

Modeling Protocol for Site-Specific Alternative Model for 1-hour SO₂ Emissions of Conemaugh and Seward Impacts in Complex Terrain Along Laurel Ridge in Western Pennsylvania

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1. Introduction

The Seward Generating Station (Seward) and Conemaugh Generating Station (Conemaugh) are both coal-fired electric generating stations located in southeastern Indiana County, PA. The stations are situated approximately 2 miles (3.3 km) apart from each other (**Figure 1-1**) adjacent to the Conemaugh River. In this area, the river is the jurisdictional boundary between Indiana County and Westmoreland County, PA. The coal-fired boilers at the stations are significant point sources of sulfur dioxide (SO₂) emissions that can impact areas located within Indiana County and areas outside of Indiana County (i.e., portions of Westmoreland and Cambria Counties). Impacts within Indiana and portions of Armstrong counties were addressed in the Indiana, PA Nonattainment Area SO₂ National Ambient Air Quality Standard (NAAQS) State Implementation Plan (SIP) revision that was approved by the U.S. Environmental Protection Agency (EPA) in September 2024.¹ Following approval of that SIP revision, EPA finalized a study that evaluated impacts in areas outside of Indiana County. The study included a dispersion modeling effort that utilized recent actual emissions from the two stations and historic meteorological data that were generated from a meteorological monitoring site located between the two stations. The findings from that modeling effort resulted in EPA redesignating select portions of Westmoreland and Cambria Counties as non-attainment for the 2010 SO₂ NAAQS.² Within this area of interest (Cambria-Westmoreland area) lies a significant elevated terrain feature known as Laurel Ridge. As shown in **Figure 1-2**, this ridge is oriented northeast to southwest and is primarily located in eastern Westmoreland County and western Cambria County.

The significant rise in elevation that is presented by Laurel Ridge relative to the boiler exhaust stack heights at Seward and Conemaugh is much more pronounced than any other surrounding terrain feature within 20 km of the facilities. The vast majority of the ridge has terrain elevations above 600 meters above sea level (ASL), with some of the highest elevations nearing 1,000 meters ASL. These heights are considerably higher than the stack tops of Conemaugh (490 meters ASL) and Seward (513 meters ASL), thus meeting the definition of complex terrain relative to the emission sources being modeled.

¹ Air Plan Approval; Pennsylvania; Attainment Plan for Indiana Nonattainment Area for the 2010 1-hour Sulfur Dioxide National Ambient Air Quality Standard. 89 FR 74836. Published September 13, 2024 with an effective date of October 15, 2024. Available at: <https://www.federalregister.gov/documents/2024/09/13/2024-20598/air-plan-approval-pennsylvania-attainment-plan-for-the-indiana-nonattainment-area-for-the-2010>

² Redesignation of Portions of Westmoreland and Cambria Counties, Pennsylvania for the 2010 Sulfur Dioxide National Ambient Air Quality Standards. 89 FR 101910. Published December 17, 2024 with an effective date of January 16, 2025. Available at: <https://www.federalregister.gov/documents/2024/12/17/2024-29229/redesignation-of-portions-of-westmoreland-and-cambria-counties-pennsylvania-for-the-2010-sulfur>

Figure 1-1: Cambria-Westmoreland, PA 1-hour SO₂ NAAQS Modeling Area of Interest

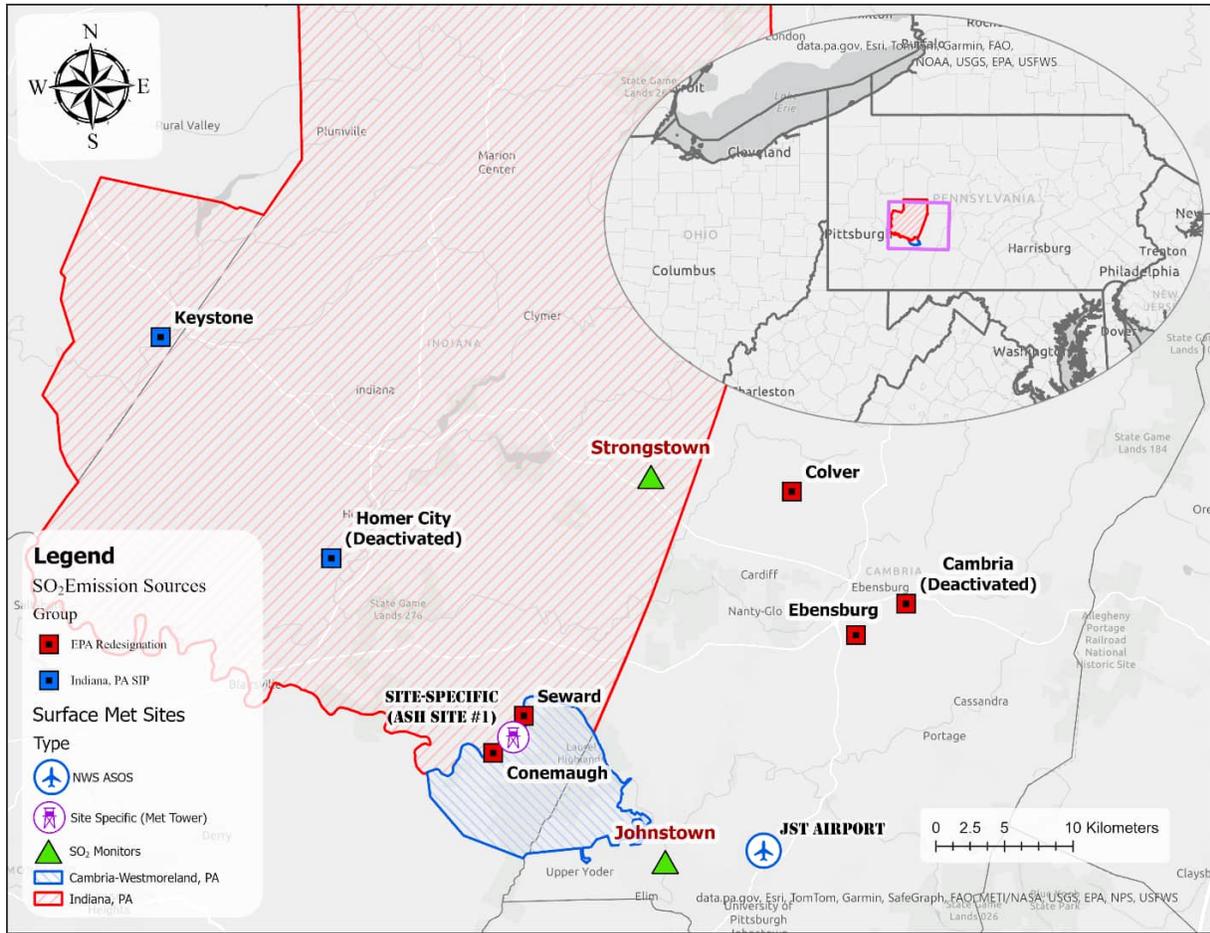
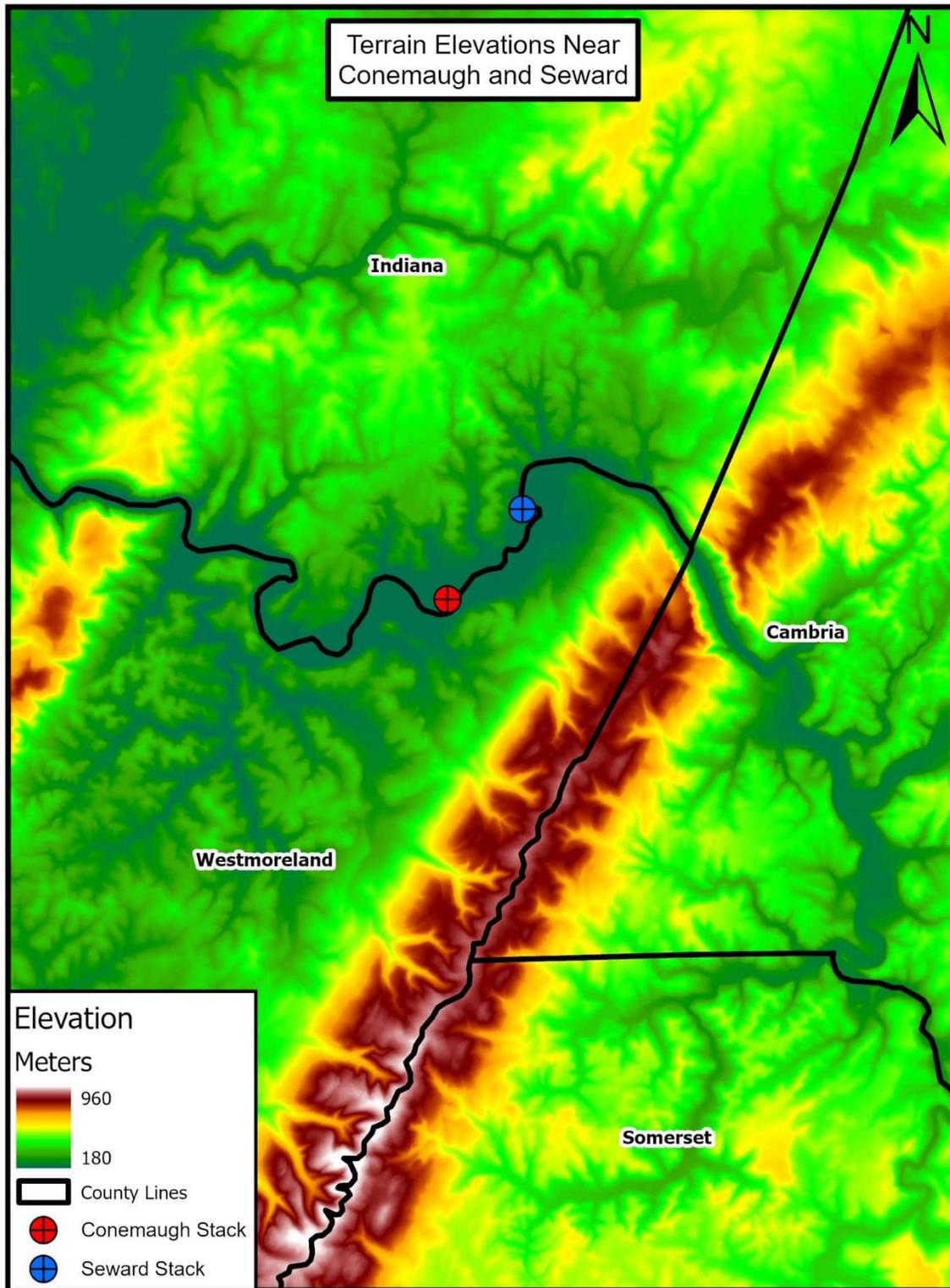


Figure 1-2: Elevation of Model Area of Interest



1.1 Unique Site-Specific Conditions

The topographic setting along with the orientation of the complex terrain relative to the SO₂ emission sources introduces unique challenges to dispersion modeling for this site-specific area. The first challenge involves strong wind directional shear. Given that the sources and the site-specific meteorological tower are located within the valley, the wind up to approximately 100 meters follows the terrain features and is predominantly from the southwest to northeast, as depicted in **Figure 1-3** (a and b).³ At higher levels, closer to stack top and above terrain heights the flow begins to turn more out of the west. This shift in direction with height is known as wind directional shear. While dispersion models, like AERMOD, are designed to account for this effect for steering the plume centerline, AERMOD does not consider the fact that the top and bottom of the rising plumes are being steered in different directions, thus resulting in additional horizontal spreading that AERMOD's formulation does not consider. In that respect, the horizontal plume extent can be underestimated by AERMOD.

There are other physical processes that act to expand the plume's horizontal spreading when it is forced to "wrap around" a complex terrain feature. Briggs (1982) noted that the plume trajectory tends to favor the "grain" of the terrain rather than going across it. Another physical process in complex terrain is the enhancement of turbulence due to eddy formation created by the flow of air passing over and around terrain obstacles. Hanna (1980), see **Attachment A**, found that sigma-theta values were increased by a factor of 1.6 during neutral conditions when the wind direction was perpendicular to the terrain.⁴

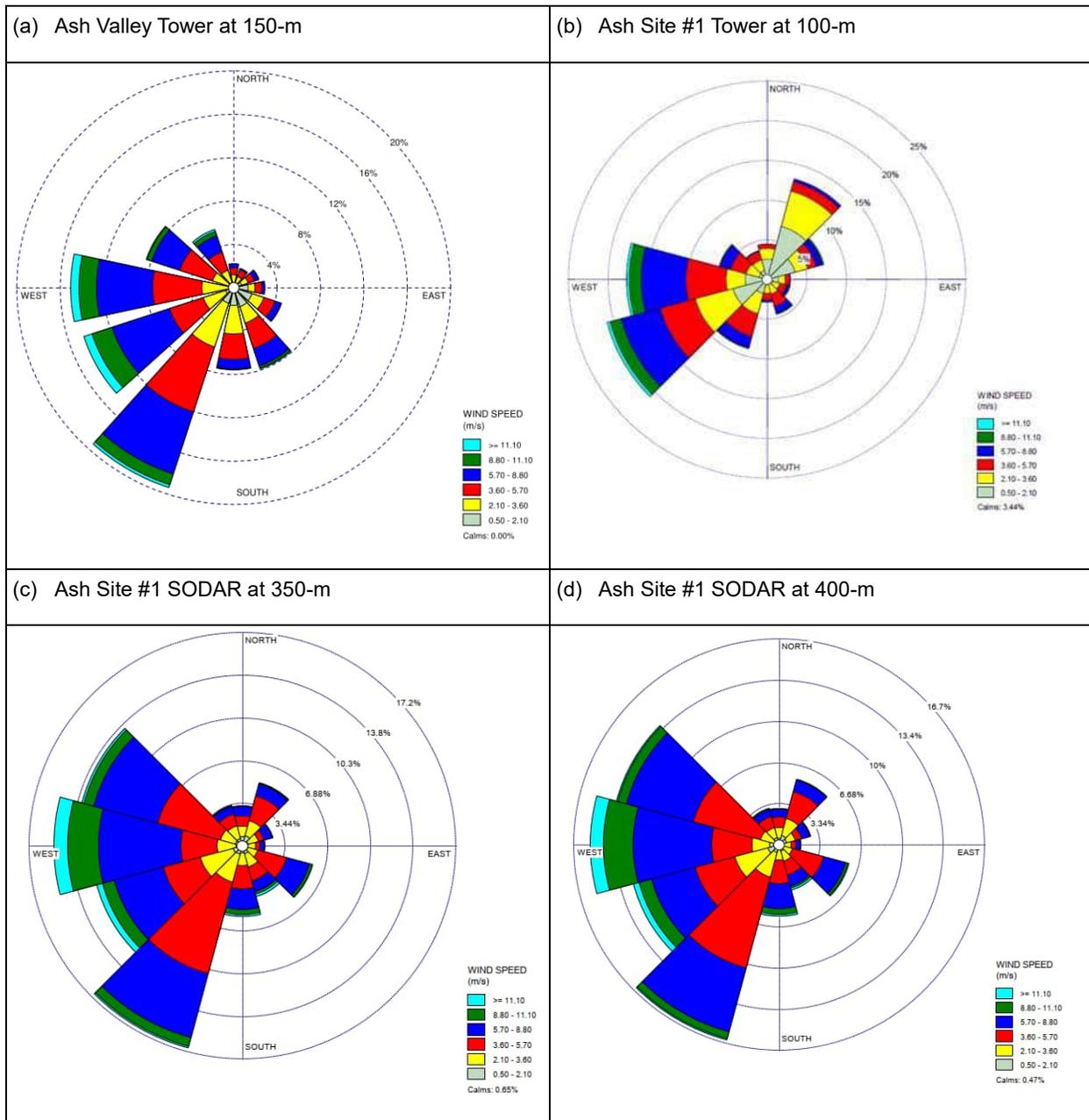
The current model formulation of AERMOD, in its regulatory form, is not configured to account for the shape of a complex terrain feature; the configuration is limited to the height of the top of the hill that each receptor is associated with. Accordingly, AERMOD configuration excludes the orientation of the terrain feature such as Laurel Ridge. For the critical case of plumes with insufficient kinetic energy (due to buoyancy / mechanical lift) to lift over the hilltop, AERMOD simply sends the plume "through" the hill and does not consider any additional dispersion due to the need for the plume to go around the hill whose shape is unaccounted for in the model. As shown in **Figure 1-3** (c and d), the predominant westerly flow at higher levels will orient the plumes from Conemaugh and Seward stacks more perpendicular to the higher Laurel Ridge terrain downwind. In contrast, Briggs' findings would indicate that the Seward and Conemaugh plumes should travel along and around the long axis of the hill, resulting in a substantial more pronounced "wrap around" effect than AERMOD would be capable of simulating.

As discussed, the area downwind of the predominant flow of Conemaugh of Seward, which is dominated by Laurel Ridge, is unique and complex in terms of dispersion modeling. AERMOD with default options would not be an appropriate model as it would tend to underestimate the plume meandering, which can be exacerbated under light winds at night, and lead to an overprediction bias of ground-level concentrations. As a result, a site-specific alternative model is warranted to more appropriately address this issue.

³ Figure 1-3 (a) shows the winds at 150 meters from the Ash Valley Tower that collected data in the early 1990s. Figure 1-3 (b) illustrates the winds from the more recent 2015-2016 Ash Site #1 Tower at 100 meters. Together with the wind roses from the select SODAR level (Figure 1-3 (c and d)) show the change in wind patterns with height for this area.

⁴ Hanna, S. R., 1990. Lateral Dispersion in Light-Wind Stable Conditions. *Il Nuovo Cimento C* 13, 889-894.
<https://doi.org/10.1007/BF02514777>

Figure 1-3: Wind Roses



Note: SODAR winds from the southwest were affected by Conemaugh cooling tower plumes. That was documented in the Indiana, PA SIP. Therefore, the data underrepresents the frequency of southwesterly to westerly flow. Also, the base elevations between the Ash Valley Tower and Ash Site #1 are about 140 meters, with the Ash Valley Tower being at a higher base elevation.

1.2 Clean Data Determination Dispersion Modeling

Following enactment of the Clean Air Act (CAA) Amendments of 1990, EPA established the “Clean Data Policy” for the 1-hour ozone NAAQS.⁵ The Clean Data Policy states that for a nonattainment area that can demonstrate attainment of the standard prior to the implementation of CAA nonattainment measures, that no additional control measures would be required so long as air quality continues to meet the standard. In an April 23, 2014 memorandum entitled “Guidance for 1-hour SO₂ Nonattainment Area SIP Submissions”, EPA provides guidance and a rationale for the application of the Clean Data Policy to the 2010 1-hour primary SO₂ NAAQS.⁶ Under the Clean Data Policy, a state may notify EPA that

⁵ 57 FR 13498, 13564 (April 16, 1992).

⁶ Guidance for 1-hour SO₂ Nonattainment Area SIP Submissions. April 23, 2014. Available at: https://www.epa.gov/sites/default/files/2016-06/documents/20140423guidance_nonattainment_sip.pdf

it believes a nonattainment area is attaining the 2010 1-hour SO₂ NAAQS and request a Clean Data Determination (CDD).

On April 8, 2025, the Pennsylvania Department of Environmental Protection (PA DEP) and EPA Region 3 informed Conemaugh and Seward that a CDD modeling demonstration is an available option to evaluate the 1-hour SO₂ NAAQS attainment status on and in the vicinity of Laurel Ridge (i.e., portions of Cambria-Westmoreland Counties). Conemaugh and Seward elected to proceed with a CDD approach. The CDD modeling should involve the use of recent actual SO₂ emissions data and meteorological data from the Ash Site #1 tower and SONic Detection And Ranging (SODAR).

The Ash Site #1 meteorological station was comprised of a multi-level tower equipped with sensors at 2, 10, 50, 75, and 100 meters (m) along with a SODAR wind profiling system (with measurements starting at 50 m and extending vertically in 50-m increments to 500 m). The location of Ash Site #1 was approximately halfway between the Seward Generating Station and Conemaugh Generating Station, as shown in **Figure 1-4**. Tower and SODAR turbulence measurements (both the standard deviation of the horizontal wind direction (sigma-theta) and the standard deviation of the vertical wind speed (sigma-w)) were collected in addition to the typical wind speed and direction, ambient temperature, and other meteorological measurements (e.g., atmospheric pressure, precipitation, etc.).

In an attempt to address concerns about potential model overprediction bias for impacts along the higher terrain of the ridge based on the discussion outlined in Section 1.1, the Stations propose to evaluate the model's performance and identify appropriate refinements based on a historical field study that involved the same primary SO₂ sources (Conemaugh and Seward) and SO₂ monitors located along the ridge within the CDD modeling area. The intention is to apply the refinements from the model performance evaluation that identify a better performing alternative model for this site-specific application and use it for the CDD modeling demonstration.

Figure 1-4: Location of Ash Site #1 Meteorological Tower and SODAR



1.3 Purpose

The purpose of this modeling protocol is to address requirements in Appendix W (40 CFR, Part 51, available at 82 FR 5182 (Federal Register, November 29, 2024), Section 3.2.2 (b)).⁷ This section of Appendix W states that an alternative model shall be evaluated from both a theoretical and a performance perspective before it is selected for use. Any one of the following three (3) separate conditions may justify use of an alternative model:

1. If a demonstration can be made that the model produces concentration estimates equivalent to 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 a given application than a comparable model in Addendum A; or
3. If there is no preferred model.

A statistical performance evaluation (option 2) has been selected to justify an alternative model for the modeling of portions of Cambria and Westmoreland Counties with SO₂ emissions from Seward and Conemaugh. The statistical performance evaluation will be 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 in Addendum A [of the guideline]. This modeling protocol describes the proposed approach to conduct a site-specific model evaluation to support the use of an alternative model. The proposed approach involves a historical field study that was located in the same area of Laurel Ridge that involves the same key SO₂ emission sources and similar meteorological profiles. The previous study has the three key elements necessary to perform the statistical analysis; (1) concurrent hourly source emissions, (2) representative hourly meteorological data, and (3) hourly monitoring data. A description of the historical field study is discussed in the following section. The 2015-2021 Ash Site #1 data collection period lacks concurrently hourly SO₂ monitoring data.

⁷ Guideline on Air Quality Models (Appendix W of 40 CFR Part 51). November 29, 2024. Available at: https://www.epa.gov/system/files/documents/2024-11/appendix_w-2024.pdf

2. Theoretical Technical Justification for Increasing the Minimum Sigma-v in AERMOD for this Site-Specific Application

During low wind speed (LWS) conditions, in both complex and simple terrain situations, the dispersion of pollutants is limited by diminished fresh air dilution. Anfossi et al.⁸ noted that in LWS conditions, dispersion is characterized by meandering horizontal wind oscillations. Sagendorf and Dickson⁹ and Wilson et al.¹⁰ found that under LWS conditions, horizontal diffusion was enhanced because of the meander, and the resulting ground-level concentrations could be much lower than that predicted by steady-state Gaussian plume models that did not account for the meander effect. It's worth pointing out that in the evaluation conducted by Anfossi et al., measured turbulence was used as input to the modeling, but for Sagendorf, Dickson, and Wilson et al., turbulence was not used to calculate sigma-v or effective wind speed. Therefore, irrespective of measured turbulence, model performance was improved by adjusting the meander effect for these studies involving complex terrain areas.

Anfossi et al. conducted an analysis of sonic anemometer data in low wind speed conditions, which they discuss as being wind speeds under 2 m/s (and especially under 0.5 m/s in stable conditions and 1.2 m/s in unstable conditions). These data, with instruments having near-zero starting wind speed thresholds, were taken in two locations: one site featured complex terrain near Graz, Austria; and the other site in simple terrain was near Tisby, Sweden. In general, these researchers consider that slow mesoscale motions (i.e., wind fluctuations with periods of 20-30 minutes) exist under all these meteorological conditions, but, as the small-scale turbulence decreases with low wind speeds, these slow mesoscale motions become the most important factor for the total variance observed in such conditions. Anfossi et al. further note that when the wind speed decreases below a certain threshold value (about 1.5 m/s), it is no longer possible to define a precise mean wind direction, and the wind direction oscillates with periods of the order of half-an-hour or more. This oscillation (meandering) seems to depend neither on topography (since it occurs also in flat terrain) nor on diurnal cycle or season. The slow mesoscale motions seem to set a lower limit for the horizontal wind component variance (the square of the standard deviation) as was also found by Hanna (1990), and not accounting for this effect can result in substantial under-predictions of plume spreading horizontally.

Other researchers have found that the amount of wind (and plume) meander in low-wind speed conditions is a function of the averaging time. For example, Finn et al. (2017)¹¹, Sun et al. (2012)¹², and Mortarini et al. (2016a)¹³ found in recent tracer experiments in the very stable boundary layer with low wind speeds that crosswind turbulence motions could be small for time scales on the order of 10 minutes or less, comparable to classical results such as Project Prairie Grass. However, wind direction and plume behavior is also observed by these investigators to abruptly shift within a typical time frame of about 30 minutes by several tens of degrees, and then remain steady for another several minutes before shifting direction again. AERMOD attempts to model this situation by weighing the plume dispersion between a random state and a Gaussian distribution. However, the rapid, episodic wind direction shifts in plume direction that are now better documented and acknowledged warrant additional model treatment to avoid simulating plume meander that is too small.

As previously introduced in Section 1.1, plume meander can also be greatly affected by vertical shear, terrain induced eddies, and flow perpendicular to significant terrain features. A parameter that is used in the computation of the horizontal plume spreading in AERMOD (which accounts for meandering in low wind conditions) is the above-mentioned standard deviation of the crosswind component, sigma-v (σ_v), which can be parameterized as being

⁸ 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.

⁹ 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>.

¹⁰ 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>.

¹¹ Finn, D., K.L. Clawson, R.M. Eckman, R.G. Carter, J.D. Rich, B.R. Reese, S.A. Beard, M. Brewer, D. Davis, D. Clinger, Z. Gao, and H. Liu, 2017. Project Sagebrush Phase 2. NOAA 380 Tech. Memo OAR ARL-275, Air Resources Laboratory, Idaho Falls, ID. 392 pp, 381 <https://doi.org/10.7289/V5/TM-OAR-ARL-275>.

¹² Sun J., L. Mahrt, R. Banta, and Y.L. Pichugina, 2012. Turbulence regimes and turbulence intermittency in the stable boundary layer during CASES-99. *J. Atmos. Sci.* 69, 338-351. <https://doi.org/10.1175/JAS-D-11-082.1>.

¹³ Mortarini L., M. Stefanello, G. Degrazia, D. Roberti, S. Trini Castelli, and D. Anfossi, 2016. Characterization of wind meandering in low-wind-speed conditions. *Bound.-Layer Meteorol.* 161, 165-182. <https://doi.org/10.1007/s10546-016-0165-6>.

proportional to the friction velocity, u^* (Smedman, 1988; Mahrt, 1998)^{14,15}. 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. Hanna¹¹ found that the hourly-averaged σ_v has a non-zero minimum value of about 0.5 m/s as the wind speed approaches zero. Chowdhury et al. (2016)¹⁶ noted, based upon research conducted by Hanna (1983) and Etling (1990)¹⁷ that a minimum σ_v of 0.5 m/s is justified as a part of the formulation for the advanced puff model SCICHEM.

Introduced in AERMOD version 12345, LOWWIND1 and LOWWIND2 non-default options were introduced to address concerns regarding model performance under low wind speed conditions. LOWWIND1 and LOWWIND2 increased the minimum sigma-v value from 0.2 m/s (default) to 0.5 m/s and 0.3 m/s, respectively. Both were hardcoded values that the user could not modify. LOWWIND3 was later introduced in AERMOD version 15151 that also increased the minimum sigma-v to 0.3 m/s but included the use of the non-default FASTALL approach. In AERMOD 18181, a new LOW_WIND keyword option replaced the former LOWWIND1, LOWWIND2, and LOWWIND3 options. The LOW_WIND option, which is a non-default alpha option in AERMOD 24142, allows the user to specify values for minimum sigma-v, minimum horizontal wind speed, and maximum meander fraction.

We are proposing to use LOW_WIND option for this application (when modeling with the on-site meteorological data for high terrain areas on portions of Laurel Ridge) that specifies a minimum sigma-v of 0.5 m/s, based on Hanna (1990), with support from a site-specific field study, which is fulfilled here by the 1990-1991 study on Laurel Ridge. Besides the technical issues about meander in stable conditions discussed above, the proposed LOW_WIND option has the effect of introducing more meander into the plume centerline concentration that results from complex terrain and wind shear effects that are characteristics of the perpendicular flow across the Conemaugh River Valley and into Laurel Ridge.

2.1 Prior Demonstration Using LOW_WIND AERMOD Option

A similar approach to using AERMOD with the LOW_WIND adjustment of the minimum sigma-v value for a rural modeling application was proposed in 2014 for an industrial facility in Tennessee (Eastman Chemical Company). A site-specific model performance evaluation study was conducted to model 1-hour SO₂ emissions from this facility. The evaluation used hourly data from a 100-meter tall tower and SODAR and the key SO₂ monitor was located in complex terrain that was oriented at an angle to the flow. After reviewing the modeling, EPA stated the following in their June 1, 2015 Approval of Alternative Model Request letter to Eastman Chemical:

“Based upon the site-specific model performance information provided by Eastman, it appears that use of the LOWWIND2 beta option with a single minimum sigma-v value of 0.4 m/s significantly improves model performance for the Ross N. Robinson, Meadowview, Skyland Drive, and B-267 monitors when compared to the regulatory default version. We are approving a minimum sigma-v value of 0.4 m/s (versus the current default value of 0.3 m/s associated with the beta LOWWIND3 option) for Eastman specific case due to the complex environment with very low wind speeds and nearby complex terrain. These influences are likely to result in significant vertical wind shear that could contribute to increased lateral plume dispersion.”

While this case in Tennessee ultimately pivoted from using the LOW_WIND alternative modeling approach to a reclassification of the environment from rural to urban¹⁸, it still demonstrates EPA's willingness to accept a higher increased minimum sigma-v value in certain complex terrain areas where the lateral dispersion parameter in AERMOD is likely underestimated under low wind conditions. A copy of the approval letter from EPA is included in Attachment B.

¹⁴ Smedman, A. S. 1988. Observations of a Multi-Level Turbulence Structure in a Very Stable Atmospheric Boundary Layer. *Boundary Layer Meteorol.* 66, 105–126.

¹⁵ Mahrt, L. 1998. Stratified Atmospheric Boundary Layers and Breakdown of Models. *Theor. Comput. Fluid Dyn.* 11, 263–279.

¹⁶ Chowdhury, B., R. I. Sykes, D. Henn, P. Karamchandani. 2016. SCICHEM Version 3.0 Technical Documentation. Available at https://sourceforge.net/projects/epri-dispersion/files/SCICHEM/SCICHEM-3.0_TechnicalDoc.pdf/download.

¹⁷ Etling, D. 1990. On plume meandering under stable stratification, *Atm. Env.*, 24A, 1979-1985.

¹⁸ In subsequent action for the Tennessee modeling application, EPA later considered an urban dispersion modeling approach which used the default AERMOD model. However, for the rural modeling approach, the larger minimum sigma-v clearly led to improved model performance.

3. Proposed Alternative Modeling Approach

The proposed approach for conducting dispersion modeling within the Cambria-Westmoreland area, as shown in **Figure 1-1**, will incorporate a site-specific alternative model. We propose the use of the LOW_WIND option in AERMOD that enables the user to increase the minimum sigma-v from the default of 0.2 m/s. The revised value will be based upon the 0.5 m/s from the 1990 Hanna paper and the outcome of a model performance evaluation using a field database that was conducted for the Laurel Ridge area.

The field dataset to be used is discussed in more detail below. It was conducted in the early 1990s and consisted of several SO₂ monitors, on-site meteorological tower, and the same key SO₂ sources that existed during the study are still in existence (i.e., Seward and Conemaugh). We are proposing to demonstrate the applicability of the LOW_WIND option (increasing the minimum sigma-v value) to address the default model's bias by revisiting the model performance that was performed in the 1990s using AERMOD for the same key sources with peak impacts occurring in the same high terrain area (i.e., Laurel Ridge).

Following the model performance evaluation between the regulatory model and the proposed alternative model (minimum sigma-v of 0.5 m/s) using the Laurel Ridge database, a second set of model runs will be conducted. This second set of model runs will use the same Laurel Ridge input data, except for the meteorological dataset. Instead, these model runs will utilize the Ash Site #1 meteorological dataset (September 2015 through August 2016) that will be used for the CDD modeling. The purpose of this round of analyses is to demonstrate that the alternative model will still result in improved performance compared to the regulatory model with the CDD meteorological dataset that includes both measured sigma-theta and sigma-w parameters. The 2015-2016 meteorological data has a similar wind pattern at the 150-m level relative to the 1990-1991 data (see **Figure 1-3**), and since the evaluation considers comparisons of observed and modeled concentrations that are unpaired in time, the second meteorological database is a reasonable supplemental check on the superior model performance of the proposed alternative model.

4. Field Study Description

In the early 1990s, a field study was conducted by TRC to determine suitable modeling approaches, especially in elevated terrain, for several coal-fired electric generating stations located in Indiana County (funded by Penelec, the former owner or operator of the four stations that were the focus of the 1990-era modeling study). Ten (10) ambient air SO₂ monitors were deployed in 1990 in the vicinity of the Keystone, Homer City, Seward, and Conemaugh stations, with several of the monitors located in areas on Laurel Ridge, as shown in **Figure 4-1**. The purpose of this study was to evaluate alternative modeling approaches for estimating air quality impacts from the stations in areas that included elevated terrain on Laurel Ridge and Chestnut Ridge. At the time the study was conducted, the 1-hour SO₂ NAAQS had not yet been established (it was promulgated in 2010). As a result, the analysis conducted by TRC focused on 3-hour, 24-hour, and annual average time periods. However, hourly averaged emissions data (collected by state-of-the-art Continuous Emissions Monitoring Systems (CEMS) at the time) and hourly averaged monitored concentrations were collected. Consequently, the ability to conduct 1-hour averaged modeling is readily available.

The one-year field study database includes the following elements:

- one-year (August 1, 1990 to July 31, 1991) of hourly measurements of SO₂ concentrations from ten (10) monitors with four (4) sited along high terrain of Laurel Ridge (Baldwin Creek, Powdermill Run, Sugar Run, and Terrys Run);
- one-year of tall-tower meteorological data from the 150-m Ash Valley meteorological tower (location is shown in **Figure 4-1**); and
- one-year of hourly SO₂ emissions and stack exhaust data from the stations involved in the study.

Additional details on the study can be obtained from the 1993 and 2003 TRC reports that are provided as attachments to this modeling protocol.

Of the 10 monitors shown in **Figure 4-1**, there are four monitors to the west and south that are not relevant for this area of Laurel Ridge (Luciusboro, Marshall Heights, Penn View, and Bear Cave). For Laurel Ridge itself (see the local area in **Figure 4-2**), the Rager Mountain monitor should not be included in the evaluation because it was situated well to the northeast of the stations and is located in an area beyond the current modeled impact area of concern. The Little Mill Creek monitor was located in the Johnstown, PA airshed southeast of the ridge centerline, and it is the closest monitor to the city. During the 1990-1991 period, this airshed experienced substantial undocumented SO₂ emissions from a sprawling Bethlehem Steel mill, coke oven works, wire manufacturing, and other associated industries (see the photo in **Figure 4-3** as an example of the industrial activity); the steel operations closed in 1992). EPA was involved in litigation at the time with Bethlehem Steel due to air quality violations (Journal of Commerce, 1987; Los Angeles Times, 1992) including excess sulfur emissions. Due to the local impacts of those sources on any monitor on the southeast side of Laurel Ridge, the Little Mill Creek monitor should not be included in this model evaluation exercise because impacts at that monitor more than any other were likely influenced by undocumented large SO₂ sources in Johnstown. Therefore, monitors on Laurel Ridge that we are proposing to select for this model evaluation study and would be impacted by Conemaugh and Seward stations rather than steel mills in Johnstown are the following four (4) sites: Powdermill Run, Baldwin Creek, Sugar Run, and Terrys Run.

The primary SO₂ emission sources were the coal-fired boilers at the Keystone, Homer City, Seward, and Conemaugh stations which were not equipped with SO₂ flue gas desulphurization (FGD) systems at the time of the field study. The ambient air monitors were sited to detect peak impacts from the stations; extensive planning efforts were expended into the siting of the network of monitors. The monitors situated along Laurel Ridge were designed to capture impacts primarily from Conemaugh and Seward, given their closer proximity, as Homer City and Keystone were located more than 20 km and 40 km away from the ridge, respectively. A modeling and monitoring protocol was prepared by TRC and approved by PA DEP and EPA and are included in **Attachments C** and **D**, respectively.^{19,20}

¹⁹ TRC, 1993. Revised Final Report on the Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge. TRC. January 13, 1993.

²⁰ TRC, 2003. Final Report. AERMOD Modeling Analyses for SO₂ NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania. TRC. March, 2003.

In 1993, EPA formally requested this database from Penelec to use in its evaluation of a new model at that time, AERMOD. EPA said that they have

"...reviewed many data bases that have been collected throughout this county. We believe that the Indiana County SO₂ data base could provide an excellent test of the new model's capability to accurately predict multi-source impacts in complex terrain."²¹

A copy of this 1993 database request from EPA is included in **Attachment E**. It turns out that this database, although sent to EPA, was not used by EPA in its AERMOD evaluations during the development of the AERMOD model. However, it was clear to EPA that it is a useful evaluation database, and is well suited to evaluate the performance of AERMOD.

4.1 Local Terrain Affecting Field Study

As previously discussed in Section 1.1, the location of the key SO₂ sources from the stacks at Conemaugh and Seward situated in the Conemaugh River Valley and the high, perpendicular (to the flow) terrain of Laurel Ridge to the east establishes a very unique dispersion environment. **Figure 4-4** illustrates the 1990 field study on a terrain map with a cross section extending west of Chestnut Ridge, passing through the Ash Valley meteorological tower collection site, across Laurel Ridge, and extending to the Johnstown SO₂ monitoring site. **Figure 4-5** shows the elevation profile path of the cross section and clearly shows the heights of the Conemaugh and Seward stacks are well below Laurel Ridge. This figure also provides a good illustration of the meteorological site relative to the localized terrain.

²¹ US EPA, 1993. EPA letter to Mr. Vincent Brisini of PENELEC. US EPA Region III. June 3, 1993 (provided as Attachment E to this document).

Figure 4-1: Location of SO₂ Monitors, Meteorological Tower, and Sources for Historical Field Study

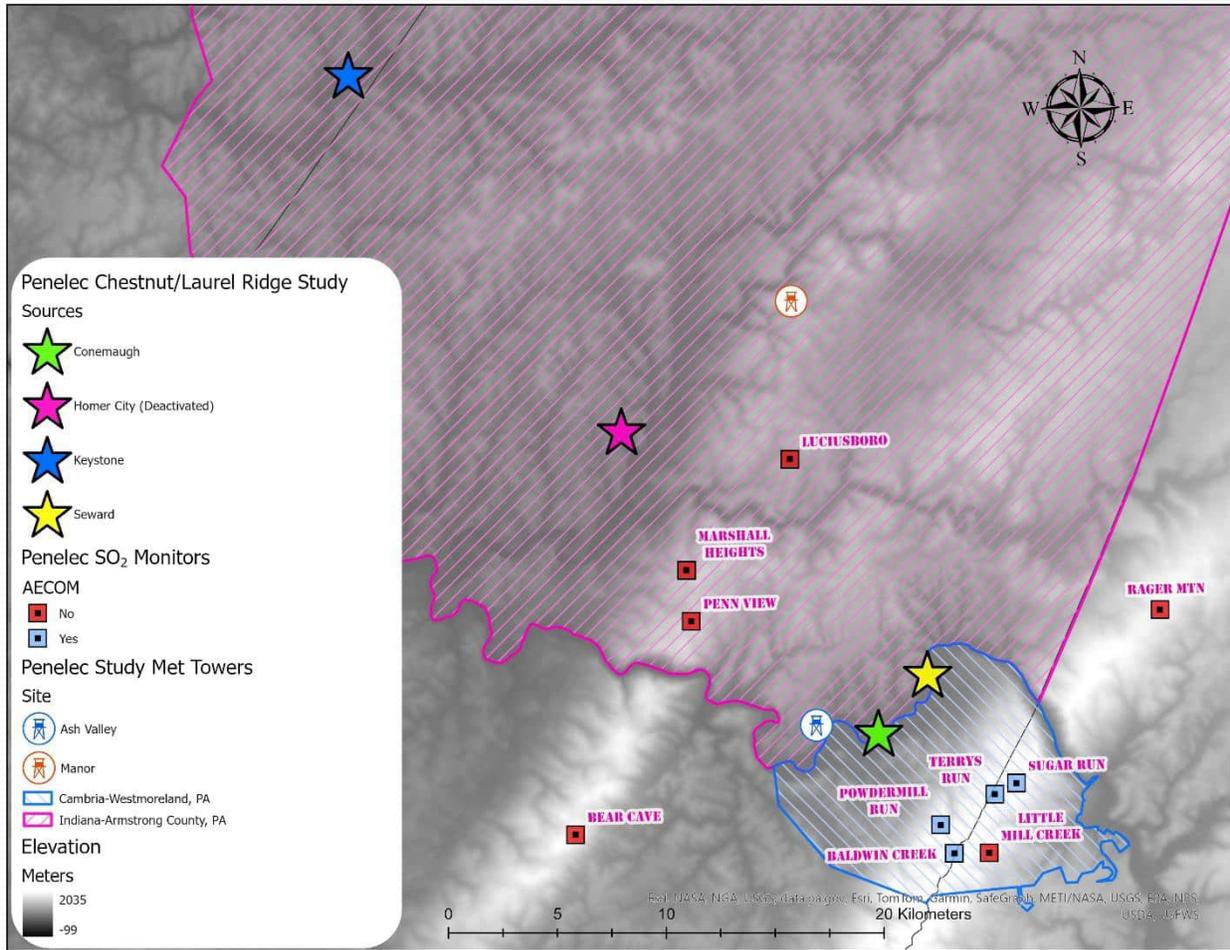


Figure 4-2: Focus of Field Study Near Laurel Ridge

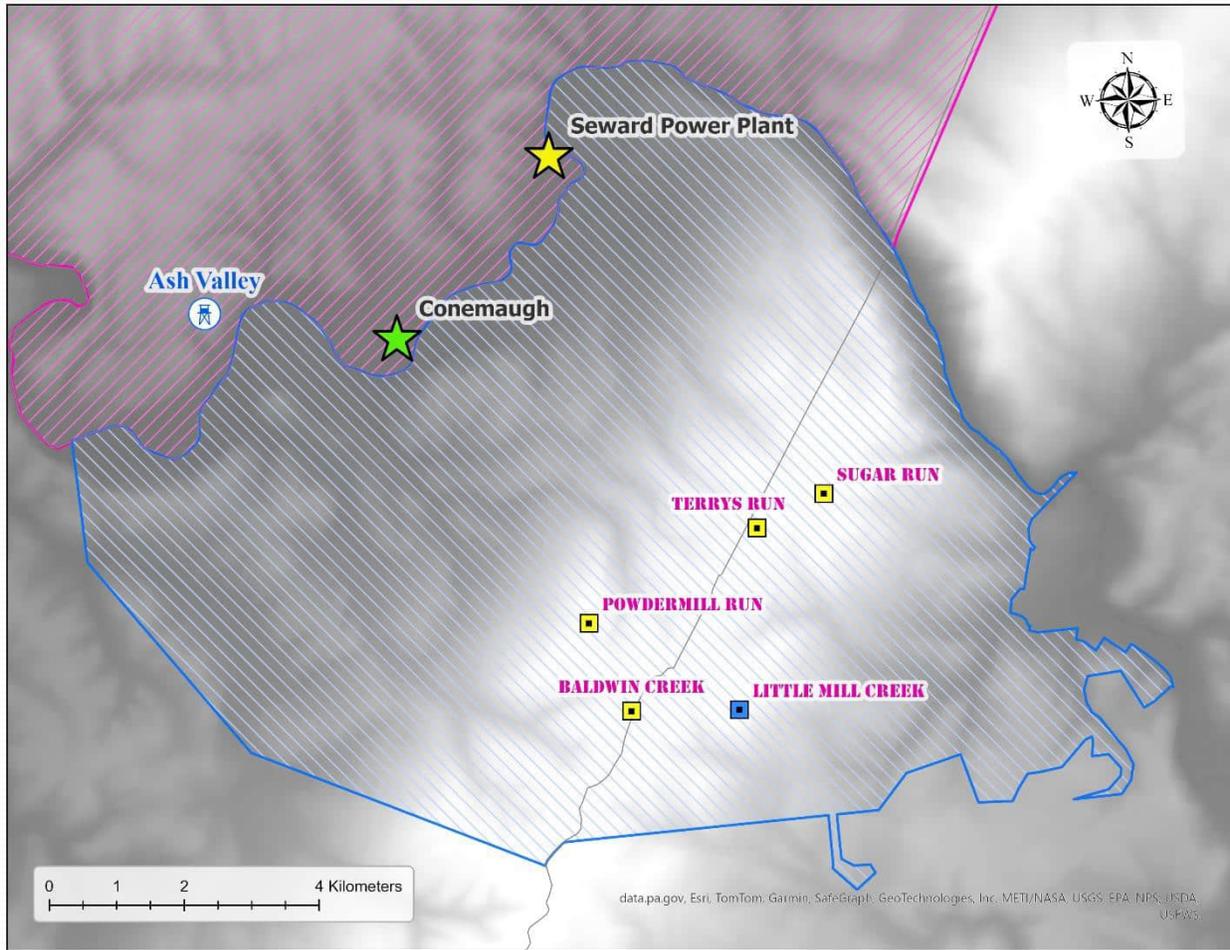


Figure 4-3: Johnstown, PA Industrial Activity during Period with Bethlehem Steel Production



Source: <https://www.indarch.mtu.edu/view.php?viewtype=item&id=1332>.

