



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

AUG 07 2018

MEMORANDUM

SUBJECT: Concurrence Request for Approval of Alternative Model: BLP/AERMOD Hybrid Approach for Modeling Fugitive Emissions from Coke Oven Batteries at the U.S. Steel Mon Valley Works - Clairton plant in Allegheny County, PA

FROM: Timothy A. Leon Guerrero, Meteorologist *TJF for*
Office of Air Monitoring and Analysis, Air Protection Division, EPA Region 3

THRU: Alice H. Chow, Associate Director *AHC*
Office of Air Monitoring and Analysis, Air Protection Division, EPA Region 3

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

EPA Region 3 is seeking concurrence from the Model Clearinghouse on a modeling approach using a combination of the Buoyant Line and Point Source model (BLP) and American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) to represent fugitive emissions from coke oven batteries at the U.S. Steel Mon Valley Works – Clairton plant located in Allegheny, Pennsylvania. Allegheny County Health Department (ACHD) has sought approval under 40 CFR Part 51, Appendix W- Guideline on Air Quality Models, paragraph 3.2.2(b)(2) to use this alternative model in its 2012 Annual Fine Particulate Matter (PM-2.5) National Ambient Air Quality Standard (NAAQS) nonattainment area State Implementation Plan (SIP) for the Allegheny County, PA nonattainment area and the 2010 1-hr SO₂ NAAQS nonattainment area SIP for the Allegheny, PA nonattainment area submitted to EPA on October 3, 2017. Justification for the approval of the alternative model is provided in the ACHD’s technical support document attached to this memorandum entitled “Alternative Modeling Technical Support Document: BLP/AERMOD Hybrid Approach for Buoyant Fugitives in Complex Terrain.”

EPA Region 3 has performed a technical review of ACHD’s submittal and propose that the use of the BLP/AERMOD hybrid alternative model should be granted in this case. A short technical analysis is included for your consideration. Please feel free to contact Alice Chow at (215) 814-2144 or Tim Leon-Guerrero at (215) 814-2192 if you have questions regarding our concurrence request.

Attachment.



EPA Region III Technical Review of Allegheny County Health Department's Request to Use BLP/AERMOD Hybrid Approach

1. Regulatory Background

On December 14, 2012, the Environmental Protection Agency (EPA) strengthened the annual, health-based particle National Ambient Air Quality Standard (NAAQS) for fine particulate matter (PM-2.5) from 15.0 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) to 12.0 $\mu\text{g}/\text{m}^3$ (2012 PM_{2.5} NAAQS, 78 FR 3085). EPA designated the entirety of Allegheny County, Pennsylvania as a nonattainment area for the 2012 PM-2.5 NAAQS on January 15, 2015, effective as of April 15, 2015, based on measured violations of the standard using 2011-2013 data (80 FR 2206). As a result of this designation, the Allegheny County Health Department (ACHD) was required to develop a State Implementation Plan (SIP) revision to demonstrate attainment of the NAAQS within 18 months of the effective date of designation. This SIP revision was due on October 15, 2016. On April 6, 2018, EPA found that ACHD had failed to make this submittal (83 FR 14759, effective date May 7, 2018).

Similarly, regarding the sulfur dioxide (SO₂) NAAQS, on June 22, 2010, EPA strengthened the primary NAAQS for SO₂ by establishing a new 1-hour standard at a level of 75 parts per billion (ppb) (2010 1-hour SO₂ NAAQS, 75 FR 35520). EPA designated a portion of Allegheny County, Pennsylvania as a nonattainment area¹ for the 2010 1-hour SO₂ NAAQS on August 5, 2013, effective as of October 4, 2013, based on measured violations of the standard using 2009-2011 data (78 FR 47191). As a result of this designation, ACHD was required to develop a SIP revision to demonstrate attainment of the NAAQS within five years of the effective date of designation. This SIP revision was due on April 4, 2015. On March 18, 2016, EPA found that Allegheny County had failed to make this submittal (81 FR 14736). On September 14, 2017, ACHD submitted the plan entitled "Revision to the Allegheny County Portion of the Pennsylvania State Implementation Plan: Attainment Demonstration for the Allegheny, PA Sulfur Dioxide Nonattainment Area 2010 Standards" to the EPA.

During the development of their attainment plan(s), ACHD used American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD), the preferred model for most near-field regulatory applications, for all sources except for fugitive emissions emanating from coke oven batteries. ACHD used an alternative Buoyant Line and Point Source Model (BLP)/AERMOD approach, referred to henceforth as the BLP/AERMOD Hybrid Approach or "Hybrid," to characterize these fugitive emissions. In this approach, ACHD generated hourly varying release heights and dispersion coefficients using BLP's Plume Rise module. Fugitive emissions were then included in EPA's preferred dispersion model, AERMOD, using multiple hourly varying volume sources with BLP Plume Rise determined release heights and initial dispersion coefficients via an hourly emission file.

Appendix W of 40 CFR Part 51 identifies models which are recommended and preferred for regulatory application and which have undergone evaluation exercises including statistical measures of model performance (appendix A to Appendix W). Under 40 CFR 51.11 2(a)(2) and 40 CFR 51 Appendix W, section 3.2, if the preferred model is inappropriate for a particular application in a SIP, the model may

¹ The Allegheny NAA is comprised of a portion of Allegheny County which includes the City of Clairton, City of Duquesne, City of McKeesport, Borough of Braddock, Borough of Dravosburg, Borough of East McKeesport, Borough of East Pittsburgh, Borough of Elizabeth, Borough of Glassport, Borough of Jefferson Hills, Borough of Liberty, Borough of Lincoln, Borough of North Braddock, Borough of Pleasant Hills, Borough of Port Vue, Borough of Versailles, Borough of Wall, Borough of West Elizabeth, Borough of West Mifflin, Elizabeth Township, Forward Township, and North Versailles Township in Pennsylvania.

be modified or another model substituted, if EPA approves the modification or substitution. Appendix W, section 3.2.2 (b) requires that an alternative model be “evaluated from both a theoretical and a performance perspective before it is selected for use,” and outlines several conditions under which an alternative model can be approved. ACHD has sought approval for an alternative BLP/AERMOD Hybrid Approach under Appendix W, section 3.2.2 (b), condition (2), where “a statistical performance evaluation has been conducted using measured air quality data, and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model in appendix A.” The justification for the alternative model is provided in the ACHD’s technical support document, “Alternative Modeling Technical Support Document: BLP/AERMOD Hybrid Approach for Buoyant Fugitives in Complex Terrain” dated July 27, 2018, and is further summarized below.

