and some overestimate bias for the alternative model for the years 2018 and 2019.

Table 5: 99th Percentile Values – Estimated and Monitored for Each Modeled Met Year (ug/m^3)

		2017			2018			2019	
Met Yr	Def	Alt	Mon.	Def	Alt	Mon	Def	Alt	Mon
2011	62.3	72.0	99.5	85.1	100.4	104.8	74.9	87.5	78.6
2012	61.9	74.2		86.4	104.0		75.2	90.4	
2013	61.8	71.4		84.4	100.0		74.4	87.3	
2014	57.3	68.6		76.5	95.8		68.0	83.4	
2015	60.8	73.5		81.2	102.4		72.0	88.9	
Ave.	60.8	71.9		82.7	100.5		72.9	87.5	

Table 5 shows the year by year 99th percentile results of the default and alternative model for the three years of monitoring and emissions as well as the 5-year average. As is shown in other tables, 2017 is underestimated using both the default and the alternative models. The alternative model compares well with the monitored value for 2018 and shows values higher than the monitored 99th percentile for 2019.

The monitored design value for the years 2017-2019 is 94.3 ug/m3. The modeled design value for the alternative model, using just emissions from 2018 (the middle year with the highest emissions) and 5 years of meteorology is 96.9 ug/m3. When accounting for the emissions variability across the three years, and selecting the peak modeled value across the 5 years of meteorology, the design value estimated by the alternative model is 89.5 ug/m3, roughly 5% below the 3-year monitored design value of 94.3 ug/m3.

Conclusions

The results of the modeling analysis show the alternate model overall predicts concentrations significantly higher than AERMOD run in regulatory default mode. When compared to the available monitoring data, the alternative model shows reasonable estimates for the three-year average metrics. There is significant variability among the three monitor years and among the 5 years of meteorology. Results for both the alternative and default model show underestimates when compared only to 2017. However, the alternative model compares very well with 2018 monitored data and shows some overprediction when compared to 2019.

The results shown above are for the actual stack height of 90 m. The 90 m height was designed to reduce the effect of downwash down to a maximum 40 percent increase in concentrations, which is one of the criteria in 40 CFR 51.100 for being granted credit for a stack height greater than GEP formula stack height. However, Wisconsin did not meet another criterion for the 90 m stack height being creditable, namely the criteria for establishment of limits requiring suitable control (presumptively NSPS limits) and that additional stack height nevertheless be necessary to avoid violations of the air quality standard. Therefore, the 90 m height is not creditable, based on stack height regulations, and Wisconsin relied instead on the formula height for their SIP attainment demonstration. That height is 75 m.

Nevertheless, this comparison of modeling results to monitored air quality, necessarily involves modeling at actual stack heights, without regard to whether the actual stack height is creditable for attainment planning purposes. However, at 90 m, hours where downwash is a significant factor are likely limited. Therefore, it is expected that at a lesser height, such as 75 m, the difference between the estimated concentrations using the alternative and the regulatory approach would be larger, making the SIP demonstration conservative relative to the actual impacts from a 90 m stack.

Based on the results shown above, the alternative modeling approach recommended by WDNR clearly performs better than the regulatory model. Additionally, the alternative modeling approach provided reasonable concentration estimates when compared to the three years of monitoring data. The alternative approach is based on data acquired from wind tunnel studies for this specific site, conducted in accordance with EPA guidance. The approach is also consistent with downwash principles regarding increased downwash impacts with increasing wind speeds. AERMOD has historically underestimated the significance of downwash from this source. The wind tunnel study demonstrated in fact that more downwash was occurring, and so the comparison described here gave the expected result that an approach that reflects the greater impact of downwash demonstrated in the wind tunnel study yields a better assessment of ambient concentrations than the standard application of AERMOD. Given the theoretical basis and the improved model performance, the alternative approach is recommended as acceptable for this specific application.