Figure 4-4: Map of Laurel Ridge Study and Elevation Cross-Section Path

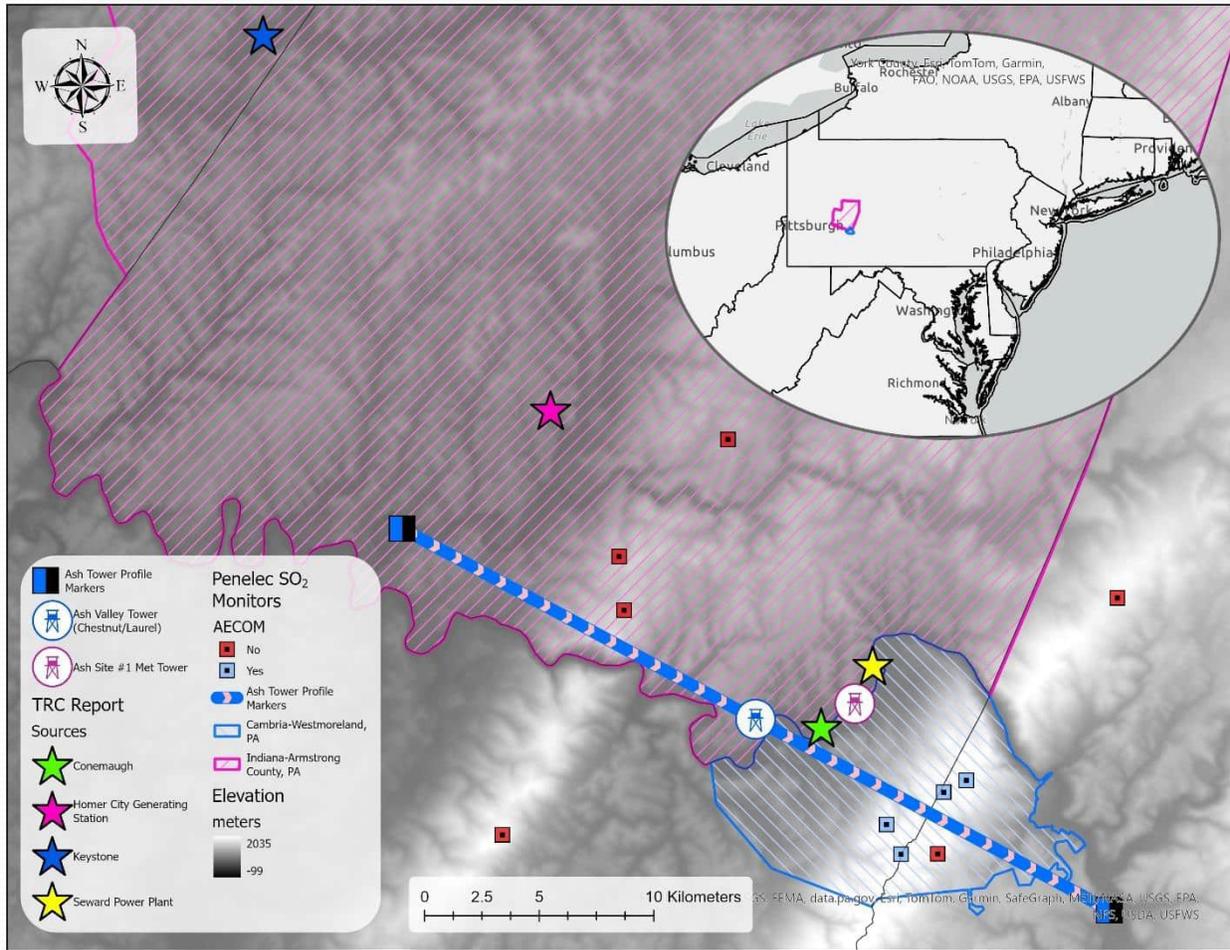
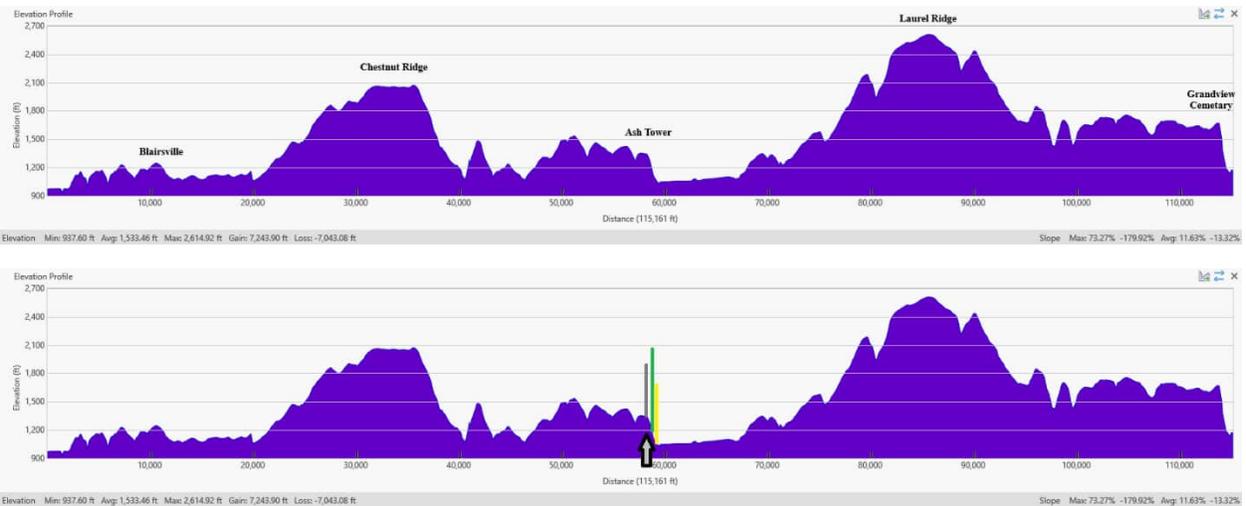


Figure 4-5: Cross-Section Profile Path



5. Proposed Modeling Procedures Using Historical 1990 Laurel Ridge Study

5.1 Dispersion Model Selection

The proposed 1990 Laurel Ridge modeling analysis will use the AERMOD dispersion model²² (Version 24142), current as of November 2024. The AERMOD modeling system consists of two preprocessors and the dispersion model. AERMET is the meteorological pre-processor component and AERMAP is the terrain pre-processor component that characterizes the terrain and generates receptor elevations along with critical hill heights for those receptors.

There will be two separate model runs, each with the following options applied:

- 1) AERMOD default option (regulatory model)
- 2) AERMOD alpha option with LOW_WIND, minimum sigma-v = 0.5 m/s (alternative model)

Both model runs will utilize the same model inputs (i.e., meteorology, emissions, etc.) as described below.

5.2 Land Use Classification

One of the factors affecting input parameters to dispersion models is the selection of either rural or urban conditions near the source site and the meteorological site(s). The choice of rural or urban for dispersion conditions at the source site depends upon the land use characteristics within 3 kilometers of the facility being modeled (Appendix W to 40 CFR Part 51)²³. Factors that affect the rural/urban choice, and thus the dispersion, include the extent of vegetated surface area, the water surface area, types of industry and commerce, and building types and heights within this area.

According to Section 7.2.1.1 of EPA's Appendix W, either a land use (Auer method) or a population density procedure should be used in determining the selection of urban vs. rural dispersion. For this application, the Auer method will be selected.

Using the Auer method recommended by the US EPA (US EPA, 2024a), urban land use types are classified as categories I1, I2, C1, R2, and R3. **Table 5-1** describes these categories and maps them to reasonably equivalent USGS Annual National Land Cover Database (NLCD) categories. While the Auer method and NLCD do not use the same terms to define their categories, the similarities between the five Auer categories and NLCD categories 23 and 24 are apparent. Thus, it is reasonable to classify annual NLCD categories 23 and 24 as urban land use.

The annual NLCD data were processed with US EPA's AERSURFACE processor (version 24142) to determine the different land use types within 3 km of the Stations. AERSURFACE is typically used to process the annual NLCD data for input to AERMET, the AERMOD model's meteorological data processor. In this case, AERSURFACE output in the form of the pixel count for each of the annual NLCD's land use types will be used to determine the total pixel count of urban land use types within 3 km.

As noted above, urban land use types were assumed to be NLCD categories 23 and 24: "Developed, Medium Intensity" and "Developed, High Intensity", respectively. The pixel count for these categories was less than 4% for Conemaugh and less than 2% for Seward of the total pixel count for all categories. Thus, the overwhelming majority (>95%) of the 3 km area around the Stations can be classified as rural land use and AERMOD will not be applied with any urban source options. **Table 5-2** and **Table 5-3** provide the pixel counts as reported in the AERSURFACE output along with respective percentages for the annual NLCD years during the study period (1990 and 1991) for Conemaugh and Seward stations, respectively.

²² See the AERMOD system documentation at <https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod>.

²³ EPA's Guideline on Air Quality Models, available at https://www.epa.gov/system/files/documents/2024-11/appendix_w-2024.pdf.

Table 5-1. Comparison of Auer and NLCD Land Use Categories

<u>Auer Urban Land Use Categories⁽¹⁾</u>			<u>USGS Annual NLCD Categories⁽²⁾</u>	
Type	Use and Structure	Vegetation	Category	Description
R2	Dense single/multi-family	< 30%	23	<u>Developed, Medium Intensity</u> – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
R3	Multi-family, two story	< 35%	24	<u>Developed, High Intensity</u> – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
I1	Heavy Industrial	< 5%		
I2	Light/moderate industrial	< 5%		
C1	Commercial	< 15%		

Notes:

⁽¹⁾ US EPA, 2024a.

⁽²⁾ Multi-Resolution Land Characteristics Consortium (MRLC).

<https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description>

Table 5-2. Land Cover Within 3 km of Conemaugh Station AERSURFACE Log File

USGS Annual NLCD Category	Description	NLCD 1990		NLCD 1991	
		Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%
11	Open Water	582	1.85%	557	1.77%
12	Perennial Ice/Snow	0	0.00%	0	0.00%
21	Developed, Open Space	1990	6.34%	1980	6.30%
22	Developed, Low Intensity	1545	4.92%	1548	4.93%
23	Developed, Medium Intensity	670	2.13%	685	2.18%
24	Developed, High Intensity	236	0.75%	236	0.75%
31	Barren Land (Rock/Sand/Clay)	1041	3.31%	1037	3.30%
32	Unconsolidated Shore	0	0.00%	0	0.00%
41	Deciduous Forest	22981	73.16%	22989	73.19%
42	Evergreen Forest	4	0.01%	4	0.01%
43	Mixed Forest	876	2.79%	876	2.79%
51	Dwarf Scrub	0	0.00%	0	0.00%
52	Shrub/Scrub	1	0.00%	0	0.00%
71	Grasslands/Herbaceous	99	0.32%	111	0.35%
72	Sedge/Herbaceous	0	0.00%	0	0.00%
73	Lichens	0	0.00%	0	0.00%
74	Moss	0	0.00%	0	0.00%
81	Pasture/Hay	1091	3.47%	1093	3.48%
82	Cultivated Crops	0	0.00%	0	0.00%
90	Woody Wetlands	290	0.92%	291	0.93%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%
95	Emergent Herbaceous Wetland	4	0.01%	3	0.01%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%
	Total	31410	100%	31410	100%

Urban land use types are shown in red, bold text.

Source: AERSURFACE (US EPA, 2024d)

Table 5-3. Land Cover Within 3 km of Seward Station AERSURFACE Log File

USGS Annual NLCD Category	Description	NLCD 1990		NLCD 1991	
		Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%
11	Open Water	666	2.12%	660	2.10%
12	Perennial Ice/Snow	0	0.00%	0	0.00%
21	Developed, Open Space	2409	7.67%	2406	7.66%
22	Developed, Low Intensity	1537	4.89%	1540	4.90%
23	Developed, Medium Intensity	379	1.21%	375	1.19%
24	Developed, High Intensity	29	0.09%	29	0.09%
31	Barren Land (Rock/Sand/Clay)	812	2.58%	806	2.57%
32	Unconsolidated Shore	0	0.00%	0	0.00%
41	Deciduous Forest	23601	75.13%	23605	75.15%
42	Evergreen Forest	4	0.01%	4	0.01%
43	Mixed Forest	337	1.07%	337	1.07%
51	Dwarf Scrub	0	0.00%	0	0.00%
52	Shrub/Scrub	8	0.03%	5	0.02%
71	Grasslands/Herbaceous	127	0.40%	131	0.42%
72	Sedge/Herbaceous	0	0.00%	0	0.00%
73	Lichens	0	0.00%	0	0.00%
74	Moss	0	0.00%	0	0.00%
81	Pasture/Hay	1278	4.07%	1288	4.10%
82	Cultivated Crops	0	0.00%	0	0.00%
90	Woody Wetlands	220	0.70%	222	0.71%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%
95	Emergent Herbaceous Wetland	5	0.02%	4	0.01%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%
	Total	31412	100%	31412	100%

Urban land use types are shown in red, bold text.

Source: AERSURFACE (US EPA, 2024d)

5.3 Meteorological Data Processing of 1990 Ash Valley Tower

The meteorological data required for input to AERMOD for the model evaluation will be processed with the latest version of AERMET (version 24142) using default options in a single control file (i.e., Stages 1 and 2 processed in the same file). One year (August 1, 1990 to July 31, 1991) of meteorological observations from the 150-m Ash Valley tower meteorological tower along with one year of concurrent upper air data from Pittsburgh International Airport, PA (for cloud cover and pressure) will be used as input to AERMET. Quarterly data capture from the Ash Valley dataset is above 96% for each quarter as shown in **Table 5-4**. **Figure 5-1** shows the meteorological tower location and measured parameters and the 150-meter wind rose is shown in **Figure 5-2**. AECOM used the TRC-generated meteorological database as input to AERMET for the on-site meteorological data component. Site-specific turbulence data (standard deviation of the horizontal wind direction (σ -theta) was collected and therefore will be included in the AERMET processing. Sigma-theta was available from the tower at the 10-meter level. As such, the ADJ_U* option will not be used in conjunction with the on-site turbulence data, as recommended by EPA in Section IV (A)(2) of Appendix W.

AERMET creates two output files for input to AERMOD:

- **SURFACE:** a file with boundary layer parameters such as sensible heat flux, surface friction velocity, convective velocity scale, vertical potential temperature gradient in the 500-meter layer above the planetary boundary layer, and convective and mechanical mixing heights. Also provided are values of Monin-Obukhov length, surface roughness, albedo, Bowen ratio, wind speed, wind direction, temperature, and heights at which measurements were taken.
- **PROFILE:** a file containing multi-level meteorological data with wind speed, wind direction, temperature, sigma-theta (σ_θ) and sigma-w (σ_w) when such data are available. In this application, turbulence data (sigma-theta) will be included as input.

For all meteorological data parameters included in the modeling, the hourly-averaged values from the dataset will be used as input to AERMET. For modeling purposes, no replacements of calms will be attempted; the meteorological tower instrumentation had a starting threshold level of 0.5 m/s and this information will be provided as input to AERMET.

Table 5-4: Quarterly Meteorological Data Capture

Quarter	Month, Year	% Data Capture ¹
1	January – March, 1991	99.54%
2	April – June, 1991	96.15%
3	July 1991, August – September, 1990	98.69%
4	October – December, 1990	99.18%

¹ Data capture from AERMOD output.

Figure 5-1: Ash Valley Tower Parameters

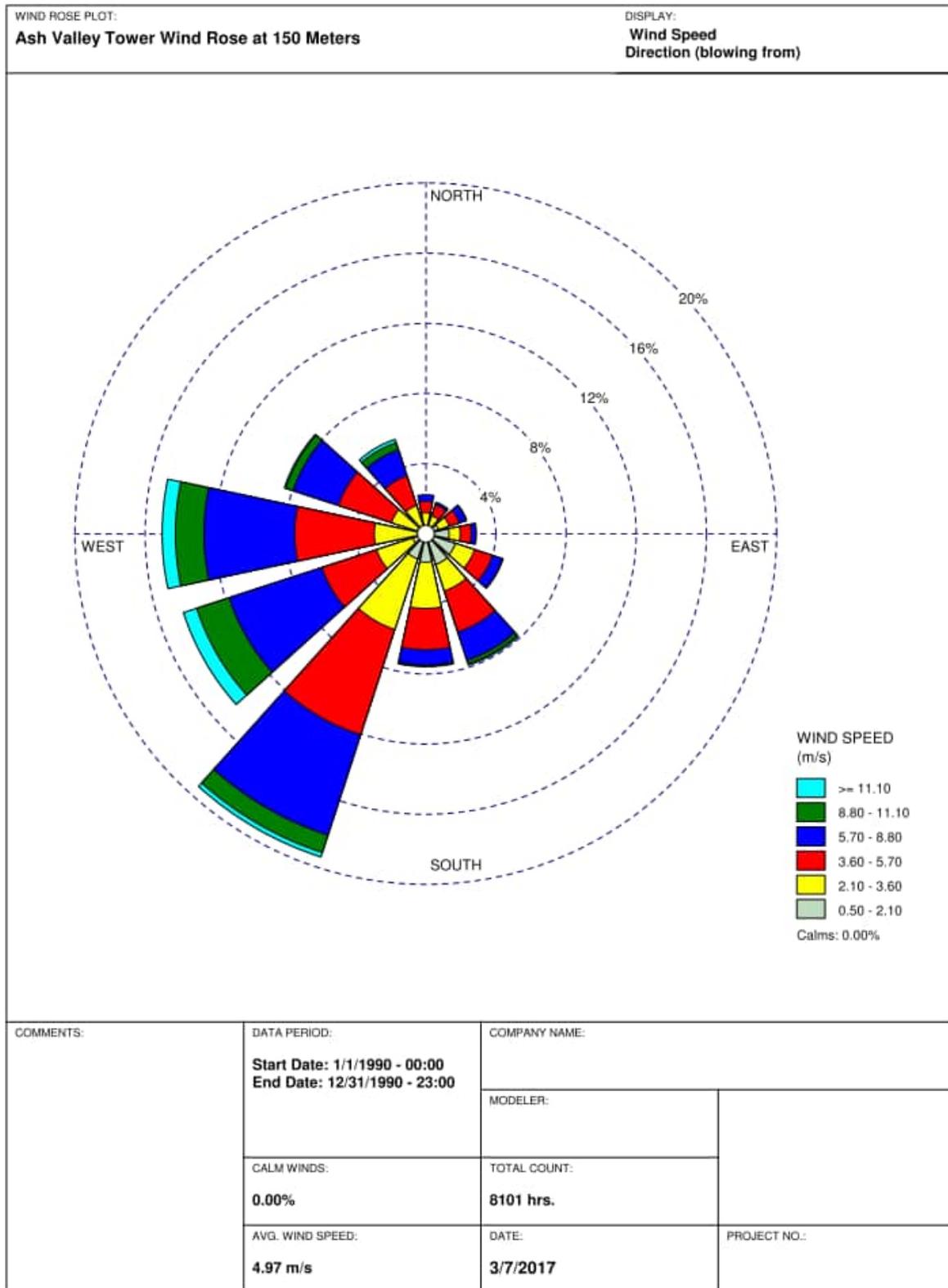
Location Description	MSL (ft.)	Above Grade (ft.)	Parameters* Monitored
(a) Ash Valley 150 Meter Tower			
Tower UTM - N = 4472558.36 - E = 661721.53			
Tower Base Plate	1401	-	-
Lower Sensor Level	1434	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1565	164 (50 m)	WD, WS
Upper Sensor Level	1695	292 (89 m)	WD, WS
Top Sensor Level	1893	492 (150 m)	WD, WS

*** Parameter Identifiers**

- WD = wind direction
- WDST = standard deviation of wind direction (sigma theta)
- WS = wind speed
- AT = ambient temperature

Note that this figure was taken from the 1993 TRC report.

Figure 5-2: Ash Valley Tower Wind Rose at 150 Meters



AERMET requires specification of site characteristics including surface roughness (z_o), albedo (r), and Bowen ratio (B_o). These parameters were developed according to the guidance provided by EPA in the November 2024 version of the AERMOD Implementation Guide²⁴ (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 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 should 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. AERSURFACE²⁵ 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.

Figure 5-3 shows an aerial photo (taken in 1994) of the area within about 1 kilometer of the tower location. AERSURFACE (Version 24142) will be used to subjectively estimate surface characteristics (roughness, Bowen ratio, and albedo) around the Ash Valley tower, which are required inputs to AERMET. Digitized land cover data will be obtained from the USGS National Land Cover Data archives²⁶ (NLCD). Since the meteorological data collection spanned across two calendar years (1990 and 1991), both annual-based NLCD files will be processed. The NLCD 1990 will be used to assign surface characteristics to the months of August through December, while the NLCD 1991 dataset will be used for January through July. The NLCD files were downloaded from USGS on July 15, 2025 and will be supplemented with the concurrent tree canopy and impervious surface data files.

In accordance with Section 3.1.1 of the AIG, a land cover analysis should be conducted to evaluate the representativeness of the surroundings of the meteorological tower and the sources to be modeled. To demonstrate this, land cover counts from the AERSURFACE log file for a 1-km radius from Conemaugh and Seward were compared to land cover counts for a 1-km radius from the Ash Valley site. Details of this analysis are presented in **Attachment F**. Furthermore, the annual average values of albedo and Bowen ratio were compared between the three (3) sites (Ash Valley, Conemaugh, and Seward). All three (3) sites revealed the same albedo value of 0.16 for both 1990 and 1991 land cover data files. For Bowen ratio, Ash Valley yielded 0.69 for both 1990 and 1991, while Conemaugh and Seward were both 0.70 for both land cover dataset years. Based on this analysis, the surrounding land cover is very similar between the Ash Valley site and the stations. Therefore, the location and ground cover around the meteorological dataset to be used in this model performance evaluation is representative of the sources to be modeled.

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 last roughness parameter for defining sectors is the "roughness flag", which can be used to apply an adjustment factor to the default roughness values for the developed categories (21, 22, 23, 24) and for pasture (81) and cultivated crops (82) categories. For the developed categories, HighZo would be used for sectors that have buildings/structures while for sectors that do not have buildings/structures and/or are predominantly paved surfaces, LowZo would be used. Based on visual inspection of the aerial and land cover within 1 km of the Ash Valley meteorological tower, all sectors will be assigned LowZo. Five (5) sectors were identified through visual inspection and professional judgement. These sectors are shown on the land cover imagery (**Figure 5-4**).

²⁴ Available at https://www3.epa.gov/ttn/scram/models/aermod/aermod_implementation_guide.pdf.

²⁵ Documentation available at http://www.epa.gov/ttn/scram/dispersion_related.htm#aersurface.

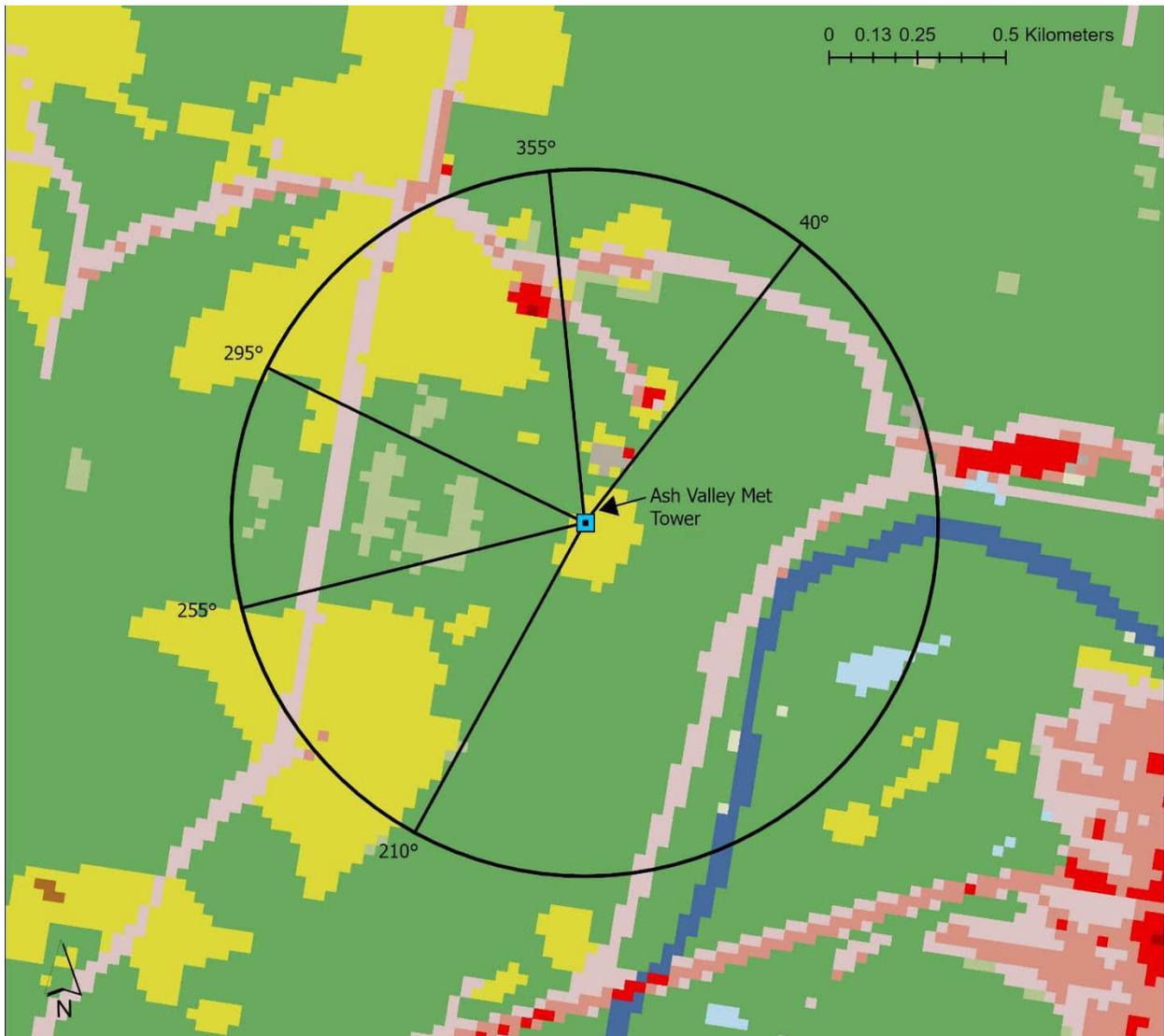
²⁶ See additional information at <http://landcover.usgs.gov/natl/landcover.php>.

Figure 5-3: Area Surrounding the Ash Valley Tower in Year 1994



A red circle represents a 1-km radius around the Ash Valley Tower.

Figure 5-4: AERSURFACE Sectors Land Cover Data



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,

1. Midsummer with lush vegetation;
2. Autumn with un-harvested cropland;
3. Late autumn after frost and harvest, or winter with no snow;
4. Winter with continuous snow on ground;
5. Transitional spring with partial green coverage or short annuals;

Consistent with the modeling conducted for the Indiana, PA SIP by EPA in their TSD²⁷, the following months will be assigned to each season for the AERSURFACE processing. These include the following:

- Winter – November, December, January, February, and March;
- Spring – April and May;
- Summer – June, July, and August;
- Autumn – September and October.

For Bowen ratio, the land use values are linked to three categories of surface moisture corresponding to 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 will 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 month was determined by comparing precipitation for the period of data to be processed to the 30-year climatological record, selecting “wet” conditions if precipitation is in the upper 30th-percentile, “dry” conditions if precipitation is in the lower 30th-percentile, and “average” conditions if precipitation is in the middle 40th percentile. The 30-year precipitation dataset selected will be from 1960 – 1989 and was obtained from the National Climatic Data Center for Pennsylvania Climate Division 9.²⁸ The monthly precipitation totals for the modeled period, which is the Pennsylvania Climate Division 9 dataset for 1990 and 1991, will be compared to the 30-year climate period. **Table 5-5** summarizes the monthly precipitation totals from Pennsylvania Climate Division 9 from 1960 through 1991. The monthly designations of surface moisture that were input to AERSURFACE are summarized in **Table 5-6**.

The closest available snow cover dataset that was used to determine winter months with snow versus winter months without snow was retrieved from the NCEI Daily Summaries Station Records.²⁹ **Table 5-7** summarizes the days with at least 1 inch of snow cover on the ground for the Derry 4 SW, PA site. Based on this data, no month will be classified with snow cover as no month in the modeled period meets the “at least 50%” threshold criteria.

The default method for determining surface roughness length (ZORAD) will be used, as recommended by EPA's AERSURFACE User's Guide³⁰.

²⁷ EPA's Docket [EPA-R03-OAR-2024-0024](#), see document EPA-R03-OAR-2024-0024-0014

²⁸ <https://www1.ncdc.noaa.gov/pub/data/cirs/climdiv/>

²⁹ <https://www.weather.gov/wrh/climate?wfo=ctp>

³⁰ https://qaftp.epa.gov/Air/aqmg/SCRAM/models/related/aersurface/aersurface_ug_v24142.pdf

Table 5-5: PA Climate Division 9 Monthly Precipitation (inches): 1960-1991

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1960	3.02	3.46	2.06	1.59	5.98	3.46	4.37	2.97	3.24	1.67	1.91	1.81	35.5
1961	2.20	3.76	4.31	5.83	3.09	4.69	4.98	3.04	2.06	2.82	3.64	2.54	43.0
1962	2.88	3.66	3.69	3.90	2.62	2.69	3.33	2.49	5.58	2.63	1.93	2.58	38.0
1963	1.73	2.27	5.83	2.40	2.11	3.53	3.42	2.70	1.61	0.38	4.19	1.96	32.1
1964	2.85	2.43	5.13	6.43	1.68	5.27	4.46	3.35	1.89	1.36	3.00	4.23	42.1
1965	4.33	2.64	3.89	2.60	2.39	1.83	2.33	3.42	4.36	3.29	2.60	0.90	34.6
1966	3.98	3.29	2.26	3.94	3.69	1.47	2.74	3.73	2.73	1.86	4.22	2.21	36.1
1967	0.95	2.64	6.39	3.86	5.56	1.34	4.89	3.78	2.88	2.81	2.78	2.72	40.6
1968	2.70	0.75	3.39	2.15	7.15	2.39	1.87	3.82	2.97	2.44	3.60	3.43	36.7
1969	2.46	0.85	1.31	3.74	2.74	3.43	6.55	3.27	1.87	2.34	2.77	4.66	36.0
1970	1.84	2.16	3.45	3.94	3.76	5.24	4.59	4.11	3.20	4.32	3.40	3.88	43.9
1971	3.01	4.17	2.63	1.02	4.29	3.46	4.90	3.95	5.00	1.44	2.90	3.41	40.2
1972	2.77	3.64	3.91	5.31	2.78	9.34	3.24	2.63	4.36	2.65	4.73	4.48	49.8
1973	2.22	2.38	3.34	5.47	4.56	4.16	2.96	3.47	4.32	3.80	3.32	3.38	43.4
1974	4.18	1.75	4.00	3.13	5.53	5.39	4.46	4.30	5.07	1.33	2.78	4.20	46.1
1975	4.12	4.06	4.34	3.00	4.12	4.85	2.33	6.69	6.04	3.30	2.11	3.38	48.3
1976	3.84	2.38	3.06	2.42	2.36	4.70	4.06	3.19	3.88	5.76	0.82	2.08	38.6
1977	1.64	1.30	4.83	4.03	2.52	3.64	6.42	4.12	3.60	2.98	3.02	3.11	41.2
1978	5.57	0.66	2.05	2.81	5.28	5.20	4.64	4.51	2.80	3.71	2.00	4.97	44.2
1979	4.96	3.32	2.09	3.78	4.87	2.24	5.37	5.42	4.85	3.79	3.14	2.11	45.9
1980	1.41	1.38	4.76	3.74	4.36	5.09	6.79	6.06	2.52	2.85	2.69	1.50	43.2
1981	0.94	4.25	2.01	5.61	3.05	6.69	5.39	2.05	4.55	3.43	1.52	2.59	42.1
1982	3.65	2.45	3.64	1.56	3.89	4.59	3.26	3.02	3.01	0.74	4.03	2.56	36.4
1983	1.32	1.53	3.50	5.14	6.07	4.14	3.13	2.86	2.74	3.95	4.13	4.13	42.6
1984	1.42	2.56	3.06	4.51	5.34	3.85	4.55	5.77	1.72	3.20	3.56	3.72	43.3
1985	1.75	1.72	4.84	2.01	5.94	3.06	5.39	3.28	1.02	2.64	11.08	2.24	45.0
1986	2.30	4.21	2.32	2.76	2.62	4.08	6.19	2.84	3.04	4.16	5.13	3.44	43.1
1987	2.66	0.72	2.61	4.96	4.08	4.31	3.07	5.58	4.97	1.72	2.62	2.81	40.1
1988	1.72	3.30	2.89	2.60	4.14	1.43	3.76	3.83	3.38	2.05	3.84	2.07	35.0
1989	2.60	3.67	5.69	2.07	6.49	7.11	3.74	2.14	4.42	3.12	2.43	1.80	45.3
1990	3.28	3.29	1.57	3.13	5.78	3.84	6.48	3.48	5.45	4.30	2.04	7.21	49.9
1991	3.24	2.23	3.57	3.51	2.43	1.85	3.66	2.20	2.54	1.14	3.04	4.26	33.7

Table 5-6: AERSURFACE Bowen Ratio Condition Designations

Year	Month	Bowen Ratio Category	Snow / No Snow
1990	August	Average	No Snow
1990	September	Wet	No Snow
1990	October	Wet	No Snow
1990	November	Dry	No Snow
1990	December	Wet	No Snow
1991	January	Wet	No Snow
1991	February	Average	No Snow
1991	March	Average	No Snow
1991	April	Average	No Snow
1991	May	Dry	No Snow
1991	June	Dry	No Snow
1991	July	Average	No Snow

Table 5-7: Monthly Snow Depth/Snow Cover Summary for Derry 4 SW, PA Station

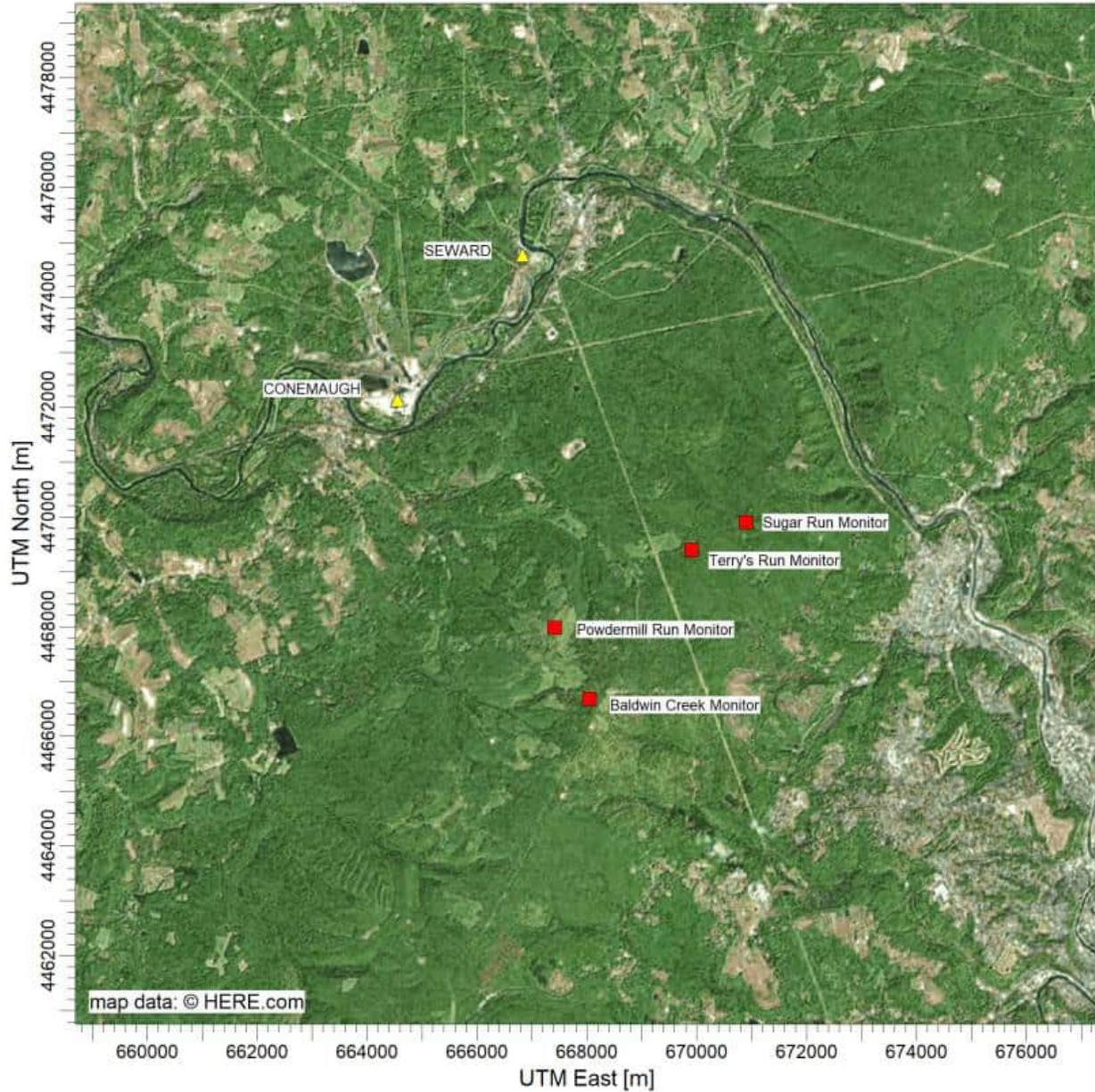
Year	Month	Days in Month	Days with Snow Cover	Missing Days	Snow Days %
1990	November	30	0	0	0.0%
1990	December	31	3	0	9.7%
1991	January	31	9	2	29.0%
1991	February	28	6	1	21.4%
1991	March	31	5	1	16.1%

Notes: Station elevation is 323.1 meters

5.4 Modeled Receptors

For the model performance evaluation, receptors will be located at the four (4) Laurel Ridge SO₂ monitoring sites (Baldwin Creek, Powdermill Run, Terry's Run, and Sugar Run) as presented in **Figure 5-5**. Consistent with Appendix W, a flagpole height of 0 meters will be used.

Figure 5-5: Proposed Laurel Ridge Receptors (Monitored Locations)



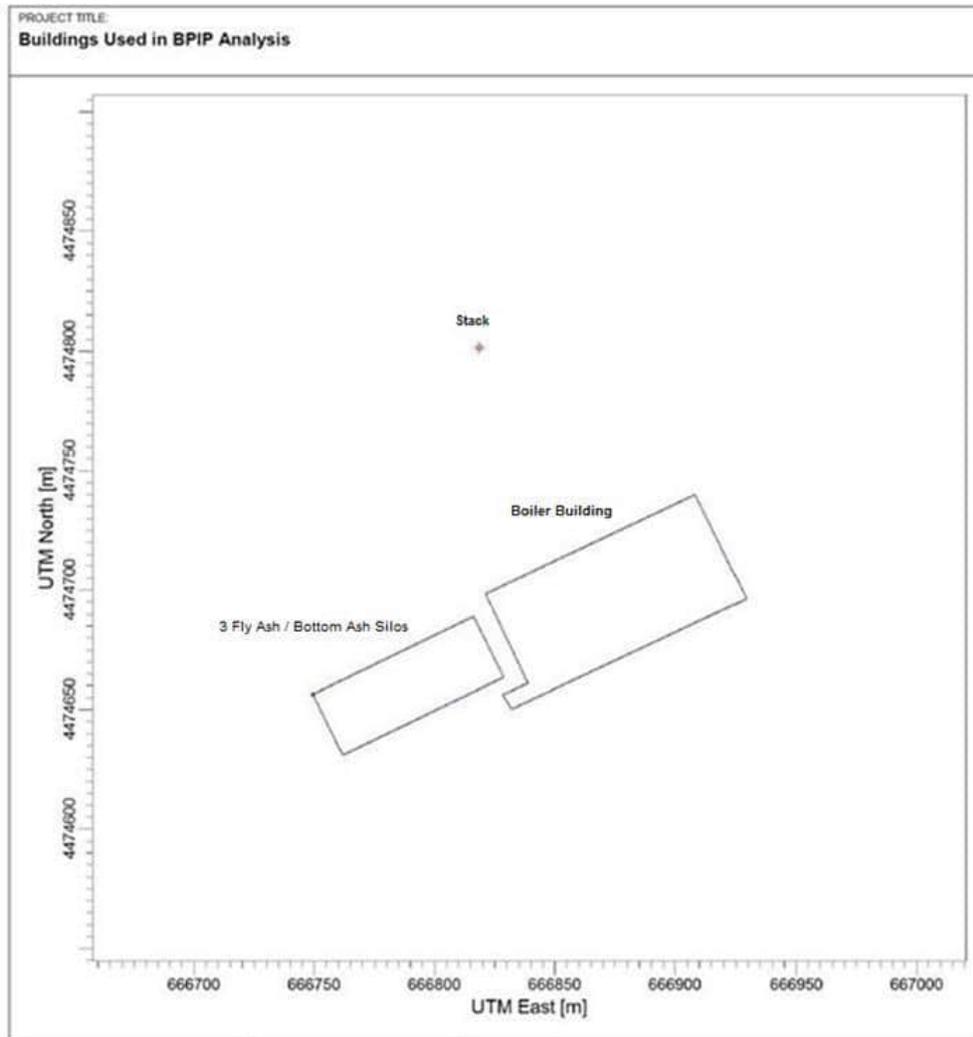
5.5 Modeled Stack Heights and Building Downwash

Consistent with guidance from EPA's SO₂ NAAQS Designations Modeling Technical Assistance Document (TAD)³¹, actual stack heights will be used so that the modeling analysis can most closely represent the actual ambient air quality conditions as influenced by the source. The potential for the source's plume to be affected by aerodynamic wakes created by the building(s) should also be evaluated in the dispersion modeling analysis. Conemaugh's stacks that were in service during the 1990 study were both 1,000 feet tall. This puts them beyond the height of downwash.

The Seward stack was built after 1970 and was built to a height of 604 feet. Inputs to AERMOD for direction-specific building dimensions will be calculated with the regulatory-approved version of the US EPA's Building Profile Input Program software (BPIP-PRIME version 04274) for the Seward stack. The locations and dimensions of the buildings/structures relative to the exhaust stacks for Seward is depicted in **Figure 5-6**.

It should be noted that the distance from Conemaugh and Seward stacks and the four (4) Laurel Ridge monitors are likely beyond the influence of building-induced downwash, given at least 5 km separates the sources and the closest monitor. Therefore, minor changes to the buildings would not have any appreciable effect on the model evaluation. The subsequent model performance report will include an analysis that compares the modeled concentrations at the monitor receptors with and without building downwash.

Figure 5-6: Seward Stack and Buildings for Plume Downwash



³¹ EPA, 2016. Sulfur Dioxide (SO₂) National Ambient Air Quality Standards Designation Modeling Technical Assistance Document. August 2016. Available at: <https://www.epa.gov/so2-pollution/technical-assistance-documents-implementing-2010-sulfur-dioxide-standard>

5.6 Emissions Data and Stack Parameters

The hourly SO₂ emissions and exhaust parameters (gas exit temperature and velocity) that were collected during the study will be used as input to the model. SO₂ emissions were collected through the use of Continuous Emissions Monitoring Systems (CEMS) for Homer City, while Keystone, Conemaugh, and Seward utilized an alternative, but PA DEP-approved, SO₂ emissions monitoring and reporting procedures. For this alternative data collection approach, coal samplers were deployed to collect integrated coal samples for each 24-hour period (twice hourly for a total of 48 samples per day). Hourly emissions rates were computed using the 24-hour averaged fuel sampling sulfur content values from the Certified Coal Sampling and Analysis System in combination with heat rates and hourly load data. These data points are available concurrent with the meteorological data from August 1990 through July 1991. **Table 5-8** summarizes the static stack parameter information of the sources included in the modeling.

The stack parameter calculations used to generate the hourly files to be used in the modeling were based on those described in the 1993 TRC Report. The 24-hour averaged fuel sampling values and hourly load data files are included in the electronic modeling archive.