2. Facility Location and Description

The U. S. Steel Mon Valley Works – Clairton Plant (Clairton Plant) is located along the west bank of the Monongahela River in the City of Clairton, which is located in southern Allegheny County approximately 18 kilometers south of Pittsburgh, PA. This area is made up of complex river valley terrain and includes rural land, densely populated neighborhoods and industrial facilities. The Monongahela River Valley, known as the Mon Valley, is historically an industrial area. Coking facilities became common in this area of Pennsylvania beginning in the decades following the American Civil War. Initial coking operations started at the current location of the Clairton Plant around 1904. These operations eventually became part of the U. S. Steel Corporation.

The Clairton Plant is the country's largest coking operation, with 708 ovens grouped into 10 batteries, and annual capability of 4.3 million tons. Coke is made by heating coal to extremely high temperatures (over 1,800° F) in an oxygen deficient atmosphere. This concentrates the carbon and removes any impurities. The coke produced is subsequently used as fuel in iron and steel production because it generates very high heat with less smoke than coal. The production of the coke itself, however, produces significant amounts of emissions including particulates and sulfur dioxide (SO₂). In 2016, the Clairton Plant emitted 550.3 tons of PM-10 and 889.9 tons of SO₂ placing it in the top five (5) emitters in Allegheny County for these pollutants².

Coking facilities are complex emission sources with multiple emission points and include numerous structures where building downwash can impact pollutant dispersion. Particulate and SO₂ emissions are produced during the coke forming process. Material/product handling processes generate numerous individual particulate emission sources while the coke production processing itself generates combustible coke oven gas (COG) that contributes to particulates and SO₂ emissions when burned. COG derived from the Clairton Plant’s coking process is collected from the ovens and sent via pipeline to the facility’s by-product plant to recover usable products. This process also reduces the COG’s sulfur content. Treated COG is then sent back to the coke ovens for combustion to heat the ovens, used in on-site boilers for steam generation, flared or transported via pipeline to other U. S. Steel Corporation facilities including Irvin and Edgar Thomson for combustion in their plating and blast furnace operations.

As noted previously, the Clairton Plant is located in the Monongahela River Valley. This part of southwest Pennsylvania resides in the Allegheny Plateau physiographic province of the Appalachian

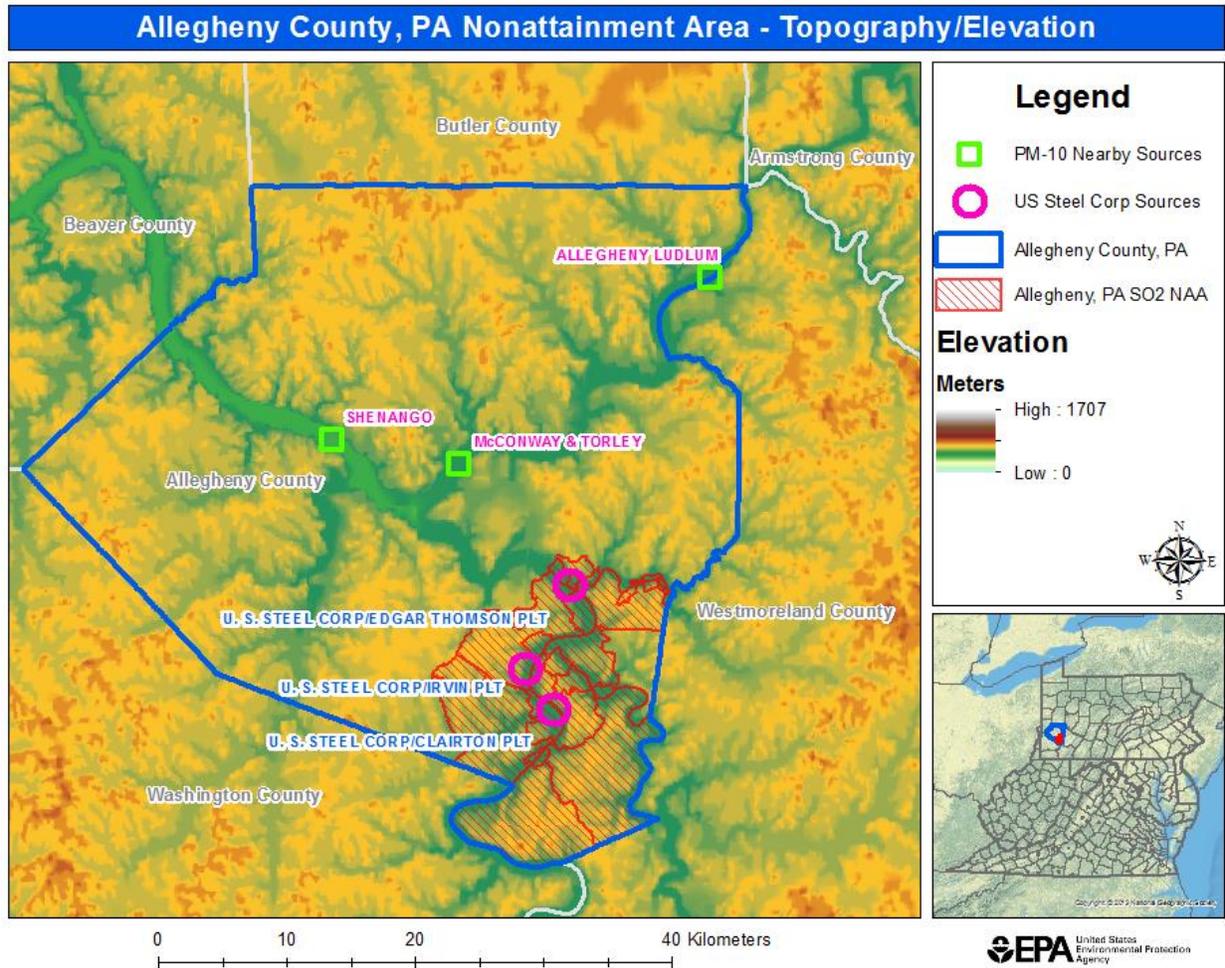
² See PA DEP eFACTS website for point source emission information for Allegheny County.
https://www.ahs.dep.pa.gov/eFACTSWeb/criteria_facilityemissions.aspx

Mountain system, which is marked by dendritic rivers systems imbedded within steep valleys were terrain rises approximately 120 meters above the (river) valley floors (Figure 1). Local air quality is often affected by terrain induced atmospheric temperature inversions that contribute to episodes of poor air quality (the 1948 Donora Smog event occurred approximately 16 miles up-river from the City of Clairton). These meteorological settings are further described in ACHD's 1-hour SO₂ SIP document with additional information included in Appendix A and Appendix C of the SIP documentation.