Table 5-8: Stack Parameters for the Evaluation Modeling Analysis

Source	UTM Coordinates (M)		Stack Height	Stack Diameter ¹	Stack Base Elevation
	Easting	Northing			
Conemaugh Unit 1	664,566.58	4,472,236.03	304.8 m ¹ (1,000 ft)	8.3 m (27.2 ft)	331.77 m ³ (1,085.0 ft)
Conemaugh Unit 2	664,624.00	4,472,226.06	304.8 m ¹ (1,000 ft)	8.3 m (27.2 ft)	331.71 m ³ (1,085.0 ft)
Seward Units 4 and 5	666,818.48	4,474,801.48	184.1 m ⁴ (604 ft)	5.3 m (17.4 ft)	334.67 m ² (1,098.0 ft)
Homer City Unit 1	652,744.07	4,486,392.88	243.8 m ¹ (800 ft)	7.3 m (24.0 ft)	365.8 m ¹ (1,200 ft)
Homer City Unit 2	652,758.60	4,486,342.52	243.8 m ¹ (800 ft)	7.3 m (24.0 ft)	365.8 m ¹ (1,200 ft)
Homer City Unit 3	652,734.16	4,486,255.51	370.6 m ¹ (1,216 ft)	6.9 m (22.6 ft)	365.8 m ¹ (1,200 ft)
Keystone Unit 1	640,186.32	4,502,350.41	243.8 m ¹ (800 ft)	8.3 m (27.2 ft)	308.5 m ¹ (1,012 ft)
Keystone Unit 2	640,230.15	4,502,398.22	243.8 m ¹ (800 ft)	8.3 m (27.2 ft)	308.5 m ¹ (1,012 ft)
¹ Table 2-1 of TRC Report (1993) ² Indiana County 1-hour SO ₂ SIP (2024) ³ Google Earth ⁴ Seward provided data					

6. Proposed Model Evaluation Performance Metrics

As discussed in Section 5, hourly SO₂ emissions and meteorology for the one-year period (August 1990 – July 1991) from the Laurel Ridge study will be used to generate modeled concentrations at the receptors situated at the four (4) monitors (Baldwin Creek, Powdermill Run, Terry's Run, and Sugar Run). An ambient background value of 26.2 µg/m³ will be added to each predicted concentration. This background value represents an average concentration when the winds were toward the northeast, southwest, and northwest (not placing the monitors downwind of the key SO₂ sources) as were calculated by TRC and listed in Table 3-6 of the 2003 TRC report. Since this background value was established using wind sectors that would likely not be heavily influenced by the four power stations (Seward, Conemaugh, Keystone, and Homer City), it is appropriate to include these sources explicitly in the model.

The 8,760 hourly 1-hour predicted concentrations, from both model runs (regulatory with defaults and alternative), and the corresponding observed concentrations at each of the four (4) Laurel Ridge monitors will be obtained. A list of the performance measures we are proposing to use in the model evaluation is provided below.

- 1) 99th percentile design concentration (predicted and observed) at each monitor, and also considering all monitors;
- 2) Quantile-Quantile (Q-Q) of the ranked hourly SO₂ predicted and observed concentrations across all four (4) monitors; and
- 3) Screening and statistical tests and their statistical measures (Robust Highest Concentrations (RHCs), fractional bias, Composite Performance Measure (CPM), and Model Comparison Measure (MCM)), described in EPA's Protocol for Determining the Best Performing Model (EPA-454/R-92-025)³².

A software package, developed by Sigma Research Corporation and Sonoma Technology, referred to as the Model Evaluation Method (MEM), designed to evaluate model performance by implementing the statistical analysis procedures contained in EPA's Protocol for Determining the Best Performing Model (EPA-454/R-92-025) will be used to assist in the performance measure calculations. A discussion is provided below on what is available and how the results will be evaluated.

6.1 Model Evaluation Methodology (MEM)

The MEM operates in three (3) stages: Screen, Boot, and Combine. Each of these stages have their own individual input files (*.INP) that are accepted by the MEM. The MEM software will be used to calculate statistics for the top 25 ranked modeled and observed concentrations. As a quality control step, the average, RHC, standard deviation, and fractional bias of the top 25 concentrations will be independently computed and compared to the output from the MEM. The statistics that are computed based upon the MEM's random number generator (i.e., for the bootstrapping technique) will not be independently evaluated due to the dependence on a random number generator.

6.1.1 Screen Stage

The first stage in MEM is the Screen Stage. There are five components to the screen input file: Job Control Pathway (JB), Observation Pathway (OB), Model Pathway (MO), Statistics Pathway (ST), and Output Pathway (OU). The job control pathway contains the keywords that provide the overall control of the model run. This pathway includes a Title, the processing option (in the first stage this was Screen), a run or not switch, and an error output declaration. The next pathway, OB, contains information about the monitor and the format of the input data set for observed hourly concentrations. The MO pathway is the model input pathway which processes the modeled hourly concentrations. Statistical analysis is conducted in the ST pathway, ST, where in our case we will base the RHC calculations on the top 25 concentrations and conducted the statistics on those data points. Lastly, the OU pathway simply states the file name and location of the output data file. All stages also produce a (*.tst) file which is the compilation and statistic result output.

³² EPA, 1992. Protocol for Determining the Best Performing Model. EPA-454/R-92-025. September 1992. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/model_eval_protocol.pdf

The purpose of the Screen Stage is to identify models that fail to perform at a minimum operation level (e.g., AFB exceeds 0.67, which means that the model RHC prediction is not within a factor of 2 of the observed RHC).

6.1.2 Boot Stage

After the Screen stage has finished, MEM evaluates the Boot input files. The Boot stage is where bootstrapping statistics are run and model statistics are conducted for comparison of individual and model-to-model performance. Just like the Screen input file, the JB, OB, and MO, pathways are the same with the exception of the procedure operation option being Boot in the JB pathway.

One new pathway is included within the Boot stage, that being the Diagnostic Pathway (DI). The diagnostic pathway contains keywords to read in the relevant observed meteorological data. The meteorological data is used to enhance the model evaluation statistics by categorizing the data set hours into wind speed and stability classes. This stage calculates the statistics (RHC and FB) grouped on each defined class.

The MEM computes the RHC using the top 26 predicted and observed concentrations, as shown below.

$$RHC = X(N) + [X_{ave} - X(N)] \times \ln\left[\frac{3N-1}{2}\right] \quad \text{(Equation 1)}$$

where:

- N = a user-specified sample size for the top concentrations (typically 25), plus 1;
- X_{ave} = average of the N-1 (typically 25) largest values; and
- X(N) = Nth largest value.

In general, the RHC calculations are performed on the entire dataset being evaluated. The fractional bias (see Equation 2 below) has been selected as the basic measure of performance in the MEM when comparing observed and predicted RHC values. Values for the fractional bias range between -2 and +2 (model over-prediction for negative values and over-prediction for positive values). Fractional biases that are equal to -0.67 are equivalent to model RHC over-predictions by a factor of two, while a fractional bias of +0.67 is equivalent to a model under-prediction by a factor of two. The absolute fractional bias (AFB) statistic (equation 2), which is the absolute value of the fractional bias (FB), is computed for each of the models for each evaluation monitor.

$$AFB = |FB| = \left| 2 \times \frac{(Observed - Predicted)}{(Observed + Predicted)} \right| \quad \text{(Equation 2)}$$

where:

- Observed = calculated RHC from observed concentrations
- Predicted = calculated RHC from modeled concentrations

The DI pathway needs a file location and the format of the data set. The data that we will use for this pathway will be the 10-m wind speed and PG stability class. Classifications of meteorological conditions are conducted under the DICLASS keyword. For our evaluation, we propose the meteorological classes shown in **Table 6-1**.

Table 6-1: Diagnostic Meteorological Classes Tested in MEM

Diagnostic Class	Wind Speed	Stability Class
1	Low wind (0-4 m/s)	Unstable (1-3)
2	Low wind (0-4 m/s)	Unstable/Neutral (3-4)
3	Low wind (0-4 m/s)	Neutral/Stable (4-6)
4	High wind (> 4 m/s)	Unstable (1-3)

5	High wind (> 4 m/s)	Unstable/Neutral (3-4)
6	High wind (> 4 m/s)	Neutral/Stable (4-6)
Diagnostic classes and associated wind speed and stability classes taken from example provided in “User’s Guide for the Model Evaluation Methodology (MEM) System for Comparing Model Performance”, Version 1.0.		

Another parameter in the Boot ST pathway is the resample parameter. The resample parameter defines which “members” within the data set are defined as resample groups, and how the data is divided for resampling. The parameters “Resample Piece”, “Resample Blkrange”, and “Resample Number”, denote how MEM shifts the sequenced data to reflect seasonal groupings (defined in Blkrange). In our modeling, we intend to use four seasons, as recommended by the MEM user guide; the seasons were December – February for winter, March – May for spring, June – August for summer, and September – November for autumn. Lastly, the “Composite” pathway allows for weighting of the diagnostic and operational components when averaging the ABF, we used the weight of 1 for operational and 1 for diagnostic, based upon guidance from EPA³³. The last pathway within the Boot stage is the OU pathway which declares the name of the output file (*.mcm).

In addition to the RHC and FB, another statistical measure is calculated, referred to as the Composite Performance Measure (CPM). The CPM is a weighted linear combination of the individual FB in an attempt to quantify the uncertainty in the ABF calculations. The uncertainty can be used to determine whether performances of selected models are significantly different for the specific monitor being evaluated. The confidence interval calculated using the bootstrap method includes results for both the 90% and 95% levels; 90% has been used by EPA in past evaluations (see, for example slides 14 and 15 in the presentation at EPA’s 11th Modeling Conference (August 12, 2015) at https://www3.epa.gov/ttn/scram/11thmodconf/presentations/1-5_Proposed_Updates_AERMOD_System.pdf).

The formula for the CPM is shown in equation 3.

$$CPM = \frac{1}{3} \overline{(AFB)}_{r,s} + \frac{2}{3} \left[\frac{(AFB)_1}{2} \right] \tag{Equation 3}$$

where:

(AFB)_{r,s} = Absolute Fractional Bias for diagnostic condition r at station s; and

(AFB)₃ = Absolute Fractional Bias for 1-hour averages.

As described in EPA’s Protocol for Determining the Best Performing Model (EPA, 1992), the smaller the CPM, the better overall performance of that model. A positive value indicates the alternative model is performing better, whereas a negative means the default model is performing better. If the CPM values for our evaluation result in a lower, yet positive value then it can be concluded that the alternative model performs better than the default for this statistical measure.

6.1.3 Combine Stage

After the CPM is computed for each candidate model, the MEM calculates the difference in two models’ CPM results; the result is the “Model Comparison Measure”, or MCM. The MCM is conducted in the final stage within MEM, referred to as the Combine stage. This stage only contains a JB and a CS pathway. The CS pathway groups individual model results together for comparison to generate the MCM. This final result is an overall statement of whether the models being compared have significantly different performance. A negative CMCM implies that the default model is performing better, while a positive value indicates the alternative model is performing better. A significant determination depends upon whether or not the confidence interval overlaps zero. If it overlaps zero, then the results are not statistically different. If there is no overlap, then there is a statistically significant difference at that confidence interval.

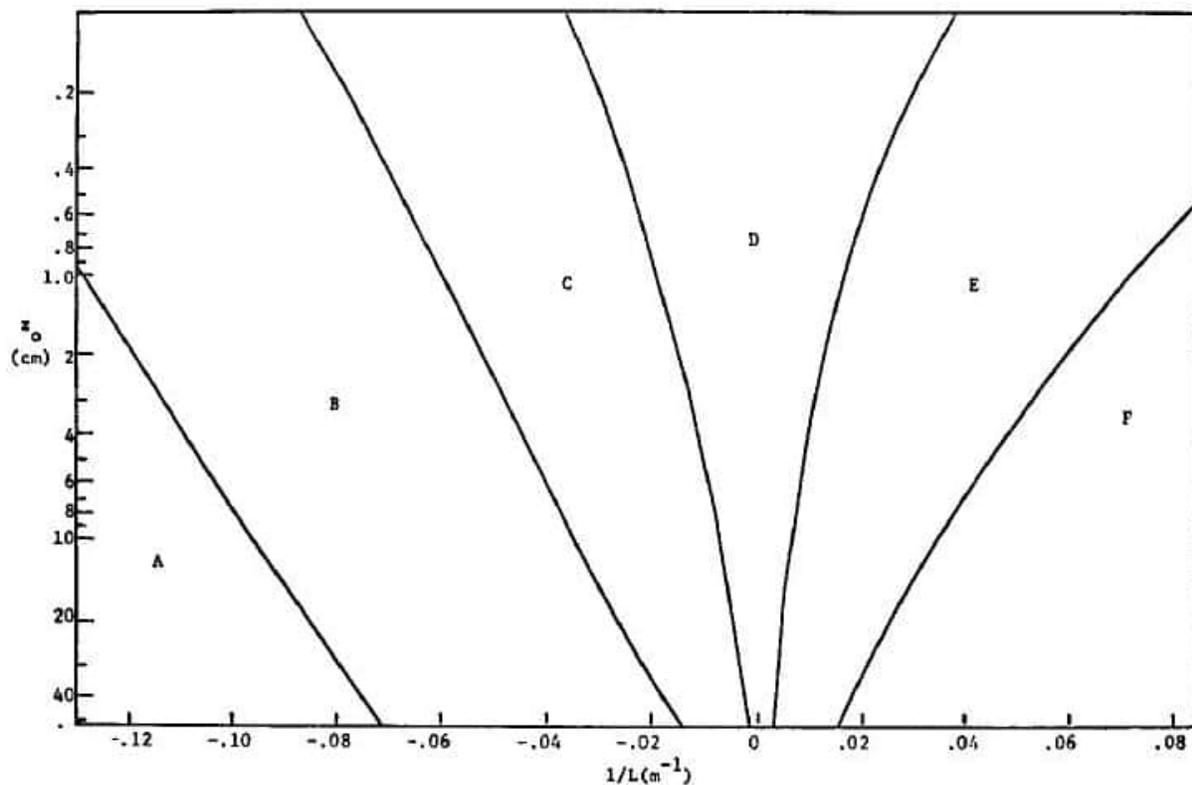
³³ Email correspondence from James Thurman (EPA) to Bob Paine (AECOM) on June 13, 2025.

6.2 Stability Class Determination for MEM Diagnostic Calculations

In order for the MEM to conduct the diagnostic statistics, which look at how the model performs under certain conditions, wind speed and stability class inputs are required. The Ash Valley meteorological tower data that will be processed through AERMET (see Section 5.3) will be used to obtain these inputs. The Pasquill-Gifford (PG) stability classes needed for the MEM diagnostic tests were calculated using the AERMET SURFACE file output; specifically with the hourly Monin-Obukhov length and the surface roughness length.

The PG stability classes were calculated according to the classic Golder (1972) algorithm that establishes a relation between the Monin-Obukhov length and surface roughness length (see **Figure 6-1**)³⁴. To create this relationship, we evaluated two points on each quasi-straight line in **Figure 6-2** at $z_0 = .01$ meters and $z_0 = 0.5$ meters and created a best fit line. **Figure 6-2** shows the good fit between these lines and the curves from Golder's paper. Stability values ranging from 1 to 6 will be calculated for every hour of the dataset.

Figure 6-1: Golder (1972) Stability Class as a Function of Surface Roughness Length and Monin-Obukhov Length

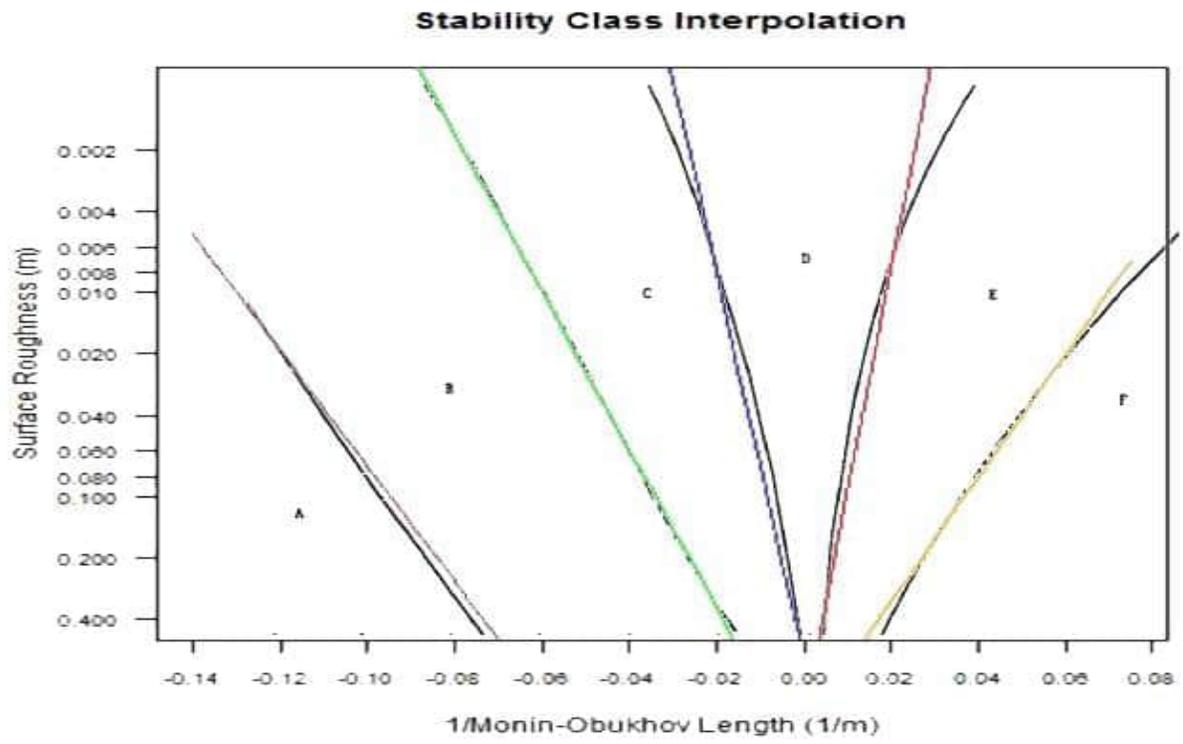


The fitted equations for PG stability class boundaries that we determined are:

$$\begin{aligned} \text{Stability A:B} &= 10^{\left(\frac{x+0.05937}{0.035315}\right)} && \text{(brown line in Figure B-13)} \\ \text{Stability B:C} &= 10^{\left(\frac{x+0.0082}{0.02589}\right)} && \text{(green line)} \\ \text{Stability C:D} &= 10^{\left(\frac{x-0.002189}{0.01059}\right)} && \text{(blue line)} \\ \text{Stability D:E} &= 10^{\left(\frac{x-0.000754}{-0.00912}\right)} && \text{(red line)} \\ \text{Stability E:F} &= 10^{\left(\frac{x-0.004079}{-0.03296}\right)} && \text{(yellow line)} \end{aligned}$$

³⁴ Golder, D: 1972, 'Relations Among Stability Parameters in the Surface Layer', *Boundary-Layer Meteorology*. **3**, 47-58. We found that the LTOPG curves correspond to a region in the middle of the stability classes shown in Figure 1 rather than the edges of the stability class areas.

Figure 6-2: Best fit lines between stability class regions defined by Golder (1972)



7. Summary of Requirements to be Fulfilled by the Laurel Ridge Study for Justification of an Alternative Model

Appendix W Section 3.2.2(e) prescribes the conditions that need to be addressed for approval of an alternative model.

- 1) The model or technique has received a scientific peer review.
The LOW_WIND technique, specifically where the minimum sigma-v is increased, has been evaluated using AERMOD in complex terrain (Hanna 1983; Hanna 1990).
- 2) The model or technique can be demonstrated to be applicable to the problem on a theoretical basis.
This application proposed to use a non-guideline, alpha low wind option (LOW_WIND) that EPA itself proposed (in a similar form as "LOWWIND3" that was proposed by EPA in 2015 for inclusion in Appendix W (as a guideline option). As discussed in Section 2, the site-specific challenges in properly accounting for the magnitude of horizontal plume meander can be more appropriately addressed using the LOW_WIND option with an increased minimum sigma-v value and is consistent with the findings from Hanna (1990).
- 3) The databases which are necessary to perform the analysis are available and adequate.
The relevance of the 1990-1991 field study to the current modeling application are discussed above. The coverage of monitors for this evaluation is comparable to other studies and are well sited relative to peak model impacts within the study area.
- 4) Appropriate performance evaluations of the model or technique are available.
These evaluations need to show that the model or technique is not inappropriately biased for regulatory application. Specifically, EPA prefers that a statistical performance evaluation has been conducted using measured air quality data and the result of that evaluation indicates that the alternative model performs better for the given application than a comparable model in Attachment A of Appendix W (default AERMOD). The discussions in this document outline how a site-specific performance evaluation using ambient monitoring data in the area of the Seward and Conemaugh stations along Laurel Ridge will be performed. The set of performance metrics that are being proposed are consistent with other site-specific alternative model requests that have received EPA-approval.
- 5) Modeling procedures to be followed have been established.
This modeling protocol provides the modeling procedures for the application of AERMOD using the LOW_WIND with a minimum sigma-v of 0.5 m/s for receptors being modeled with the on-site meteorological data. The modeling procedures outlined in the protocol are consistent with those described in Appendix W.

Upon completion of the model performance evaluation and approval from PADEP and EPA, the Stations would utilize the better-performing, site-specific model, which is anticipated to be the alternative model (i.e., LOW_WIND with a minimum sigma-v value of 0.5 m/s) to carry out the CDD modeling for the Cambria-Westmoreland area. The CDD modeling would use the more recent one-year on-site Ash Site #1 meteorological dataset (September 2015 – August 2016) and recent 3-year period of SO₂ emissions (2022 – 2024) for the modeled sources. The one-year meteorological dataset would be repeated for each year of the emissions. The meteorological data to be utilized from September 2015 through August 2016 from Ash Site #1 would include measured turbulence of both sigma-theta and sigma-w. The subsequent report for this model performance evaluation will include an analysis of the Laurel Ridge study emissions and monitoring data with the use of the following two separate meteorological datasets: (1) the September 2015 through August 2016 from Ash Site #1 meteorological data and (2) the September 1990 through August 1991 collected from the Ash Valley Tower. This supplemental analysis will be used to demonstrate this dataset still yields improved performance with the alternative model, while still being conservative relative to the monitoring data.

Attachment A

Hanna, 1990: Lateral Dispersion in Light-Wind Stable Conditions Paper

Lateral Dispersion in Light-Wind Stable Conditions (*) (**).

S. R. HANNA

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(ricevuto l'1 Febbraio 1990)

Summary. — At downwind distances of 400 m or less, the angular standard deviation, σ_{θ} , of the lateral distribution of pollutants released from a point source over a given time period is shown to equal the standard deviation, σ_{θ} , of the wind direction fluctuations observed over the same time period. Data taken during light wind, stable conditions at two field sites (Idaho Falls, ID, and Oak Ridge, TN) are used in this analysis. This relation is most reliable if the pollutant concentration distribution is observed on a circle at constant distance from the source (*i.e.*, on a polar coordinate system).

PACS 92.60 - Meteorology.

1. - Introduction.

As the wind speed decreases, the hourly averaged standard deviation, σ_{θ} , of the wind direction increases. This phenomenon is common knowledge among weather observers and forecasters, who use the terminology «light and variable winds». Because lateral dispersion, σ_y , is directly proportional to σ_{θ} , it is important to account for this «meandering» effect in plume dispersion models. Mitchell and Timbre [1] and Van der Hoven [2] suggest empirical formulae that account for the increased σ_y in light-wind, stable conditions, and Hanna [3] and Hanna *et al.* [4] expand these methods for use in applied dispersion models. However, there are very few available data bases that can be used for further model development and testing.

This paper describes an analysis of some stable light-wind field data collected by the U.S. Nuclear Regulatory Commission (NRC) in Idaho and Tennessee [2, 5, 6]. These data were also reviewed and summarized by Draxler [7]. The NRC was concerned specifically with the fact that hourly-averaged plumes had been observed to be much wider than plumes predicted by the Pasquill-Gifford-Turner procedures during very stable conditions. Each field experiment consisted of 11 one-hour tracer tests, with concentrations observed at monitors located on circles with radii 100 m, 200 m, and 400 m. The Idaho site was flat with a median observed wind speed of 1.21 m/s and the

(*) Paper presented at the GNFAO/EURASAP Meeting, Turin, September 1989.

(**) To speed up publication, proofs were not sent to the author and were supervised by the Scientific Committee.

Tennessee site was moderately hilly with a median observed wind speed of 0.31 m/s. The low wind speeds in Tennessee could be resolved only with laser anemometers. The following conclusions related to lateral dispersion are presented in the final reports for these two studies.

Best agreement with observed concentrations is given by models that use meandering enhancement at low wind speed (*e.g.*, the Idaho National Engineering Laboratory (INEL) empirical lateral dispersion curves, a «split- σ » approach, or observed lateral turbulence, σ_θ).

When the plume covers 90° or more of a monitoring arc, a polar coordinate system rather than a rectilinear system should be used to calculate dispersion.

Hanna *et al.* [4] proposed a simple formula for σ_θ that accounted for the plume meandering discussed in the first conclusion. In a subsequent report, they generalized their model so that it employed the polar coordinate system mentioned in the second conclusion. A comparison of the σ_y formula predictions with the Idaho Falls observations is given below.

2. – Formulae for σ_y in light-wind stable conditions.

The data collected by the Idaho Falls scientists provide an excellent opportunity for testing the formulae suggested by Hanna *et al.* [4]:

$$(1) \quad \sigma_y = i_y x (1 + 0.0001x)^{-1/2},$$

where i_y is the lateral turbulence intensity, σ_v/u , which equals σ_θ (in rad) for small i_y or σ_θ . In general, $\sigma_\theta = \arctg i_y$. Observations of i_y may be used in eq. (1), or it may be parameterized through the formula

$$(2) \quad i_y = (0.5 \text{ m/s})/u,$$

which assumes that the hourly-averaged σ_v maintains a value of about 0.5 m/s even as the wind speed approaches zero. This empirical result is based on observations from many sites, including data from experiments over water and over complex terrain [4]. These experiments suggest that the $\sigma_v \sim 0.5 \text{ m/s}$ relation is valid over all types of terrain and that the larger values of i_y or σ_θ observed over complex terrain are actually due to lower wind speeds over that type of terrain. However, it should be pointed out that when σ_v is plotted *vs.* u at any site, the σ_v values typically exhibit a scatter of about $\pm 0.3 \text{ m/s}$ about the $\sigma_v \sim 0.5 \text{ m/s}$ relation.

Equations (1) and (2) are based in the rectilinear system, with σ_y and σ_v assumed to be perpendicular to the direction of the mean plume axis. They are valid as long as the small angle approximation, $\theta \approx \arctg \theta$ is valid, where θ is in rad. As θ increases beyond about 0.5 rad (28°), this approximation has an error of more than 10%. Consequently, when σ_y/x or i_y are greater than about 0.5 rad, it is better to rewrite the equations in their more general form, valid on a polar coordinate system:

$$(3) \quad \sigma_{\theta c} = \sigma_\theta (1 + 0.0001x)^{-1/2},$$

$$(4) \quad \sigma_\theta = \arctg ((0.5 \text{ m/s})/u),$$

where x is the radial distance from the source, $\sigma_{\theta c}$ is the standard deviation (in rad) of the concentration distribution observed on an arc along a circle around the source, and σ_{θ} is the standard deviation (in rad) of the wind direction observations [8]. Both $\sigma_{\theta c}$ and σ_{θ} have a maximum of 1.83 rad (105°), which is the standard deviation of a uniform distribution around the circle.

3. - Description of tracer data and meteorological data.

The Sagendorf and Dickson [5] and Wilson *et al.* [6] reports contain data from the Idaho Falls and Oak Ridge experiments, respectively. These reports do not give values of the angular standard deviation of the concentration distribution, $\sigma_{\theta c}$, but do provide tables containing all of the concentration data for each monitor. We used these data to calculate $\sigma_{\theta c}$ for all 22 runs at the 100 m arc. The observations used in this analysis are presented in table I, which includes the wind speed, u , the standard

TABLE I. - Listing of data from the Oak Ridge (OR) and Idaho Falls (IF) Sites.

Test	u (m/s)	σ_{θ} (rad)	Stability class (from dT/dz)	$\sigma_{\theta c}$ (rad)
OR1	0.49	not observed	E	0.65
OR2	0.42	at Oak Ridge	F	0.80
OR3	0.31		D	0.69
OR4	0.15		E	1.12
OR5	0.26		E	1.15
OR6	0.23		E	1.45
OR7	0.32		E	1.00
OR8	0.34		E	1.57
OR9	0.23		E	0.77
OR10	0.75		D	0.44
OR11	0.29		E	1.23
IF4	1.21	0.21	G	0.20
IFS	0.88	0.50	G	0.50
IF6	1.29	0.20	D	0.18
IF7	0.90	0.39	G	0.36
IF8	0.75	1.26	E	0.99
IF9	0.80	0.31	E	0.21
IF10	1.66	0.38	G	0.58
IF11	1.92	0.66	G	0.67
IF12	1.08	1.06	F	0.42
IF12	1.61	0.21	G	0.38
IF14	1.47	0.33	G	0.32

deviation of wind direction fluctuations, σ_{θ} , the stability class, and the standard deviation of the concentration distribution, $\sigma_{\theta c}$. The stability class is not used in our analysis, but is included in case other researchers wish to analyze these data from another viewpoint. Since the square-root term in eq. (3) is 0.995 for x equal to 100 m, it can be ignored and the following simple approximation to eq. (3) can be tested with

these data:

$$(5) \quad \sigma_{\theta c} = \sigma_{\theta}.$$

At the Idaho Falls site, the standard deviation of the wind direction fluctuations, σ_{θ} , was observed by fast-response wind instruments on a tower. At the Oak Ridge site, the wind speed was so light (median wind speed of 0.31 m/s) that it would not move conventional wind instruments. Consequently no σ_{θ} data are available at that site. Orthogonal sets of laser instruments with 350 m path lengths were used to determine the mean wind at Oak Ridge. The observed $\sigma_{\theta c}$ was therefore compared with observed σ_{θ} only at the Idaho Falls site. The observed $\sigma_{\theta c}$ was compared with parameterized σ_{θ} (*i.e.*, $\sigma_{\theta} = \arctg((0.5 \text{ m/s})/u)$) at both sites.

4. - Comparisons of model predictions with observations.

Figure 1 compares the $\sigma_{\theta c}$ and σ_{θ} observations from the Idaho Falls site, showing good agreement for most of the data points. Six of the eleven σ_{θ} observations are within $\pm 10\%$ of the $\sigma_{\theta c}$ observations, and the median σ_{θ} and $\sigma_{\theta c}$ also agree within $\pm 10\%$. It can be concluded that, for observed σ_{θ} in the range from 0.2 to 1.25 rad (11.5° to 72°), the formula $\sigma_{\theta c} = \sigma_{\theta}$ is quite accurate.

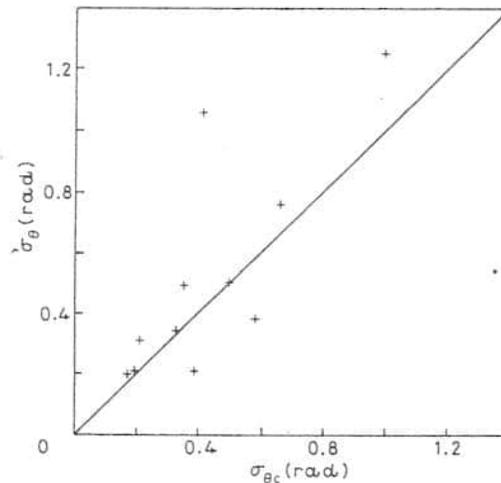


Fig. 1. - Idaho Falls observations of $\sigma_{\theta c}$ from concentration observations on 100 m arc, compared with observations of σ_{θ} from wind instruments.

Figure 2 contains the comparison of observed $\sigma_{\theta c}$ with parameterized σ_{θ} (from eq. (3)) for both the Idaho Falls and Oak Ridge sites. The cloud of points from Idaho Falls is located at lower values of σ_{θ} than the cloud of points from Oak Ridge, due to the difference in wind speeds at the two sites. The observed concentrations were distributed all around the monitoring circle during several runs in Oak Ridge, where the wind speeds were very low. Thus this is as severe a test of the formula as one is likely to find. It is seen that there is little bias on the figure, with better than $\pm 1\%$

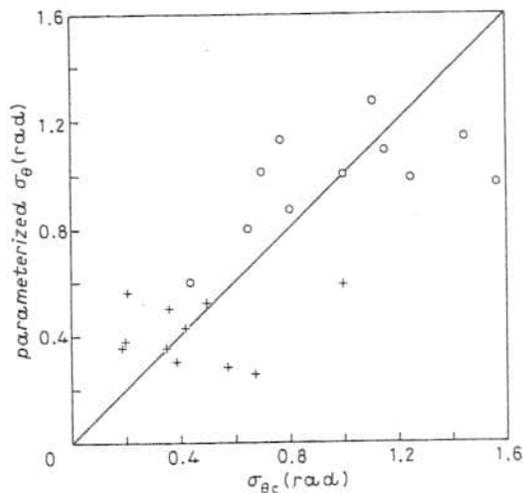


Fig. 2. - Idaho Falls (+) and Oak Ridge (o) observations of $\sigma_{\theta c}$ compared with parameterized $\sigma_{\theta} = (\text{tg}^{-1}((0.5 \text{ m/s})/u))$ based on wind speed observations.

agreement in the medians at each site. Considering all the points, there are 7 of the 22 that agree within $\pm 20\%$, and 17 of the 22 that agree within $\pm 50\%$. Even though the correlation of σ_{θ} with $\sigma_{\theta c}$ is relatively low at each site, the correlation is much better when the data from both sites are plotted together. Thus the parameterization of σ_{θ} is acceptable.

It is concluded that eqs. (3) and (4), suggested by Hanna *et al.* [4] and DiCristofaro and Hanna [8] for lateral diffusion during stable, light-wind conditions, produce quite good agreement with independent field data. The data suggest that the observed $\sigma_{\theta c}$ is within $\pm 50\%$ of the predicted value about 70% of the time. Of course, the assumption of a Gaussian distribution breaks down as σ_{θ} increases beyond about 60° , since there is pollutant material at all points of the compass. In this case, Sagendorf and Dickson [5] show that a probability distribution function (p.d.f.) model is desirable, where the p.d.f. of the angular distribution of concentrations is assumed to be equivalent to the p.d.f. of the angular distribution of wind direction observations. However, this method requires more detailed processing of the wind direction data, and does not significantly improve the predictions of maximum concentrations on the arc.

* * *

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REFERENCES

- [1] A. E. MITCHELL and K. O. TIMBRE: *Atmospheric stability class from horizontal wind fluctuation*, in *Proceedings of the LXXII Annual Meeting of the Air Pollution Control Association*, paper 79-29.2 (1979).

- [2] I. VAN DER HOVEN: *Nucl. Saf.*, 17, 223 (1976).
- [3] S. R. HANNA: *J. Clim. Appl. Meteorol.*, 22, 1424 (1983).
- [4] S. R. HANNA, L. L. SCHULMAN, R. J. PAINE, J. E. PLEIM and M. BAER: *J. Air Poll. Control Assoc.*, 35, 1039 (1985).
- [5] J. F. SAGENDORF and C. R. DICKSON: *Diffusion under Low Windspeed, Inversion Conditions*, NOAA Tech. Memo. ERL ARL-52, ARL, Idaho Falls, Idaho (1974).
- [6] R. B. WILSON, G. E. START, C. R. DICKSON and N. R. RICKS: *Diffusion under Low Windspeed Conditions near Oak Ridge, TN*. NOAA Tech. Memo. ERL ARL-61, Idaho Falls, Idaho (1976).
- [7] R. R. DRAXLER: *Diffusion and transport experiments*, Ch. 9 in *Atmospheric Science and Power Production*, DOE/TIC-27601, NTIS, Springfield, VA, 22161, pp. 413-415 (1984).
- [8] D. C. DICRISTOFARO and S. R. HANNA: *Uncertainties in the Offshore and Coastal Dispersion (OCD) model*, in *LXXXII Annual Meeting of Air and Waste Management Association*, Paper 89-150.2 (1989).

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in Low Windspeeds
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Torino, September 5-7, 1989

edited by

D. Anfossi and A. Longhetto

Attachment B

Sullivan County Alternative Model Approval Letter



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
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61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

JUN 01 2015

Mr. Barry R. Stephens
Director
Division of Air Pollution Control
Tennessee Department of Environment and Conservation
William R. Snodgrass Tennessee Tower
312 Rosa L. Parks Avenue, 15 Floor
Nashville, Tennessee 37243

RE: Approval of Alternative Model Request
Modeling of Sulfur Dioxide Emissions from Eastman Chemical Company
Sullivan County, Tennessee, 2010 Sulfur Dioxide National Ambient Air Quality Standards
(NAAQS) Nonattainment Area

Dear Mr. Stephens:

This letter provides our approval of an alternative model for the attainment demonstration required pursuant to Section 172(c) of the Clean Air Act (CAA), for the Nonattainment Area State Implementation Plan (SIP) for the Sullivan County, Tennessee 2010 1-hour sulfur dioxide (SO₂) Nonattainment Area. The attainment demonstration must contain an air quality modeling analysis which demonstrates that the emission limits in the plan will provide for timely attainment of the standard. The U. S. Environmental Protection Agency's guidance memorandum titled: "Guidance for 1-Hour SO₂ Nonattainment Area SIP Submissions," dated April 23, 2014, indicates that the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) is the recommended model for SO₂ attainment demonstration modeling analyses. However, the guidance memo also provides flexibility for consideration for use of alternative models on a case-by-case basis when an adequate demonstration is made that the alternative model performs better than AERMOD for a particular application. An adequate demonstration should meet the criteria provided in Section 3.2.2(d) of the EPA's Guideline on Air Quality Models contained in 40 CFR Part 51, Appendix W.

The Eastman Chemical Company has proposed to use an alternative modeling system, which they have called "EASTMOD," to model the SO₂ emissions from their facility located in the Sullivan County SO₂ Nonattainment Area. Based upon a review of all of the information that has been provided by Eastman since the original proposal in 2014, the EPA is approving portions of the proposed changes to the AERMOD Modeling System that are incorporated into the EASTMOD proposal and not approving other portions of the proposal. We have determined that the following modifications to the regulatory AERMOD modeling system are acceptable for modeling Eastman's SO₂ emissions: use of the beta ADJ_U* option in the meteorological preprocessor, AERMET, and use of the LOWWIND2 beta option in AERMOD (with a 0.4 m/s minimum sigma-v value). We have determined that Eastman's proposal to modify the LOWWIND2 beta option to allow use of split minimum sigma-v values for stable and unstable atmospheric conditions is not acceptable.

The EPA has performed considerable testing of both the beta ADJ_U* option in AERMET and the LOWWIND2 beta option in AERMOD using multiple tracer-studies¹. Since Eastman has shown that the combination of these beta options has improved model performance for their site-specific case, the EPA believes that these alternative model options are appropriate for Tennessee's SO₂ attainment demonstration SIP modeling. As has been stated in previous technical review comments², the EPA continues to have concerns about Eastman's proposal to use split minimum sigma-v values for unstable (0.4 m/s) and stable (0.6 m/s) atmospheric conditions, due in part to the fact that the AERMOD model formulation incorporates a horizontal plume meander component that effectively increases lateral plume spread, especially under low wind stable conditions. As a result of these concerns, the EPA does not believe that the additional information provided by Eastman on March 3, 2015, justifies use of this proposed change to the model.

Based upon the site-specific model performance information provided by Eastman³, it appears that use of the LOWWIND2 beta option with a single minimum sigma-v value of 0.4 m/s significantly improves model performance for the Ross N. Robinson, Meadowview, Skyland Drive and B-267 monitors when compared to the regulatory default version of AERMOD. We are approving a minimum sigma-v value of 0.4 m/s (versus the current default value of 0.3 m/s associated with the beta LOWWIND2 option) for Eastman specific case due to the complex dispersion environment associated with very low wind speeds and nearby complex terrain. These influences are likely to result in significant vertical wind shear that could contribute to increased lateral plume dispersion.

As indicated in our Technical Review Comments dated September 5, 2014, we have determined that the proposed AERLIFT component of EASTMOD is a source characterization procedure and is not an integral part of the AERMOD Modeling System. Therefore, it is not subject to the Appendix W, Section 3.2.2 alternative model evaluation criteria. We have considered the AERLIFT procedure separately from the modifications proposed to be made to the actual AERMOD Modeling System. In order to fully address the modeling procedures being proposed by Eastman, we are also providing our decisions regarding application of the AERLIFT procedure in this letter. Based upon the entirety of information provided by Eastman regarding AERLIFT, the EPA believes that the AERLIFT procedure is acceptable for use in modeling the five closely-spaced stacks at the B-253 powerhouse, but is not acceptable for the two B-83 stacks.

The additional information provided by Eastman in its March 3, 2015, submittal³ clearly indicates that use of AERLIFT for the five closely spaced B-253 stacks improves model performance at the Ross N. Robinson, Skyland Drive and Meadowview monitor locations and shows a small improvement for the B-267 monitor location when compared to the no-AERLIFT cases. The studies in the references cited by both the EPA and Eastman in previous correspondence provide supporting information for use of AERLIFT for the five closely-spaced (approx. 15 meters apart) B-253 stacks. Conversely, the use of AERLIFT for the two B-83 stacks that are relatively far apart (approx. 50 meter or 11 stack diameters apart) results in very little change to the model performance at the Ross N. Robinson, Skyland Drive, Meadowview and B-267 monitor locations when compared to the no-AERLIFT cases. As has been pointed out in previous EPA comments², the literature appears to be consistent regarding the lack of any

¹ EPA Webinar dated August 12, 2014

(http://www.epa.gov/ttn/scram/webinar/AERMOD_13350_Update/AERMOD_System_Update_Webinar_01-14-2014_FINAL.pdf)

² Email from Rick Gillam (EPA) to Haidar Al-Rawli (TDEC) on November 16, 2015, email from Rick Gillam (EPA) to Stephen Gossett (Eastman) dated February 4, 2015, and email from Scott Davis (EPA) to Barry Stephens (TDEC) on April 13, 2015.

³ Eastman's Responses to Comments dated October 8, 2014, January 20, 2015, and March 3, 2015.

plume rise enhancement for two stacks spaced far apart like the B-83 stacks. The lack of performance improvement with AERLIFT for the B-83 stacks is consistent with the studies which question plume rise enhancement for two far apart stacks. Therefore, the EPA does not believe it is appropriate to approve the use of AERLIFT for the B-83 stacks. The EPA also notes that the additional information provided by Eastman indicates that the importance of the AERLIFT procedure will be greatly reduced for the future attainment year modeling case, in which the B-253 SO₂ emissions will be mostly eliminated by the fuel switch from coal to natural gas for the B-253 boilers.

In summary, we approve the following modifications to the EPA's regulatory AERMOD modeling system (version 14134) for modeling of SO₂ emissions from the Eastman facility for this site-specific SO₂ attainment demonstration modeling application: use of the beta ADJ_U* option in the meteorological preprocessor, AERMET, and use of the LOWWIND2 beta option in AERMOD (with a 0.4 m/s minimum sigma-v value). This approval is being made pursuant to Section 3.2.2(d) of 40 CFR Part 51, Appendix W, and is only applicable for this specific modeling application. Use of these modifications for other applications of the EPA's regulatory AERMOD modeling system are subject to review and approval on a case-by-case basis. Also, please note that our approval of the use of these alternative model options does not represent any determination or disposition on the actual attainment demonstration modeling that will be used for the Sullivan County SO₂ Nonattainment Area SIP nor does it make any final approvability determinations concerning other components of the attainment demonstration SIP submission. If you have any questions regarding the contents of this letter, please contact Rick Gillam at (404) 562-9049.

Sincerely,



Beverly H. Banister

Director

Air, Pesticides and Toxics Management Division

Attachment C

TRC 1993 Model Performance Study for Laurel Ridge

***Revised Final Report on the
Model Performance Comparison Study
for Laurel Ridge and Chestnut Ridge***

TRC

TRC Environmental Corporation

REVISED FINAL REPORT ON THE
MODEL PERFORMANCE COMPARISON STUDY
FOR LAUREL RIDGE AND CHESTNUT RIDGE

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EXECUTIVE SUMMARY

A model performance comparison study was conducted to determine the most appropriate dispersion modeling approach for estimating air quality impacts on elevated terrain in the region northwest of Johnstown, PA. This report describes the study, which was designed based on the U.S. Environmental Protection Agency's (EPA) "Interim Procedures for Evaluating Air Quality Models (Revised)", (EPA, 1984) and was conducted in accordance with the "Protocol for Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge", (TRC, 1991).

The modeling protocol was formally approved by the Pennsylvania Department of Environmental Resources (PaDER) and EPA on January 20, 1992. The protocol presented the study design, including the monitoring network; established the basis for judging model performance; and described the intended application of the winning model to estimate air quality impacts and to assess the adequacy of emission limits for specific sources. Relevant portions of the modeling protocol are summarized in this report.

The original version of this report was dated July 10, 1992. However, in late August, a number of minor discrepancies were identified in the stack parameter data (i.e., stack i.d., exit velocity, etc.) for certain Penelec power plants in the Laurel/Chestnut Ridge area. As a result, TRC has repeated the model performance comparison study based on the updated stack parameter data. This revised report describes the model performance comparison results obtained using the updated stack parameter data. All other aspects of the study remain unchanged from those described in the July 10, 1992 version of this report.

The study described in this report involved performance comparisons between the Large Area Power Plant Effluent Study (LAPPES) model and the Rough

Terrain Diffusion Model (RTDM). The study results show that LAPPES is the superior model for determining the air quality impacts of the power plants operated by Penelec in the Laurel Ridge and Chestnut Ridge area. LAPPES outperformed RTDM under all conditions and met the scoring criteria specified in the modeling protocol. Complete details on the model performance comparison procedures and results are provided in this report.

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1.0 INTRODUCTION

The Pennsylvania Electric Company (Penelec) operates four major coal-fired generating facilities in the Laurel Ridge/Chestnut Ridge area of southwestern Pennsylvania. Seward Station, Conemaugh Station, Homer City Station, and Keystone Station are all located within a distance of 25 miles of one another. The air quality impacts of these facilities can overlap, leading to regulatory concerns regarding the attainment and maintenance of National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO₂) in the region. Air quality impacts at high terrain locations are a particular concern.

New allowable SO₂ emission limits must be determined for the Penelec-operated facilities in the Laurel/Chestnut Ridge area because of the 1985 stack height regulations (which affect both the Seward and Homer City Unit 3 stacks) and the 1990 Clean Air Act Amendments (which affect Conemaugh Station). These new SO₂ emission limits must be established by dispersion modeling analyses.

Applicable EPA guidance requires the use of two models to determine air quality impacts in terrain that is defined as "intermediate complex terrain" (i.e., terrain between the stack top and plume height elevations). The applicable guideline models for the Laurel/Chestnut Ridge area are MPTER (EPA, 1980), for terrain elevations below plume height, and RTDM (ERT, 1987), for terrain elevations above stack top. For receptors with elevations between stack top and plume height, EPA requires comparing MPTER and RTDM predictions hour-by-hour and selecting the higher value.

The Large Area Power Plant Effluent Study was carried out in the Laurel Ridge/Chestnut Ridge area between 1967 and 1972. The LAPPES model was originally developed by Penelec for application to this region (Slowik, A.A., J.M. Austin, G.N. Pica, 1977). Penelec would prefer to use the LAPPES dispersion model for terrain above stack top throughout the study region.

Previous studies for other locations have shown that RTDM overpredicted at elevated terrain locations by a factor of two or more, when the EPA-specified model options were used. By contrast, LAPPES has not shown substantial prediction bias in comparisons with observed air quality.

The model performance comparison study was required to obtain PaDER and EPA approval for the use of LAPPES instead of RTDM/MPTEP to establish emission limits for the Penelec power plants in the Laurel/Chestnut Ridge area. The criteria for approval to use LAPPES included minimum scoring requirements and a demonstration that LAPPES performs better than RTDM/MPTEP, based on comparisons to measured air quality.

As described in the EPA Interim Procedures document and TRC's February 1991 modeling protocol, the required approach for the model comparison study began with the design of the monitoring network, using modeled predictions of the air quality impacts across the region. Initial dispersion modeling for the monitoring network design was performed in 1987, and changes to the then existing monitoring network were proposed. A modeling report and proposed network design were provided to PaDER and EPA Region III for review (TRC, 1987). After several iterations and additional modeling analyses in response to regulatory agency review comments, the final network design was approved in 1990 (letter from J. Slade, PaDER to V. Brisini, Penelec, dated May 4, 1990).

The February 1991 protocol (as approved by PaDER and EPA on January 20, 1992) for evaluating model performance defined 1) procedures to run the models to obtain predictions comparable to measured air quality concentrations; 2) the statistical measures to be used as performance indicators; 3) the calculations to determine each model's performance score; and 4) the criteria for determining the winning model. The protocol also discussed the intended use of the winning model including the choice of model inputs, the sources to be modeled, the derivation and use of representative background air quality

concentrations, appropriate receptor arrays, and any required adjustments for underpredictions by the LAPPES model.

This revised report is based on updated stack parameter data provided to TRC by Penelec on September 9, 1992. The report revisions pertain only to the new stack parameter data and the corresponding model performance comparison results. All other aspects of the study remained unchanged from those described in the original July 10, 1992 report.

The results of the model comparison, for both the original and revised stack parameter data, can be summarized as follows:

- LAPPES, by all measures, is the model which best simulates the air quality impacts at elevated terrain from Penelec-owned and operated sources in the Laurel/Chestnut Ridge region.
- LAPPES outperformed RTDM under all conditions in the study and met the scoring criteria specified in the modeling protocol to be selected as the winning model.
- The LAPPES model showed no bias toward underprediction of the measured SO₂ concentrations for the 3-hour and 24-hour averaging periods.
- RTDM did not estimate air quality impacts accurately in elevated terrain for the physical circumstances modeled in this study, and scored poorly in the model performance evaluation.

Section 2 of this report addresses background issues and the project history. The database used for the model comparison study is described in Section 3. The statistical measures used to evaluate model performance are explained in Section 4. The revised model performance comparison results are contained in Section 5, while the study conclusions and references are provided in Sections 6 and 7, respectively.

2.0 STUDY DESIGN

This section provides the foundation for the design of the model performance evaluation study. It includes a discussion of the regulatory setting, a description of the source and source environment, a technical description of the reference and proposed models, a summary of the preliminary modeling performed to design the monitoring network, and a discussion of other technical issues pertaining to the intended use of the winning model.

2.1 Regulatory Setting

The primary regulatory issue pertaining to this study concerns the impact of SO₂ emissions from Penelec-operated sources on air quality at elevated terrain locations north and west of Johnstown, Pennsylvania. The dispersion models RTDM and MPTER predict frequent violations of the short-term NAAQS for SO₂ at current allowable emissions rates. For over 11 years, Penelec has operated an extensive network of ambient SO₂ monitors, which measure peak concentrations substantially lower than those predicted by RTDM and MPTER on high terrain.

The regulatory status of the study region is further complicated by the fact that stacks at two Penelec-operated facilities are subject to Good Engineering Practice (GEP) stack height limitations, and both have actual stack heights in excess of "GEP formula" height (see Section 2.2). Beginning in 1995, at least one Penelec-operated facility (Conemaugh) will also be subject to Phase I of the Acid Rain provisions of the 1990 Clean Air Act, which impose restrictions on annual SO₂ emissions.

2.2 Sources and Source Environment

The Penelec-operated sources and regional terrain are illustrated in Figure 2-1. Dispersion modeling has consistently indicated that peak

short-term SO₂ concentrations are expected on the elevated terrain portions of Laurel Ridge and Chestnut Ridge, which are oriented north-northeast to south-southwest. The Conemaugh and Seward Generating Stations are located between the ridges, while Homer City and Keystone are located northwest of both ridges.

The Pennsylvania State Implementation Plan (SIP) SO₂ emission limitations expressed as pounds per million British thermal units (lbs/MMBtu) for major fossil fuel-fired boilers follow:

<u>Averaging Period</u>	<u>Allowable lbs SO₂ per MMBtu Heat Input</u>
Thirty-day running average not to be exceeded at any time	3.7
Daily average not to be exceeded more than 2 days in any running 30-day period	4.0
Daily average maximum not to be exceeded at any time	4.8

Source characteristics and maximum allowable emission rates are summarized in Tables 2-1 and 2-2.

Stack heights for these sources range from 182.9 m (600 feet) for Seward to 370.6 m (1,216 feet) for Homer City Unit 3. Most of the stacks were constructed prior to 1970 and are not subject to GEP stack height limitations. The exceptions are Homer City Unit 3 and Seward. For Homer City Unit 3, the GEP stack height was determined to be 260 m (853 feet), based on the results of a fluid modeling study to assess downwash due to cooling towers. The Seward stack was built after 1970 and exceeds GEP formula height based on building dimensions. A fluid modeling study for Seward determined that the existing 182.9 m (600 feet) stack height is required to avoid excessive concentrations due to terrain-induced downwash effects.

TABLE 2-1

FIXED STACK PARAMETERS COMPILED FOR THE
LAUREL/CHESTNUT RIDGE DISPERSION MODELING ANALYSIS

Source	UTM Coordinates (KM)		Stack Height	Stack Diameter	Stack Base Elevation (ft)
	East	North			
Conemaugh Unit 1	664.58	4472.00	304.8 m (1,000 ft)	8.3 m (27.2 ft)	1,088.5*
Conemaugh Unit 2	664.58	4472.00	304.8 m (1,000 ft)	8.3 m (27.2 ft)	1,088.5*
Homer City Unit 1	652.77	4486.11	243.8 m* (800 ft)	7.3 m (24.0 ft)	1,200
Homer City Unit 2	652.77	4486.11	243.8 m* (800 ft)	7.3 m (24.0 ft)	1,200
Homer City Unit 3	652.77	4486.11	370.6 m* (1,216 ft)	6.9 m (22.6 ft)	1,200
Keystone Unit 1	640.18	4502.15	243.8 m (800 ft)	8.3 m* (27.2 ft)	1,012*
Keystone Unit 2	640.18	4502.15	243.8 m (800 ft)	8.3 m* (27.2 ft)	1,012*
Seward Units 4 and 5	666.81	4474.68	182.9 m (600 ft)	5.3 m (17.4 ft)	1,085*

* Revised data provided by Penelec on 9/9/92.

TABLE 2-2

MAXIMUM CAPACITY (100%) EMISSION RATES AND
STACK PARAMETERS COMPILED FOR THE LAUREL/CHESTNUT RIDGE DISPERSION
MODELING ANALYSIS

Source	SO ₂ Emission Factor Limit (lb/MMBtu)	Generator Capacity* (MW)	Heat Input* (MMBtu/MWh)	SO ₂ Emission Rate*	Exit Velocity*	Exit Temperature*
Conemaugh Unit 1	4.8	893	8.82	4763.5 g/s (37,806 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Conemaugh Unit 2	4.8	893	8.82	4763.5 g/s (37,806 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Homer City Unit 1	4.8	662	9.02	3611.3 g/s (28,662 lb/hr)	30.0 m/s (98.4 ft/s)	440°K (333°F)
Homer City Unit 2	4.8	650	9.01	3541.9 g/s (28,111 lb/hr)	30.0 m/s (98.4 ft/s)	440°K (333°F)
Homer City Unit 3	1.2	682	9.20	948.7 g/s (7,529 lb/hr)	30.7 m/s (100.7 ft/s)	440°K (333°F)
Keystone Unit 1	4.8	893	8.97	4844.5 g/s (38,449 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Keystone Unit 2	4.8	893	8.97	4844.5 g/s (38,449 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Seward Units 4 and 5	4.8	214	10.36	1340.8 g/s (10,642 lb/hr)	23.3 m/s (76.4 ft/s)	418°K (293°F)

* Revised data provided by Penelec on 9/9/92.

2.3 Description of Models

The alternative model used in the model comparison study was LAPPES. EPA has designated as the reference model a combination of RTDM and MPTER. For each source, MPTER was used for all receptors below stack top. Above stack top, either RTDM or MPTER applied, depending upon which model predicts higher concentrations. These models are described below.

2.3.1 LAPPES (Proposed Model)

The LAPPES model is named for the Large Area Power Plant Effluent Study carried out in western Pennsylvania between 1967 and 1972. LAPPES is a non-guideline model that was developed for use in complex terrain areas. The LAPPES model was originally tested in the Chestnut Ridge area of Pennsylvania, where it was demonstrated to outperform EPA's Complex I model. LAPPES has subsequently been used in other ridge and valley terrain settings. The version of LAPPES proposed for this study is a modified version of the Complex II computer code.

Distinguishing features of the LAPPES model include:

- Empirical dispersion coefficients based on Pasquill and Gifford.
- For unstable conditions, Class A stability shifted to Class B.
- Enhanced horizontal plume spread under stable conditions to account for plume meander.
- Plume rise calculated as a function of downwind distance using Briggs plume rise equations.
- Enhanced initial plume growth due to buoyancy-induced dispersion.
- Plume height adjusted as a function of stability class and underlying terrain height.

Perhaps the most important feature is the algorithm to adjust the effective plume height in response to terrain higher than stack height. The

plume height is gradually reduced to a certain minimum height as it passes over elevated terrain. The minimum height is one-half the unadjusted plume height for non-stable conditions and 35 percent of the unadjusted plume height for stable conditions. This allows the simulated plume to respond to the flow effects caused by the terrain.

Dispersion Coefficients - The LAPPES model employs the standard Gaussian plume formulation with full ground reflection. Vertical dispersion coefficients are unmodified Pasquill-Gifford (P-G) coefficients as calculated by MPTER. Horizontal coefficients are also unmodified P-G values for unstable and neutral conditions. For stable conditions, σ_y is enhanced by:

$$\sigma_y = \sigma_y (P-G) / (0.4 * u_E^{.3})$$

where:

$$\sigma_y (P-G) = \text{Pasquill-Gifford } \sigma_y$$

$$u_E = u - 0.5$$

u = wind speed at stack top (m/s)

If u < 1 m/s, $u_E = .5$ m/s

If u > 9 m/s, $u_E = 8.5$ m/s

This σ_y enhancement for plume meander represents an empirical adjustment of P-G values, based on plume behavior observed during the LAPPES experiments. Under stable conditions, the P-G σ_y values are increased by a factor ranging from 1.32 to 3.08, depending upon the wind speed.

Stability Class A was not considered appropriate for tall stack sources by the developers of LAPPES (A.A. Slowik, J.M. Austin, G.N. Pica, 1977), based on empirical observations of plume behavior. Hours with stability Class A input are therefore modeled by LAPPES using P-G dispersion curves for Class B stability.

Plume Rise - Plume rise is calculated using the BEH072 subroutine from models in the EPA Users Network for Applied Modeling of Air Pollutants (UNAMAP), modified to include a factor of 2.6 (instead of 2.4) under stable conditions.

Plume Height Adjustment - Under unstable and neutral conditions, LAPPES employs a plume height adjustment factor of 0.5, as Complex I and RTDM do. With this adjustment, the effective plume height, H_E , between plume centerline and ground level is given by:

$$H_E = h + \Delta H - 0.5z, \quad z \leq h + \Delta H$$

$$H_E = 0.5 (h + \Delta H), \quad z > h + \Delta H$$

where:

z = terrain elevation above stack base

h = stack height

ΔH = plume rise

For stable conditions, the effective plume height is given by:

$$H_E = h + \Delta H - z, \quad z \leq (h + \Delta H)/1.7$$

$$h + \Delta H - 0.65z, \quad \frac{(h + \Delta H)}{1.7} < z \leq (h + \Delta H)$$

$$0.35 (h + \Delta H), \quad z > h + \Delta H$$

For low terrain elevations, this treatment corresponds to full terrain subtraction. As the terrain elevation increases, the effective plume height reaches the minimum approach distance and then remains constant.

2.3.2 RTDM (Reference Model)

The RTDM formulation is fully described in the document User's Guide to the Rough Terrain Diffusion Model (RTDM) Rev. 3.2 (ERT, July 1987).

RTDM version 3.2 is a sequential version of the ERT Rough Terrain Diffusion Model, and is based upon the case-study model, RTDM.WC, submitted to EPA in August 1980. The model can be used in flat or complex terrain, but it has features specifically designed for simulating plume dispersion in complex terrain.

The "default" version of RTDM is recommended by EPA as a third-level screening model for complex terrain applications using on-site meteorological data. Specific default features employed by RTDM in estimating ground-level concentrations are listed below:

- Reflection of plume mass from the ground is limited by the second law of thermodynamics, so that the maximum concentrations cannot increase with distance downwind. (This feature is termed "partial ground reflection.")
- In stable conditions, a critical height (H_{crit}) is computed from the wind speed, the terrain height and the strength of the inversion. Plumes below this height are allowed to impinge on the terrain.
- The effects of buoyant entrainment can be accounted for in calculating plume size.
- Transitional plume rise may be employed in model computations until the downwind distance to equilibrium plume height is reached by the plume.
- During neutral and unstable conditions or above H_{crit} in stable conditions, a "half-height" correction simulates the effect of terrain-induced plume modifications on ground-level concentrations.
- Decrease in plume rise due to stack-tip downwash can be accounted for.
- Uniform crosswind concentration distribution over a 22.5 degree sector is assumed.
- Different wind speeds are used for calculating plume rise and dilution. For plume rise, the wind speed at stack top is used. Plume dilution is estimated using the wind speed at plume height.
- Vertical dispersion is based on ASME dispersion coefficients.

When the "partial ground reflection" option is employed in RTDM, the concentration at a receptor point depends upon the travel path of the plume (the upwind concentrations) as well as the location of the receptor itself. This is a feature found in few Gaussian models, and it requires the RTDM user to supply detailed terrain information in each of 36 directions (at 10° intervals). The required terrain data consist of downwind distances to successive contour heights (at constant height intervals) starting below stack top elevation and ending at the highest point along each direction within the study region.

2.3.3 MPTER (Reference Model)

The MPTER model is intended for multi-source applications in rural areas with flat or moderate terrain (up to stack height). MPTER is a standard Gaussian model and employs the Pasquill-Gifford dispersion coefficients for both horizontal and vertical dispersion. In the regulatory mode, MPTER includes the following features:

- Final plume rise (distance-independent) based on Brigg's equations.
- Enhanced initial plume growth due to buoyancy-induced dispersion.
- Stack-tip downwash.
- Full terrain subtraction for all stabilities. No terrain above stack top.

For complex terrain applications, MPTER is recommended by EPA only for terrain below stack top. For receptors with actual elevation above stack top, an elevation equal to stack top is used with MPTER.

2.4 Monitoring Network Design

The design of a site-specific model evaluation requires a preliminary analysis of the sources and the dispersive setting of the sources in order to site monitors which will adequately characterize the situation and provide representative source-receptor relationships. Since the regulatory models are generally concerned with predicting maximum impacts, monitor placement should attempt to reflect areas of expected concentration maxima. To anticipate areas of maximum concentrations in order to correctly place monitors, TRC conducted preliminary modeling for Penelec utilizing RTDM/MPTER and LAPPES in 1987.

In 1987, Penelec's Laurel/Chestnut Ridge monitoring network contained 15 SO₂ sampling sites and the preliminary modeling was performed using meteorological measurements collected from April 15, 1981 through April 14, 1982 at a 70-foot meteorological tower located at Penn View (see Figure 2-1). Additional details on the preliminary modeling, including the modeling approach, sources, receptors, meteorological data, and results, are provided in TRC's February 1991 modeling protocol.

The preliminary modeling in 1987 produced the following information about the models and the predicted concentration fields near the Penelec sources:

- Peak concentration predictions by RTDM/MPTER at the existing Laurel Ridge monitors were higher than peak predictions by LAPPES by a factor of 2 to 3.
- Predictions by LAPPES at the existing monitoring locations were generally representative of the highest predictions at any receptors.
- Peak predictions by RTDM/MPTER for Laurel Ridge occurred at receptors northwest of the existing monitors, at lower terrain elevations and closer to Conemaugh and Seward Stations. A new monitoring site, Powdermill Run, was added to represent these locations (see Figure 2-1).

- The nonattainment region on Laurel Ridge predicted by RTDM/MPTER extended northeast beyond the Rager Mountain monitor and southwest at least 10 km beyond Baldwin Creek.
- A second nonattainment region was predicted by RTDM/MPTER on Chestnut Ridge, south of the Conemaugh River. A new monitoring site, Bear Cave, was added to represent this region (see Figure 2-1).

The following changes were also made to Penelec's Laurel/Chestnut Ridge monitoring network as a result of the 1987 monitoring network design study:

- The 70-foot meteorological tower at Penn View was replaced by two new meteorological towers located at Ash Valley and Manor (see Figure 2-1).
- The existing Laurel Ridge SO₂ monitor was replaced by the Sugar Run SO₂ monitor when it was discovered that the data recorded at the Laurel Ridge site were subject to interference from a nearby radio transmission tower.
- Seven non-essential SO₂ monitors were decommissioned (Creekside, Parkwood, Brush Valley, Ramsey Run, Armagh, Gas Center, West Fairfield), since data collected at these sites were not needed for the model performance evaluation study.

The SO₂ monitoring sites selected in the 1987 preliminary analysis have now been modeled as discrete receptors using Ash Valley and Manor meteorological data to obtain paired predicted and observed SO₂ concentration data for this model performance comparison study.

2.5 Intended Model Application

Following completion of the 1987 preliminary analysis, three important technical issues were raised by EPA Region III regarding the study design and the intended application of the winning model. The first issue (see Section 1.0), concerned the requirement to compare and merge hourly prediction files by source and receptor for the RTDM/MPTER "reference model" combination. This procedure, wherein maximum hourly concentrations are selected, was used for the RTDM/MPTER portion of the model performance comparison.

Second, the model comparison study objectives were clarified, to indicate that LAPPES would be tested against RTDM/MPTER for elevated terrain locations, and that the study results would only apply for elevated terrain. Therefore, in the future when modeling is performed to determine emission limits, LAPPES (the best performing model) will be used to predict impacts only for receptors above stack top elevation. (Penelec could have undertaken an additional model comparison effort to test LAPPES versus MPTER on lower terrain, but elected not to pursue this option.)

The third issue concerned the applicability of the study results to Seward Generating Station, with its shorter stack. Results from the preliminary analysis indicated that peak short-term impacts from Seward are predicted by RTDM/MPTER at receptors with terrain elevations on Laurel Ridge substantially lower than the locations of maximum combined impacts. (Combined impacts were dominated by predictions for Conemaugh Generating Station.) Specifically, peak short-term impacts from Seward alone were predicted on Laurel Ridge at elevations between 2,000 and 2,250 feet, while peak combined impacts were generally predicted at elevations of 2,500 feet and above. At these higher elevations, the impacts of Seward predicted by RTDM/MPTER were roughly half of the peak values predicted at lower elevations.

From a regulatory perspective, monitoring stations representative of peak predictions by RTDM/MPTER for Seward would be needed in order to demonstrate that LAPPES performs better than RTDM for Seward Station. Candidate monitor locations were judged to be inaccessible, particularly during winter, and are remote from any existing source of electric power. Penelec, after investigating the feasibility and costs associated with installing and operating monitors in such locations, elected not to pursue this supplementary monitoring as part of the present study. Therefore, when modeling is performed to determine future emission limits, RTDM/MPTER will be used to estimate the Seward Station's impacts.

3.0 DATABASE FOR MODEL PERFORMANCE COMPARISON

The preliminary analysis served to identify locations where peak concentrations were predicted by each model. The study design analysis also identified the need for on-site meteorological measurements consistent with current regulatory guidance. The procedures used and decisions made in selecting the monitoring sites are discussed in the February 1991 modeling protocol. The locations of the ten SO₂ monitors and two meteorological towers used for this model comparison study are shown in Figure 2-1. Figure 3-1 provides greater detail of the region surrounding the five Laurel Ridge SO₂ monitoring sites. Site elevations and coordinates for the meteorological towers are provided in Table 3-1, and for the SO₂ monitoring stations in Table 3-2.

The meteorological measurements are described below in Section 3.1, which also explains how model inputs were determined from available measurements. The SO₂ monitoring network is discussed in Section 3.2. A previous reassessment of the adequacy of the network coverage of peak concentration predictions is summarized in Section 3.3. This network coverage analysis, performed for the February 1991 modeling protocol, reflected updated modeling based on one year of meteorological data from the Ash Valley and Manor meteorological towers. Estimation of background concentrations is discussed in Section 3.4. Emission estimates are described in Section 3.5.

3.1 Meteorological Measurements

Two meteorological towers were used to gather on-site measurements to support dispersion modeling (see Figure 2-1). The Ash Valley (AV) meteorological tower is located approximately 3 km northwest of Conemaugh Station, at a base elevation of 1,401 feet. This site was chosen to obtain meteorological measurements representative of transport and dispersion

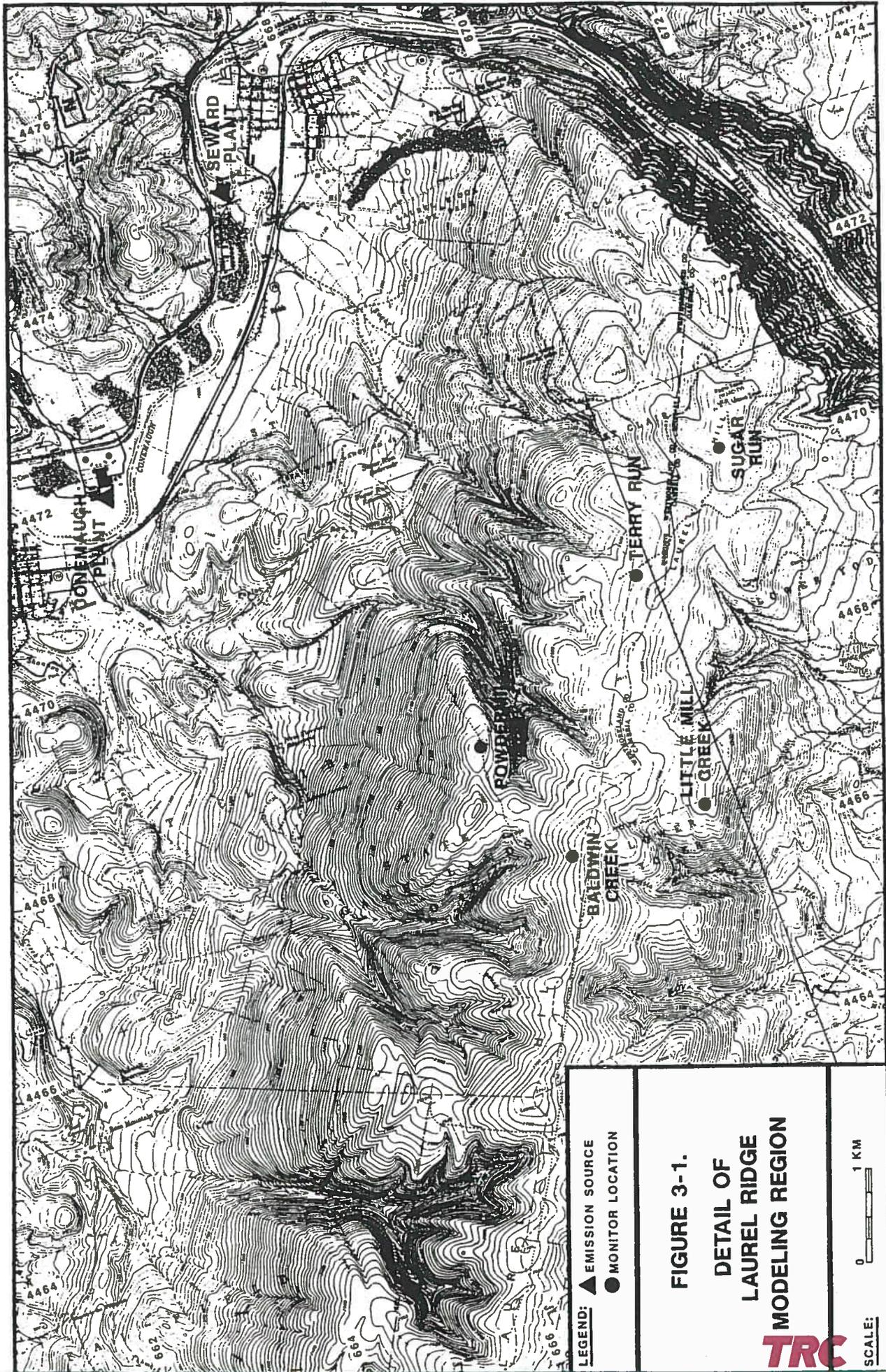


TABLE 3-1

METEOROLOGICAL MONITORING SITES FOR
LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

Location Description	MSL (ft.)	Above Grade (ft.)	Parameters* Monitored
(a) Ash Valley 150 Meter Tower			
Tower UTM - N = 4472558.36			
- E = 661721.53			
Tower Base Plate	1401	-	-
Lower Sensor Level	1434	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1565	164 (50 m)	WD, WS
Upper Sensor Level	1695	292 (89 m)	WD, WS
Top Sensor Level	1893	492 (150 m)	WD, WS
(b) Manor 100 Meter Tower			
Tower UTM - N = 4492005.66			
- E = 660560.42			
Tower Base Plate	1730	-	-
Lower Sensor Level	1763	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1894	164 (50 m)	WD, WS
Upper Sensor Level	2058	328 (100 m)	WD, WS

* Parameter Identifiers

WD = wind direction

WDST = standard deviation of wind direction (sigma theta)

WS = wind speed

AT = ambient temperature

TABLE 3-2

LOCATIONS OF SO₂ MONITORS FOR
LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

Site Name	UTM (E) (km)	UTM (N) (km)	Elevation (feet)
Marshall Heights	655.755	4479.660	1,880
Penn View	655.970	4477.320	2,030
Rager Mountain	677.490	4477.860	2,480
Bear Cave	650.660	4467.530	2,623
Sugar Run	670.900	4469.900	2,660
Terrys Run	669.910	4469.390	2,580
Little Mill Creek	669.650	4466.700	2,640
Baldwin Creek	668.050	4466.680	2,720
Powdermill Run	667.420	4467.980	2,584
Luciusboro	660.500	4484.760	1,660

conditions for Conemaugh and Seward Stations. Measurements at the 10 m level are intended for determining atmospheric stability class. The "upper" sensor level at 89 m above tower base provides wind speed measurements at Seward stack top elevation. The "top" sensor level at 150 m provides wind direction measurements for estimating plume transport for both Seward and Conemaugh, plus wind speed measurements representative of Conemaugh stack top. The Conemaugh stack top elevation is almost 200 feet higher than tower top. The models adjust the measured wind speeds to account for this difference.

The Manor meteorological tower is located approximately 9 km northeast of Homer City Station, with a base elevation of 1,730 feet. The 10 m sensor level again provides measurements to determine atmospheric stability class. The upper (100 m) sensor level was used for stack top wind speed measurements for both the Homer City and Keystone Stations. Wind directions from this level were used to predict plume transport for Homer City and Keystone.

Meteorological input files were created using measurements from the two on-site meteorological towers at Ash Valley and Manor for the one year study period, from August 1, 1990 through July 31, 1991. Source-specific meteorological files were defined to provide wind speed, wind direction and atmospheric stability values most appropriate for each station, as summarized in Table 3-3.

Table 3-3 also indicates both the substitution hierarchy used to replace missing data and the number of hours used from each monitoring location for each parameter. The table shows the substitution hierarchy in descending order; the top listed monitoring location was the primary data source for each input variable. In cases where only one or two hours were missing, interpolated values were used.

For all of the meteorological parameters (except the Seward Station stack top wind speed), Table 3-3 shows that the primary data source was used for

TABLE 3-3

METEOROLOGICAL DATA SOURCES, SUBSTITUTION HIERARCHY FOR MISSING DATA, AND HOURS OF DATA USED FOR MODELING

	<u>Homer City and Keystone</u>		<u>Conemaugh</u>		<u>Seward</u>	
	Parameter	Number of Hours Used	Parameter	Number of Hours Used	Parameter	Number of Hours Used
Wind Direction	M-100	8,446	AV-top	8,643	AV-top	8,643
	M-50	208	AV-upper	95	AV-upper	95
	AV-top	106	M-100	22	M-100	22
	AV-upper	0	M-50	0	M-50	0
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0
Stack Top Wind Speed	M-100	8,371	AV-top	8,197	AV-upper	7,176
	M-50	282	AV-upper	541	AV-mid	1,562
	AV-top	107	M-100	22	M-100	22
	AV-upper	0	M-50	0	M-50	0
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0
Plume Height Wind Speed	M-100	8,371	AV-top	8,197	AV-top	8,197
	M-50	282	AV-upper	541	AV-upper	541
	AV-top	107	M-100	22	M-100	22
	AV-upper	0	M-50	0	M-50	0
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0
Atmospheric Stability	M-10	8,559	AV-10	8,418	AV-10	8,418
	AV-10	201	M-10	342	M-10	342
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0

AV = Ash Valley
M = Manor
Pitt NWS = Pittsburg National Weather Service

AV-top = 150 m
AV-upper = 89 m
AV-mid = 50 m

more than 90 percent of the hours in the year, and when data were missing from the primary source, substitution below the secondary level was seldom necessary. Although available, National Weather Service (NWS) data from Greater Pittsburgh Airport were never used.

For stability class, the EPA recommended scheme based on 10 m wind speed, sigma theta and solar angle was used as the primary approach. Sigma theta cutoff values for Manor were adjusted for surface roughness. Based on an analysis of 1989-90 meteorological measurements, a surface roughness length of 2.3 cm was used. No such adjustment was required at Ash Valley. Figures 3-2 and 3-3 provide frequency distributions for the atmospheric stability class values determined for the Ash Valley and Manor monitoring locations, respectively.

3.2 Ambient Sulfur Dioxide Measurements

The SO₂ monitoring network includes ten stations, with six on Laurel Ridge and three on Chestnut Ridge (see Figure 2-1). Luciusboro and two of the Chestnut Ridge Stations, Penn View and Marshall Heights, have relatively low terrain elevations. Neither RTDM/MPTER nor LAPPES has predicted any NAAQS exceedances at these three monitors, nor have any been observed in over eleven years of operation. Their primary function for the model comparison study is to supplement the network for estimating background concentrations.

The new Powdermill Run monitor is the site located closest to Conemaugh Station. Powdermill Run is roughly 1 km west of the ridge top and about 200 feet below the peak elevation. Powdermill Run was sited to represent the primary "hot spot" location predicted by RTDM/MPTER on Laurel Ridge in the 1987 preliminary analysis. Sugar Run, Baldwin Creek, Little Mill Creek and Terrys Run are also located within the portion of Laurel Ridge where both RTDM/MPTER and LAPPES predict the highest short-term average SO₂

Figure 3-2

Stability Class Frequencies for the
Ash Valley Meteorological Data Set

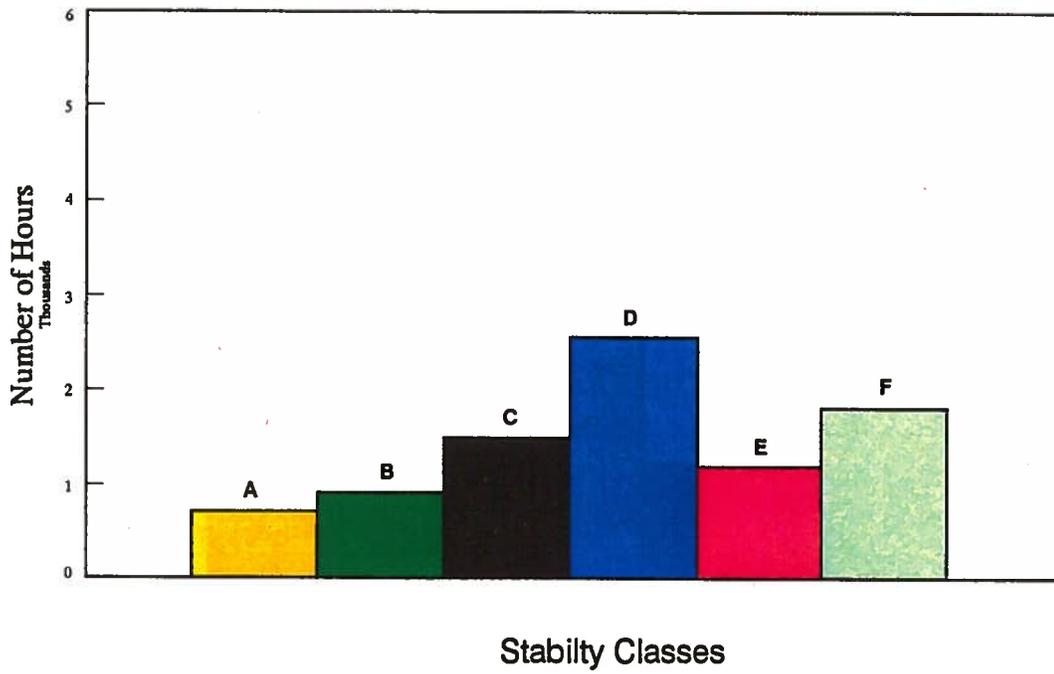
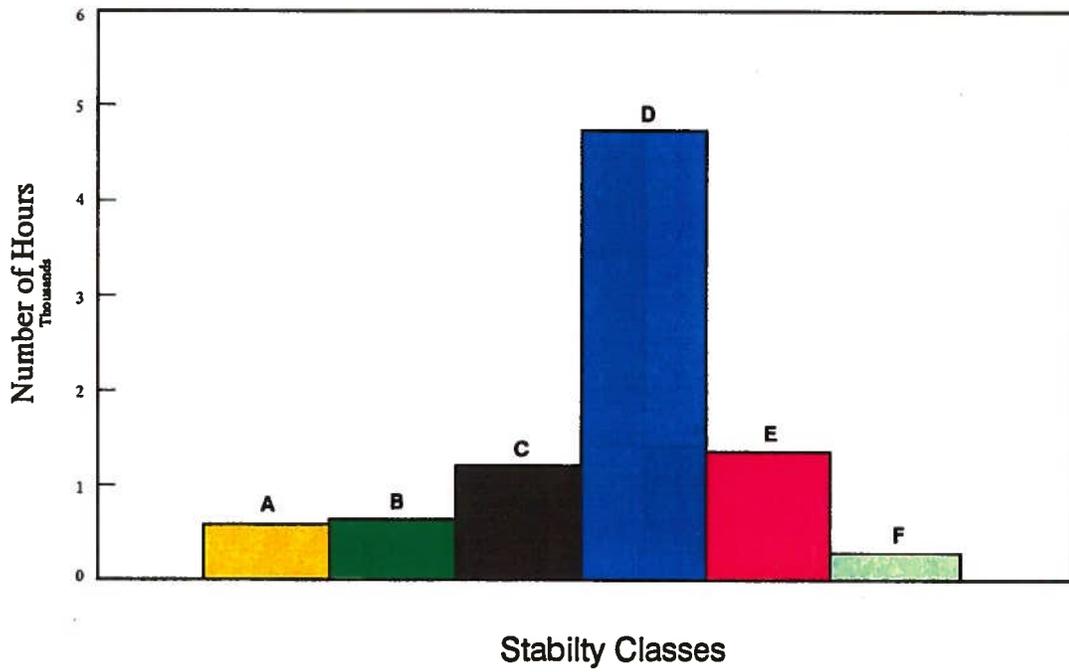


Figure 3-3

Stability Class Frequencies for the
Manor Meteorological Data Set



concentrations. The Bear Cave and Rager Mountain monitors are located in other areas where RTDM/MPTEP predicted nonattainment; they serve to ensure that the study results are applicable to the larger geographic region where Penelec wishes to use LAPPES in place of RTDM/MPTEP.

3.3 Assessment of Network Coverage

The ability of the monitoring network to provide measurements representative of peak predicted concentrations for the study region was thoroughly reevaluated in the February 1991 modeling protocol. The adequacy of the monitoring network was confirmed for various combined applications of the RTDM, MPTEP and LAPPES models for all the Penelec-operated SO₂ emission sources. This validation of the monitoring network was performed using September 1988 through August 1989 meteorological data recorded at the Ash Valley and Manor Towers. Peak 3-hour and 24-hour concentrations predicted for an array of 399 receptors were compared to the peak average concentrations predicted at the seven highest-terrain SO₂ monitoring locations (i.e., not including Luciusboro, Penn View and Marshall Heights). The procedure employed was to identify the maximum predicted concentration and receptor location for episodes with peak predicted impacts, and then to identify predictions at monitor locations for the same episodes among the listed high-five predictions.

A summary of the results of the February 1991 modeling analyses performed to reassess the coverage of the SO₂ monitoring network follows:

- The monitoring network provides excellent coverage for the use of RTDM/MPTEP and LAPPES/MPTEP for both the Laurel Ridge and Chestnut Ridge regions of the study area.
- On Laurel Ridge, the Powder Mill Run and Baldwin Creek monitors provide the best coverage for RTDM/MPTEP, while the peak concentrations predicted by LAPPES/MPTEP are spread over a wider area.

- On Chestnut Ridge, the coverage provided by the Bear Cave monitor is excellent for the peak concentrations predicted by both RTDM/MPTER and LAPPES/MPTER.
- The monitoring network also provides adequate coverage for the use of RTDM/MPTER for Seward Station combined with LAPPES/MPTER for all the other Penelec sources.

3.4 Background Air Quality

The lowest hourly SO₂ concentration measured by any station in the monitoring network was chosen as the background concentration for each hour. Neither Penelec nor the regulatory agencies are aware of any significant SO₂ emission sources within the study region, except for Penelec-operated sources. Consequently, background estimates should reflect regional-scale contributions from distant source regions, rather than unidentified local contributions.

Table 3-4 provides a summary of the measured SO₂ concentration data obtained from Penelec's Laurel/Chestnut Ridge monitoring network during the period from August 1, 1990 through July 31, 1991. The table shows values for 1) all the available hours of SO₂ data as well as 2) only those hours used to define background SO₂ concentrations. For each monitoring site, the table lists 1) the number of hours where SO₂ data were a) available and b) used to define background, 2) the average SO₂ concentration for a) the available hours and b) the hours used to define background, and 3) the highest 1-hour average SO₂ concentration for a) the available hours and b) the hours used to define background.

Table 3-4 shows that the monitor with the most available hours of SO₂ data was Luciusboro (8676 hours), while the monitor used most often to determine background was ~~Baldwin Creek~~ ^{Luciusboro 2044} (2016 hours). The table shows that the highest average SO₂ concentration (~~35.6~~ ^{51.0} μg/m³) was recorded at Rager Mountain, while ~~Bear Cave~~ ^{Luciusboro} recorded the highest average SO₂ concentration (~~81.8~~ ^{17.4} μg/m³) based on

TABLE 3-4

SUMMARY OF THE MONITOR NETWORK
SULFUR DIOXIDE CONCENTRATION VALUES
(AUGUST 1, 1990 - JULY 31, 1991)

Monitor Name	Number of Hours		Average for the		Highest 1 - Hour for the	
	Available	Used for Background	Available Hours ($\mu\text{g}/\text{m}^3$)	Background Hours ($\mu\text{g}/\text{m}^3$)	Available Hours ($\mu\text{g}/\text{m}^3$)	Background Hours ($\mu\text{g}/\text{m}^3$)
BALDWIN CREEK	8652	2016	✓ 18.9	8.49	791 #2	113
BEAR CAVE	8326	✓ 1041	✓ 20.4	81.8	765 #1	✓ 396
LITTLE MILL CREEK	7776	✓ 541	✓ 18.7	59.4	1040 #1	✓ 215
MARSHALL HEIGHTS	8605	✓ 1022	✓ 21.5	42.9	652 #1	✓ 210
PENN VIEW	8586	✓ 630	✓ 20.3	36.1	550 #9	✓ 152
POWDERMILL RUN	8371	✓ 745	✓ 17.0	26.4	584 #2	✓ 181
RAGER MTN.	8395	✓ 765	✓ 35.6	19.3	841 #1	✓ 157
SUGAR RUN	7464	✓ 345	✓ 26.9	18.4	980 #1	✓ 126
TERRYS RUN	8583	✓ 565	✓ 23.0	18.4	951 #1	✓ 115
LUCIUSBORO	8676	✓ 1090	✓ 19.1	23.6	611 #1	✓ 144

the hours of data used to define background. The highest 1-hour average SO₂ concentration (1040 µg/m³) was recorded at Little Mill Creek and the highest 1-hour average background SO₂ concentration (396 µg/m³) was recorded at ^{Marshall} Bear Cave. ^{Heights} Table 3-4 shows that all the SO₂ monitoring sites achieved the 80 percent minimum data capture requirement.

The SO₂ concentration data in Table 3-4 show that the highest background SO₂ concentrations were recorded at the Bear Cave, Little Mill Creek and ^{Laurel/Chestnut Ridge} Marshall Heights monitoring sites. Thus, during hours when all the monitors are recording high SO₂ concentrations, i.e., when high background SO₂ concentrations are being transported into the Laurel/Chestnut Ridge area from other regions, these three monitors tend to record the lowest SO₂ concentrations among all the monitors. Based on the locations of the Marshall Heights, Bear Cave, and Little Mill Creek monitors (see Figure 2-1), high background SO₂ concentrations are apparently transported into the Laurel/Chestnut Ridge area when the wind is blowing roughly from the west, southwest and south, respectively.

3.5 Emission Data

Actual hourly SO₂ emissions and exhaust gas parameters for each stack at each generating station were required as model inputs for the model comparison study. Stack temperature, exhaust gas flow and exit velocity are not measured continuously for any stack.

These parameters were calculated from hourly load records, based on the following equations:

$$\begin{aligned}v_s &= v_{100} (L/L_{100}) \\T_s &= 2T_{50} + (T_{100} - T_{50}) 2L/L_{100} - T_{100} \\Q &= SEL (0.126 \text{ g hr} / \text{ lb sec})\end{aligned}$$

where:

v_s = Exit speed, m/sec
 T_s = Exit temperature, K
 Q = SO₂ emission rate, g/sec
 L = Operating load, MW
 L_{100} = Operating load at 100% capacity, MW
 v_{100} = Exit speed at 100% load, m/sec
 T_{100} = Exit temperature at 100% load, K
 T_{50} = Exit temperature at 50% load, K
 E = Operating Heat Input Rate, 10⁶ Btu/MWh
 S = Fuel sulfur emission factor, lb SO₂/10⁶ Btu

Hourly gross operating load data were obtained for each generating unit. Continuous emission monitor data for Homer City were used along with load and heat rate data to calculate mass emission rates for Homer City Units 1, 2, and 3. For all other generating stations, the 24-hour average fuel sampling sulfur content values from the Certified Coal Sampling and Analysis System were used in combination with heat rates and hourly load data to calculate hourly emission rates. The 24-hour average fuel sampling sulfur content values are composites obtained from 48 samples per day, taken twice hourly.