Temperature inversions occur when the air at the surface becomes cooler than the air above it, i.e., the rate of cooling of the air is greatest at ground level and less at elevated levels (which typically occurs during the overnight hours). The cooler, heavier air then settles within the river valleys and limits vertical mixing trapping emissions and contributing to elevated pollution levels. These conditions occur most often shortly after sunset and last through about midmorning as solar heating begins to drive vertical mixing that eventually breaks up the morning inversion. Emissions from sources within the Mon Valley can become trapped under these inversions contributing to episodes of poor air quality³.

³ See the Allegheny County Health Department's daily Air Dispersion Conditions & Outlook available at: <https://www.alleghenycounty.us/Health-Department/Programs/Air-Quality/Monitored-Data.aspx>

Figure 1. Allegheny County PM-10 Model Evaluation Overview



3. BLP/AERMOD Hybrid Approach-Technical Basis

Generating final coke products from coal involves prodigious amounts of heat. As noted previously, coke ovens themselves operate at temperatures that can exceed 1,800° F. While emissions from coking operations can be well controlled at times, the nature of the production process generates opportunities for fugitive emissions that must be accounted for in any modeling demonstration. Fugitive particulate and SO₂ are generated from leaks in the COG collection system (from stand pipes, manholes or flue ducts that can be caused by system upsets that generate brief episodes of positive pressure in the collection system that break air-flow seals), coke oven charging events, leaks from malfunctioning and/or imperfect coke oven door seals, coke oven door opening events, coke oven pushing events, hot-car transportation, coke handling operations and coke quenching activities. Based on the Clairton Plant's reported fugitive emissions from EPA's National Emission Inventory (NEI), fugitive emissions accounted for approximately 37% of the total emissions for primary PM-10 emissions, approximately 27% of the total emissions for primary PM-2.5 and approximately 12% of the total SO₂ emissions.

These types of fugitive emissions are not easily characterized using the standard emission categories available in most air-dispersion models, for example the point, volume and area source characterizations

used in AERMOD, since these sources involve super-heated materials that generate emissions that are very buoyant with respect to normal ambient temperatures. Historically, coke oven fugitive emissions have been modeled using a technique that accounts for these emissions' initial buoyancy. Previous PM-10 SIPs for Allegheny County and Steubenville-Weirton, OH-WV have used alternative modeling techniques that have involved using EPA's BLP model, more specifically using emission source estimates of temperature and vertical velocity as input into BLP's Plume Rise module to yield estimated plume rise along with initial vertical and lateral dispersion characteristics then treating emissions as (hourly varying) VOLUME sources within AERMOD. These memos are referenced as 91-III-12, 93-III-06, and 94-III-02 in the Model Clearinghouse Information Storage and Retrieval System⁴. A similar approach was used in EPA's *Risk Assessment Document for Coke Oven MACT Residual Risk*⁵. ACHD's approach to modeling these types of buoyant fugitive emissions from the Clairton Plant, previously referred to as the BLP/AERMOD Hybrid Approach, was most recently used in its 1-hour SO₂ SIP modeling demonstration⁶.

With the release of AERMOD version 15181, a new model source type BUOYLINE was created for buoyant line sources, based on algorithms ported from the BLP model. ACHD anticipated that this new source characterization method would be useful in the development of its 1-hour SO₂ modeling demonstration to support the SIP limits imposed on the Clairton Plant. After analyzing the dispersion model results using AERMOD's current source characterization for buoyant line sources (BUOYLINE) ACHD noted several deficiencies. From the Allegheny, PA 2017 1-hour SO₂ SIP documentation (Appendix A), these deficiencies with AERMOD's BUOYLINE source characterization are:

- Impacts from buoyant line sources are likely overpredicted
- Maximum impacts from buoyant line sources are occurring in incorrect locations
- Theoretical enhanced plume rise for inline (parallel) wind directions is not evident in resultant plume impacts
- While more than one physical line can be modeled as a BUOYLINE, all lines must be modeled at the same average buoyancy properties (temperature, flow, dimensions) Note: Clairton Coke works currently operates five (5) different coke oven battery lines
- AERMOD results in fatal errors for many line configurations (including several small lines)
- DEBUG output was not available for buoyant line sources (AERMOD versions 15181 and 16216r) for more thorough review of model output
- Buoyant line sources in the NAA are likely better modeled as smaller segments, instead of a large line plume in complex terrain

ACHD tested several other source characterization approaches for the Clairton Plant's fugitive coke oven emissions including using AERMOD's standard POINT and VOLUME source characterizations, virtual POINT sources with an average release height that exceeded the actual coke oven battery height and use of AERMOD's urban source characterization to simulate the coke oven battery's "heat island" impact (enhanced overnight turbulence/SO₂ half-life enhancements). After a comparison of different source characterizations, ACHD concluded that using the BLP/AERMOD Hybrid Approach produced the most realistic model results for its 1-hour SO₂ SIP.

⁴ <https://cfpub.epa.gov/oarweb/MCHISRS/index.cfm?fuseaction=main.search>

⁵ Report dated December 22, 2003, and available at: https://www.epa.gov/sites/production/files/2016-01/documents/coke_rra.pdf

⁶ <https://www.alleghenycounty.us/Health-Department/Programs/Air-Quality/Regulations-and-SIPs.aspx>

To accomplish this Hybrid approach, ACHD needed to perform several steps to use BLP plume rises for its hourly varying volume sources. This process was described in section 3.1 of ACHD's technical support document with a more detailed explanation included in Appendix B and G of ACHD's technical support document. This methodology was also used in ACHD's 1-hr SO₂ SIP modeling demonstration and was described in Appendix A – Addendum of ACHD's SO₂ SIP documentation.