Table 3-5 summarizes the SO₂ emission rates produced by each of the Penelec power plant stacks during the period from August 1, 1990 through July 31, 1991. The table shows the heat input rate, fuel sulfur content and emission rate for each stack. The values shown for the last two parameters are based on the number of valid operating days and hours per year.

3.6 Model Options

Tables 3-6 through 3-9 summarize the regulatory options and related input data used for the RTDM, LAPPES and MPTER model comparison analyses. Table 3-6 contains source-dependent model option data, and Tables 3-7 through 3-9 present the other options used in the RTDM, LAPPES and MPTER models, respectively. All the options were activated in accordance with EPA guidance and the February 1991 modeling protocol. The tables are discussed briefly below.

Table 3-5

Summary of the Penelec Power Plant Sulfur Dioxide
Emission Rates
(August 1, 1990 – July 31, 1991)

Source Name	Heat Input Rate (MMBtu/ MWhr)	Average SO2 Emission Rate	
		from Fuel Sampling (lb/MMBtu)	When Operating (g/s)
Conemaugh Unit 1	8.82	3.30	2975
Conemaugh Unit 2	8.82	3.45	3156
Homer City Unit 1	9.02	2.37	1537
Homer City Unit 2	9.01	2.34	1522
Homer City Unit 3	9.20	1.13	834
Keystone Unit 1	8.97	2.71	2458
Keystone Unit 2	8.97	2.71	2501
Seward Unit 4	10.36	2.55	130
Seward Unit 5	10.36	2.56	458

Table 3-6

Source Dependent Model Option Data

Power Plant	Anemometer Heights (m)*		PR004 (c)	Wind Speed Profile Exponents (for stability classes 1-6, respectively)					
	# 1 (a)	# 2 (b)		0.18	0.16	0.18	0.26	0.35	0.58
Conemaugh	245.1	245.1	1	0.18	0.16	0.18	0.26	0.35	0.58
Homer City	261.5	261.5	1	0.06	0.08	0.11	0.22	0.25	0.26
Keystone	318.8	318.8	1	0.06	0.08	0.11	0.22	0.25	0.26
Seward	185.9	246.3	2	0.18	0.16	0.18	0.26	0.35	0.58

* above the stack base elevation

(a) # 1 for RTDM; single anemometer height for LAPPES and MPTER

(b) # 2 for RTDM

(c) dilution wind speed option number for RTDM

TABLE 3-7
RTDM MODEL OPTIONS

Model Parameters:

- PR0001: Horizontal Scale is 1000.000 Meters Per User Unit
 - PR0002: Vertical Scale is .305 Meters Per User Unit
 - PR0003: Wind Speed Scale is .447 m/sec Per User Unit
 - PR0004: Anemometer #1 Height Above ZA (Used for Plume Rise) is (see Table 3-6)
If Available, Anemometer #2 Height Above ZA (Used for Plume Dilution) is (see Table 3-6)
Dilution Wind Speed Option is (see Table 3-6) (If 0, One Wind Speed--at Stack Height--is
Used for Plume Rise and Dilution
If 1, Wind Speed at Level #1 is Extrapolated to Stack-Top Height for Plume Rise and to
Plume Height for Dilution
If 2, Wind Speed at Level #1 is Extrapolated to Stack-Top Height for Plume Rise, and the
Speed at Level #2 is Extrapolated to Plume Height for Dilution)
ZA (Height in Meters Above Stack Base Elevation where the Wind Speed Profile is Assumed
to Originate) = .000
 - PR0005: Default Wind Speed Profile Exponents as a Function of Stability Class (1-6,
respectively): (see Table 3-6)
 - PR006: Dispersion Coefficients are Briggs Rural/ASME-1979 (Unless Replaced by On-Site Turbulence
Data)
 - PR009: Partial Plume Penetration of Mixing Lids is Not Being Used
 - PR010: Buoyancy-Enhanced Plume Dispersion is Used; Parameter Alpha is: 3.162
 - PR011: Unlimited Mixing Height Used for Stable Condition
 - PR012: Transitional Plume Rise is Used
 - PR013: Plume Path Coefficients for Stability Classes 1-6: .500, .500, .500, .500, .500, .500
 - PR014: Default Vertical Potential Temperature Gradients Used for Stable Plume Rise (Classes 5 &
6): .0200, .0350
 - PR015: Stack-Tip Downwash is Used
 - PR016: Y-Component Turbulence Intensity Values are Not Provided; Stability Class is Used to
Obtain Sigma-Y.
 - PR017: Z-Component Turbulence Intensity Values are Not Provided; Stability Class is Used to
Obtain Sigma-Z.
 - PR018: Hourly Vertical Potential Temperature Gradients are Not Provided to Determine Stable
Plume Rise; Use Default Values (see PR014)
 - PR019: Hourly Vertical Potential Temperature Gradients are Not Provided to Determine HCRIT; Use
Default Values (see PR014)
 - PR020: Wind Direction Shear is Not Used in Computation of Sigma-Y.
 - PR021: Hourly Values of Wind Speed Profile Exponent are Not Provided; Use Defaults (see PR005)
 - PR022: Partial Reflection Algorithm is Being Used; Keyword Terrain Must be Used to Read in
Terrain
 - PR023: Sector Averaging is Used for All Stabilities
Sector Widths (Deg) for Stabilities 1-6 are: 22.50, 22.50, 22.50, 22.50, 22.50, 22.50
 - PR024: Hourly Emissions Data are Available and Will Replace the Constant Values Specified in the
Stacks Section
 - PR025: Detailed Information About Each Case will Not Be Printed
-

TABLE 3-8

LAPPES MODEL OPTIONS

Option	Option List	Option Specification 0 = Ignore Option 1 = Use Option
<u>Technical Options</u>		
1	Terrain Adjustments	1
2	Do Not Include Stack Downwash Calculations	0
3	Do Not Include Gradual Plume Rise Calculations	0
4	Calculate Initial Plume Size	1
<u>Input Options</u>		
5	Read Met Data from Cards	0
6	Read Hourly Emissions	1
7	Specify Significant Sources	0
8	Read Radial Distances to Generate Receptors	0
<u>Printed Output Options</u>		
9	Delete Emissions with Height Table	1
10	Delete Met Data Summary for Average Period	1
11	Delete Hourly Contributions	1
12	Delete Met Data on Hourly Contributions	1
13	Delete Final Plume Rise Calc on Hourly Contributions	1
14	Delete Hourly Summary	1
15	Delete Met Data on Hourly Summary	1
16	Delete Final Plume Rise Calc on Hourly Summary	1
17	Delete Avg-Period Contributions	1
18	Delete Averaging Period Summary	1
19	Delete Avg Concentrations and Hi-5 Tables	0
<u>Other Control and Output Options</u>		
20	Run is Part of a Segmented Run	0
21	Write Partial Conc to Disk or Tape	0
22	Write Hourly Conc to Disk or Tape	1
23	Write Avg-Period Conc to Disk or Tape	0
24	Punch Avg-Period Conc onto Cards	0
25	Complex Terrain Option	6

Anemometer Height is: (see Table 3-6)

Exponents for Power-Law Wind Increase with Height are: (see Table 3-6)

Terrain Adjustments are: .500, .500, .500, .500, .000, .000

Zmin is: 10.0

TABLE 3-9

MPTEP MODEL OPTIONS

Option	Option List	Option Specification 0 = Ignore Option 1 = Use Option
<u>Technical Options</u>		
1	Terrain Adjustments	1
2	Do Not Include Stack Downwash Calculations	0
3	Do Not Include Gradual Plume Rise Calculations	1
4	Calculate Initial Plume Size	1
<u>Input Options</u>		
5	Read Met Data from Cards	0
6	Read Hourly Emissions	1
7	Specify Significant Sources	0
8	Read Radial Distances to Generate Receptors	0
<u>Printed Output Options</u>		
9	Delete Emissions with Height Table	1
10	Delete Met Data Summary for Average Period	1
11	Delete Hourly Contributions	1
12	Delete Met Data on Hourly Contributions	1
13	Delete Final Plume Rise Calc on Hourly Contributions	1
14	Delete Hourly Summary	1
15	Delete Met Data on Hourly Summary	1
16	Delete Final Plume Rise Calc on Hourly Summary	1
17	Delete Avg-Period Contributions	1
18	Delete Averaging Period Summary	1
19	Delete Avg Concentrations and Hi-5 Tables	0
<u>Other Control and Output Options</u>		
20	Run is Part of a Segmented Run	0
21	Write Partial Conc to Disk or Tape	0
22	Write Hourly Conc to Disk or Tape	1
23	Write Avg-Period Conc to Disk or Tape	0
24	Punch Avg-Period Conc onto Cards	0
<u>Default Option</u>		
25	Use Default Option	0

Anemometer Height is: (see Table 3-6)

Exponents for Power-Law Wind Increase with Height are: (see Table 3-6)

Terrain Adjustments are: .000, .000, .000, .000, .000, .000

The anemometer heights shown in Table 3-6 are relative to the stack base elevations at each power plant. With RTDM, plume height and plume dilution can be calculated using wind speed data collected at two levels. For Conemaugh, Homer City and Keystone, the plume height and plume dilution wind speeds were extrapolated from meteorological tower top wind speeds only. The Ash Valley 150 meter level data were used for Conemaugh, and the Manor 100 meter level data were used for Homer City and Keystone. For Seward, Ash Valley upper level (89 meter) data were used for stack top wind speed, and Ash Valley tower top level (150 meter) data were used for plume height wind speed.

The wind speed profile exponents in Table 3-6 were derived using the on-site data. The selection of the wind speed profile exponents was the same in all three models. These data were available from analyses performed on the site-specific wind speeds (when scaling factors were derived to implement the meteorological data substitution for the different tower level wind speeds). Sensitivity analyses performed indicated that the use of site-specific exponents in RTDM and LAPPES as opposed to the RTDM regulatory default exponents resulted in marginally higher concentration predictions for both models.

Since LAPPES is a non-regulatory model there is no specific EPA guidance to reference with respect to the model inputs. However, the model options were chosen to follow the approach described in the modeling protocol and the general regulatory specifications for RTDM. The most distinguishing feature of LAPPES is the treatment of terrain (Section 2.3.1). The LAPPES terrain treatment was selected by setting model option number 25 to a value of 6.

The MPTER options selected were standard for typical regulatory applications, and follow those contained in the modeling protocol (Section 2.3.3).

4.0 STATISTICAL PROTOCOL FOR PERFORMANCE COMPARISON

The model evaluation data base included one year of ambient SO₂ air quality measurements from the network of ten monitors sited to measure peak short-term (3-hour and 24-hour average) concentrations. The data base also included predicted hourly concentrations from the reference model (RTDM/MPTER) and LAPPES/MPTER.

The protocol for model comparison defined the procedure which was used to score each model's performance and to select the winning model. The scoring procedures involved three elements: defining the performance measures, i.e., the specific characteristics of the observed and predicted values which were compared; assigning weights to the different performance measures; and specifying the numerical basis for assigning a performance score to each model.

4.1 Objectives

The objective of the Laurel/Chestnut Ridge model comparison study was to select that model which is the best predictor of peak short-term (3-hour and 24-hour average) SO₂ concentrations produced by the combined impacts of Penelec-operated sources at elevated terrain locations.

For regulatory applications, the magnitude of the highest second-highest 3-hour and 24-hour average predicted concentrations is the most critical factor for determining whether ambient standards are satisfied. Accounting for the contributions of individual emission sources to peak concentrations is also important for establishing emission limits. It is therefore desirable to predict the time and location of peak impacts correctly.

In order to estimate correctly how often critical impacts are likely to occur, it is also important for the models to predict peak impacts for appropriate meteorological conditions. Model performance was therefore also assessed as a function of meteorology.

4.2 Performance Measures

The performance measures and associated maximum possible point scores used in the Laurel/Chestnut Ridge model comparison study are summarized in Table 4-1. The magnitudes assigned to the maximum possible scores emphasize model performance for estimating peak short-term concentrations, since the network design analysis indicated that short-term concentrations will be controlling for setting emission limits.

The first performance measure, highest second-highest 3-hour and 24-hour average values, was considered to represent the "design concentration" for the monitoring network. A maximum of 30 out of 135 possible points, with equal weight for 3-hour and 24-hour values was assigned to this performance measure. The predicted design value must be within a factor of two of the observed value for points to be received.

The second set of performance measures involved the second-highest observed and predicted values at each station. Specific measures included the average difference over all stations, and the mean squared error, normalized by the standard deviations of the observed and predicted values. A maximum total of 49 points was available for these measures.

The third set of measures involved comparison of the average of the top N observed and predicted values, with N ranging from 25 for 1-hour averages to 10 for 24-hour averages. N was varied in recognition that the total sample size decreases as averaging time increases. These measures were assigned a maximum total of 21 points.

The fourth and fifth sets of performance measures were related to scientific evaluation. Peak observed and predicted values were compared for subsets based on meteorology, directly parallel to the comparisons in Items 1 and 3. Five subsets were defined by stability and stack top wind speed:

TABLE 4-1

SUMMARY OF SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

<u>Performance Measure</u>	<u>Possible Score</u>
1. Highest second high values	
3-hour average	15
24-hour average	15
2. Second high by station, paired by location	
a. Average difference (fractional bias)	
1-hour	5
3-hour	15
24-hour	15
b. Mean square error (normalized)	
1-hour	2
3-hour	6
24-hour	6
3. Top N values - fractional bias on average values	
a. 1-hour (N=25)	3
b. 3-hour (N=20)	9
c. 24-hour (N=10)	9
4. Second high by meteorological category (1 hour only - five categories)	
fractional bias - each category	10
5. Top N values by meteorological category (1 hour only - five categories)	
N = one percent of hours in category	
$10 \leq N \leq 25$	
fractional bias on average values - each category	5
6. All values - paired in time and location (1-hour)	
a. Average difference - fractional bias	7
b. MS error (normalized)	3
7. Annual average (each station)	
a. Highest observed vs. highest predicted (fractional bias)	5
b. Average observed vs. average predicted (fractional bias)	<u>5</u>
Total	135

1. Unstable (Class A, B, C)
2. Neutral, low wind speed (Class D; $u \leq 4$ m/s)
3. Neutral, high wind speed (Class D; $u > 4$ m/s)
4. Stable, low wind speed (Class E, F; $u \leq 4$ m/s)
5. Stable, high wind speed (Class E, F; $u > 4$ m/s)

Tower-top wind speeds and stability class values from Ash Valley were used to define the meteorological categories. A maximum total of 15 points was included for items 4 and 5. Comparisons were based only on 1-hour averages.

Item 6 involved all values, paired in time and location. Measures included the average difference and mean-squared error. These measures reflect the average bias and scatter associated with hourly predictions and were included primarily for scientific evaluation. A maximum total of 10 points was available for these items.

The final item concerned annual averages. Performance measures included comparison of the maximum annual values and the average difference over all monitors. A maximum total of 10 points was assigned for annual averages.

Overall, 25 points were allocated to peak one-hour values, 45 each to peak 3-hour and 24-hour values, 10 for the average of all values, and 10 for annual averages. Roughly equal weight was given to peak values compared without regard to location and to peak values paired by location.

The winning model will be used to estimate both the magnitude of peak concentrations and the relative contribution of different sources for the purpose of determining future emission limits. Source contributions are closely linked to specific receptor locations.

4.3 Methods for Calculating Point Scores

The calculation methods used for assigning point scores based on model performance are outlined in Table 4-2. For bias, all point scores were based on the absolute fractional bias (AFB). Fractional bias (FB) represents the

TABLE 4-2

PERFORMANCE SCORE CALCULATION METHODS FOR
LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

-
1. Highest second high values - absolute fractional bias (AFB)
 - Score = $P(1-1.5 \text{ AFB})$, $\text{AFB} \leq 2/3$
 - Score = 0 , $\text{AFB} > 2/3$

Where P = possible score (15 for both the 3-hour and 24-hour averages, as indicated in Table 4-1)

 2. Second high by station
 - a. Average difference - AFB (same equation as Item 1)
 - b. Normalized RMS Error (NRMSE)
 - Score = $p(1-0.5 \text{ NRMSE})$, $\text{NRMSE} \leq 2$
 - Score = 0 , $\text{NRMSE} > 2$

 3. Top N values - fractional bias on average values
 - Score = $P(1 - 2.5 \text{ AFB})$, $\text{AFB} \leq 0.4$
 - Score = 0 , $\text{AFB} > 0.4$

 4. Second high by meteorological category - AFB (same equation as Item 1)

 5. Top N values by meteorological category - AFB on average of N values (same equation as Item 3)

 6. All values - paired in time and location
 - a. Average difference - AFB (same equation as Item 3)
 - b. Normalized RMS Error (NRMSE)
 - Score = $P(1 - 0.5 \text{ NRMSE})$, $\text{NRMSE} \leq 2$
 - Score = 0 , $\text{NRMSE} > 2$

 7. Annual average
 - a. AFB (same equation as Item 3)
 - b. AFB (same equation as Item 3)
-

difference between observed and predicted values, normalized by the average of the same observed and predicted values.

$$FB = \frac{(Obs - Pred)}{0.5 (Obs + Pred)}$$

where Obs and Pred represent the observed and predicted values being compared. FB can range in value between -2 and +2. A value of zero for FB represents perfect agreement between observed and predicted values. When observed and predicted values agree within a factor of 2, the FB will range between -2/3 and +2/3. Absolute fractional bias (AFB) represents the absolute value of the fractional bias and ranges between 0 and 2. The AFB gives equal weight to over- and underprediction, based on the ratio of the observed and predicted values.

The root mean-squared error (RMSE) is a measure of the magnitude of the differences between pairs of observed and predicted values. The mean-squared error (MSE) is given by:

$$MSE = \frac{1}{N} \sum_i (O_i - P_i)^2$$

where:

O_i , P_i and N are defined above.

The RMSE is simply the square root of the MSE. For performance scoring, the RMSE was normalized by the average observed value.

Performance scoring based on the AFB was similar for items 1, 2a and 4 in Table 4-2. A perfect score would be received when the AFB = 0. Zero score would be received unless observed and predicted values agree within a factor of two. Agreement within a factor of two for peak values is one generally

recognized measure of acceptable model performance. The performance score would decrease linearly as the AFB increases from 0 to 2/3. For example, if the highest second-highest predicted and observed 3-hour concentrations for model A are 1000 $\mu\text{g}/\text{m}^3$ and 750 $\mu\text{g}/\text{m}^3$, respectively, then

$$\text{AFB} = \frac{|750 - 1000|}{0.5 (750 + 1000)} = \frac{250}{875} = 0.286$$

The score received by model A would then be

$$S = P (1 - 1.5 \text{ AFB}) = 15 (1 - .429) = 8.57$$

For items 3, 5, 6a and 7, the scores were also based on the AFB. These measures depend on averages over a number of peak concentrations, rather than single-value comparisons. Averages are subject to less uncertainty than single extreme values. The "acceptable range" of model performance was therefore narrower for these measures. Zero score would be received unless the observed and predicted average values agree within a factor of 1.5 (corresponding to an AFB = 0.40).

For Items 2b and 6b, a perfect score would be received for an RMSE = 0. No score would be received if the RMS error is more than twice as large as the average of the observed values. As the RMSE increases, the model score decreases. For example, if the RMSE is 25 $\mu\text{g}/\text{m}^3$ and the average observed concentration value is 15 $\mu\text{g}/\text{m}^3$, the model score would be

$$S = 3 \left(1 - 0.5 \frac{25}{15}\right) = 0.50$$

4.4 Selection Criteria

After point scores were calculated for each item, the total performance scores for the reference model and the proposed model were compared. In order to have been selected for future use, the proposed model must have achieved a performance score of at least 30 points and must have scored higher than the reference model.

5.0 MODEL COMPARISON RESULTS

The LAPPES model scored 52.03 points in the revised comparison study and the reference model, RTDM/MPTER, scored 2.73 points. LAPPES therefore achieved the two performance goals of outscoring the reference model and achieving a minimum of 30 points using the protocol scoring scheme. This section discusses the scoring and is organized by performance measure. Tables 5-1 and 5-2 provide a summary of the revised scoring for LAPPES and RTDM/MPTER by performance measure. Appendix A details the statistical calculations and the basis for the scoring.

5.1 Highest Second-High 3-Hour and 24-Hour Averages

This measure accounted for 22 percent of the total possible points in this comparison study and provided LAPPES with 29 percent (15.16) of its total points. LAPPES overpredicted by 41 percent and 38 percent for the 3-hour and 24-hour values, respectively. Both of these are within the factor of two criteria set forth to score any points. RTDM/MPTER overpredicted by 1304 percent and by 716 percent for the 3-hour and 24-hour averages, respectively, and scored zero points.

5.2 Highest Second-High by Station

For the 1-hour averaging period, the highest second-high observed SO₂ concentration of 929 µg/m³ occurred at the Little Mill Creek receptor (M3). LAPPES predicted a highest second-high value of 1473 µg/m³ at the same receptor (M3). RTDM/MPTER predicted a highest second-high 1-hour average concentration value of 12074 µg/m³ at the Powdermill Run (M6) receptor. LAPPES overpredicted by up to a factor of 2.6, while the RTDM/MPTER overpredictions ranged up to a factor of 22.6. On average, LAPPES overpredicted this measure by a factor of 1.6, while RTDM/MPTER overpredicted

TABLE 5-1

SUMMARY OF SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY
LAPPES MODELING RESULTS

Performance Measure	Score (Actual/Possible)	
1. Highest Second High Values		
3-hour average	7.37	15
24-hour average	7.79	15
2. Second High by Station, Paired by Location		
a. Average Difference (fractional bias)		
1-hour	1.75	5
3-hour	8.29	15
24-hour	7.30	15
b. Mean Square Error (normalized)		
1-hour	1.31	2
3-hour	4.47	6
24-hour	4.61	6
3. Top N Values - Fractional Bias on Average Values		
a. 1-hour (N=25)	0.00	3
b. 3-hour (N=20)	0.00	9
c. 24-hour (N=10)	0.00	9
4. Second High by Meteorological Category (1-hour only - five categories)		
Fractional Bias - Each Category	3.32	10
5. Top N Values by Meteorological Category (1-hour only - five categories)		
N = one percent of hours in category 10 <= N <= 25		
Fractional Bias on Average Values - Each Category	0.57	5
6. All Values Paired in Time and Location (1-hour)		
a. Average Difference - Fractional Bias	0.00	7
b. MS Error (normalized)	0.00	3
7. Annual Average (each station)		
a. Highest Observed vs. Highest Predicted (fractional bias)	3.08	5
b. Average Observed vs. Average Predicted (fractional bias)	2.16	5
Totals	52.03	135

TABLE 5-2

SUMMARY OF SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY
RTDM MODELING RESULTS

Performance Measure	Score (Actual/Possible)	
1. Highest Second High Values		
3-hour average	0.00	15
24-hour average	0.00	15
2. Second High by Station, Paired by Location		
a. Average Difference (fractional bias)		
1-hour	0.00	5
3-hour	0.00	15
24-hour	0.00	15
b. Mean Square Error (normalized)		
1-hour	0.00	2
3-hour	0.00	6
24-hour	0.00	6
3. Top N Values - Fractional Bias on Average Values		
a. 1-hour (N=25)	0.00	3
b. 3-hour (N=20)	0.00	9
c. 24-hour (N=10)	0.00	9
4. Second High by Meteorological Category (1-hour only - five categories)		
Fractional Bias - Each Category	2.07	10
5. Top N Values by Meteorological Category (1-hour only - five categories)		
N = one percent of hours in category 10 <= N <= 25		
Fractional Bias on Average Values - Each Category	0.66	5
6. All Values Paired in Time and Location (1-hour)		
a. Average Difference - Fractional Bias	0.00	7
b. MS Error (normalized)	0.00	3
7. Annual Average (each station)		
a. Highest Observed vs. Highest Predicted (fractional bias)	0.00	5
b. Average Observed vs. Average Predicted (fractional bias)	0.00	5
Totals	2.73	135

by a factor of 5.4. RTDM/MPTEr gained no points on this measure for both fractional bias and MSE, while LAPPES gained 1.75 and 1.31 points for fractional bias and MSE, respectively.

For the 3-hour averaging period, LAPPES predicted a highest second-high value of 740 $\mu\text{g}/\text{m}^3$ at the Sugar Run monitor (M8). RTDM predicted a highest second-high value of 7383 $\mu\text{g}/\text{m}^3$ at the Powdermill Run monitor (M6). The highest second-high observed SO_2 concentration value was 464 $\mu\text{g}/\text{m}^3$ at the Terrys Run monitor site (M9). When the data were paired in this manner, RTDM/MPTEr overpredicted the measured concentrations by up to a factor of 22.8 and, on average, by a factor of 5.8. LAPPES scored considerably better, with a maximum overprediction of less than a factor of two and an average overprediction of 1.4. LAPPES scored 8.29 points on the absolute fractional bias portion of this measure and 4.47 points on the MSE portion. This measure provided LAPPES with 12.76 points and 25 percent of its total score. RTDM/MPTEr did not receive any points for this measure.

For the 24-hour averaging period, both models overpredicted on average, but this measure showed cases at individual monitors where both LAPPES/MPTEr and RTDM/MPTEr underpredicted. Both models underpredicted the highest second-high at the Marshall Heights (M4) and Luciusboro (M10) monitors. LAPPES also underpredicted the highest second-high at the Bear Cave (M2) and Penn View (M5) monitors. However, on average, RTDM/MPTEr overestimated this measure by a factor of 4.5 and LAPPES overestimated by a factor of only 1.1. The absolute value of the fractional bias was used in the analysis to prevent underprediction and overprediction from compensating for each other in the aggregate statistics, which would result in an artificially higher score. Even with this compensatory effect removed, LAPPES scored 7.30 points on the absolute fractional bias portion and 4.61 points on the MSE portion of this measure. This measure accounted for 23 percent of the LAPPES point total while RTDM/MPTEr scored zero.

The Marshall Heights and Luciusboro monitors are located at the lowest terrain elevations of the ten monitors included in the study. The Luciusboro monitor is located below all the Penelec power plant stack top elevations, and the Marshall heights monitor is located below all the stack top elevations except those of Keystone and Seward. Thus, the peak predicted impacts at these two monitors are primarily attributable to those calculated by the MPTER model (see Figure 5-1). Many of the peak predicted impacts at the Penn View monitor are also likely to be attributable to the MPTER model, as the Penn View monitor is also located at a relatively low elevation (i.e., below the stack top elevations of Conemaugh and Homer City 3 and only 30 feet above the stack top elevations of Homer City 1 & 2).

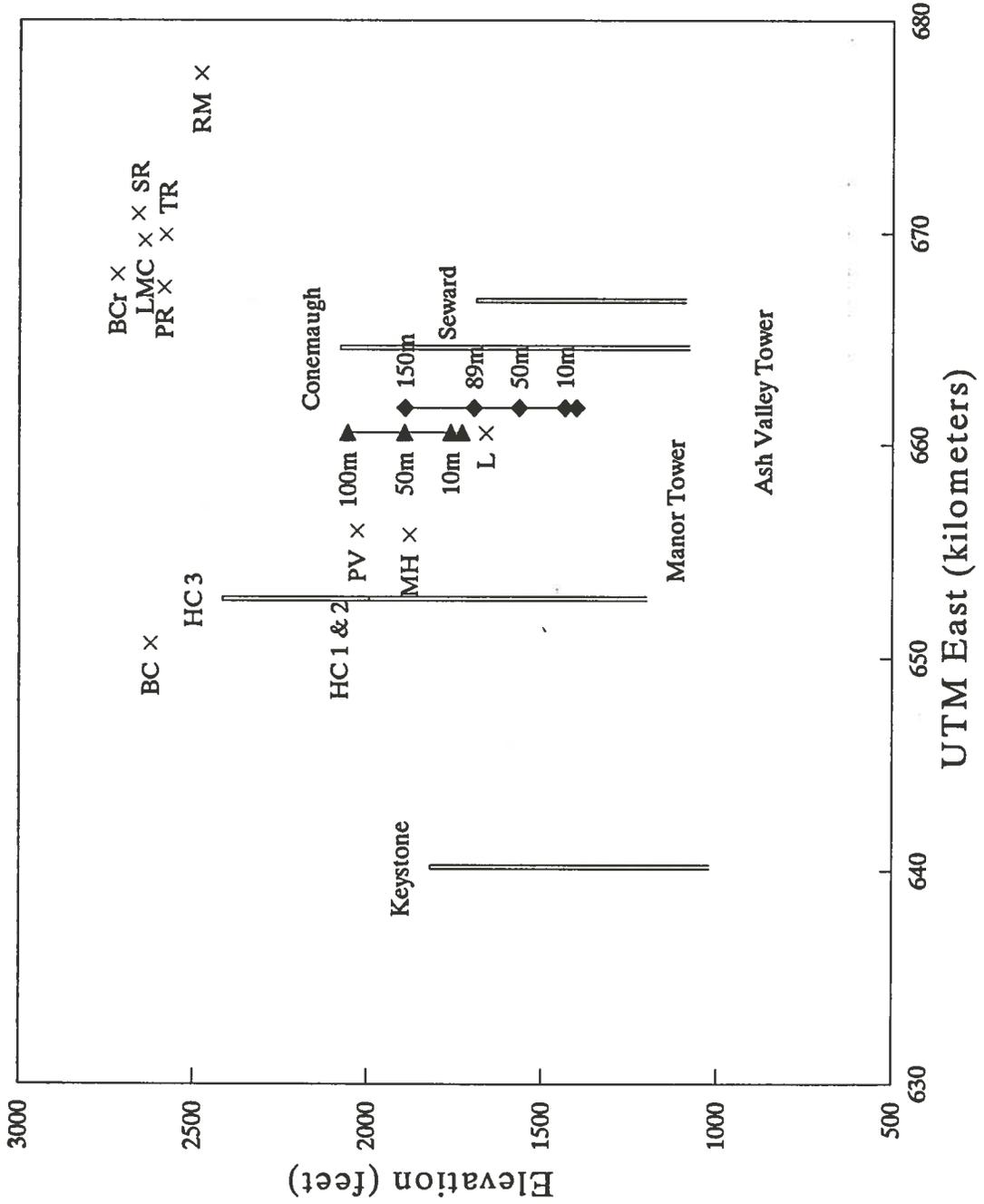
As shown in Figures 5-2 through 5-4, the LAPPES model provided much better simulations for the 1-hour, 3-hour and 24-hour average concentrations at the individual monitors and for the overall monitoring network. At most of the monitors, the LAPPES model's predictions were less than a factor of two higher than the measured concentrations. In contrast, the RTDM/MPTER model's predictions were usually much higher than the measured concentrations.

5.3 Fractional Bias on Average of Top N Values

As noted in the other 1-, 3- and 24-hour average measures, LAPPES outperformed RTDM/MPTER in predicting the magnitude of the high second-high monitored concentrations, and points were awarded to LAPPES because the predicted concentrations were within a factor of two of the monitored concentrations. In the top N value measures, the point threshold was set at a lower FB of 0.40 (which corresponds to an over/underprediction of 50 percent). Neither model scored on this measure for either the 1-, 3- or 24-hour averaging periods, though LAPPES was within a factor of two overprediction (average fractional bias = 0.6667) for all of these cases.

Figure 5-1a

Cross-Sectional View of the Laurel/Chestnut Ridge Model Comparison Study Area with the Penelec Power Plant Stacks, Meteorological Towers and Sulfur Dioxide Monitoring Sites (Facing North)



Legend:

SO2 Monitors:

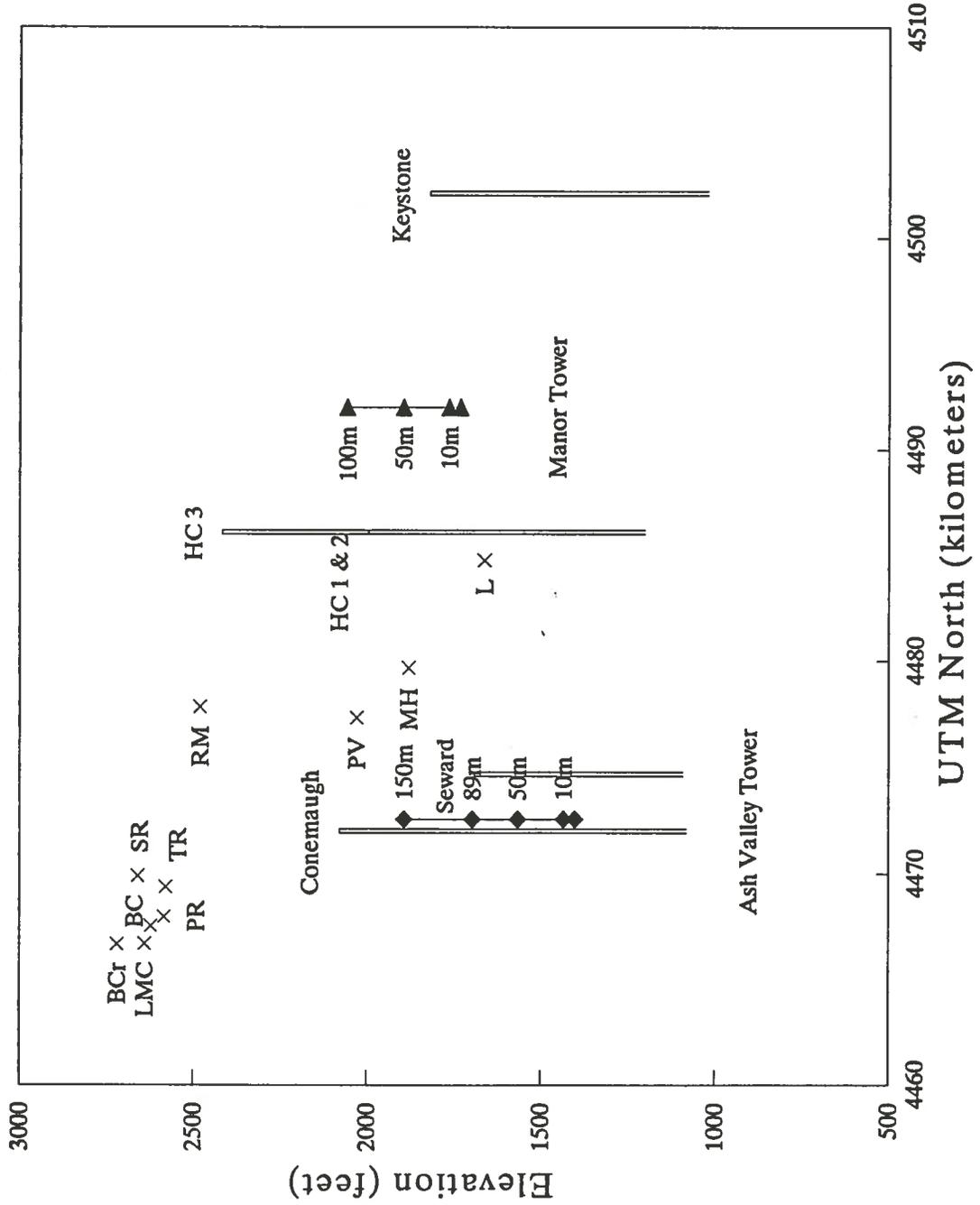
- BC = Bear Cave
- BCr = Baldwin Creek
- L = Luciusboro
- LMC = Little Mill Creek
- MH = Marshall Heights
- PR = Powdermill Run
- PV = Penn View
- RM = Rager Mountain
- SR = Sugar Run
- TR = Terrys Run

Power Plants:

- HC1 = Homer City 1
- HC2 = Homer City 2
- HC3 = Homer City 3

Figure 5--1b

Cross-Sectional View of the Laurel/Chestnut Ridge Model Comparison Study Area with the Penelec Power Plant Stacks, Meteorological Towers and Sulfur Dioxide Monitoring Sites (Facing West)



Legend:

SO2 Monitors:

- BC = Bear Cave
- BCr = Baldwin Creek
- L = Luciusboro
- LMC = Little Mill Creek
- MH = Marshall Heights
- PR = Powdermill Run
- PV = Penn View
- RM = Rager Mountain
- SR = Sugar Run
- TR = Terrys Run

Power Plants:

- HC1 = Homer City 1
- HC2 = Homer City 2
- HC3 = Homer City 3

Figure 5-2
 Comparisons Of the Modeled and Monitored
 High Second High 1-Hour Average Concentrations ($\mu\text{g}/\text{m}^3$)

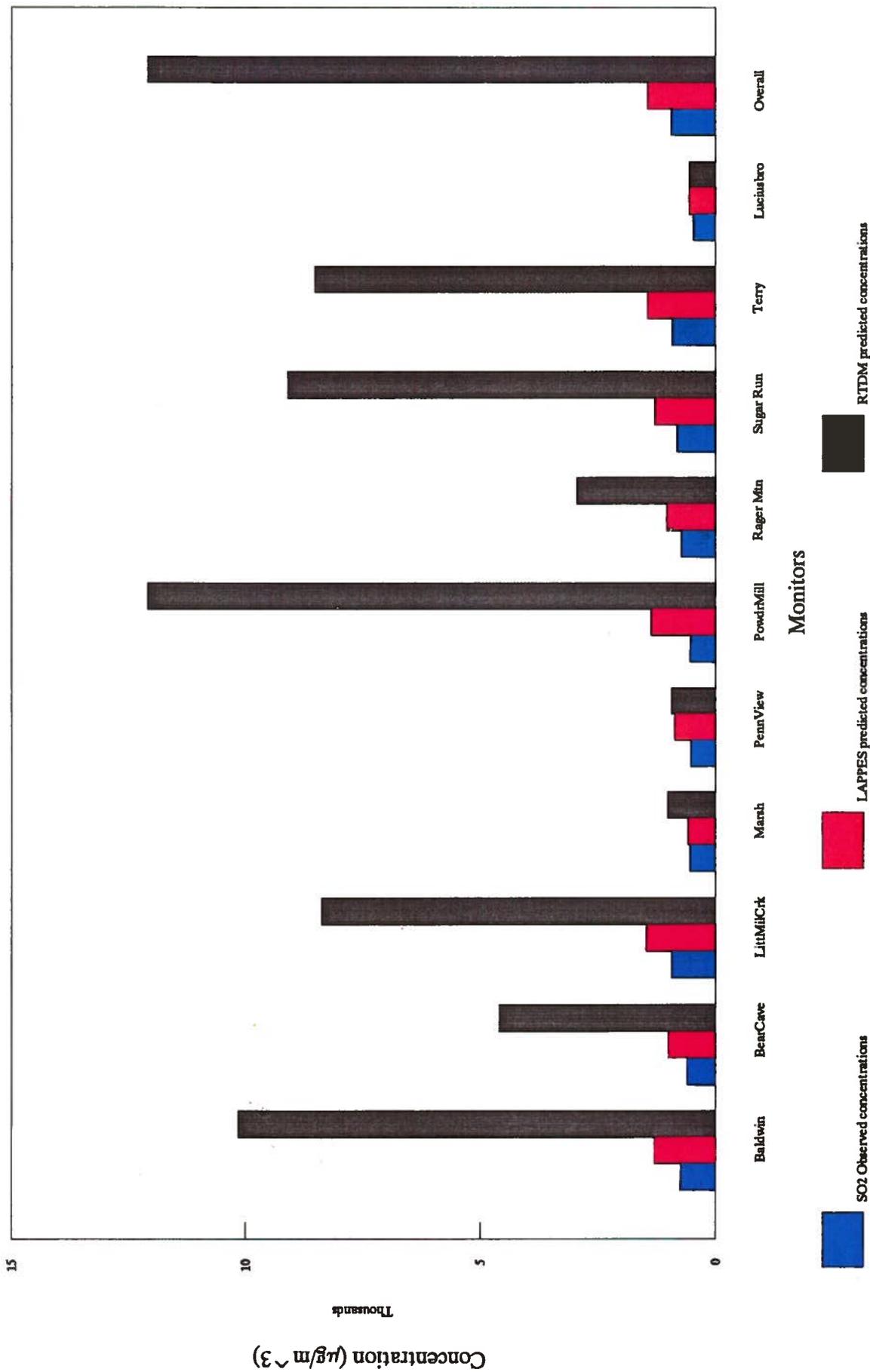


Figure 5-3
 Comparisons of the Modeled and Monitored
 High Second High 3-Hour Average Concentrations ($\mu\text{g}/\text{m}^3$)

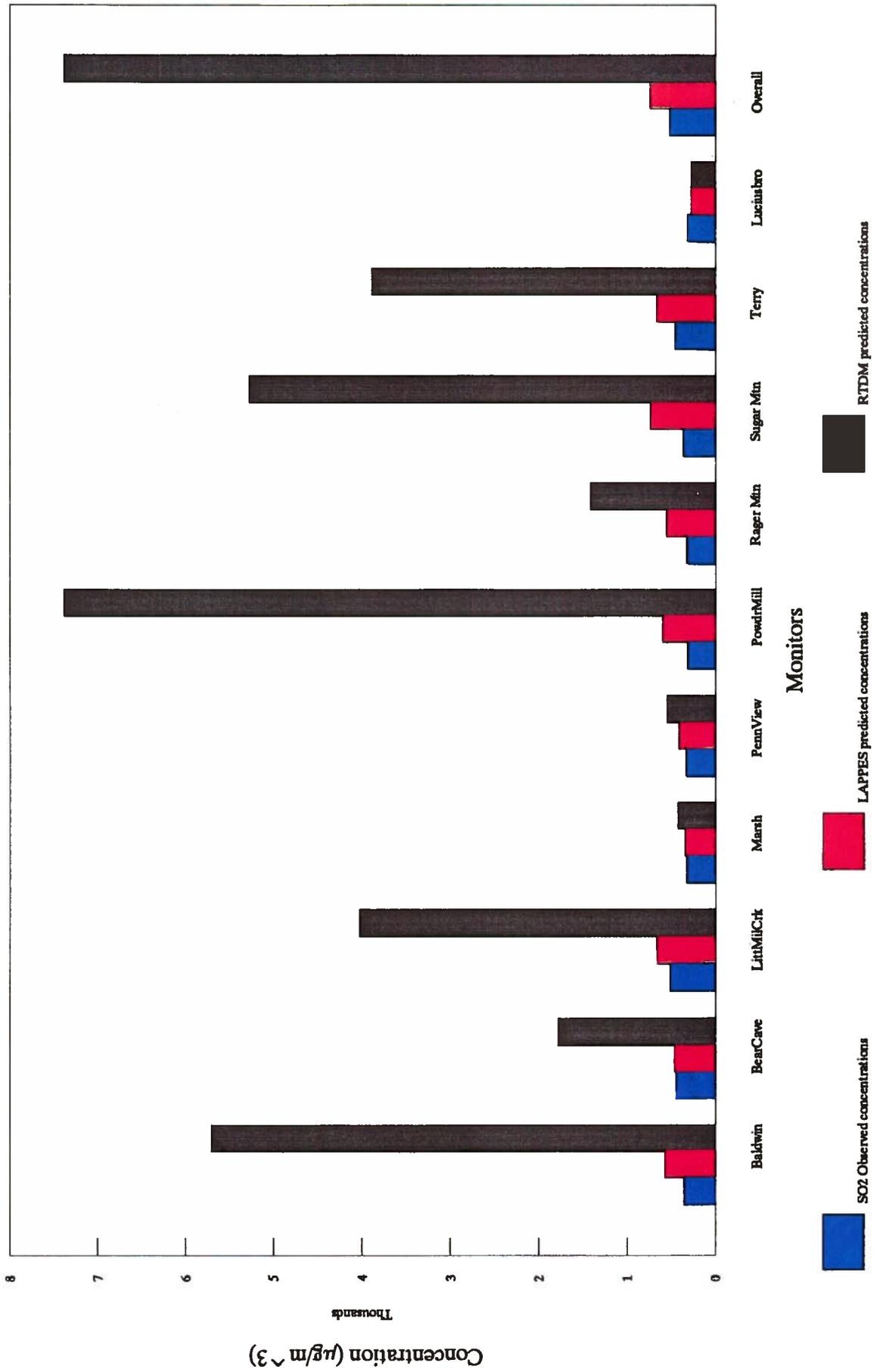
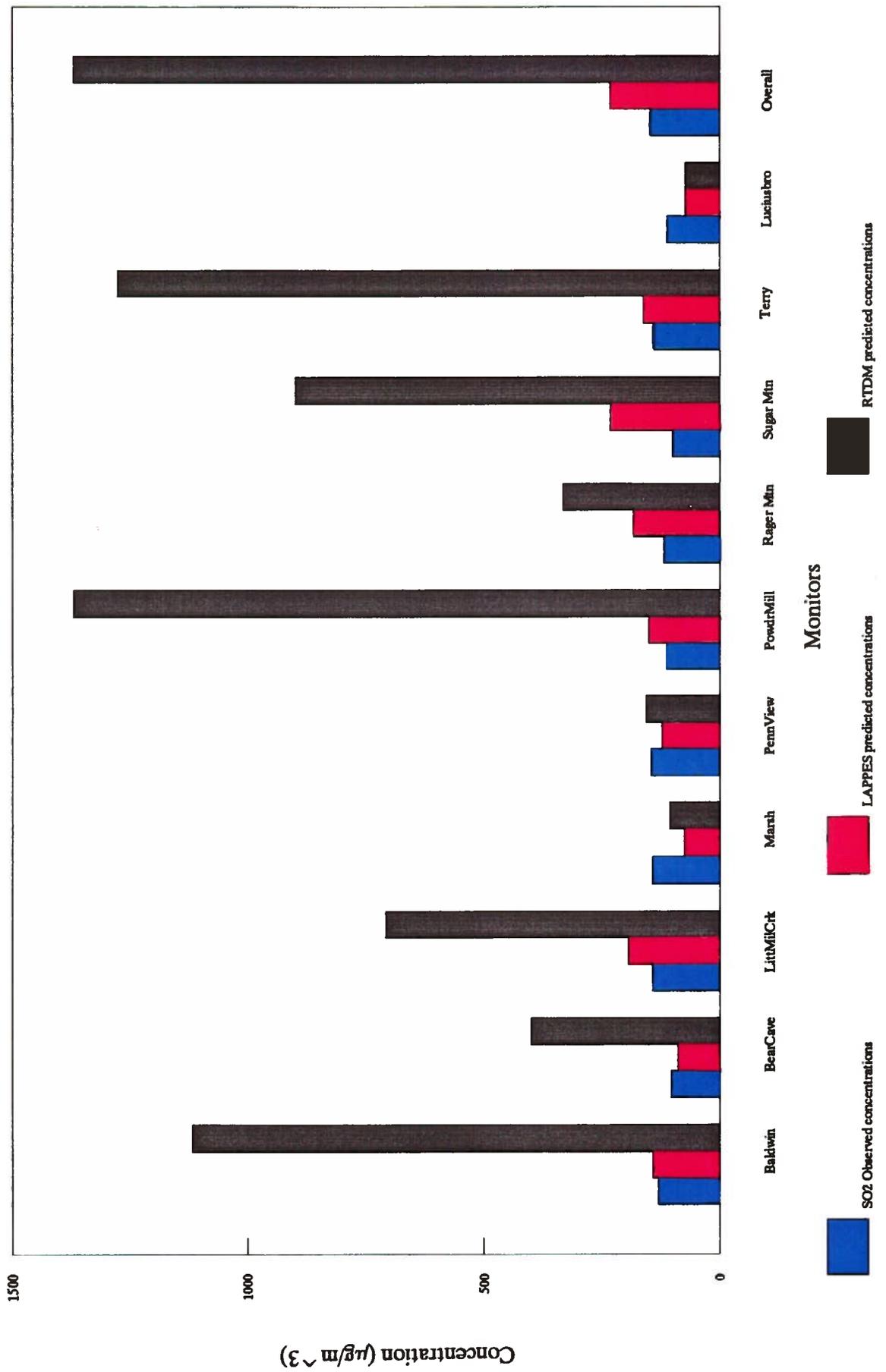


Figure 5-4
 Comparisons of the Modeled and Monitored
 High Second High 24-Hour Average Concentrations ($\mu\text{g}/\text{m}^3$)



Although the scoring results do not indicate which model performed better in this measure, Figure 5-5, for example, definitely demonstrates that the LAPPES model's predictions were much better than those of the RTDM/MPTER model.

5.4 Second High by Meteorological Category

The performance of Gaussian dispersion models can be dependent upon meteorological conditions. Therefore the measured and predicted SO₂ concentration data were sorted into five stability/wind speed categories based on the classifications described in Section 4.2 so that model performance could be graded by meteorology. The distribution of hours by category was used to determine the number of predicted and observed values to be compared in the next performance measure. Table 5-3 and Figure 5-6 show the calculated distribution of hours by meteorological category for the Ash Valley data set. Appendix B contains detailed information regarding the observed data and modeled predictions for LAPPES and RTDM/MPTER sorted by meteorological category.

The models predicted the highest second-high concentrations more accurately under unstable atmospheric conditions (Category 1) than they did under stable conditions (Categories 4 and 5). RTDM/MPTER scored its first points of the evaluation on this measure, as it predicted within a factor of two in unstable and high wind speed neutral meteorology.

However, neither model scored any points for predictions during high wind speed stable meteorology conditions (Category 5). Under high wind speed neutral and stable conditions, the LAPPES SO₂ concentration predictions were much closer to the monitored values than were the predictions from RTDM/MPTER. LAPPES scored points in Categories 1 through 4 and missed scoring in Category 5 by overpredicting by just over a factor of two (AFB of 0.81). The RTDM/MPTER SO₂ concentration predictions were much higher in Categories 2,

Figure 5-5
 Comparisons of the Modeled and Monitored
 Top 20 3-Hour Average Concentrations ($\mu\text{g}/\text{m}^3$)

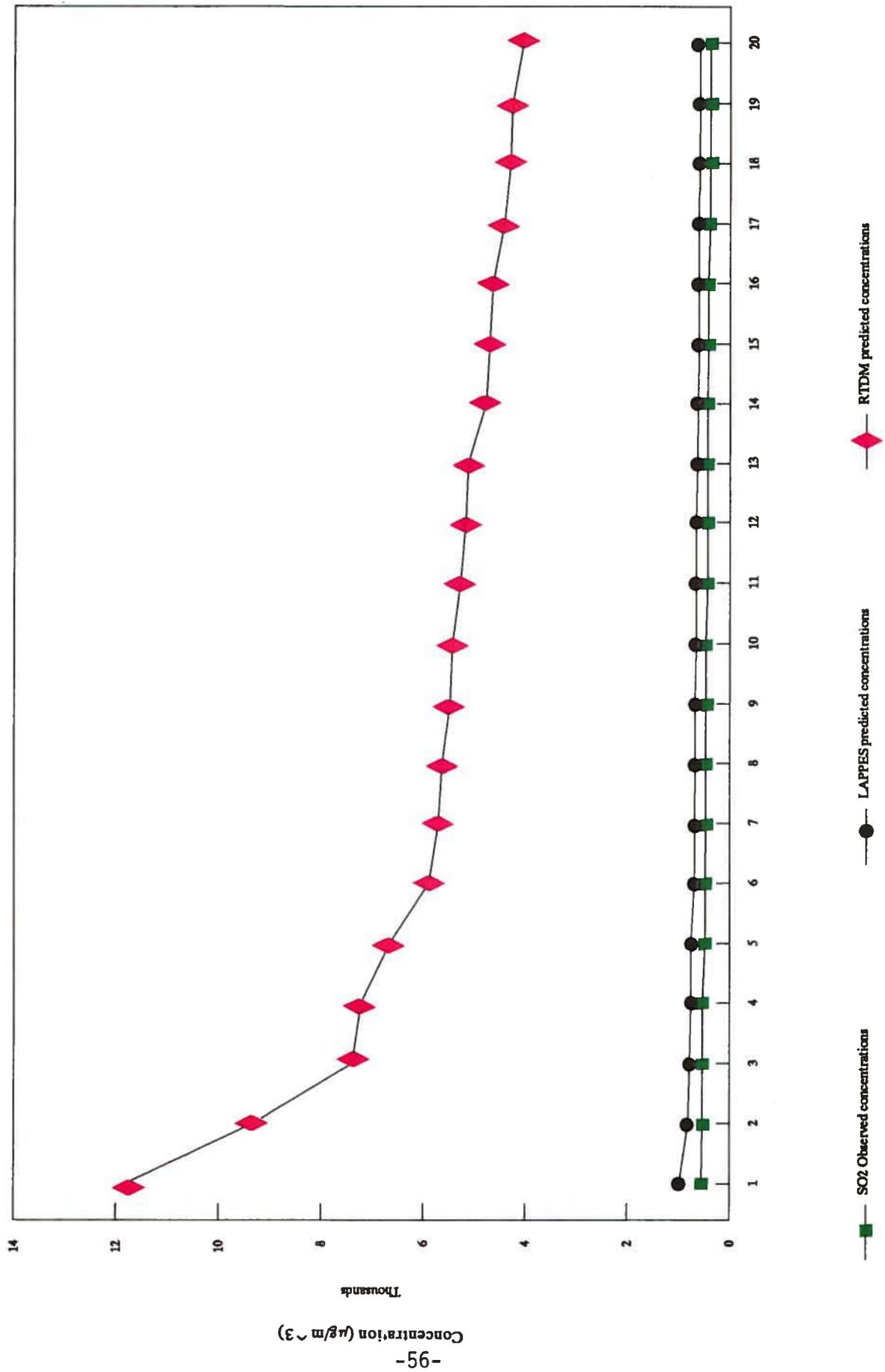


TABLE 5-3

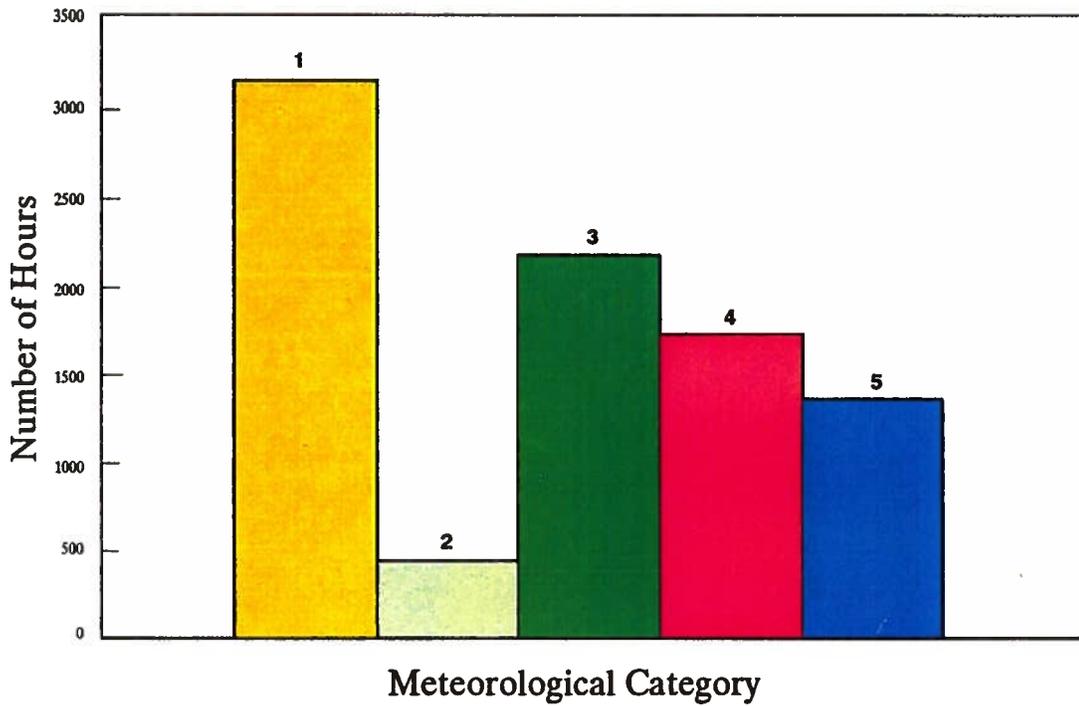
DISTRIBUTION OF HOURS
BY METEOROLOGICAL CATEGORY
FROM THE ASH VALLEY DATA SET

Meteorological Category	Number of Hours	One Percent of Hours (N)
1	3,154	32 *25
2	405	4 *10
3	2,154	22
4	1,706	17
5	1,341	13

* (10 < = N < = 25)

Figure 5-6

Distribution of Hours
by Meteorological Category
from the Ash Valley Data Set



- 1 = unstable, low wind speed
- 2 = neutral, low wind speed
- 3 = neutral, high wind speed
- 4 = stable, low wind speed
- 5 = stable, high wind speed

4 and 5, with the highest overpredictions occurring in stable, low wind speed conditions (Category 4). For this category, LAPPES had a fractional bias of 0.55 compared to a fractional bias of 1.75 for RTDM/MPTER. Although not fully reflected in the scoring, the performance of LAPPES in three of the five meteorological categories was considerably better than that of RTDM/MPTER for predicting the magnitude of the highest second-high 1-hour average values.

5.5 Top N Values Sorted by Meteorological Category

For each model, the top N values were compared for each of the five meteorological categories described above.

In support of the results discussed in Section 5.4, both models again scored points when the averages of the top 25 concentrations measured and predicted in unstable meteorological conditions (Category 1) were examined. In this case, LAPPES underpredicted by approximately 16 percent, while RTDM/MPTER overpredicted by approximately 15 percent. For meteorological category 2, LAPPES overpredicted by less than a factor of 1.6. For stable and low wind speed conditions (Category 4), RTDM/MPTER overpredicted by approximately a factor of 16, while LAPPES overpredicted by approximately a factor of two. However, no points were attained by either model in any meteorological category other than category 1.

5.6 All Values Paired in Time and Space

Predictions for both models were evaluated at each monitor location, for each hour of the study period. The absolute fractional bias on average differences for all values was calculated, as well as the mean square error, normalized by the average observed value. Most Gaussian formulations have trouble with this measure. Point by point correlations are typically low, but this is not considered important because only the maximum or second-high

values for a given averaging time, regardless of location, are typically used in regulatory modeling. Point by point fractional bias and the normalized error were very large for both models in this study. Neither model scored any points on this measure.

5.7 Annual Average: Highest Observed vs. Highest Predicted

LAPPES performed better than RTDM/MPTER in predicting the overall highest annual average. LAPPES also predicted the location correctly for this performance measure. However, the highest predicted annual average SO₂ concentration was 23 percent lower than the actual observed value at the Rager Mountain monitor site (M7). RTDM/MPTER overpredicted for this measure by a factor of over two and did not score any points.

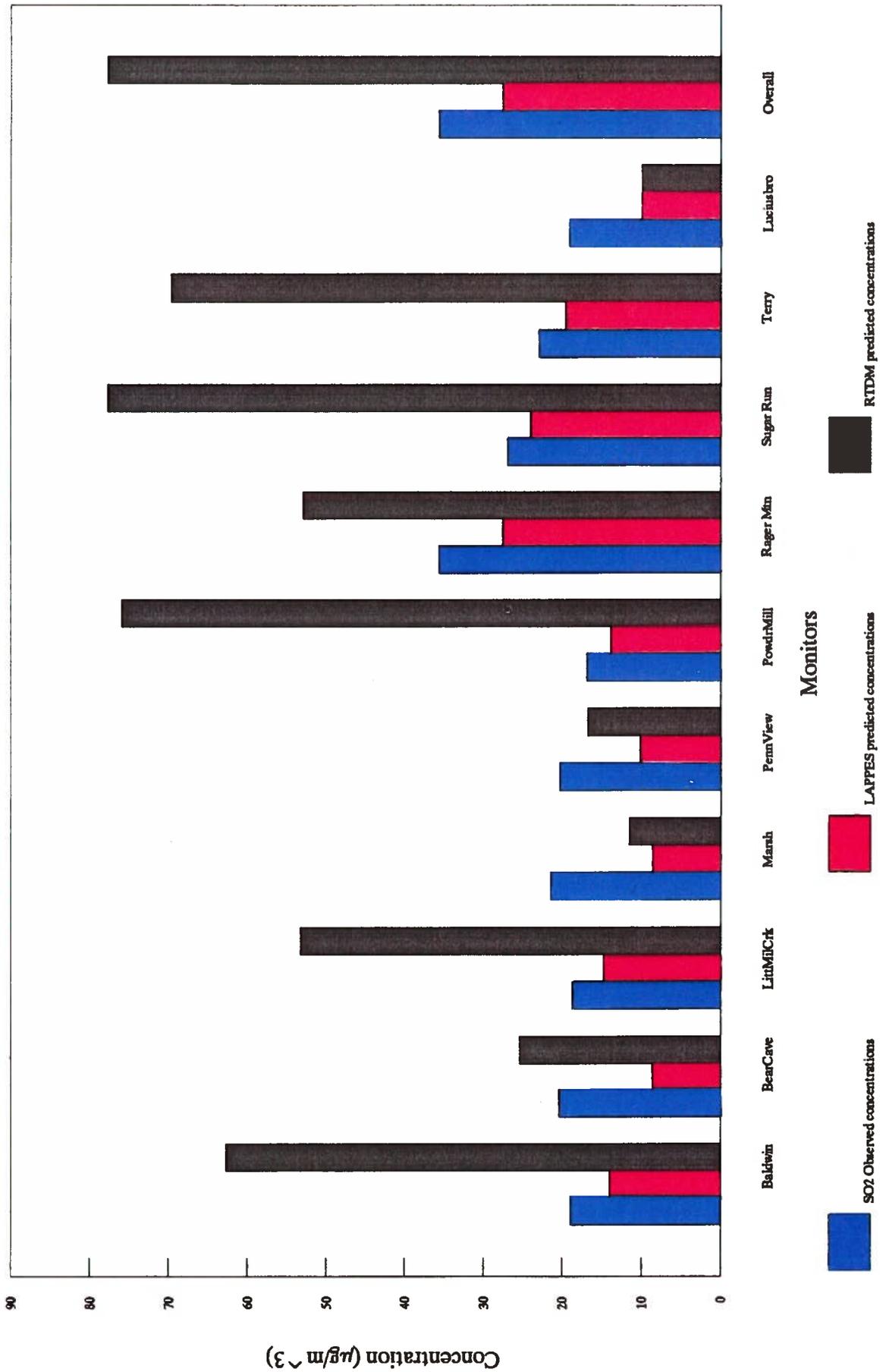
5.8 Annual Average: Average Observed vs. Average Predicted

LAPPES performed reasonably well when averages of the annual average model predictions and observed values were compared. However, LAPPES underpredicted the average annual observed value at all the monitoring locations. Nonetheless, the average predicted value over all locations was within 32 percent of the average of the annual observed values.

RTDM/MPTER again overpredicted by a factor of over two for the average of the annual values. As did LAPPES, RTDM/MPTER also underpredicted for the Marshall Heights (M4), Penn View (M5) and Luciusboro (M10) monitoring locations. At the Powermill Run (M6) monitor, RTDM/MPTER overpredicted by a factor of approximately 4.5.

As shown in Figure 5-7, the LAPPES model always underpredicted the annual average concentrations, while RTDM/MPTER frequently greatly overpredicted the concentrations.

Figure 5-7
 Comparisons of the Modeled and Monitored
 High Annual Average Concentrations ($\mu\text{g}/\text{m}^3$)



6.0 CONCLUSIONS

LAPPES/MPTEP clearly outperformed the reference model in this revised study. The total score for LAPPES/MPTEP was 52.03, and this was much greater than the 2.73 points scored by the reference model, RTDM/MPTEP. The point total for the LAPPES/MPTEP model also exceeded the 30 points required of an alternative model by the model comparison protocol. LAPPES/MPTEP overpredicted on the 3- and 24-hour average Top N measured values by approximately a factor of 1.5 for both cases, therefore no underprediction correction will be necessary.

In general, the study pointed out some of the known weaknesses of the Gaussian models. They do not predict well in stable atmospheric circumstances where local flows may dominate and the spatial representativeness of single point meteorology is limited. These types of models also generally do poorly in point by point comparison statistics because small, short period atmospheric motions are simply impossible to anticipate or simulate exactly.

Conversely, LAPPES/MPTEP has demonstrated that it is a far superior model to RTDM/MPTEP at this site. The stringent cut-off which prevented either model from scoring if the prediction was over a factor of two greater than the observed value (or a factor of 1.5 in some of the scoring) means that a LAPPES/MPTEP prediction which was a factor of 2.5 greater than the observed value was given the same score (0) as an RTDM/MPTEP prediction that was 10 or more times larger than the observed value. This happened often in this study.

According to the model comparison protocol, the implications of this study are as follows:

- LAPPES/MPTEP will be applied to estimate impacts at elevated terrain locations above stack top on Laurel Ridge and Chestnut Ridge. Regulatory modeling procedures will be used to estimate impacts at any other locations.
- For Seward, RTDM/MPTEP will be used to predict impacts.

- MPTER will be used to predict impacts at all receptors below stack top, for each source.
- Receptor grids will utilize actual terrain elevations at receptor locations.
- Meteorological inputs will be developed using the same procedures applied for the performance comparison. Meteorological data collected for the performance comparison will be used for the model application.
- Emissions from all sources will be modeled at maximum load and maximum allowable emissions.
- Model options will be chosen to match those selected for the performance comparison.
- Hourly background concentrations will be determined from air quality measurements, following the performance comparison procedures.

7.0 REFERENCES

EPA, "User's Guide for MPTER - A Multiple Point Gaussian Dispersion Algorithm with Optional Terrain Adjustment," April 1980.

EPA, "Interim Procedures for Evaluating Air Quality Models (Revised)," 450/4-84-023, September 1984.

ERT, "User's Guide to the Rough Terrain Diffusion Model (RTDM) (Rev. 3.20)," Doc. #P-D535-585, July 1987.

Slowik, A.A., J.M. Austin, and G.N. Pica, "Plume Dispersion Modeling in Complex Terrain Under Stable Atmospheric Conditions," Paper for Presentation at the 70th Annual Meeting of the Air Pollution Control Association, June 1977.

TRC, "Modeling Analysis to Determine Predicted Concentrations and to Assess the Existing Monitoring Network for the Laurel Ridge/Chestnut Ridge Region," September 1987.

TRC, "Protocol for Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge," February 1991.

APPENDIX A

PERFORMANCE SCORING FOR LAUREL/CHESTNUT RIDGE
MODEL COMPARISON STUDY - SUMMARY OF STATISTICAL SCORING

MODEL COMPARISON STUDY
 SUMMARY OF STATISTICAL SCORING
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 M. ANDERSON 8/6/92

Penelec Ambient SO2 Monitors

name	elev	no.	UTM E	UTM N
M1 BALDWIN	2720 ft.	1	668.05	4466.68
M2 BEARCAVE	2623 ft.	2	650.66	4467.53
M3 LITTMCR	2640 ft.	3	669.65	4466.70
M4 MARSH	1890 ft.	4	655.76	4479.66
M5 PENNVIEW	2030 ft.	5	655.97	4477.32
M6 POWDRMILL	2584 ft.	6	667.42	4467.98
M7 RAGER MTN	2480 ft.	7	677.49	4477.86
M8 SUGAR RUN	2660 ft.	8	670.90	4469.90
M9 TERRY	2580 ft.	9	669.91	4469.39
M10 LUCIUSBORO	1660 ft.	10	660.50	4484.76

Performance Scoring :

1. HIGHEST SECOND-HIGH CONCENTRATION VALUES : ABSOLUTE FRACTIONAL BIAS

	Concentrations in $\mu\text{g}/\text{m}^3$			Absolute Fractional Bias		SCORE: = $P(1-1.5 \text{ AFB}), \text{AFB} \leq 2/3$ = 0.00, $\text{AFB} > 2/3$
	3-hour	24-hour	3-hour	24-hour	SCORE: LAPPES RTDM	
SO2 OBS.	525.73	167.95			3 hr 7.37	24 hr 7.79
LAPPES	740.54	231.99	0.3393	0.3202	0.00	0.00
RTDM	7383.24	1369.85	1.7341	1.5631		

Running Subtotals:
LAPPES 15.16
RTDM 0.00

2. HIGHEST SECOND HIGH BY STATION:

1-HOUR AVERAGE CONCENTRATION: HIGHEST SECOND-HIGH

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNWV	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
SO2 OBS.	736.20	607.80	928.50	542.30	518.80	534.50	725.70	817.40	914.40	463.70
LAPPES	1299.36	995.18	1472.57	579.28	856.13	1374.03	1028.68	1283.56	1440.69	549.86
RTDM	10148.70	4591.44	8362.16	1014.59	933.39	12074.25	2946.73	9082.95	8508.00	549.86

Concentrations in $\mu\text{g}/\text{m}^3$

2a. AVERAGE DIFFERENCE - 1 hour average

FB:

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNWV	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	AFB
	(observed - predicted) / (0.5(observed + predicted))										
LAPPES	-0.5533	-0.4833	-0.4532	-0.0659	-0.4907	-0.8798	-0.3454	-0.4438	-0.4469	-0.1700	0.4332
RTDM	-1.7295	-1.5324	-1.6002	-0.6067	-0.5710	-1.8304	-1.2096	-1.6697	-1.6118	-0.1700	1.2531
SCORE: = P(1 - 1.5 AFB), AFB <= 2/3 = 0.00, AFB > 2/3											LAPPES: 1.75 RTDM: 0.00

Running Subtotals:
LAPPES 16.91
RTDM 0.00

24-HOUR AVERAGE CONCENTRATION: HIGHEST SECOND - HIGH

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNWV	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
Concentrations in $\mu\text{g}/\text{m}^3$										
SO2 OBS.	129.49	103.33	142.85	143.50	145.85	112.21	118.63	99.81	139.18	111.73
LAPPES	141.75	88.57	194.18	76.02	122.21	149.68	182.57	231.99	160.91	72.06
RTDM	1117.38	399.44	707.48	106.26	156.35	1369.85	332.25	896.35	1275.07	72.06

2A. AVERAGE DIFFERENCE - 24 hour average

FB:

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNWV	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
(observed - predicted) / (0.5(observed + predicted))										
LAPPES	-0.0904	0.1538	-0.3046	0.6148	0.1764	-0.2862	-0.4246	-0.7967	-0.1448	0.4317
RTDM	-1.5846	-1.1779	-1.3280	0.2982	-0.0695	-1.6972	-0.9476	-1.5992	-1.6063	0.4317
										AFB
										0.3424
										1.0740

SCORE:
 = $P(1 - 1.5 \text{ AFB}), \text{ AFB} < 2/3$
 = $0.00, \text{ AFB} > 2/3$

LAPPES: 7.30
 RTDM: 0.00

Running Subtotals:
 LAPPES 38.28
 RTDM 0.00

3. Top N Values -- fractional bias on average values

3a. 1 -- hour (N = 25) Concentrations in µg/m3

Rank	SO2 OBS.	LAPES	RTDM
1	1032.30	1641.90	12864.80
2	982.50	1591.91	12074.25
3	945.80	1512.53	11966.89
4	943.20	1472.57	11437.26
5	922.20	1440.69	10970.30
6	914.40	1413.97	10834.92
7	822.70	1391.85	10409.07
8	817.40	1378.29	10408.97
9	788.60	1374.03	10341.76
10	772.90	1357.81	10180.34
11	770.30	1321.87	10148.7
12	765.00	1315.26	9959.96
13	757.20	1314.45	9798.45
14	749.30	1299.36	9533.84
15	746.70	1283.56	9506.57
16	736.20	1275.81	9338.52
17	733.60	1266.30	9315.87
18	725.70	1262.11	9288.62
19	723.10	1255.19	9097.51
20	720.50	1242.35	9082.95
21	712.60	1223.95	8900.11
22	712.60	1220.36	8822.72
23	702.20	1216.08	8691.91
24	696.90	1206.83	8598.60
25	694.30	1206.78	8508.78
Average Values	795.53	1339.43	10003.27

Fractional Bias On Average Values :

LAPES 0.509522
RTDM 1.705327

SCORE: P (1 - 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

0.00
0.00

Running Subtotals:

LAPES 42.90
RTDM 0.00

3b. 3 - hour (N = 20) Concentrations in $\mu\text{g}/\text{m}^3$

Rank	SO2 OBS.	LAPPES	RTDM
1	544.10	978.31	11826.13
2	525.73	802.41	7330.13
3	524.00	761.93	7383.24
4	524.00	740.54	7199.86
5	464.63	739.61	6646.04
6	464.63	671.07	5888.93
7	458.50	669.59	5705.61
8	458.50	668.57	5631.02
9	454.10	661.99	5468.92
10	454.10	648.24	5420.90
11	422.70	643.96	5270.73
12	422.70	639.28	5160.79
13	419.20	622.12	5118.91
14	419.20	607.72	4769.04
15	418.33	601.94	4702.67
16	410.47	601.24	4634.53
17	374.67	596.68	4412.92
18	374.67	591.91	4288.27
19	374.67	578.78	4253.96
20	374.67	577.87	4035.86

Average Values

444.18

670.19

5757.42

Fractional Bias On Average Values :

LAPPES 0.405629

RTDM 1.713507

SCORE: P (1 - 2.5 AFB), AFB \leq 0.4
0, AFB $>$ 0.4

0.00

0.00

Running Subtotals:

LAPPES 42.90

RTDM 0.00

3c. 24 - hour (N = 10) Concentrations in $\mu\text{g}/\text{m}^3$

Rank	SO2 OBS.	LAPPES	RTDM
1	174.88	286.07	1485.78
2	167.95	269.61	1369.85
3	146.99	254.00	1361.67
4	146.68	239.13	1290.67
5	145.84	235.21	1275.07
6	143.50	231.99	1207.49
7	143.50	217.08	1169.83
8	142.85	202.87	1117.38
9	142.85	194.18	1069.74
10	139.18	182.57	992.28

Average Values 149.42 231.27 1233.98

Fractional Bias On Average Values:

LAPPES 0.430000
 RTDM 1.567957

SCORE: P (1 - 2.5 AFB), AFB \leq 0.4
 0, AFB > 0.4

Running Subtotals:
 LAPPES 42.90
 RTDM 0.00

4. Second High By Meteorological Category
(1 - hour only, Five Categories)
Concentrations in $\mu\text{g}/\text{m}^3$

	Category 1	Category 2	Category 3	Category 4	Category 5
SO2 Obs.	945.80	626.20	725.70	817.40	676.00
LAPPES	765.30	781.47	1314.45	1440.69	1591.91
RTDM	968.74	1392.8	1377.88	12074.25	4685.21

Fractional Bias :					
	Category 1	Category 2	Category 3	Category 4	Category 5
LAPPES	0.210975	0.220606	0.577163	0.552051	0.807713
RTDM	0.023964	0.759386	0.620067	1.746378	1.495636

SCORE: P (1-1.5*AFB) , AFB <= 2/3					
	Category 1	Category 2	Category 3	Category 4	Category 5
LAPPES	1.367074	1.338183	0.268510	0.343848	0.00
RTDM	1.928108	0.00	0.139800	0.00	0.00

Subtotal:
3.317615
2.067908

Running
Subtotals:
LAPPES 46.21
RTDM 2.07

5. Top N Values by Meteorological Category
 (1 – hour only, Five Categories)
 Concentrations in $\mu\text{g}/\text{m}^3$

N = one percent of hours in category

Fractional bias on average values – each category

Scoring: 5 points (1 point each category)

Number of Hours In Each Category :		N
cat	hours	1%
1	3154	32 *25
2	405	4 *10
3	2154	22
4	1706	17
5	1341	13

* 10 \leq N \leq 25

Category 1 Top N (N=25) Hours 1 - hour Concentration in $\mu\text{g}/\text{m}^3$				
Rank	S02 Obs.	LAPPES	RTDM	
1	1032.30	929.57	1062.23	
2	945.80	765.30	968.74	
3	943.20	743.95	944.96	
4	922.20	723.13	925.92	
5	914.40	716.88	909.48	
6	822.70	692.42	907.38	
7	772.90	646.09	883.31	
8	770.30	626.08	881.39	
9	765.00	623.36	872.55	
10	757.20	623.02	861.31	
11	749.30	613.10	851.93	
12	723.10	598.26	843.68	
13	712.60	593.75	837.52	
14	696.90	589.14	831.74	
15	694.30	585.75	818.56	
16	689.10	582.09	816.51	
17	676.00	571.19	815.92	
18	662.90	569.73	815.91	
19	655.00	569.71	814.94	
20	652.40	568.11	807.90	
21	649.80	566.83	804.02	
22	641.90	564.80	801.45	
23	636.70	563.77	790.02	
24	620.90	558.90	786.52	
25	613.10	556.13	785.14	

Average Values : 748.80 629.64 857.56

Fractional Bias on Average Values : SCORE: P (1 - 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

LAPPES 0.172887 0.567762

RTDM 0.135413 0.661467

Running Subtotals:
LAPPES 46.78
RTDM 2.73

Category 2 Top N (N=10) Hours 1 - hour Concentration in $\mu\text{g}/\text{m}^3$				
Rank	SO2 Obs.	LAPPES	RTDM	
1	720.50	1255.19	1408.60	
2	626.20	781.47	1392.80	
3	448.00	724.16	1332.03	
4	445.40	715.56	1220.68	
5	432.30	689.53	1093.27	
6	419.20	666.48	992.61	
7	408.70	627.39	911.39	
8	398.20	615.97	908.68	
9	393.00	598.81	829.57	
10	387.80	598.51	803.78	

Average Values : 467.93

727.31

1089.34

Fractional Bias on Average Values :

SCORE: P (1 - 2.5 AFB), AFB \leq 0.4
0, AFB $>$ 0.4

LAPPES 0.434018

0.00

RTDM 0.798077

0.00

Running Subtotals:
LAPPES
RTDM

46.78
2.73

Category 3 Top N (N=22) Hours 1 - hour Concentration in $\mu\text{g}/\text{m}^3$				
Rank	SO2 Obs.	LAPES	RTDM	
1	746.70	1321.87	1557.45	
2	725.70	1314.45	1377.38	
3	550.20	1180.20	1282.77	
4	542.30	1173.37	1244.06	
5	534.50	1158.02	1216.84	
6	487.30	1068.12	1207.70	
7	461.10	1067.39	1188.27	
8	427.10	1031.33	1184.32	
9	424.40	1011.16	1140.78	
10	421.80	970.87	1130.92	
11	419.20	952.54	1122.17	
12	414.00	901.06	1115.68	
13	403.50	892.45	1058.49	
14	403.50	856.95	1042.60	
15	398.20	848.27	1008.59	
16	398.20	843.92	981.55	
17	390.40	830.03	972.74	
18	382.50	806.22	953.34	
19	379.90	801.94	924.53	
20	366.80	799.92	911.06	
21	364.20	793.11	904.13	
22	353.70	789.61	885.13	

Average Values : 454.33 973.31 1109.57

Fractional Bias on Average Values : SCORE: P (1 - 2.5 AFB), AFB \leq 0.4
0, AFB > 0.4

LAPES 0.72705 0.00

RTDM 0.83796 0.00

Running Subtotals:
LAPES
RTDM

46.78
2.73

Category 4 Top N (N=17) Hours 1 - hour Concentration in $\mu\text{g}/\text{m}^3$				
Rank	SO2 Obs.	LAPPES	RTDM	
1	982.50	1512.53	12864.80	
2	817.40	1440.69	12074.25	
3	788.60	1413.97	11966.89	
4	736.20	1391.85	11437.06	
5	733.60	1378.29	10970.30	
6	712.60	1374.03	10834.92	
7	681.20	1357.81	10409.07	
8	652.40	1315.26	10408.97	
9	584.30	1299.36	10341.76	
10	537.10	1283.56	10180.34	
11	518.80	1275.81	10148.70	
12	510.90	1266.30	9959.96	
13	503.00	1262.11	9798.45	
14	495.20	1242.35	9533.84	
15	492.60	1223.95	9506.57	
16	489.90	1216.08	9338.52	
17	474.20	1206.83	9315.87	

Average Values : 673.74 1351.66 10876.57

Fractional Bias on Average Values : SCORE: P (1 - 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

LAPPES 0.669420 0.00
RTDM 1.766677 0.00

Running Subtotals:
LAPPES 46.78
RTDM 2.73



Category 5
Top N (N=13) Hours
1 - hour Concentration in $\mu\text{g}/\text{m}^3$

Rank	SO2 Obs.	LAPPES	RTDM
1	702.20	1641.90	5345.56
2	676.00	1591.91	4685.21
3	600.00	1472.57	4517.95
4	586.90	1220.36	4355.83
5	571.20	1206.78	4203.94
6	568.50	1136.82	3993.08
7	563.30	1104.63	3805.17
8	560.70	946.21	3795.14
9	542.30	942.55	3794.04
10	516.10	941.06	3785.69
11	510.90	929.17	3757.63
12	510.90	896.82	3746.29
13	503.00	889.64	3726.35

Average Values : 570.15 1147.72 4116.30

Fractional Bias on Average Values : SCORE: P (1 - 2.5 AFB), AFB \leq 0.4
0, AFB $>$ 0.4

LAPPES 0.672423 0.00
RTDM 1.51336 0.00

Running Subtotals:
LAPPES 46.78
RTDM 2.73



6. All Values – Paired in time and Location

a. Average Difference – fractional bias

THE AVERAGE FRACTIONAL BIAS FOR LAPPES IS: 1.57
THE AVERAGE FRACTIONAL BIAS FOR RTDM IS : 1.56

b. MS Error (normalized)

THE NRMSE FOR LAPPES IS: 3.71
THE NRMSE FOR RTDM IS : 16.50

SCORING: No points (NRMSE > 2, AFB > 2/3)

7. Annual Average – Each Station

- a. Highest Observed vs. Highest Predicted (fractional bias)
- b. Average Observed vs. Average Predicted (fractional bias)

Average by station :	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNWV	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
SO2 Obs.	18.94	20.35	18.70	21.47	20.33	16.92	35.58	26.93	22.98	19.11
LAPPES	13.94	8.59	14.75	8.59	10.16	13.80	27.52	24.07	19.58	9.94
RTDM	62.68	25.40	53.22	11.52	16.76	75.95	52.91	77.70	69.65	9.94

a. Highest Observed = 35.58
 LAPPES Highest = 27.52
 RTDM Highest = 77.70

fractional bias = 0.255468
 fractional bias = 0.743644

a. LAPPES score = 3.063994
 a. RTDM score = 0.00

b. Average Observed = 22.13
 LAPPES Average = 15.09
 RTDM Average = 45.57

fractional bias = 0.378079
 fractional bias = 0.692485

b. LAPPES score = 2.164406
 b. RTDM score = 0.00

GRAND
 TOTALS :
 LAPPES 52.03
 RTDM 2.73

APPENDIX B

LISTINGS OF 25 MAXIMUM CONCENTRATIONS
BY METEOROLOGICAL CATEGORY

**Top 25 1-hour Average SO₂ Concentrations
 Predicted by LAPPES, Sorted by
 Meteorological Category**

Category 1			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	929.57	30,18	1
2	765.30	152,17	1
3	743.95	30,17	1
4	723.13	168,12	1
5	716.88	168,12	1
6	692.42	152,17	1
7	646.09	152,13	1
8	629.08	222,17	1
9	623.36	69,14	1
10	623.02	164,11	1
11	613.10	147,16	1
12	598.26	182,15	1
13	593.75	263,18	1
14	589.14	17,15	1
15	585.75	69,16	1
16	582.09	190,11	1
17	571.19	344,15	1
18	569.73	213,15	1
19	569.71	152,18	1
20	568.11	241,14	1
21	566.83	152,16	1
22	564.80	213,16	1
23	563.77	130,15	1
24	558.90	222,17	1
25	556.13	13,13	1

Top 25 1-hour Average SO₂ Concentrations
 Predicted by LAPPES, Sorted by
 Meteorological Category

Category 2			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1255.19	297,19	2
2	781.47	79,19	2
3	724.16	39,03	2
4	715.56	297,19	2
5	689.53	351,03	2
6	666.48	6,22	2
7	627.39	318,05	2
8	615.97	89,21	2
9	598.81	39,03	2
10	598.51	351,03	2
11	592.19	79,19	2
12	589.37	351,03	2
13	579.78	351,03	2
14	556.45	284,19	2
15	523.93	39,05	2
16	520.72	39,05	2
17	515.95	323,21	2
18	487.55	6,24	2
19	472.62	297,19	2
20	469.81	6,20	2
21	458.95	89,21	2
22	443.72	30,19	2
23	430.30	6,23	2
24	416.96	56,07	2
25	338.95	351,03	2

Top 25 1-hour Average SO₂ Concentrations
 Predicted by LAPPES, Sorted by
 Meteorological Category

Category 3			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1321.87	2,24	3
2	1314.45	38,21	3
3	1180.20	2,24	3
4	1173.37	84,19	3
5	1158.02	38,18	3
6	1068.21	84,19	3
7	1067.39	219,21	3
8	1031.33	38,23	3
9	1011.16	38,22	3
10	970.87	38,18	3
11	952.54	218,24	3
12	901.06	38,24	3
13	892.45	38,24	3
14	856.95	39,02	3
15	848.27	108,01	3
16	843.92	54,07	3
17	830.03	39,01	3
18	806.22	299,02	3
19	801.94	2,24	3
20	799.92	219,21	3
21	793.11	38,21	3
22	789.61	84,19	3
23	769.69	57,19	3
24	752.62	56,02	3
25	742.25	260,22	3

Top 25 1-hour Average SO₂ Concentrations
 Predicted by LAPPES, Sorted by
 Meteorological Category

Category 4			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1512.53	219,22	4
2	1440.69	298,09	4
3	1413.97	10,09	4
4	1391.85	219,22	4
5	1378.29	219,22	4
6	1374.03	171,07	4
7	1357.81	171,07	4
8	1315.26	10,09	4
9	1299.36	340,22	4
10	1283.56	324,09	4
11	1275.81	197,23	4
12	1266.30	1,02	4
13	1262.11	184,04	4
14	1242.35	351,02	4
15	1223.95	351,02	4
16	1216.08	184,04	4
17	1206.83	353,20	4
18	1203.64	324,21	4
19	1184.39	184,07	4
20	1168.16	192,01	4
21	1154.57	261,02	4
22	1150.09	351,04	4
23	1148.64	171,07	4
24	1143.56	71,03	4
25	1137.18	36,23	4

**Top 25 1-hour Average SO₂ Concentrations
 Predicted by LAPPES, Sorted by
 Meteorological Category**

Category 5			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1641.90	299,23	5
2	1591.91	3,03	5
3	1472.57	213,05	5
4	1220.36	164,22	5
5	1206.78	213,05	5
6	1136.82	164,22	5
7	1104.63	299,23	5
8	946.21	213,05	5
9	942.55	244,23	5
10	941.06	107,03	5
11	929.17	31,23	5
12	896.82	164,22	5
13	889.64	2,23	5
14	851.41	73,03	5
15	848.02	2,21	5
16	808.30	128,21	5
17	790.27	58,06	5
18	749.06	54,20	5
19	737.69	139,01	5
20	737.04	57,20	5
21	725.07	336,23	5
22	718.10	3,03	5
23	705.85	134,23	5
24	699.21	155,05	5
25	696.11	327,08	5

Top 25 1-hour Average SO₂ Concentrations
 Predicted by RTDM, Sorted by
 Meteorological Category

Category 1			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1062.23	168,12	1
2	968.74	168,12	1
3	944.96	164,11	1
4	925.92	30,18	1
5	909.48	182,15	1
6	907.38	124,18	1
7	883.31	17,15	1
8	881.39	168,12	1
9	872.55	152,17	1
10	861.31	124,14	1
11	851.93	213,12	1
12	843.68	168,13	1
13	837.52	115,12	1
14	831.74	182,16	1
15	818.56	168,13	1
16	816.51	69,14	1
17	815.92	213,12	1
18	815.91	69,16	1
19	814.94	152,16	1
20	807.90	152,13	1
21	804.02	152,17	1
22	801.45	196,13	1
23	790.02	152,18	1
24	786.52	152,15	1
25	785.14	344,15	1

**Top 25 1-hour Average SO₂ Concentrations
 Predicted by RTDM, Sorted by
 Meteorological Category**

Category 2			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1408.60	284,20	2
2	1392.80	284,20	2
3	1332.03	284,20	2
4	1220.68	297,19	2
5	1093.27	351,03	2
6	992.61	25,09	2
7	911.39	284,20	2
8	908.68	284,20	2
9	829.57	6,22	2
10	803.78	297,19	2
11	774.74	284,20	2
12	739.03	318,05	2
13	735.60	79,19	2
14	731.02	213,07	2
15	716.11	213,07	2
16	709.54	6,23	2
17	680.90	213,07	2
18	657.03	6,09	2
19	648.23	39,05	2
20	622.64	122,22	2
21	608.95	323,21	2
22	605.04	39,03	2
23	603.74	6,24	2
24	600.42	39,03	2
25	599.93	297,19	2

Top 25 1-hour Average SO₂ Concentrations
 Predicted by RTDM, Sorted by
 Meteorological Category

Category 3			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1557.45	2,24	3
2	1377.38	2,24	3
3	1282.77	2,24	3
4	1244.06	84,19	3
5	1216.84	2,24	3
6	1207.70	2,24	3
7	1188.27	38,21	3
8	1184.32	38,22	3
9	1140.78	219,21	3
10	1130.92	38,23	3
11	1122.17	84,19	3
12	1115.68	38,18	3
13	1058.49	38,22	3
14	1042.60	38,23	3
15	1008.59	38,24	3
16	981.55	219,21	3
17	972.74	39,02	3
18	953.34	218,24	3
19	924.53	39,01	3
20	911.06	38,24	3
21	904.13	38,21	3
22	885.13	219,21	3
23	866.52	39,02	3
24	862.50	38,18	3
25	848.27	108,01	3