4. BLP/AERMOD Hybrid Approach Simulation Details and Performance Evaluation

ACHD conducted a model performance evaluation using actual PM-10 emissions from several sources in Allegheny County including the Clairton Plant and two (2) other U. S. Steel Corporation facilities. Figure 1 shows the locations of ACHD's modeled sources along with local elevations. The model evaluation utilizes the basic model platform that was used in the recently developed 1-hour SO₂ SIP and ongoing work to develop the Allegheny County, PA PM-2.5 SIP. A brief description of the modeling platform along with the results of a statistical analysis will be presented in this section. Dispersion model results using different AERMOD source characterization approaches are statistically compared with three (3) different PM-10 monitors located to the east and north of the Clairton Plant. The statistical analysis shows that the BLP/AERMOD Hybrid Approach, as discussed earlier, provides the best method for reproducing impacts from the fugitive coke oven emissions coming from the coke oven operations at the Clairton Plant. It is assumed that this PM-10 statistical analysis would support the use of the BLP/AERMOD Hybrid Approach for ACHD's 1-hour SO₂ and PM-2.5 SIP modeling demonstrations. AERMOD treats both PM-10 and SO₂ as inert pollutants, and therefore they would have similar dispersion characteristics, and are directly scalable and comparable. The remainder of this section provides a summary of the different modeling components included in ACHD's statistical analysis.

PM-10 Emissions: ACHD used actual 2011 emissions for its statistical analysis. A total of six (6) facilities were included in the modeling analysis. These include all three (3) U. S. Steel Corporation facilities in southern Allegheny County as well as three (3) other “near-by” sources. Modeled emissions represent 2011 actual emissions. EPA compared each facility's PM-10 modeled yearly emission totals with information from EPA's 2011 NEI and determined that facility yearly emissions totals were nearly identical for all modeled sources. Modeled emissions for the Clairton Plant were slightly higher than the 2011 NEI due to ACHD's recalculations of the plant's quenching emissions. These recalculations were made to account for an improved understanding of emission releases during the coke quenching process.

Each facility's emissions were broken down into point, (poly) area, volume, and (Hybrid) volume sources in the PM-10 model simulation. Table 1 lists the source type category totals for ACHD's PM-10 simulations. The Clairton Plant has several source categories coinciding with the different source characterization runs used in ACHD's statistical analysis. These include a source count that excludes all coke oven battery fugitive emissions, accounting for the coke oven battery fugitives using representative point sources, using representative volume sources, using the BUOYLINE source characterization, and finally using BLP Plume Rise Hybrid hourly varying volume sources. Modeled source locations were downloaded into GIS for visual inspection to ensure the proper spatial locations for the different sources (see building downwash for additional details).

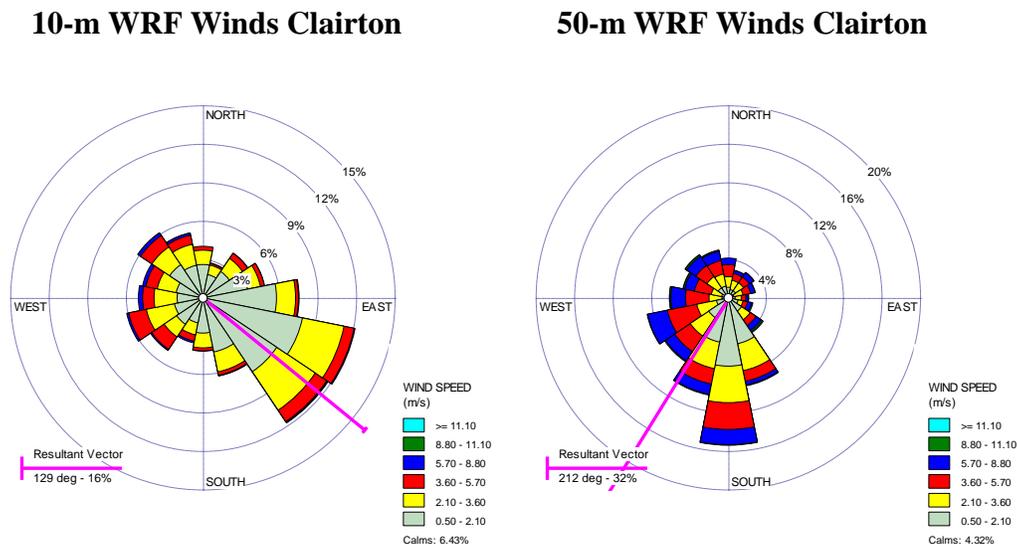
Table 1. Facility PM-10 Modeled Source Characterization Summary

Facility	Point	PolyArea	Volume	Hybrid	BUOYLINE	Total
Allegheny Ludlum	40					40
McConway & Torley	10					10
Shenango	17					17
U. S. Steel Edgar Thomson	39		46			85
U. S. Steel Irvin	25		7			32
U. S. Steel Clairton (No Batteries)	53	2	56			111
U. S. Steel Clairton (Point Batteries)	117	2	56			175
U. S. Steel Clairton (Volume Batteries)	53	2	120			175
U. S. Steel Clairton (BUOYLINE Batteries)	53	2	56		4	115
U. S. Steel Clairton (Hybrid Batteries)	53	2	56	71		182

Meteorological Data and Processing: Terrain induced complex night-time flows and inversions play a prominent role in air pollution episodes in the Mon Valley. Correctly capturing these local atmospheric conditions is an important step in properly modeling the impacts of the emissions from the large sources that are often located along the lowest points in the river valleys. Complex air flows within these valleys cannot be captured using local National Weather Service sites since these collection points are typically located on the higher elevations of the Allegheny Plateau; for aviation safety purposes, most airports in western Pennsylvania are sited in the more exposed portions of any elevated terrain. For this reason, ACHD developed a modeling platform that used the Weather and Research Forecasting (WRF) model to simulate the complex airflow in the Mon Valley. WRF output was extracted using EPA’s Mesoscale Model Interface Program or MMIF (version 3.4) to develop the meteorological input files used in AERMOD. The WRF model was run at an approximately 440 m grid resolution around the three (3) U. S. Steel Corporation sources. The other three (3) sources used WRF input from the outer 1.3 km domain. Additional information on ACHD’s meteorological model set up can be found in section 4.1.3 and Appendix D of its technical support document.

ACHD conducted a WRF model performance evaluation in Appendix F of its 1-hour SO₂ SIP documentation and a MMIF evaluation in Appendix H of its 1-hour SO₂ SIP submittal. WRF appeared to adequately reproduce locally induced wind field patterns based on local National Weather Station ASOS sites, partial local sodar collection near the Clairton Plant and tower data available from the nearby Beaver Valley Nuclear Station. Additional analysis by EPA Region 3 also indicated that WRF is adequately simulating the local in-valley complex wind flows that are important to local emission transport. Figure 2 shows the 10-m and 50-m WRF output (as extracted by MMIF and processed through AERMET) for the 440-m grid cell representing the Clairton Plant. The wind roses, produced using Lakes Environmental’s WRPLOT software, show wind structure changes as one rises above the Mon Valley floor. Figure 3 shows the surface file wind fields extracted from ACHD’s 440-m WRF grid overlain with local topography and illustrates the complex wind flow the model is simulating within the Mon Valley.

Figure 2. WRPLOT Wind Roses for the 2011 WRF (440-m Grid) Simulation

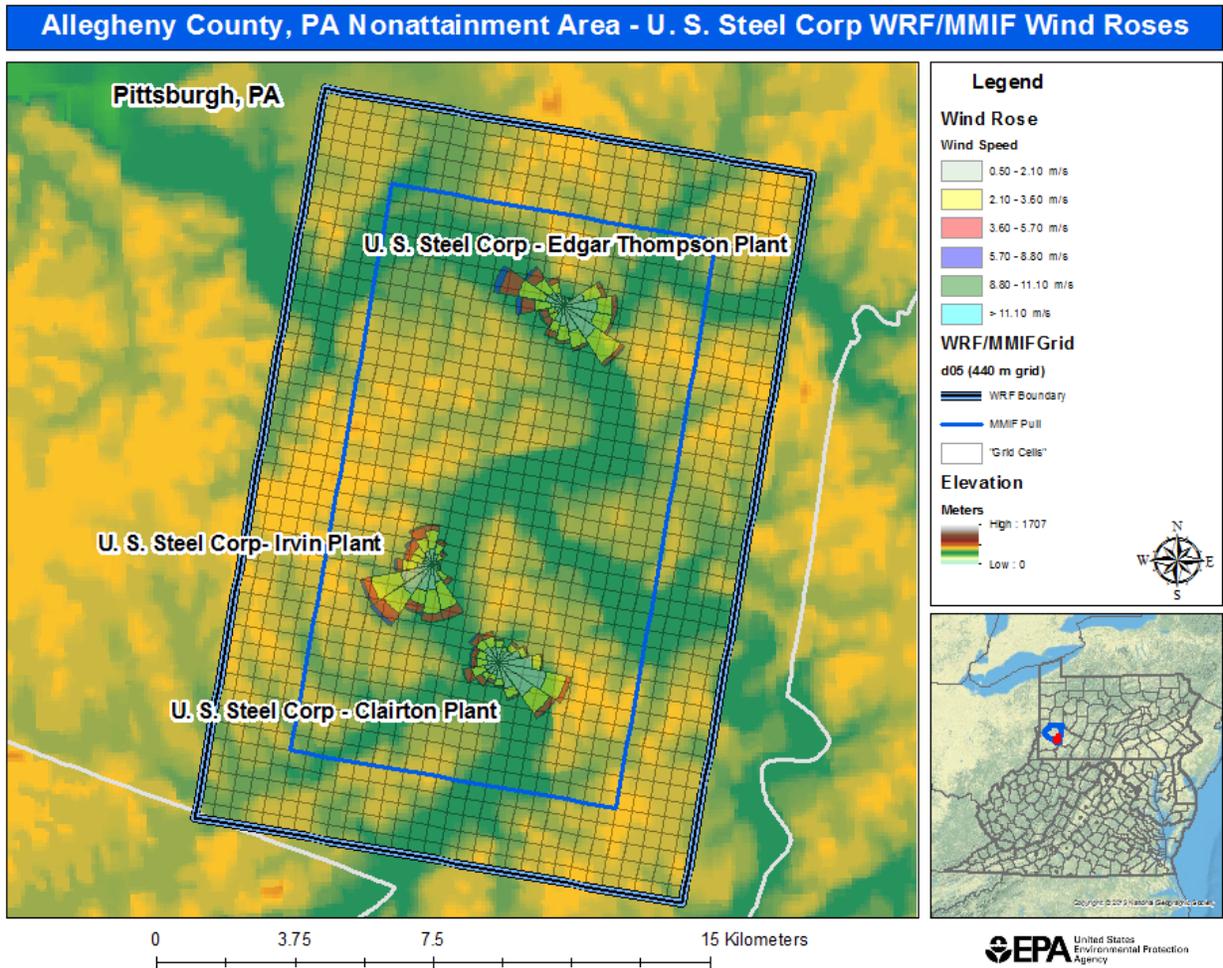


Building Downwash Parameterization: ACHD constructed detailed building information for the three (3) U. S. Steel Corporation sources as part of their 1-hr SO₂ SIP modeling analysis (see Appendix J of ACHD’s 1-hour SO₂ SIP documentation). Since the modeling used for the statistical test predates the time period used for ACHD’s 1-hour SO₂ SIP, there may be instances when some building structures and sources would need to be removed from their original 1-hour SO₂ modeling platform.

EPA Region 3 examined the Building Profile Input Program (BPIP) input files provided by the ACHD. Building and source locations from the BPIP input files by porting these files into GIS for visual inspection. A total of 183 structures were included in the ACHD’s BPIP analysis for the U. S. Steel Corporation facilities. No significant errors in building locations were noted. A total of 299 individual sources (from the Hybrid runs) were included in the ACHD’s BPIP files for downwash consideration. Building downwash was only considered for the U. S. Steel Corporation facilities (U. S. Steel Mon Valley Works). Downwash from the other three (3) nearby PM-10 sources should have little or no impact in the immediate vicinity of the Clairton and Irvin plants where the PM-10 monitors used in the statistical analysis reside. Modeled sources included traditional point sources plus other sources of particulate emissions including material handling processes, road emissions and local tugboat/barge mobile emissions.