**Top 25 1-hour Average SO₂ Concentrations
 Predicted by RTDM, Sorted by
 Meteorological Category**

Category 4			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	12864.80	165,01	4
2	12074.25	36,24	4
3	11966.89	36,23	4
4	11437.26	36,22	4
5	10970.30	142,23	4
6	10834.92	341,07	4
7	10409.07	345,06	4
8	10408.97	75,05	4
9	10341.76	75,05	4
10	10180.34	360,23	4
11	10148.70	165,01	4
12	9959.96	36,24	4
13	9798.45	340,22	4
14	9533.84	133,21	4
15	9506.57	152,23	4
16	9338.52	36,23	4
17	9315.87	341,07	4
18	9288.62	69,02	4
19	9097.51	75,01	4
20	9082.95	131,01	4
21	8900.11	183,06	4
22	8822.72	219,24	4
23	8691.91	36,22	4
24	8598.60	36,24	4
25	8508.78	131,01	4

Top 25 1-hour Average SO₂ Concentrations
 Predicted by RTDM, Sorted by
 Meteorological Category

Category 5			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	5345.56	190,01	5
2	4685.21	213,23	5
3	4517.95	138,03	5
4	4355.83	134,24	5
5	4203.94	134,02	5
6	3993.08	190,01	5
7	3805.17	217,22	5
8	3795.14	69,05	5
9	3794.04	101,04	5
10	3785.69	30,09	5
11	3757.63	44,23	5
12	3746.29	258,21	5
13	3726.35	134,02	5
14	3720.33	3,03	5
15	3715.98	137,22	5
16	3691.50	128,21	5
17	3662.00	30,09	5
18	3613.55	213,04	5
19	3536.18	101,04	5
20	3519.53	101,02	5
21	3506.18	213,23	5
22	3470.28	107,02	5
23	3431.97	3,03	5
24	3350.92	121,21	5
25	3308.03	134,24	5

Top 25 1-hour Average Measured SO2 Concentrations
Sorted by Meteorological Category

Category 1			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	1032.20	131,12	1
2	945.80	253,12	1
3	943.20	128,11	1
4	922.20	177,11	1
5	914.40	323,14	1
6	822.70	75,13	1
7	772.90	223,12	1
8	770.30	128,13	1
9	765.00	238,13	1
10	757.20	270,15	1
11	749.30	323,13	1
12	723.10	227,10	1
13	712.60	342,12	1
14	696.90	131,14	1
15	694.30	227,10	1
16	689.10	324,12	1
17	676.00	75,12	1
18	662.90	270,14	1
19	655.00	160,13	1
20	652.40	323,13	1
21	649.80	128,12	1
22	641.90	240,09	1
23	636.70	223,12	1
24	620.90	128,16	1
25	613.10	261,15	1

Top 25 1-hour Average Measured SO₂ Concentrations
Sorted by Meteorological Category

Category 2			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	720.50	224,08	2
2	626.20	254,08	2
3	448.00	324,10	2
4	445.40	227,09	2
5	432.30	197,08	2
6	419.20	354,09	2
7	408.70	144,07	2
8	398.20	253,09	2
9	393.00	164,08	2
10	387.80	107,09	2
11	382.50	220,08	2
12	356.30	227,09	2
13	351.10	254,08	2
14	343.20	194,24	2
15	322.30	93,03	2
16	309.20	144,07	2
17	254.10	354,08	2
18	230.60	324,10	2
19	222.70	37,20	2
20	217.50	254,08	2
21	214.80	171,08	2
22	212.20	254,08	2
23	212.20	235,09	2
24	212.20	289,20	2
25	209.60	71,10	2

Top 25 1-hour Average Measured SO2 Concentrations
Sorted by Meteorological Category

Category 3			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	746.70	359,24	3
2	725.70	319,08	3
3	550.20	305,03	3
4	542.30	195,21	3
5	534.50	40,24	3
6	487.30	234,09	3
7	461.10	166,08	3
8	427.10	240,08	3
9	424.40	52,23	3
10	421.80	161,08	3
11	419.20	19,09	3
12	414.00	52,24	3
13	403.50	60,20	3
14	403.50	77,22	3
15	398.20	342,11	3
16	398.20	305,10	3
17	390.40	234,24	3
18	382.50	53,01	3
19	379.90	100,24	3
20	366.80	319,24	3
21	364.20	121,01	3
22	353.70	31,01	3
23	345.80	39,22	3
24	345.80	11,02	3
25	343.20	53,06	3

Top 25 1-hour Average Measured SO2 Concentrations
Sorted by Meteorological Category

Category 4			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	982.50	85,02	4
2	817.40	68,08	4
3	788.60	85,01	4
4	736.20	228,04	4
5	733.60	68,09	4
6	712.60	227,06	4
7	681.20	107,04	4
8	652.40	234,07	4
9	584.30	228,03	4
10	537.10	157,06	4
11	518.80	194,23	4
12	510.90	228,04	4
13	503.00	235,07	4
14	495.20	68,09	4
15	492.60	298,02	4
16	489.90	68,08	4
17	474.20	85,02	4
18	463.70	93,06	4
19	453.30	241,03	4
20	448.00	235,06	4
21	442.80	85,01	4
22	434.90	234,05	4
23	434.90	85,02	4
24	429.70	345,08	4
25	421.80	185,05	4

**Top 25 1-hour Average Measured SO₂ Concentrations
Sorted by Meteorological Category**

Category 5			
Rank	Concentration ($\mu\text{g}/\text{m}^3$)	Day,hr	Meteorological Category
1	702.20	240,07	5
2	676.00	44,03	5
3	600.00	319,07	5
4	586.90	43,24	5
5	571.20	129,06	5
6	568.50	305,08	5
7	563.30	319,06	5
8	560.70	318,24	5
9	542.30	305,09	5
10	516.10	166,06	5
11	510.90	346,08	5
12	510.90	240,07	5
13	503.00	346,02	5
14	503.00	346,05	5
15	497.80	346,01	5
16	497.80	345,23	5
17	489.90	30,08	5
18	487.30	163,01	5
19	484.70	43,24	5
20	469.00	359,23	5
21	437.50	305,01	5
22	437.50	330,24	5
23	432.30	342,08	5
24	429.70	43,24	5
25	427.10	346,04	5

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Attachment D

TRC 2003 AERMOD Modeling Analysis for SO₂ NAAQS for Laurel and Chestnut Ridges



Customer-Focused Solutions

AERMOD MODELING ANALYSES FOR SO₂ NAAQS COMPLIANCE FOR POWER PLANTS IN THE LAUREL RIDGE AND CHESTNUT RIDGE REGION OF PENNSYLVANIA

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EXECUTIVE SUMMARY

Reliant Energy Mid-Atlantic Power Holdings, LLC. (Reliant Energy) operates three major coal-fired electric generating facilities in the Laurel Ridge and Chestnut Ridge area of southwestern Pennsylvania: Keystone, Conemaugh and Seward. Another major power plant, Edison Mission Energy's Homer City Station (formerly operated by GPU Genco) is also located within this area. These plants are clustered over a relatively small geographical region with complex terrain, which has led to regulatory concerns regarding the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO₂).

This report is the latest update to the compliance demonstrations prepared at the behest of the Pennsylvania Department of Environmental Protection (PADEP). The informal request to update the modeling resulted from emission source changes at Seward Generating Station due to the Seward CFB Repowering Project. This study supersedes the supplemental AERMOD Modeling Analyses for SO₂ NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania (TRC, 1999) that were performed in support of the Modeling Analyses for SO₂ NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania (Compliance Demonstration). These original analyses were performed using the Multiple Point with Terrain (MP-TER) model, the Rough Terrain Diffusion Model (RTDM), and the Large Area Power Plant Effluent Study (LAPPES) model (TRC, 1998b). Other supporting studies previously completed include the CALPUFF Application for Laurel Ridge (Earth Tech, 1998) and the Model Comparison Study for Seward Generating Station (TRC 1998a). The Compliance Demonstration (TRC, 1998b) was intended to provide the basis to establish appropriate SO₂ emission rate limits for the four Laurel Ridge and Chestnut Ridge power plants that will assure attainment and maintenance of the SO₂ NAAQS.

In 1991, The American Meteorology Society (AMS) and the U.S. Environmental Protection Agency (EPA) formed a joint working group to develop a single model to replace the current guideline models for industrial sources and complex terrain. Since 1991, the AMS/EPA Regulatory Model Improvement Committee (AERMIC) has been developing and testing the AERMIC Model (AERMOD) using several EPA data bases. The results of those tests indicate that AERMOD outperforms the current guideline models. AERMIC has proposed that AERMOD become a guideline

model following public review and comment. Since 1999, AERMIC has released several Beta test versions of AERMOD (01247 and 02222) that incorporate the PRIME building downwash algorithms. In April 2000, EPA released a Proposed Rule in the Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (SIP) (Guideline on Air Quality Models) that proposed “revising section 4 of the Guideline to replace ISC3 by AERMOD as a state-of-the-art practice technique for many air quality impact assessments.” (EPA, 2000a) Currently, EPA anticipates that AERMOD will become the Guideline model sometime in 2003.

When the new, state-of-the-art AERMOD complex terrain dispersion model became available, Reliant Energy agreed to provide the additional analyses contained in the previous AERMOD report (TRC, 1999). The objective of the revised AERMOD modeling analyses described in this updated report is to use the latest version of the model and current plant data to demonstrate compliance with the SO₂ NAAQS in support of the previous compliance demonstrations for the Laurel/Chestnut Ridge region sources combined.

As described herein, the updated AERMOD compliance demonstration modeling was performed by TRC Environmental Corporation (TRC) in general accordance with the previous AERMOD and MPTER/RTDM/LAPPES compliance demonstrations, and the model performance evaluation for Seward submitted to the PADEP (TRC, 1999, 1998b and 1998a, respectively). The revised AERMOD compliance demonstration modeling analyses were performed using revised emission rates and stack parameter data provided by Reliant Energy are based on the following modifications to the Laurel/Chestnut Ridge sources: 1) Seward Station re-powered and 2) Homer City Unit 3 scrubbed. Because AERMOD is designed to predict air pollutant concentrations in all terrain settings, it has been used to evaluate simple, intermediate and complex terrain impacts from the four power plants combined for the compliance demonstration.

The revised AERMOD modeling results for the Laurel/Chestnut Ridge region show compliance with the 3-hour, 24-hour and annual average SO₂ NAAQS, based on Seward Station re-powered and Homer City Unit 3 scrubbed. Thus, compliance has been shown based on the following SO₂ emission rates for each source:

<u>Station</u>	<u>3-hour average</u>	<u>Annual and 24-hour average</u>
Conemaugh Units 1 and 2	0.2 lbs/MMBtu	0.2 lbs/MMBtu
Keystone Unit 1	3.92 lbs/MMBtu	4.0 lbs/MMBtu
Keystone Unit 2	3.92 lbs/MMBtu	4.0 lbs/MMBtu
Homer City Unit 1	4.0 lbs/MMBtu	4.0 lbs/MMBtu
Homer City Unit 2	4.0 lbs/MMBtu	4.0 lbs/MMBtu
Homer City Unit 3	0.4 lbs/MMBtu	0.4 lbs/MMBtu
Seward Units 4 and 5	0.6 lbs/MMBtu	0.6 lbs/MMBtu

All of the results are consistent with the sources' current allowable SO₂ emission rate with the exception of Keystone Units 1 and 2. The current allowable limits at these sources are 4.0 pounds per million British thermal units (lbs/MMBtu) as opposed to the modeled maximum emission rate of 3.92 lbs/MMBtu.

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1.0 INTRODUCTION

Energy Mid-Atlantic Power Holdings, LLC (Reliant Energy) operates three major coal-fired electric generating facilities in the Laurel Ridge and Chestnut Ridge area of southwestern Pennsylvania: Keystone, Conemaugh and Seward. Another major power plant, Edison Mission Energy's Homer City Station (formerly operated by GPU Genco) is also located within this area. These plants are all clustered over a relatively small geographic region. The size of the facilities, their close proximity to one another, and the complex terrain that characterizes the region have led to regulatory concerns regarding the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO₂) in the region. This report is the latest update to the compliance demonstrations prepared at the behest of the Pennsylvania Department of Environmental Protection (PADEP). The informal request to update the modeling resulted from emission source changes at Seward Generating Station due to the Seward CFB Repowering Project.

For many years, Reliant Energy and its predecessors, initially the Pennsylvania Electric Company (Penelec) and later GPU Genco, have been working in cooperation with the PADEP, formerly the Pennsylvania Department of Environmental Resources (PADER), and the U.S. Environmental Protection Agency (EPA) Region III to determine appropriate emission limits for the four affected power plants. This report presents supporting AERMOD modeling analyses related to that effort.

In the absence of an approved alternative when the studies were initially undertaken, EPA guidance would have required the use of two models to determine air quality impacts in the region: the Multiple Point with Terrain (MPTEP) model (EPA, 1980) for simple and intermediate terrain, and the Rough Terrain Diffusion Model (RTDM) (ERT, 1987) for intermediate and complex terrain. As an alternative, Penelec proposed to use the Large Area Power Plant Effluent Study (LAPPES) model which Penelec developed from a field program conducted from 1967 to 1972 in the Laurel/Chestnut Ridge region of Pennsylvania. Previous studies at other locations have shown that RTDM over-predicted at elevated terrain locations by more than a factor of two. In contrast, LAPPES has proven to be a modest over-predictor. Therefore, it represented the station operators' preferred model for establishing emission limits. A model performance comparison study was carried out to gain PADEP and EPA approval to use LAPPES instead of RTDM to set emission limits for the then Penelec-

operated power plants. EPA's "Interim Procedures" document (EPA, 1984) was followed from the beginning of the study and culminated in a model comparison report which showed the LAPPES model to be superior to RTDM/MPTEP for determining air quality impacts at elevated locations in the Laurel/Chestnut Ridge area of Pennsylvania (TRC, 1993).

Although LAPPES was demonstrated to be the best model for use in the compliance modeling analyses for the Laurel/Chestnut Ridge area, its use was limited under the criteria of the model performance comparison study. Initially, it was anticipated that RTDM/MPTEP would be used in the compliance modeling for Seward Station because prospective monitoring locations on a small portion of the elevated terrain on Laurel Ridge were judged to be either inaccessible or logistically prohibitive, presumably leaving the testing of model performance for Seward incomplete. However, based on model comparison studies, subsequent analyses (TRC, 1998a) have demonstrated that LAPPES is more appropriate than RTDM/MPTEP for Seward Station.

Since 1995, Conemaugh has used limestone flue gas de-sulfurization wet scrubbers (scrubbers) to control SO₂ emissions to satisfy Phase I of the Acid Rain provisions of the 1990 Clean Air Act Amendments (CAAA). The scrubbers exhaust from a new, shorter stack with significantly reduced plume rise that could not be evaluated in the model performance comparison study. Furthermore, no model comparisons have been conducted to evaluate the performance of LAPPES on a plume similar to that produced by the Conemaugh scrubbers. Therefore, RTDM/MPTEP were used in the compliance modeling to determine SO₂ emission limits in elevated terrain for Conemaugh, while LAPPES was used in elevated terrain for Keystone, Homer City and Seward. MPTEP was used for all plants for receptors below stack top and in combination with RTDM for intermediate terrain (i.e., between stack top and plume height) for Conemaugh. However, to support the compliance modeling analyses obtained using the combination of RTDM, MPTEP and LAPPES, it was recommended that AERMOD be used in a subsequent modeling analysis to confirm the emission limits that were derived from the original compliance demonstration (TRC, 1998b) for each power plant.

Since the initial AERMOD modeling analyses were performed (TRC, 1999), Seward Station has been re-powered with clean coal technology circulating fluidized bed (CFB) boilers designed to combust coal refuse and coal (TRC, 2000), and Homer City has recently installed a wet scrubber on

Unit 3. Revised AERMOD modeling analyses have been performed for all the Laurel/Chestnut Ridge sources to confirm that the modifications to the Seward Station and Homer City Unit 3 sources continue to demonstrate compliance with the NAAQS for SO₂.

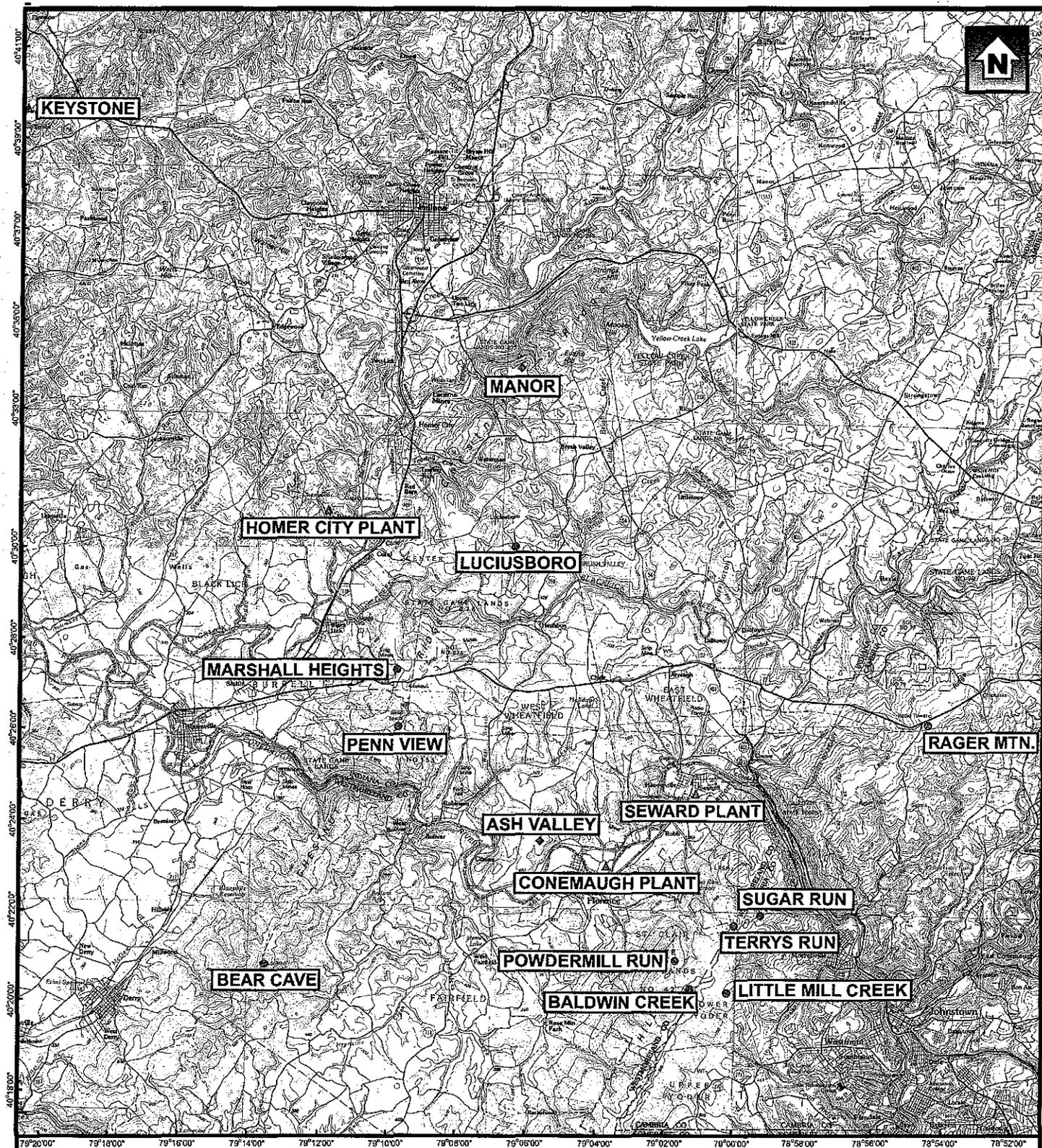
TRC, on behalf of Penelec, submitted a modeling protocol (TRC, 1994) outlining the RTDM/MPTEP and LAPPES modeling procedures for all of the then Penelec-operated power plants in the Laurel/Chestnut Ridge region. PADEP and EPA reviewed the modeling protocol and provided comments in letters dated May 22, 1996 (PADEP, 1996a) and May 28, 1996 (EPA, 1996). GPU Genco responded to those comments in a letter dated October 31, 1996 (GPU Genco, 1996), and PADEP approved the protocol with minor changes in a letter dated December 11, 1996 (PADEP, 1996b). The results presented herein reflect the modeling methodology outlined in that protocol, as amended in accordance with the PADEP and EPA comments, and modified to use AERMOD for all the Laurel/Chestnut Ridge power plants, as discussed above.

2.0 OVERVIEW OF THE AERMOD COMPLIANCE MODELING ANALYSES

The locations of the power plants in the Laurel/Chestnut Ridge area and the regional terrain are shown in Figure 2-1. Previous dispersion modeling has indicated that peak short-term SO₂ concentrations should be expected on the higher terrain of Laurel Ridge and Chestnut Ridge, just northwest of Johnstown, Pennsylvania. The RTDM/MPTEP model combination predicts violations of the short-term NAAQS for SO₂ at current allowable emission rates. However, for over 13 years, an extensive SO₂ monitoring network operated by Reliant Energy measured peak concentrations much lower than those predicted. For the model comparison study period, the monitors recorded second high concentrations that were all less than 60 percent of the short-term NAAQS. This pattern of disparity led to the aforementioned efforts to obtain regulatory approval for the use of the LAPPES model and the submittal of the Compliance Demonstration based on MPTEP/RTDM/LAPPES (TRC, 1998b).

Under agreement of the affected parties in 1999, a new, more sophisticated model, AERMOD, was investigated to support the MPTEP/RTDM/LAPPES Compliance Demonstration of the NAAQS for SO₂. Since 1991, the American Meteorological Society (AMS) and the U.S. Environmental Protection Agency (EPA) Regulatory Model Improvement Committee, (AERMIC) have been developing and testing the AERMIC Model (AERMOD) using several approved EPA atmospheric dispersion data sets. The model development process consisted of initial model development, evaluation, internal review, revised model formulation, performance evaluation and sensitivity testing, external review and submission to EPA's Office of Air Quality Planning and Standards (OAQPS) for consideration as a regulatory model (EPA, 1998a). The intent of EPA is to use AERMOD as a guideline model to be incorporated into the Guideline on Air Quality Models (EPA, 2001).

AERMOD has been subjected to model performance evaluations against several of the current guideline models such as the ISCST3, CTDMPLUS and RTDM models. The results show that AERMOD performed just as well as or better than current guideline models in terms of predicting concentrations in simple and complex terrain settings. In 1999, the first version of AERMOD (98314) was used to support the MPTEP/RTDM/LAPPES SO₂ NAAQS Compliance Demonstration for all sources in the Laurel/Chestnut Ridge region. For this updated report, the latest Beta Test



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 0 1/4
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FIGURE 2-1
STUDY REGION AND
MONITORING SITES

Date: 03/03 Project No. 33275

version of AERMOD with PRIME (02222) has been used to support an additional SO₂ NAAQS compliance demonstration for all sources in the Laurel/Chestnut Ridge region.

For the RTDM, MPTER and LAPPES Compliance Demonstration modeling analyses, PADEP identified two additional sources in the region which had not been included in previous modeling: Cambria Cogen, Inc. and Ebensburg Power Company. These additional sources were also modeled using AERMOD and are included in the predictions of the previous and current reports. Since there are no other major sources of SO₂ in the region, background SO₂ concentrations were developed from the monitored data to represent the contributions of all other SO₂ sources.

Previously, AERMOD was used to predict concentrations in simple, intermediate and complex terrain for all SO₂ emission sources in the Laurel/Chestnut Ridge area. AERMOD was run with the same 3 and 24 hour emission rate limits that were developed for the previous MPTER/RTDM/LAPPES Compliance Demonstration modeling analyses. For the current modeling analyses, AERMOD was run with the revised allowable SO₂ emission rates.

For the updated AERMOD analyses, four initial polar receptor grids were developed around Keystone, Homer City, Conemaugh and Seward, respectively, using the AERMAP terrain preprocessor program. The program requires Digital Elevation Model (DEM) data available from the U.S. Geological Survey to extract receptor locations and their heights for each receptor grid. The 30 meter horizontal resolution, 7.5 minute DEMs were used as AERMAP input. The receptor spacing included 0.5 km increments from 0.5 to 5 km, 1 km increments from 5 to 10 km and 2 km increments from 10 to 20 km in the four grids. The Keystone, Homer City, Conemaugh and Seward receptor grids consisted of 720 receptor points each. This methodology produced a total of 2,880 receptor points throughout the Laurel/Chestnut Ridge region. The receptor networks were designed for evaluating the single source and combined source impacts of all the Laurel/Chestnut Ridge power plants using AERMOD. Additional refined arrays were included in the areas of predicted maximum combined impacts.

The sources of meteorological input data used for the updated AERMOD compliance modeling were the same as those used for the previous MPTER/RTDM/LAPPES Compliance Demonstration, i.e., measurements from two on-site meteorological towers at Ash Valley and Manor developed from the one-year period from August 1, 1990 through July 31, 1991. The meteorological

data were processed using AERMOD's meteorological preprocessor AERMET. This program extracted wind speed, wind direction, temperature and the turbulence measurements from the two on-site meteorological towers at Ash Valley and Manor from all levels to calculate planetary boundary parameters for the surface file and profile file that the AERMOD modeling system uses to predict concentrations.

The concentration predictions from AERMOD were added to the background concentrations and compared to the NAAQS for SO₂, as shown below.

NAAQS		Background Concentrations
Averaging Time	Concentrations (µg/m ³)	
3-hour	1,300*	See Section 3.5
24-hour	365*	
Annual	80	

* Highest second-high values

3.0 MODELING PROCEDURES

The objective of the modeling analyses is to demonstrate compliance with the SO₂ NAAQS for the Laurel/Chestnut Ridge sources using AERMOD with the revised source parameter data and allowable SO₂ emission rates to supplement and support the previous MP/TER/RTDM/LAPPES and AERMOD compliance demonstrations (TRC, 1998b and 1999, respectively). The modeling procedures used for the updated AERMOD compliance modeling analyses were conducted following the 1994 modeling protocol for these sources (TRC, 1994), the agency comments on the protocol (PADEP, 1996a and b), the latest EPA Guideline on Air Quality Modeling (EPA, 2001) and the Revised Draft User's Guide For The AMS/EPA Regulatory Model-AERMOD, (EPA 2002a, 2002b, and 2002c).

The revised source parameter and allowable SO₂ emissions data were used for this updated AERMOD study. The receptor and meteorological data were re-processed using the latest versions of AERMAP and AERMET, AERMOD's terrain and meteorological data pre-processors, respectively. These pre-processors are part of the AERMOD modeling system and can only be used with AERMOD at the present time. Four polar receptor arrays, centered around each of the Laurel/Chestnut Ridge power plants, were developed using the AERMAP terrain pre-processor, and DEMs of the surrounding area. The same on-site meteorological monitoring period used in the previous MP/TER/RTDM/LAPPES and AERMOD compliance demonstrations was used in the updated AERMOD modeling. However, the on-site meteorological data were processed using the latest version of the AERMOD meteorological pre-processor AERMET. A detailed discussion of the meteorological data processing is presented in Section 3.4. The same method used to calculate background concentrations in the MP/TER/RTDM/LAPPES Compliance Demonstration (TRC, 1998b) was used in this analysis. The default model options for AERMOD, which follow regulatory default model options, were used (listed in Section 3.6).

In the RTDM/MP/TER versus LAPPES model performance comparison protocol (TRC, 1994), it was found that 100 percent load conditions for each station produced the maximum impacts. Therefore, all power plants were modeled at 100 percent load and allowable SO₂ emission rates for the AERMOD compliance analyses.

3.1 Source Data

Characteristics of the power plant stacks and the other modeled sources in the Laurel Ridge and Chestnut Ridge area are summarized in Tables 3-1 and 3-2.

Stack heights for the major sources range from 160 m (525 feet) for Conemaugh to 260 m (853 feet) for Homer City Unit 3. Most of the stacks were constructed prior to 1970 and are not subject to Good Engineering Practice (GEP) stack height limitations. The exceptions are Conemaugh, Homer City Unit 3 and Seward. The Conemaugh stack was constructed to the GEP formula height of 160 m (525 feet) to service the scrubber. The new Homer City Unit 3 stack was modeled at actual scrubber stack height of 260 m (853 feet). This height conforms to GEP stack height based on the results of a fluid modeling study to assess downwash due to cooling towers (Peterson, 1987).

The Seward stack was built after 1970 and exceeds the GEP formula height based on building dimensions. A fluid modeling study for Seward determined that the existing 183 m (600 feet) stack height is required to avoid excessive concentrations due to terrain-induced downwash effects (Peterson, 1989). However, as a result of the CFB re-powering project, Seward Station's emission characteristics changed, along with the construction of new structures that affected the calculated GEP formula height (TRC, 2001). For the SO₂ compliance demonstration, the CFB boilers' stack was modeled at the revised GEP formula height of 152 m (500 feet).

3.2 Receptor Grid

Four initial receptor grids were developed using AERMOD's terrain preprocessor, AERMAP. AERMAP defines a height scale (h_c) that represents terrain in the vicinity of the receptor. The AERMAP processor is a required portion of the AERMOD model package and must be used to develop the receptor arrays.

The receptor grids were constructed using rings of receptors spaced at 10 degree intervals on 36 radials out to a distance of 20 kilometers for the Keystone, Homer City, Conemaugh and Seward grids. The grid origins were placed at the locations of the Keystone, Homer City, Conemaugh and Seward Stations. The receptor spacing was:

TABLE 3-1
Fixed Stack Parameters Compiled for the
Laurel/Chestnut Ridge Compliance Modeling Analyses

Source	UTM Coordinates (km)		Stack Height	Stack Diameter	Stack Base Elevation (m)
	East	North			
Keystone Unit 1	640.18	4,502.15	243.8 m (800 ft)	8.29 m (27.2 ft)	308
Keystone Unit 2	640.18	4,502.15	243.8 m (800 ft)	8.29 m (27.2 ft)	308
Homer City Unit 1	652.77	4,486.11	243.8 m (800 ft)	7.32 m (24.0 ft)	366
Homer City Unit 2	652.77	4,486.11	243.8 m (800 ft)	7.32 m (24.0 ft)	366
Homer City Unit 3	652.77	4,486.11	370.6 m ⁽¹⁾ (1,216 ft)	6.90 m (22.6 ft)	366
Conemaugh Units 1 & 2	664.54	4,471.81	160 m (525 ft)	12.1 m ⁽²⁾ (39.8 ft)	332
Seward Units 4 & 5	666.81	4,474.68	182.9 m ⁽³⁾ (600 ft)	5.26 m (17.3 ft)	331
Cambria Cogen, Inc. Units 1 & 2	694.80	4,483.30	70.1 m (230 ft)	2.29 m (7.5 ft)	664
Ebensburg Power	691.10	4,481.54	76.2 m (250 ft)	2.59 m (8.5 ft)	660

- 1) GEP height: 260 m (853 ft) used for compliance modeling
- 2) Effective stack diameter for two adjacent flues within a single stack
- 3) GEP height: 152.4 m (500 ft) used for compliance modeling

TABLE 3-2
Maximum Capacity (100%) Emission Rates and Stack Parameters
Compiled for the Laurel/Chestnut Ridge Compliance Modeling Analyses

Source	SO₂ Emission Factor Limit (lb/MMBtu)	Heat Input (MMBtu/hour)	SO₂ Emission Rate (grams/second)	Exit Velocity	Exit Temperature
Keystone Unit 1	3.92 (3-hour) 4.0 (24-hour and annual)	8,551 8,717	4,309.5 (3-hour) 4,393 (24-hour and annual)	26.8 m/s (87.9 ft/s)	423°K (301°F)
Keystone Unit 2	3.92 (3-hour) 4.0 (24-hour and annual)	8,551 8,717	4,309.5 (3-hour) 4,393 (24-hour and annual)	26.8 m/s (87.9 ft/s)	423°K (301°F)
Homer City Unit 1	4.0 (3, 24 and annual)	6,500	3,276 (3, 24 and annual)	27.4 m/s (90.0 ft/s)	422°K (300°F)
Homer City Unit 2	4.0 (3, 24 and annual)	6,500	3,276 (3, 24 and annual)	27.4 m/s (90.0 ft/s)	422°K (300°F)
Homer City Unit 3	0.4 (3, 24 and annual)	6,800	343 (3, 24 and annual)	27.4 m/s (90 ft/s)	330°K (135°F)
Conemaugh Units 1 & 2	0.2 (3, 24 and annual)	16,560	417 (3, 24 and annual)	20.1 m/s (66 ft/s)	323°K (122°F)
Seward Units 4 and 5	0.6 (3, 24 and annual)	5,064	383 (3, 24 and annual)	32.0 m/s (105 ft/s)	347°K (165°F)
Cambria Cogen, Inc. Units 1 & 2	0.495	968	60.5	27.6 m/s (90.5 ft/s)	466°K (380°F)
Ebensburg Power	0.537	645	43.6	18.3 m/s (59.9 ft/s)	422°K (300°F)

- 500 meter spacing from 0.5 km to 5 km from the stacks
- 1 km spacing from 5 km to 10 km from the stacks
- 2 km spacing beyond 10 km from the stacks

Figures 3-1 through 3-5 depict the four radial receptor grids that were used in the updated AERMOD modeling analyses. Figure 3-1 covers the entire study region and shows all the receptors in the four radial receptor grids for the four power plants. Figures 3-2 through 3-5 depict only the inner portions (i.e., within 10 km) of the radial receptor grids for the Keystone, Homer City, Conemaugh and Seward Stations, respectively. Although there were no predicted violations on the radial receptor grids, maximum impact "hot spots" were predicted at a receptor on the Keystone radial grid (3-hour and 24-hour average) and a receptor on the Homer City radial grid (annual average). Additional modeling was therefore conducted for two refined Cartesian receptor arrays (2 km by 2 km rectangles with 100 meter spacing), which were centered on these two "hotspots." The predicted 3-hour and 24-hour average "hotspots" were primarily attributable to Keystone Station, whereas the predicted annual average "hotspot" was attributable to all four power plants. The refined Keystone and Homer City receptor arrays are shown on Figures 3-1 and 3-2, respectively. A total of 3,760 receptors were therefore used in the updated AERMOD modeling analyses.

AERMOD calculates impacts at all receptor locations (simple, intermediate and complex terrain); therefore, AERMAP receptors were not eliminated or modified for AERMOD modeling throughout the Laurel/Chestnut Ridge region.

3.3 Meteorological Data

On-site meteorological data collected from the Ash Valley (AV) and Manor towers during the period of August 1, 1990 through July 31, 1991 were processed for this AERMOD modeling study. The instrumentation, their placement on the towers, and data acquisition and processing were consistent with regulatory guidance. The tower site locations are depicted in Figure 2-1. Table 3-3 shows the tower elevations and coordinates.

The AV meteorological tower is located approximately 3 km northwest of Conemaugh Station, at a base elevation of 1,401 feet. Data from this tower are representative of transport and dispersion conditions in its region and for Conemaugh and Seward Stations.

TABLE 3-3
Meteorological Monitoring Sites for the
Laurel/Chestnut Ridge Compliance Modeling Analyses

Location Description	Elevation MSL (ft.)	Above Grade (ft.)	Parameters* Monitored
(a) Ash Valley 150 Meter Tower			
Tower UTM coordinates E = 661,722 (m) N = 4,472,558 (m)			
Tower Base Plate	1,401	---	---
Lower Sensor Level	1,434	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1,565	164 (50 m)	WD, WS
Upper Sensor Level	1,695	292 (89 m)	WD, WS
Top Sensor Level	1,893	492 (150 m)	WD, WS
(b) Manor 100 Meter Tower			
Tower UTM coordinates E = 660,560 (m) N = 4,492,006 (m)			
Tower Base Plate	1,730	---	---
Lower Sensor Level	1,763	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1,894	164 (50 m)	WD, WS
Upper Sensor Level	2,058	328 (100 m)	WD, WS

- * Parameter Identifiers
- WD = Wind Direction
- WDST = Standard Deviation of Wind Direction (Sigma Theta)
- WS = Wind Speed
- AT = Ambient Temperature

The Manor meteorological tower is located approximately 9 km northeast of Homer City Station, with a base elevation of 1,730 feet. Data from this tower are representative of transport and dispersion conditions in its region and for Keystone and Homer City Stations.

3.4 Meteorological Data Processing

The AERMOD meteorological pre-processor, AERMET, was used to process the August 1, 1990 to July 31, 1991 AV and Manor tower data with NWS surface and morning upper air data (RAWINSONDE data) from Pittsburgh, PA. AERMET is a multi-stage processing package that ultimately produces two meteorological input files used by AERMOD, the surface file and the profile file. The surface file contains the calculated Planetary Boundary Layer parameters such as: friction velocity, Monin-Obukov length, convective velocity scale, mechanical and convective mixing heights, sensible heat flux, and the lowest level of observed wind data, turbulence and temperature. Surface characteristics of the modeling domain region were selected using site-specific and wind directionally-dependant median roughness lengths, Bowen ratios and Albedo. The median surface roughness lengths were calculated using a FORTRAN program that was developed in accordance with the latest on-site meteorological guideline (EPA, 2000b). The program reads in the site-specific 10 and 50 meter levels of wind data and calculates the median surface roughness lengths. The profile file contains all levels of tower wind speed and direction data, and the 10 meter level temperature and sigma theta data. The multiple sensor levels provide measurements to determine vertical profiles of wind speed and wind direction. The following sections describe each stage of the meteorological data processing using AERMET.

3.4.1 AERMET Stage 1

Stage 1 processing entails extraction and quality assessment of the National Climatic Data Center (NCDC) TD-1440 format and TD-6201 format hourly surface and upper air sounding data from Pittsburgh, respectively. The period of record was the same as for the on-site data collection. AERMET reads in the data and quality assesses (QA) for missing data, values outside of the upper and lower bound default values and data inconsistencies. Currently, AERMET does not replace missing or suspect data. AERMET reads the on-site data from the AV and Manor towers in a formatted Fortran READ statement. The data were quality assured and missing data were reported.

3.4.2 AERMET Stage 2

Stage 2 of the processing combines the hourly surface data, upper air data and on-site meteorological data into a single ASCII file. The output file is formatted so that each block of data contains 24-hours of on-site, NWS surface and upper air observations.

3.4.3 AERMET Stage 3

The final stage of processing reads in the merged file output from Stage 2 and site-specific parameters that characterize the modeling domain and produce two output meteorological files for input to AERMOD. For the Manor and AV towers, the Albedo and Bowen ratios were derived from Tables 4-1 and 4-2 contained in the AERMET User's Guide. The land use in the general vicinity of the towers was judged to be grassland. In addition, hourly Pittsburgh surface data were reviewed and it was determined that the winter of 1990 had below normal snowfall. From this, it was determined that snow cover was not prevalent during the 1990-1991 winter season, and therefore, as recommended in the AERMET User's Guide, the albedo was set to the fall season values throughout the winter. The Bowen ratios were based on normal rainfall throughout each season of the year.

TRC calculated site-specific surface roughness lengths (z_0) using the 10- and 50-meter (m) level wind speed and wind direction data collected from the AV and Manor towers for the period from August 1, 1990 through July 31, 1991. Site-specific surface roughness lengths were calculated using 30 and 90 degree wind direction sectors with wind speeds of greater than or equal to 5 meters per second (m/s). TRC incorporated the methodologies in EPA's On-Site Meteorological Program Guidance For Regulatory Modeling Applications (EPA, 2000b) by calculating the seasonal surface roughness length for the four seasons and two sets of wind direction sectors.

The program uses the following equation to calculate surface roughness values based on hourly wind speed observations at the lowest two levels on each tower:

$$z_0 = e^{**}[u_U \ln(z_L) - u_L \ln(z_U)] / (u_U - u_L)$$

where:

e = the natural log base (2.71828),

** = indicates that the following term is an exponent,

u_U = the scalar wind speed at the middle level of the tower,

z_L = the height of the scalar wind speed measurements at the lower level of the tower (10 m),

u_L = the scalar wind speed at the lower level of the tower, and

z_U = the height of the scalar wind speed measurements at the middle level of the tower (50 m).

Tables 3-4 and 3-5 provide a summary of the site-specific median z_0 values calculated for the AV/Manor towers, by 30 degree wind direction sectors, 90 degree wind direction sectors, and seasons. Averages of the wind direction sector medians and the overall average z_0 values were also computed. The lower z_0 values are associated with small wind speed differences between the 10 and 50 meter levels in a given wind direction sector. These low wind speed differences with height are attributable to the existence of very few obstructions upwind in these sectors. Higher z_0 values are associated with large wind speed differences with height, which are caused by obstructions such as higher terrain and more trees within a given wind direction sector.

Since the number of valid hours in some of the 30 degree wind direction sectors was less than 1 percent of the total valid hours with wind speeds greater than 5 m/s (647 hours for AV and 2,656 hours for Manor), the average of the valid median z_0 values (6.59 cm for AV and 4.73 cm for Manor) was computed and selected for these sectors (per AERMOD User's Guide recommendation). As shown in Table 3-5, the observed median z_0 value was 0.013 cm (0.00013 meters) for the 240-270 degree wind direction sector at the Manor tower. That value, however, is below the AERMET program's minimum z_0 threshold of 0.10 cm (0.001 meters). Since that wind direction sector included many valid hours with wind speeds greater than 5 m/s, the substitute z_0 value used was the 0.10 cm minimum threshold value instead of the aforementioned 4.73 cm average of the valid median values.

When the wind data were binned into four 90 degree wind direction quadrants, the calculated median z_0 values were lower than the mean values for three of the four bins because larger numbers of valid hours with small differences between the wind speeds with height were associated with these three quadrants.

Since the median surface roughness values in 30 degree wind direction sectors provided more resolution, these values were used as input to AERMET. The calculated surface characteristics were put into an input file and AERMET Stage 3 was run with the surface, upper air and on-site data to calculate Planetary Boundary Layer parameters for the surface file. A profile file was also generated that contains all levels of wind speed, direction and 10 meter level turbulence and temperature data

TABLE 3-4
Site-Specific Surface Roughness (Z_0)
Calculated using Ash Valley Met. Data

Wind Direction Sector (deg.)	No. of Valid Hours	Range of z_0 (cm)	Median z_0 (cm)	Mean z_0 (cm)	Selected z_0 (cm)
0-30*	0	0	0	0	6.59
30-60*	2	31.41-40.00	35.71	35.71	6.59
60-90*	0	0	0	0	6.59
90-120*	0	0	0	0	6.59
120-150*	6	0.68-24.50	10.94	10.90	6.59
150-180	31	0.06-55.02	4.70	9.02	4.70
180-210*	5	2.32-20.3	4.43	8.19	6.59
210-240	88	2.91-62.60	18.11	20.16	18.11
240-270	275	0.85-47.99	10.97	12.65	10.97
270-300	182	0.01-47.74	4.01	4.88	4.01
300-330	48	0.04-10.51	1.05	2.06	1.05
330-360	10	0.10-1.81	0.71	0.81	0.71
Average of the valid medians			6.59		
0-90*	2	31.41-40.00	35.71	35.71	6.63
90-180	37	0.61-55.02	4.90	9.33	4.90
180-270	368	0.85-62.60	11.72	14.39	11.72
270-360	240	0.14-47.74	3.27	4.15	3.27
Average of the valid medians			6.63		
Season					
Winter	275	0.61-55.02	6.18	9.36	6.18
Spring	190	0.01-43.10	7.61	11.39	7.61
Summer	10	5.88-45.43	9.20	16.31	9.20
Autumn	172	10.04-62.60	7.12	10.50	7.12
Average of the valid medians			7.53		
Overall	647	0.01-62.60	7.13	10.37	

* Too few events to compute a valid median

TABLE 3-5
Site-Specific Surface Roughness (Z_0)
Calculated using Manor Met. Data

Wind Direction Sector (deg.)	No. of Valid Hours	Range of Z_0 (cm)	Median Z_0 (cm)	Mean Z_0 (cm)	Selected Z_0 (cm)
0-30*	0	0	0	0	4.73
30-60*	0	0	0	0	4.73
60-90*	7	22.85-31.78	28.19	27.63	4.73
90-120	106	0.00-113.62	19.47	30.84	19.47
120-150	325	0.00-165.50	0.32	7.06	0.32
150-180	28	0.005-106.96	9.21	18.66	9.21
180-210	51	0.00-62.36	1.78	6.61	1.78
210-240	546	0.00-32.71	0.22	2.25	0.22
240-270	530	0.00-293.73	0.013	2.75	0.10
270-300	903	0.00-79.18	0.25	2.24	0.25
300-330	157	0.00-27.18	6.54	7.53	6.54
330-360*	2	17.89-55.71	36.80	36.80	4.73
Average of the valid medians			4.73		
0-90*	7	22.85-31.78	28.19	27.63	1.09
90-180	460	0.00-165.50	2.34	13.25	2.34
180-270	1127	0.00-293.73	0.43	2.66	0.43
270-360	1062	0.00-79.18	0.50	3.09	0.50
Average of the valid medians			1.09		
Season					
Winter	960	0.00-293.73	0.04	3.57	0.04
Spring	830	0.00-165.50	0.32	4.75	0.32
Summer	191	0.00-113.62	0.94	11.02	0.94
Autumn	675	0.00-106.96	0.86	4.58	0.86
Average of the valid medians			0.54		
Overall	2656	0.00-293.73	0.25	4.73	

* Too few events to compute a valid median

for AERMOD. The profile file contains multiple levels for AERMOD to extrapolate wind speeds up to plume height using its internal power law equation. The surface profile files produced by AERMET from the AV and Manor tower data were used as input to AERMOD.