PM-10 Monitor Information: ACHD used PM-10 monitoring data from 2011 collected at three (3) monitors located to the east and northeast of the Clairton Plant. Figure 4 shows the locations of the three (3) PM-10 monitors ACHD used in their statistical analysis. All three (3) PM-10 monitoring sites are located at higher elevations (above 300 m) than the nearby U. S. Steel Corporation Irvin and Clairton plants. For comparison, modeled source base elevations at Irvin are 287 m and at Clairton are 231 m.

Figure 3. WRF/MMIF Wind Roses for U. S. Steel Corporation Facilities in the Mon Valley



EPA compared the monitoring data pulled from EPA’s Air Quality System (AQS) with the monitoring data used in the ACHD’s statistical analysis. The monitoring data used for the statistical analysis generally matched the hourly data extracted from AQS. For statistical purposes, ACHD reset all negative hourly monitor values along with all zero monitor values to $1 \mu\text{g}/\text{m}^3$. This reflects the background values it pulled from its CAMx PM-2.5 modeling analysis, which is being used for the ACHD’s PM-2.5 modeling demonstration. Additional information on the CAMx run can be found in section 4.2 of ACHD’s technical support document. Negative PM-10 values indicate the monitors have been properly “zeroed” and are therefore not necessarily invalid hours. Each monitor also appears to have a significant number of hours with values at or near zero indicating the area is not inundated with an abundance of local source influences; spikes in hourly PM-10 values and periods of very low values appear to support a relatively small number of significant sources in the immediate area of the PM-10 monitors. Table 2 summarizes the hourly PM-10 monitor values for the three (3) sites used in ACHD’s statistical analysis. Max and min hourly values, average and median values, valid hours and the number of hours with monitor concentrations $\leq 1 \mu\text{g}/\text{m}^3$ and $< 0 \mu\text{g}/\text{m}^3$ are all listed in the table for 2011.

Figure 4. PM-10 Monitor Locations

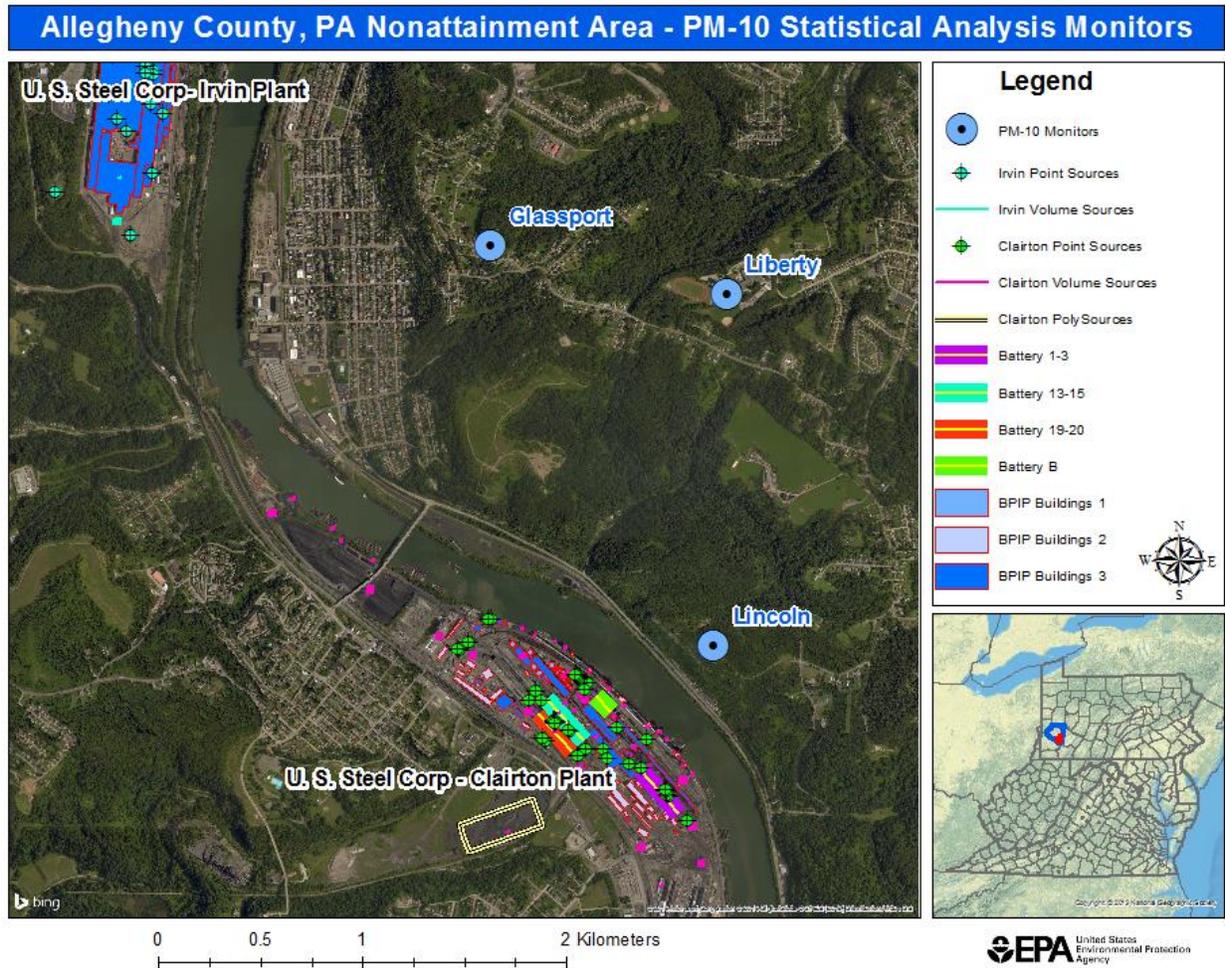


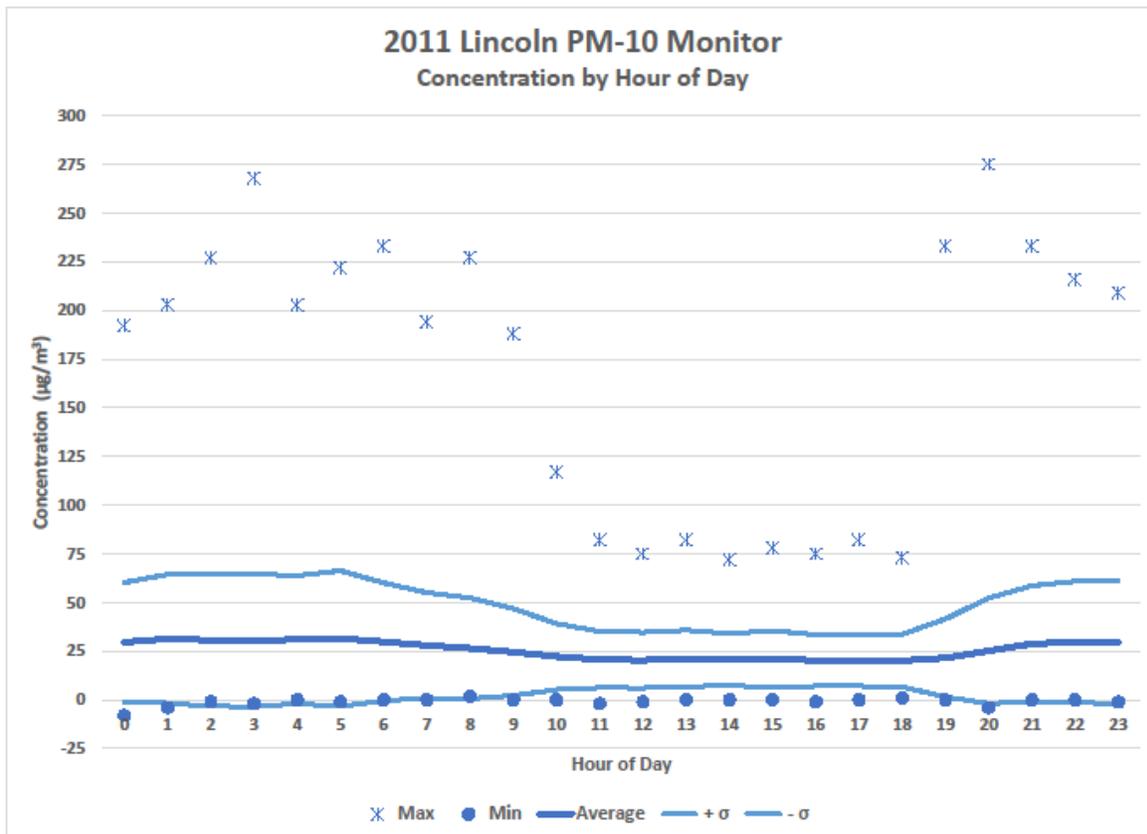
Table 2. AQS 2011 PM-10 Monitor Statistics ($\mu\text{g}/\text{m}^3$)

	Lincoln	Liberty	Glassport
Max	275	197	206
Min	-8	-6	-8
Median	19	14	13
Average	25.7	19.6	18.4
Valid Hours	8,535	8694	8470
Hours $\leq 1 \mu\text{g}/\text{m}^3$	87	331	295
Hours $< 0 \mu\text{g}/\text{m}^3$	12	79	53

All three (3) PM-10 monitors show a strong diurnal signal with the highest hourly 2011 monitor concentrations occurring during the overnight hours. Daytime PM-10 concentrations are usually lower and show less overall variability. Overnight PM-10 peak concentrations are over three (3) times higher than daytime peak concentrations. ACHD has concluded that these monitor peaks are due to local overnight temperature inversions capping or trapping emissions within the Mon Valley. It should be noted that these monitors are located at higher elevations than the emission sources.

Figure 5 shows this diurnal pattern at the Lincoln PM-10 monitor. This type of diurnal pattern is also observed in local 1-hour SO₂ monitor concentrations. The figure shows monitor concentration statistics by hour of day for 2011. While the other monitors are not shown, the higher overnight PM-10 concentrations at the Lincoln monitor tend to persist later in the morning than either the Glassport or Liberty PM-10 monitors.

Figure 5. Lincoln PM-10 Monitor by Hour of Day Statistics for 2011



AERMOD Runs: ACHD conducted a series of PM-10 simulations using EPA’s AERMOD air dispersion modeling system (version 18081). The basic platform, generally described in the previous sections, was developed for the Allegheny, PA 1-hour SO₂ Nonattainment Area modeling demonstration. An AERMOD settings summary for the PM-10 simulations is available in section 4.1.2 of ACHD’s technical support document.

Several modifications to the modeling system were made for this PM-10 modeling demonstration including source emission re-development, reprocessing the WRF prognostic meteorology using the most recent guidance using MMIF (version 3.4) to remove minimum wind speed thresholds, and using the most recent version of the AERMOD model and its preprocessors (the 1-hr SO₂ SIP demonstration

used version 16216r). Additional documentation for the statistical runs can be found in the ACHD's modeling protocol for the development of its PM-2.5 SIP modeling demonstration.