3.5 Background Concentrations

Background concentrations were developed to represent contributions from distant and unidentified sources not explicitly being modeled in the compliance evaluation of the Laurel Ridge and Chestnut Ridge region. These were determined by meteorological category using the full year of monitored data collected at all 10 monitors during the model evaluation study. A total of 28 meteorological categories was used, with average hourly concentrations determined for each category based on the average of the measurements at all upwind monitors (relative to the plants) under each category. For the compliance evaluation modeling, the background concentration was determined hourly, depending on the meteorological condition.

The procedure used is consistent with guidance provided in EPA's modeling guideline (EPA, 2001). The guideline recommends using data for the meteorological conditions of concern collected at monitors not impacted by the sources being modeled. A constant background concentration was not selected for all 3-hour or 24-hour averages throughout the year because the hourly meteorological conditions do not remain constant throughout the averaging period.

The background analysis was conducted using AV tower wind speed and wind direction data from the 150 meter level and sigma theta stability classification data from the 10 meter level. This tower was used because it is the closer of the two towers to the area of highest predicted concentrations. Wind direction was separated into four 90 degree quadrants, wind speed was divided into low, medium, and high categories, and stability was broken up into stable, unstable, and neutral categories as follows:

Wind Direction Quadrant (degrees)	Stability	Wind Speed (m/s)
1-90	Stable (E,F)	0-3
91-180	Neutral (D)	3.01-8
181-270	Unstable (A, B, C)	>8.01
271-360		

The meteorological data were then examined on an hour-by-hour basis to determine which of the ten monitors were impacted by any of the power plants in the region. For each hour, a monitor was considered to be impacted by a power plant if it lay anywhere within a 90 degree sector downwind of the plant. This was done for each of the power plants and each of the monitors. If a monitor was determined to be impacted by any one of the power plants, its concentration for that hour was not used in the background calculation. The background concentration was calculated for each hour as the average from among all monitors not impacted by one of the power plants during the hour. Under certain wind directions, all monitors were determined to be impacted by at least one power plant. For each of these conditions, the minimum reported concentration from all of the monitors was used for that hour.

Each hourly average concentration from among all monitors not influenced by a power plant during the hour was placed in the appropriate meteorological category bin. For the stable and unstable categories, the medium and high wind speed cases were combined due to the few occurrences of these categories in the data set. Thus, the number of meteorological categories used totaled 28. The concentrations accumulated in the above process for each meteorological data category were then summed and the average concentration among all hours for each category was determined. A file of hourly background concentrations for each of the meteorological categories was created. Table 3-6 lists the resulting background concentrations and related meteorological categories.

The average background concentrations in Table 3-6 were then added to each hour's model-predicted concentrations depending upon the meteorological conditions that cause the prediction. After the background concentrations were added to the hourly predictions, total SO₂ concentrations for all the appropriate averaging periods were calculated using CALMPRO.

3.6 Model Options

Table 3-7 shows the AERMOD model options and source input echo for a sample 24-hour average run. Other averaging periods use different emission parameters as shown in Table 3-2. The default model options shown in Table 3-7 were automatically invoked as per the AERMOD User's Guide and follow the latest EPA modeling guidance. The base elevation of the anemometer heights shown in Table 3-3 for both the Manor and Ash Valley towers were used for all the power plants in the Laurel/Chestnut Ridge area.

TABLE 3-6
Determination of the Background SO₂ Concentrations
as a Function of the Meteorological Conditions

Bin Number	Flow Vector Quadrant	Stability	Wind Speed (m/s)	Average (µg/m ³)	Number of Monitor-hours Used	Number of Times Minimum Was Used	Number of Hours in Bin
1	Northeast	Stable	0-3	34.2	3,725	0	471
2	Northeast	Stable	gt 3	49.6	8,718	0	1,131
3	Northeast	Neutral	0-3	47.5	508	0	65
4	Northeast	Neutral	3-8	45.3	4,355	0	591
5	Northeast	Neutral	gt 8	29.0	3,338	0	479
6	Northeast	Unstable	0-3	65.1	2,462	0	332
7	Northeast	Unstable	gt 3	40.8	8,256	0	1,164
8	Southeast	Stable	0-3	25.9	234	119	157
9	Southeast	Stable	gt 3	19.5	476	218	289
10	Southeast	Neutral	0-3	28.4	66	34	45
11	Southeast	Neutral	3-8	23.0	1,009	566	695
12	Southeast	Neutral	gt 8	20.3	475	176	251
13	Southeast	Unstable	0-3	38.5	272	139	180
14	Southeast	Unstable	gt 3	24.7	1,087	468	644
15	Southwest	Stable	0-3	26.4	975	0	137
16	Southwest	Stable	gt 3	12.1	795	0	108
17	Southwest	Neutral	0-3	20.7	198	0	32
18	Southwest	Neutral	3-8	10.0	643	0	88
19	Southwest	Neutral	gt 8	10.7	68	0	10
20	Southwest	Unstable	0-3	28.8	1,004	0	146
21	Southwest	Unstable	gt 3	8.1	676	0	99
22	Northwest	Stable	0-3	28.0	2,672	0	384
23	Northwest	Stable	gt 3	9.4	2,588	0	364
24	Northwest	Neutral	0-3	24.4	574	0	85
25	Northwest	Neutral	3-8	10.7	1,232	0	177
26	Northwest	Neutral	gt 8	7.1	263	0	39
27	Northwest	Unstable	0-3	32.8	1,881	0	274
28	Northwest	Unstable	gt 3	9.5	2,148	0	321

**TABLE 3-7
AERMOD Model Options**

Model Is Setup For Calculation of Average CONCentration Values.

Model Uses RURAL Dispersion Only.

Model Uses Regulatory DEFAULT Options:

1. Stack-tip Downwash.
2. Model Accounts for ELEVated Terrain Effects.
3. Use Calms Processing Routine.
4. Use Missing Data Processing Routine.
5. "Upper Bound" Values for Supersquat Buildings.
6. No Exponential Decay

Model Assumes No FLAGPOLE Receptor Heights.

Model Calculates 3 Short Term Average(s) of: 1-HR 3-HR 24-HR and Calculates PERIOD Averages

This Run Includes: 5 Source(s); 5 Source Group(s); and 441 Receptor(s)

The Model Assumes A Pollutant Type of: SO₂

Model Set To Continue RUNning After the Setup Testing.

Output Options Selected:

- Model Outputs Tables of PERIOD Averages by Receptor
- Model Outputs Tables of Highest Short Term Values by Receptor (RECTABLE Keyword)
- Model Outputs Tables of Overall Maximum Short Term Values (MAXTABLE Keyword)
- Model Outputs External File(s) of Concurrent Values for Postprocessing (POSTFILE Keyword)

NOTE: The Following Flags May Appear Following CONC Values: c for Calm Hours,
m for Missing Hours, b for Both Calm and Missing Hours

Misc. Inputs: Base Elev. for Pot. Temp. Profile (m MSL) = 527.30; Decay Coef. = 0.000; Rot. Angle = 0.0;
Emission Units = GRAMS/SEC; Emission Rate Unit Factor = 0.10000E+07; Output Units =
MICROGRAMS/M3

MODELOPTs:

CONC
DEFAULT
ELEV

SOURCE ID	EMMISSION RATE (g/s)	POINT SOURCE DATA						
		UTM-X (meters)	UTM-Y (meters)	Z (meters)	STACK HEIGHT (meters)	EXHAUST TEMP (°k)	EXIT VEL (m/s)	DIAMETER (meters)
KEYS12	0.86190E+04	640180.0	4502150.0	308.0	244.00	423.00	26.80	8.29
HCITY12	0.65520E+04	652770.0	4486110.0	366.0	244.00	422.00	27.40	7.32
HCITY3	0.34300E+03	652770.0	4486110.0	366.0	260.00	330.00	27.40	6.90
CAMBERIA	0.60500E+02	694800.0	4483300.0	664.0	70.20	466.00	27.60	2.29
EBENS	0.43600E+02	691100.0	4481540.0	660.0	76.20	422.00	18.30	2.59

3.7 Model Application

The latest version of AERMOD (02222) was used for this modeling study to update the previous Compliance Demonstration for the SO₂ NAAQS for all the Laurel/Chestnut Ridge region sources combined.

The source input data used by AERMOD for the Laurel/Chestnut Ridge sources are shown in Tables 3-1 and 3-2. The towers and sensors from which the meteorological input data were obtained to model each source are shown in Table 3-3. The receptor grids shown in Figures 3-1 through 3-5 were used with AERMOD to predict impacts from all the sources combined.

In the AERMOD modeling analysis the Ash Valley meteorological data were used to model Conamaugh and Seward Stations, while the Manor data were used to model Keystone and Homer City Stations. This approach was consistent with the MPTER/RTDM/LAPPES Compliance Demonstration utilizing local meteorological measurements to best represent transport conditions. Thus, the available meteorological data were used to represent the closest sources for the aforementioned meteorological data sets.

4.0 MODELING RESULTS

Table 4-1 summarizes the model predicted SO₂ regulatory basis concentrations for the proposed compliance emission rates based on the source-specific meteorological tower locations. The table shows the maximum regulatory averaging period predicted concentrations from any of the modeled receptor grids. The table reiterates the source emission rates, provides the impact contributions of each power plant and shows the total predicted concentrations including background for the 3-hour, 24-hour and annual averaging periods. The table also displays the location coordinates for the receptors where the controlling concentrations were predicted to occur. The Ebensburg Power and Cambria Cogen sources were predicted to contribute little or no impact to the controlling concentrations.

Table 4-1 shows that the predicted controlling highest second-high 3-hour and 24-hour concentrations occur on the Keystone refined grid at two receptors located approximately 3 and 4 kilometers to the east of Keystone Station with elevations of 308 (1,010) and 334 (1,096) meters (feet), respectively. Table 4-1 indicates that the predicted 3-hour and 24-hour concentrations are due primarily to the impacts from Keystone Station (i.e., 96 percent). All the other nearby sources, i.e., Homer City (Units 1, 2 and 3), Conemaugh and Seward, contribute less than 1 percent of the highest second-high 3-hour and 24-hour average concentrations. The background concentrations make approximately 3.8 and 17.5 percent contributions to the highest second-high 3 and 24-hour average concentrations, respectively.

The maximum annual average concentration shown in Table 4-1 occurs on the Homer City coarse grid at a receptor located approximately 21 kilometers to the east of Homer City Station with an elevation of 606 meters (1,988 feet). The maximum predicted annual concentration results from contributions from all the sources. Each of the sources, i.e., Keystone, Homer City (Units 1, 2 and 3), Conemaugh and Seward, contributes between 1 and 14 percent of the highest annual average concentration, with the smallest contribution from Homer City Unit 3 and the largest from Conemaugh Station. The background concentration makes the single largest contribution (56 percent) to the highest annual average concentration.

The updated AERMOD modeling results show that operation of all of the power plants combined at the emission rates specified in Table 3-2 produce modeled compliance with the SO₂ NAAQS for all averaging periods as shown in Table 4-1. All of the results are consistent with the

sources' current allowable SO₂ emission rate with the exception of Keystone Units 1 and 2. The current allowable limits at these sources are 4.0 lbs/MMBtu as opposed to the modeled maximum emission rate of 3.92 lbs/MMBtu.

Table 4-1
Multi-source Impacts for the Source-Specific Meteorological Data

3-Hour Average																		
Averaging Period	Julian Day	Ending Hour	Grid ID	Receptor Location			SO ₂ Concentrations (µg/m ³)								Total w/o Background	Background	Total	NAAQS
				UTM-X (m)	UTM-Y (m)	Elevation (m)	Source Contributions Without Background											
				Keystone 1&2	Homer City 1	Homer City 2	Homer City 3	Conemaugh	Seward 4&5	Cambria & Ebensburg								
3-Hour *	32	15	Keystone	643,080	4,502,250	308	1248.56	0.670	0.670	0.080	0.160	0.170	0.020	1250.33	48.89	1299.22	1,300	
							Emission Limits (lbs/MMBtu)											
							3.92	4.0	4.0	0.4	0.2	0.6						
							Emission Limits (lbs/hr)											
							68,408	26,001	26,001	2,722	3,310	3,040						
24-Hour Average																		
Averaging Period	Julian Day	Ending Hour	Grid ID	Receptor Location			SO ₂ Concentrations (µg/m ³)								Total w/o Background	Background	Total	NAAQS
				UTM-X (m)	UTM-Y (m)	Elevation (m)	Source Contributions Without Background											
				Keystone 1&2	Homer City 1	Homer City 2	Homer City 3	Conemaugh	Seward 4&5	Cambria & Ebensburg								
24-Hour *	32	24	Keystone	644,180	4,501,850	334	219.78	0.140	0.140	0.020	0.050	0.050	0.010	220.19	46.80	266.99	365	
Annual	N/A	N/A	Homer City	672,870	4,486,110	606	5.15	3.91	3.91	0.50	7.91	3.48	0.100	24.96	32.29	57.25	80	
							Emission Limits (lbs/MMBtu)											
							4.0	4.0	4.0	0.4	0.2	0.6						
							Emission Limits (lbs/hr)											
							69,732	26,001	26,001	2,722	3,310	3,040						

5.0 REFERENCES

- Earth Tech, 1998: "CALPUFF Application for Laurel Ridge", October 1998.
- EPA, 1980: "User's Guide for MPTEP - A Multiple Point Gaussian Dispersion Algorithm with Optional Terrain Adjustment," April 1980.
- EPA, 1984: "Interim Procedures for Evaluating Air Quality Models (Revised)," 450/4-84-023, September 1984.
- EPA, 1996: Letter from Dennis Lohman to Jane Mahinske (DEP), May 28, 1996.
- EPA, 2000a: "Part 51 -- Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (Guideline on Air Quality Models); Proposed Rule", 40 CFR, April 21, 2000.
- EPA, 2000b: "On-Site Meteorological Program Guidance for Regulator Modeling Applications," EPA-454/R-99-005, February 2000.
- EPA, 2001: "Appendix W to Part 51 - Guideline on Air Quality Models", 40 CFR, July 1, 2001.
- EPA, 2002a: "Revised Draft User's Guide for the AMS/EPA Regulatory Model - AERMOD", August 2002.
- EPA, 2002b: "Revised Draft User's Guide for the AERMOD Terrain Preprocessor (AERMAP)", August 2002.
- EPA, 2002c: "Revised Draft User's Guide for the AERMOD Meteorological Preprocessor (AERMET)", August 2002.
- ERT, 1987: "User's Guide to the Rough Terrain Diffusion Model (RTDM) (Rev. 3.20)," Doc. #P-D535-585, July 1987.
- GPU Genco, 1996: Letter from Keith Schmidt to Jane Mahinske (DEP), October 31, 1996.
- PADEP, 1996a: Letter from Jane Mahinske to Keith Schmidt (GPU Genco), May 22, 1996.
- PADEP, 1996b: Letter from Jane Mahinske to Keith Schmidt (GPU Genco), December 11, 1996.
- Peterson, 1987: "Fluid Modeling for Good Engineering Practice Stack Height at Homer City Generating Station," CPP Project 86-0338HC, October 1987.
- Peterson, 1989: "GEP Stack Height Evaluation for Pennsylvania Electric Company's Seward Power Plant," CPP Project 86-0336, January 1989.

TRC, 1991: "Protocol for Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge," February 1991.

TRC, 1993: "Revised Final Report on the Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge," January 1993.

TRC, 1994: "Modeling Protocol for SO₂ NAAQS Compliance Analyses for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania," April 1994.

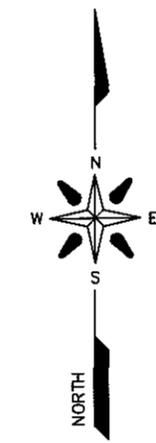
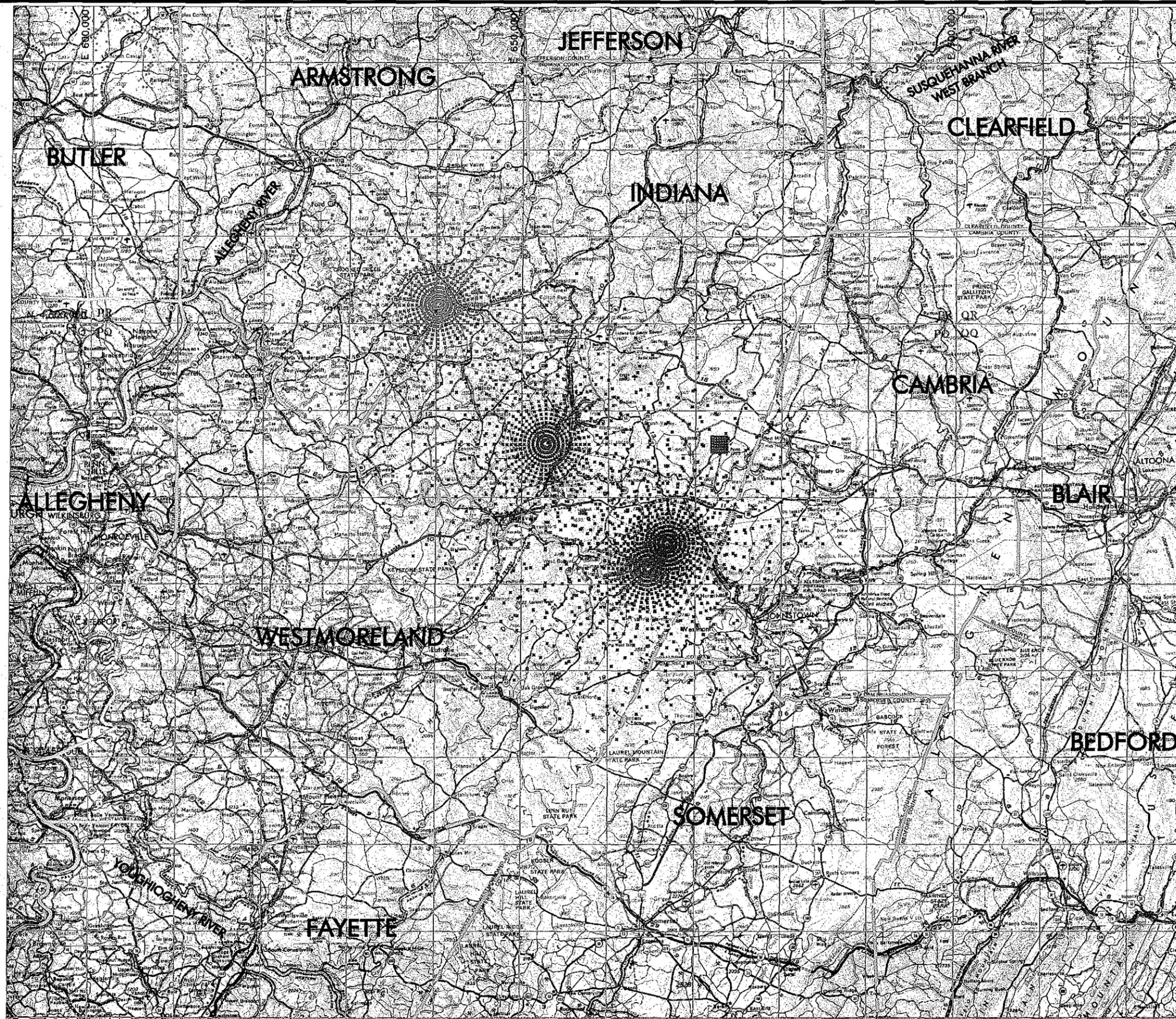
TRC, 1998a: "Model Comparison Study for Seward Generating Station," October 1998.

TRC, 1998b: "Modeling Analyses for SO₂ NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania," December 1998.

TRC, 1999: "AERMOD Modeling Analyses for SO₂ NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania," July 1999.

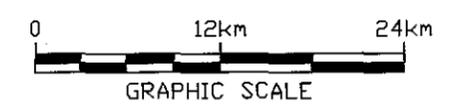
TRC, 2000: "Amended Plan Approval Application for the Seward CFB Repowering Project," September 2000.

TRC, 2001: "Revised Seward CFB Repowering Project AERMOD Modeling Analyses for CO NAAQS/PSD Compliance," February 2001.



LEGEND

- X KEYSTONE OUTER GRID
- X HOMER CITY OUTER GRID
- X SEWARD OUTER GRID
- X CONEMAUGH OUTER GRID
- X HOMER CITY REFINED GRID



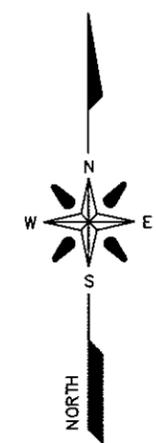
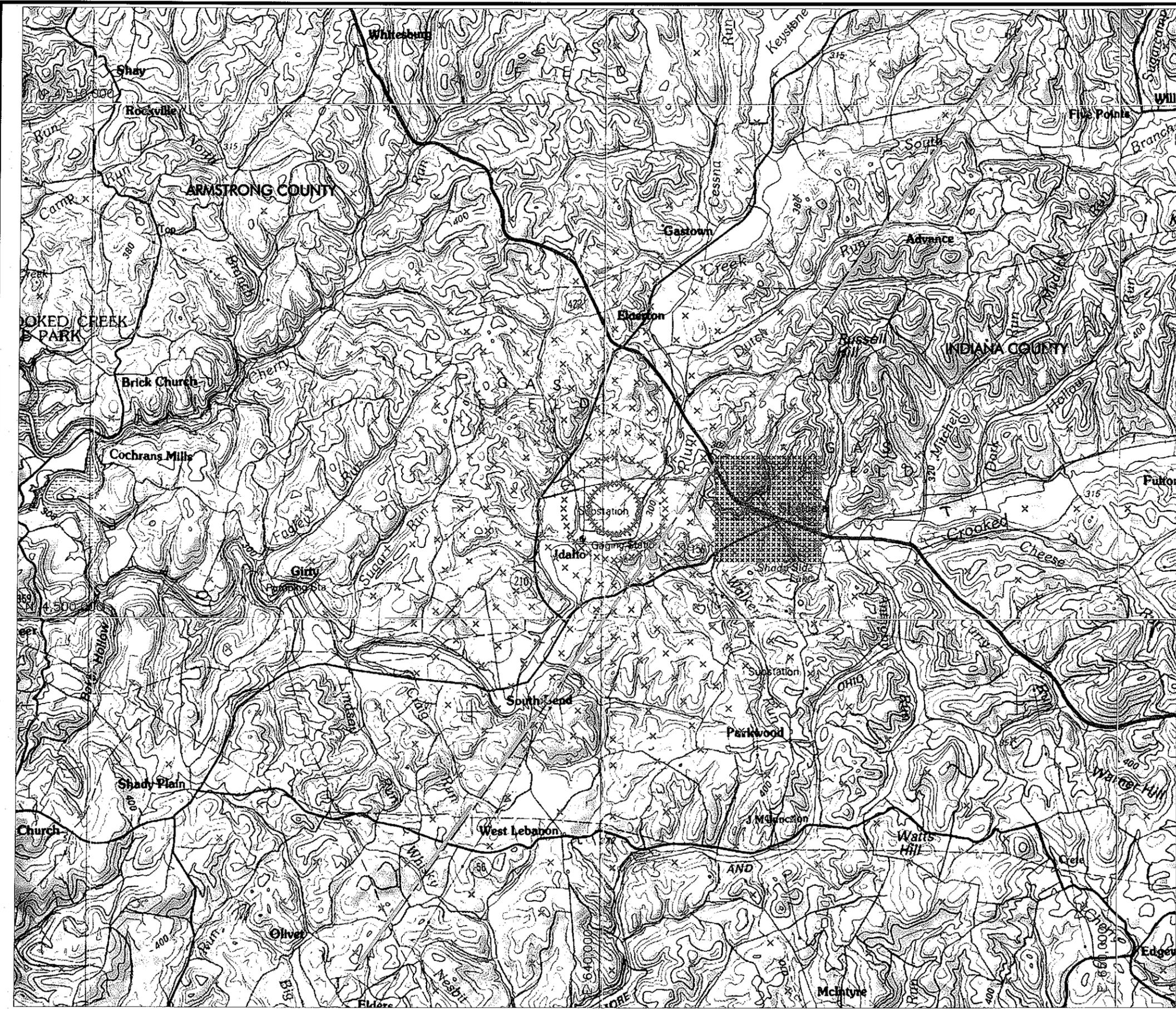
TRC Environmental Corporation 5 Waterside Crossing
Windsor, CT 06095
(860) 289-8631

RELIANT ENERGY PENNSYLVANIA

**FIGURE 3-1
RADIAL RECEPTOR GRIDS
HOMER CITY REFINED GRID
2x2 km, 100 METER SPACING**

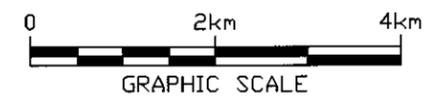
Date: 02/03 Project No. 33275-0000-0000

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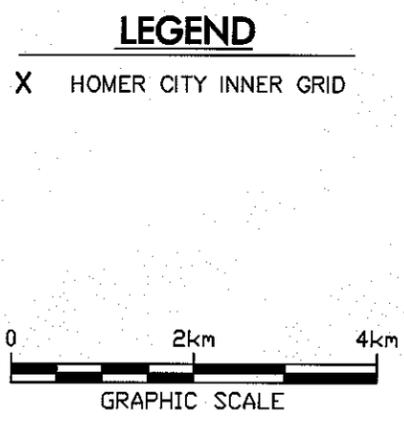
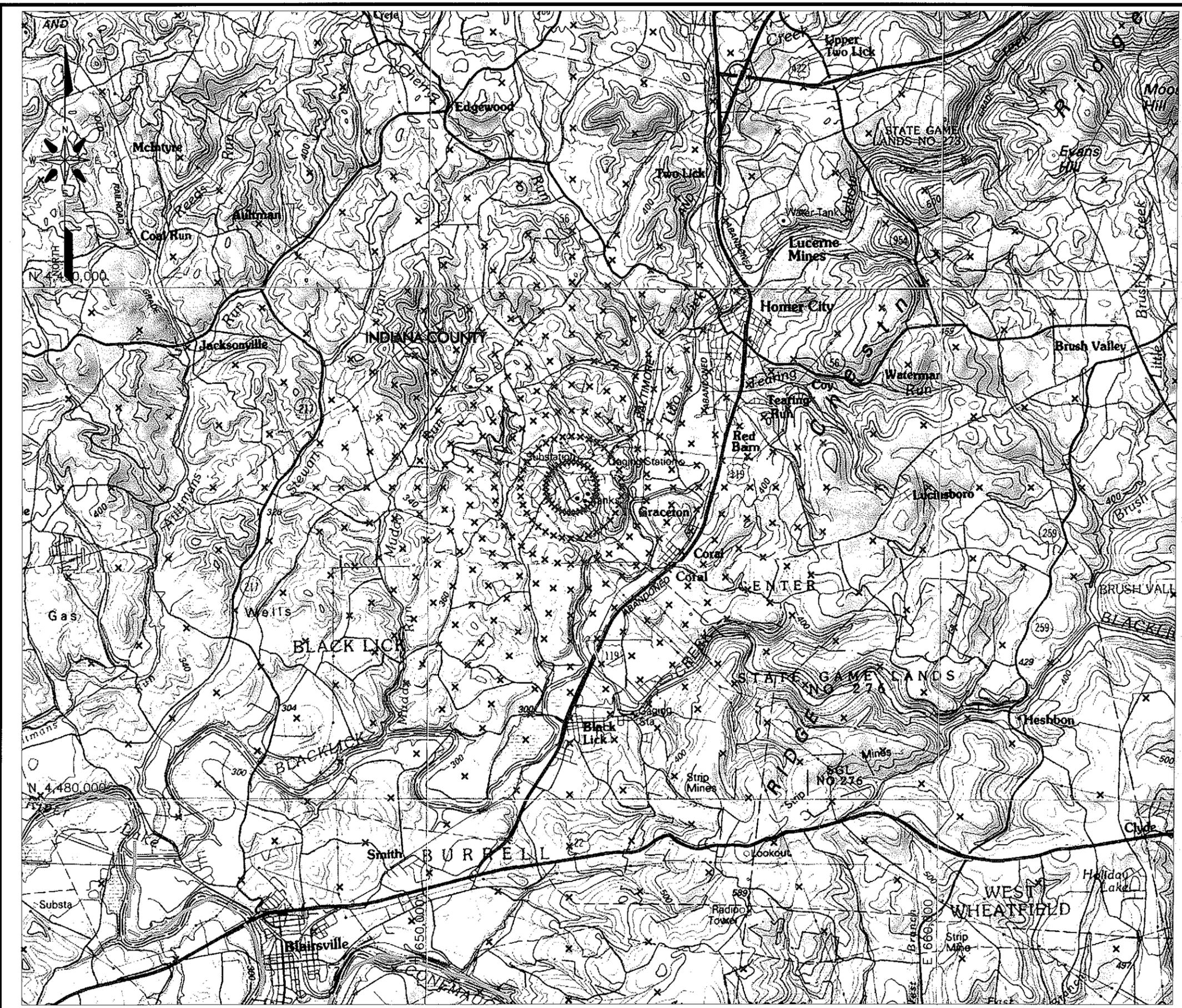


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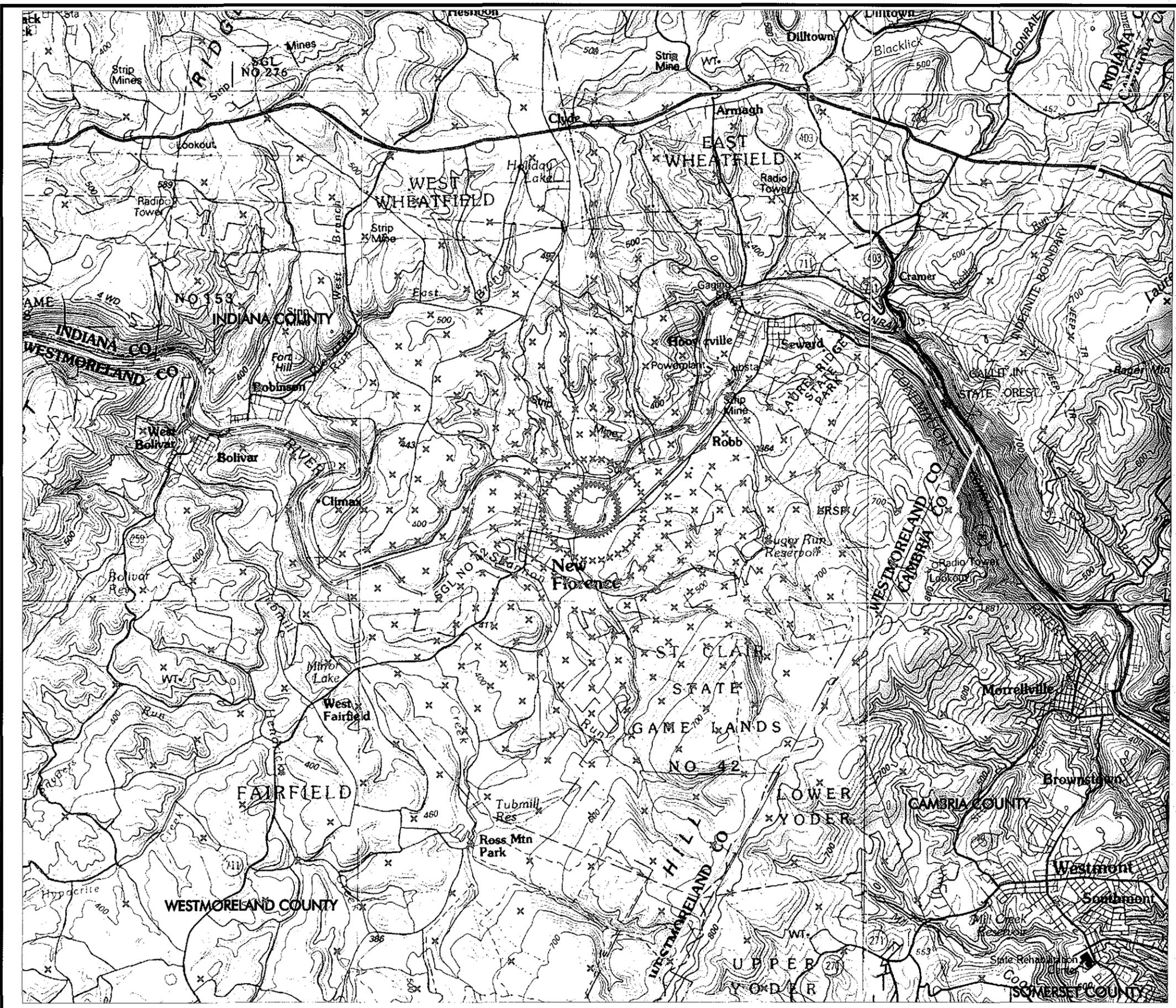
- X KEYSTONE INNER GRID
- x KEYSTONE REFINED GRID



<p>TRC Environmental Corporation</p>	<p>5 Waterside Crossing Windsor, CT 06095 (860) 289-8631</p>
	<p>RELIANT ENERGY PENNSYLVANIA</p>
<p>FIGURE 3-2 KEYSTONE INNER GRID-0.5 km TO 9 km KEYSTONE REFINED GRID 2x2 km, 100 METER SPACING</p>	
<p>Date: 02/03</p>	<p>Project No. 33275-0000-0000</p>

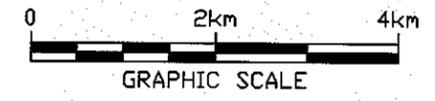


<p>TRC Environmental Corporation</p>	<p>5 Waterside Crossing Windsor, CT 06095 (860) 289-8631</p>
<p>RELIANT ENERGY PENNSYLVANIA</p>	
<p>FIGURE 3-3 HOMER CITY INNER GRID-0.5 km TO 9 km</p>	
<p>Date: 02/03</p>	<p>Project No. 33275-0000-0000</p>

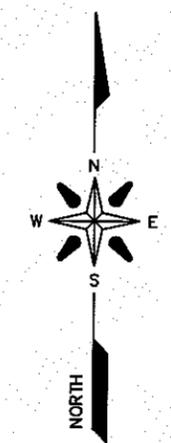
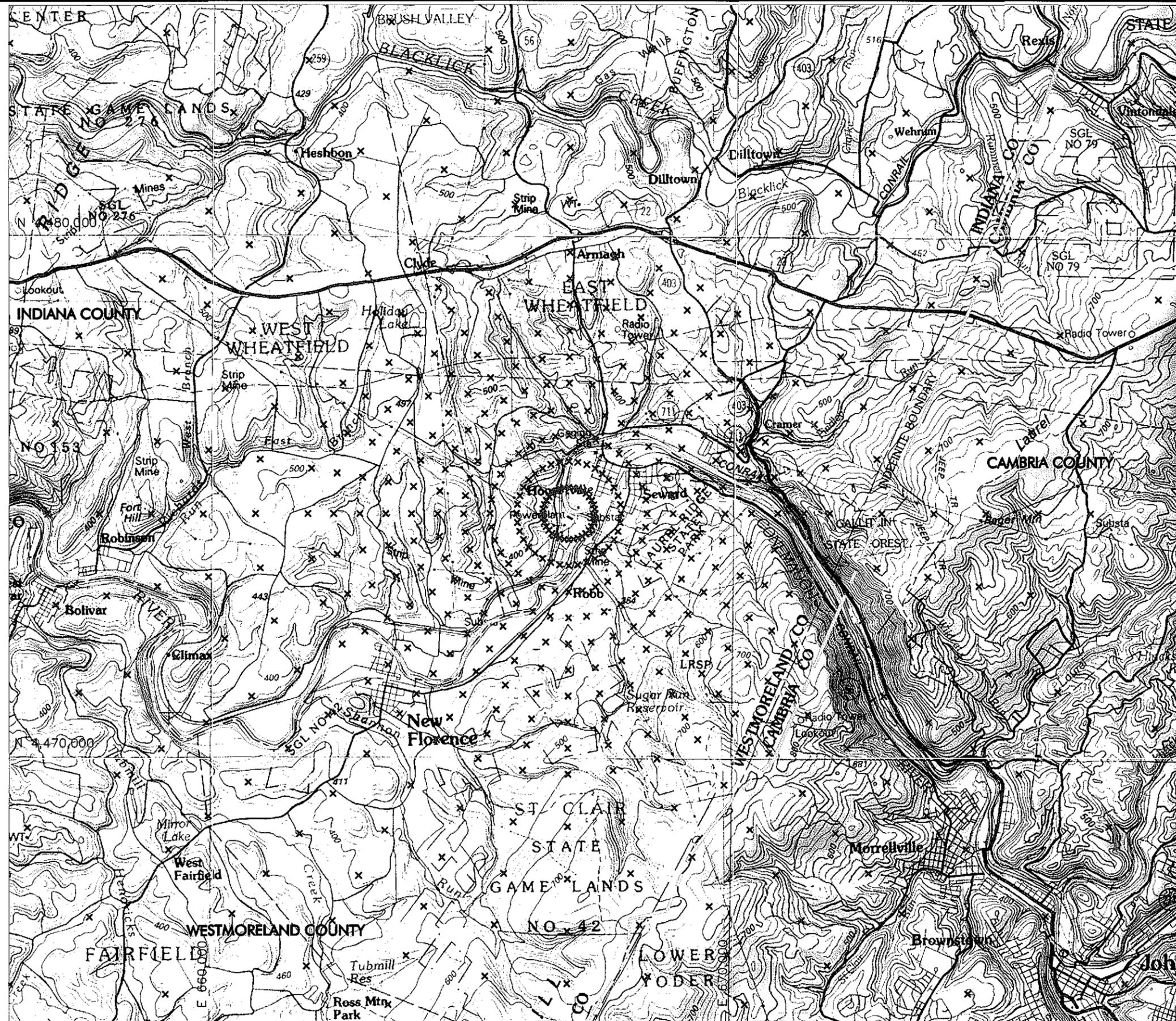


LEGEND

X CONEMAUGH INNER GRID

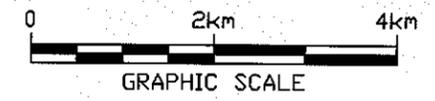


<p>TRC Environmental Corporation</p>	<p>5 Waterside Crossing Windsor, CT 06095 (860) 289-8631</p>
	<p>RELIANT ENERGY PENNSYLVANIA</p>
<p>FIGURE 3-4 CONEMAUGH INNER GRID-0.5 km TO 9 km</p>	
<p>Date: 02/03</p>	<p>Project No. 332375-0000-00000</p>



LEGEND

X SEWARD INNER GRID



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RELIANT ENERGY
 PENNSYLVANIA

FIGURE 3-5
SEWARD INNER GRID-0.5 km TO 9 km

Date: 02/03

Project No. 33275-0000-00000

Attachment E

Letter from EPA Region 3 Requesting Laurel Ridge Study Database



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
841 Chestnut Building
Philadelphia, Pennsylvania 19107-4431



Mr. Vincent J. Brisini
PENELEC
1001 Broad St.
Johnstown, PA 15907

JUN 3 1993

Vince
Dear Mr. Brisini:

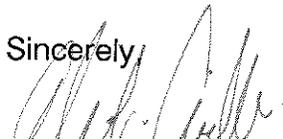
Approximately two years ago the American Meteorological Society (AMS) and the Environmental Protection Agency (EPA) formed a joint committee - AERMIC (the AMS/EPA Model Improvement Committee) - to introduce state-of-the-science modeling concepts into regulatory dispersion models. AERMIC's primary emphasis is on the replacement of the longstanding PGT stability classification approach to dispersion. The AERMIC intends to replace PGT with an approach that relies of PBL parameterizations. The goal of this effort is to develop a replacement for the EPA ISC model. Additionally, we expect this model to handle complex terrain without invoking an entirely different conceptual framework. If successful we will finally have a regulatory model that is applicable for all source types in all terrain. The AERMIC model would obviate the need for employing an "intermediate terrain analysis."

We have completed the conceptual design of the new model and we are presently in the coding phase. Once the model has been coded, we will need to test its performance. The AERMIC has planned a two phased model performance evaluation. The first phase is designed to help in the final development of the model. The second phase will be an independent test of the model's performance compared with present guideline models.

The success of this new approach rests in its ability to reproduce what has been measured to occur in nature. Since this model is slated to handle many types of applications, the AERMIC must evaluate it against a variety of data bases. The AERMIC has reviewed many data bases that have been collected through out this country. We believe that the Indiana County SO₂ data base could provide an excellent test of the new models capability to accurately predict multi-source impacts in complex terrain. Therefore, on behalf of AERMIC, I am requesting an electronic copy of the full year of source, ambient SO₂, and meteorological data which makeup the Indiana County SO₂ data base. If provided, AERMIC intends to use it as a phase II data bases.

I would like to thank you for your consideration with the hope that we can use this high quality data base in our efforts. If you have any questions, or would simply like to discuss the project please give me a call at (215) 597-6563.

Sincerely,



Alan J. Cimorelli

Attachment F

Land Cover Figures for Comparison of Modeled Sources to Meteorological Tower Site

Table F-1. Land Cover Within 1 km of Conemaugh Station and Ash Valley Tower AERSURFACE Log File (1990)

USGS Annual NLCD Category	Description	Conemaugh Station		Ash Valley Meteorological Tower		Percent Difference
		Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	192	5.50%	71	2.03%	3.47%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	232	6.64%	307	8.78%	-2.14%
22	Developed, Low Intensity	386	11.05%	35	1.00%	10.05%
23	Developed, Medium Intensity	416	11.91%	12	0.34%	11.57%
24	Developed, High Intensity	225	6.44%	1	0.03%	6.41%
31	Barren Land (Rock/Sand/Clay)	206	5.90%	12	0.34%	5.56%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	1624	46.51%	2288	65.46%	-18.96%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	0	0.00%	102	2.92%	-2.92%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	50	1.43%	4	0.11%	1.32%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	24	0.69%	642	18.37%	-17.68%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	135	3.87%	21	0.60%	3.27%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	2	0.06%	0	0.00%	0.06%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
Total		3492	100%	3495	100%	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Table F-2. Land Cover Within 1 km of Conemaugh Station and Ash Valley Tower AERSURFACE Log File (1991)

USGS Annual NLCD Category	Description	Conemaugh Station		Ash Valley Meteorological Tower		Percent Difference
		Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	186	5.33%	72	2.06%	3.27%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	227	6.50%	307	8.78%	-2.28%
22	Developed, Low Intensity	386	11.05%	35	1.00%	10.05%
23	Developed, Medium Intensity	429	12.29%	12	0.34%	11.94%
24	Developed, High Intensity	225	6.44%	1	0.03%	6.41%
31	Barren Land (Rock/Sand/Clay)	196	5.61%	12	0.34%	5.27%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	1629	46.65%	2289	65.49%	-18.84%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	0	0.00%	102	2.92%	-2.92%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	54	1.55%	4	0.11%	1.43%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	24	0.69%	640	18.31%	-17.62%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	135	3.87%	21	0.60%	3.27%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	1	0.03%	0	0.00%	0.03%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
Total		3492	100%	3495	100%	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Table F-3. Land Cover Within 1 km of Seward Station and Ash Valley Tower AERSURFACE Log File (1990)

USGS Annual NLCD Category	Description	Seward Station		Ash Valley Meteorological Tower		Percent Difference
		Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	195	5.56%	71	2.03%	3.53%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	373	10.64%	307	8.78%	1.86%
22	Developed, Low Intensity	290	8.27%	35	1.00%	7.27%
23	Developed, Medium Intensity	43	1.23%	12	0.34%	0.88%
24	Developed, High Intensity	5	0.14%	1	0.03%	0.11%
31	Barren Land (Rock/Sand/Clay)	428	12.21%	12	0.34%	11.87%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	2027	57.83%	2288	65.46%	-7.63%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	4	0.11%	102	2.92%	-2.80%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	29	0.83%	4	0.11%	0.71%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	27	0.77%	642	18.37%	-17.60%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	83	2.37%	21	0.60%	1.77%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	1	0.03%	0	0.00%	0.03%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
Total		3505	100%	3495	100%	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Table F-4. Land Cover Within 1 km of Seward Station and Ash Valley Tower AERSURFACE Log File (1991)

USGS Annual NLCD Category	Description	Seward Station		Ash Valley Meteorological Tower		Percent Difference
		Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	196	5.59%	72	2.06%	3.53%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	373	10.64%	307	8.78%	1.86%
22	Developed, Low Intensity	291	8.30%	35	1.00%	7.30%
23	Developed, Medium Intensity	42	1.20%	12	0.34%	0.85%
24	Developed, High Intensity	5	0.14%	1	0.03%	0.11%
31	Barren Land (Rock/Sand/Clay)	423	12.07%	12	0.34%	11.73%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	2027	57.83%	2289	65.49%	-7.66%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	4	0.11%	102	2.92%	-2.80%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	33	0.94%	4	0.11%	0.83%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	27	0.77%	640	18.31%	-17.54%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	83	2.37%	21	0.06%	1.77%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	1	0.03%	0	0.00%	0.03%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
Total		3505	100%	3495	100%	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)