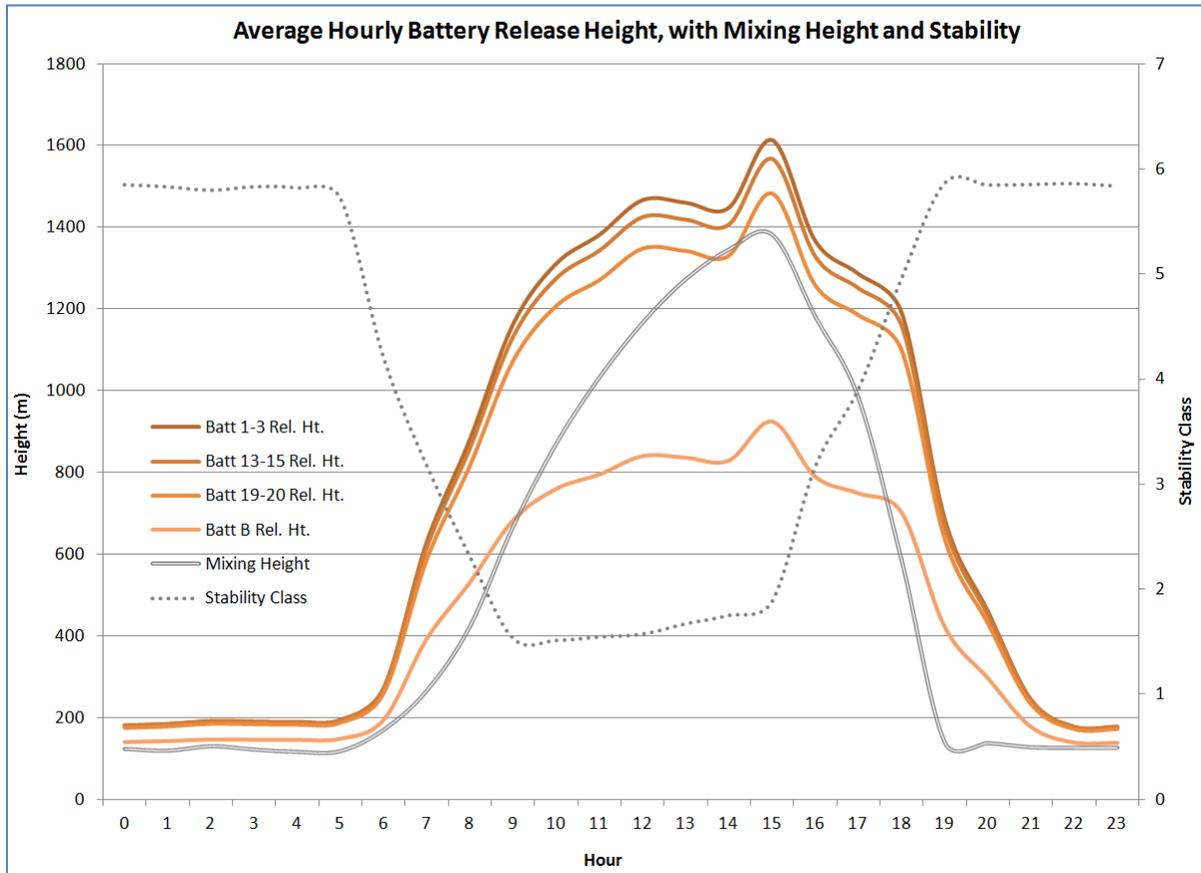
As noted previously, ACHD constructed a series of AERMOD simulations to create modeled concentrations for three (3) PM-10 monitors located near U. S. Steel Corporation's Irvin and Clairton plants. Meteorological and monitoring data from 2011 were constructed to develop the model to monitor database for the statistical comparison for the different methods of accounting for the Clairton Plant's fugitive coke oven emissions. AERMOD was run using the same (regulatory) default options, which included stack-tip downwash, elevated terrain impacts, calms processing, missing data processing with no exponential decay. Other options utilized included the low-wind ADJ_U* option, regulatory MMIF data processing steps, use of the BULKRN Delta-T and SolarRad option for SBL with MMIF and meteorological data that includes TEMP substitutions. AERMOD's OTHER pollutant ID was used during all simulations to allow proper capture of the model output.

Four (4) separate AERMOD simulations were completed for each characterization of the Clairton Plant's coke oven fugitive emissions. This included the current AERMOD regulatory source characterization (BUOYLINE), an approximate Point source characterization, an approximate Volume source characterization, and the Hybrid (Volume) source characterization. ACHD documented the estimated temperature and vertical velocities used to calculate the Buoyancy Flux (F') needed for both the BUOYLINE input and information provided to the BLP's (modified) Plume Rise module used to calculate the initial release height and vertical and lateral dispersion characteristics of the hourly varying volume sources (referred to as the Hybrid approach by the ACHD). A more detailed discussion of the development of the F' calculations used in the PM-10 simulations can be found in section 3.2 of ACHD's technical support document.

Use of the BLP plume rise algorithm can lead to extremely high source release calculations and at times very large initial vertical dispersion terms that are passed into AERMOD for the Hybrid analysis. Figure 6 (taken from Appendix B from ACHD's technical support document) displays the average plume rises by hour of day for each of the four (4) batteries included in the modeling analysis. There is a definitive diurnal pattern for all of the fugitive coke oven release heights with higher values concentrated during the daytime hours. Some of this difference between overnight and daytime release heights calculated from the BLP Plume Rise module may be due to differences in the plume rise calculations, which are separated into stable (overnight) and neutral or above (daytime) conditions.

EPA also examined plume rise calculations and initial vertical plume dimensions for the different battery ovens at the Clairton Plant. Plume rise and initial vertical plume dimensions were taken from the hourly varying volume source file included in the modeling files included as part of ACHD's alternative model request (obtained from the AERMOD model files used for the demonstration "MODEL_FILES.zip" file, BAATS_2011.prn). There are hours in which BLP Plume Rise calculations can approach or exceed 3,000 m and vertical plume dimensions exceed 500 m (see Appendix at the end of this technical support document for further analysis). While these calculations could be considered excessive, they are almost exclusively occurring during the daytime hours when the atmosphere is expected to be well mixed. Potential BLP plume rises and initial vertical dimensions are also occurring during hours when monitor values are relatively low and not during the critical overnight hours when the highest monitor (and model) concentrations are determining compliance with the NAAQS (design values).

Figure 6. (From Appendix B of ACHD’s TSD) Average BLP Plume Rise by Battery



To do the statistical comparison between the modeled and monitored 2011 data, ACHD placed model receptors surrounding the three (3) PM-10 monitoring sites. The model receptors were generated using 10-m resolution USGS NED data processed using AERMAP version 18081 (AERMAP settings are listed in section 4.1.4 of ACHD’s technical support document). A 10-m flagpole receptor was used for the model receptor located at the actual site of the Liberty PM-10 monitor. This monitor resides on the second floor of a school building. The receptors, other than the flagpole receptor placed at the Liberty monitor, represent surface concentrations when in reality most monitors collect samples several meters above the ground.

The AERMOD runs completed by ACHD were post processed using the CALPOST utility. This was done since each of the modeled sources used separately processed AERMET files to account for the complex winds impacting the areas surrounding the three (3) U. S. Steel facilities. Separate AERMOD runs were made for each modeled source then post processed using the CALPOST utility to combine the source-specific AERMOD results for comparison to the PM-10 monitor data. A similar process was performed for the Allegheny, PA 1-hour SO₂ SIP modeling demonstration. This approach was taken with proper EPA consultation and discussed in more detail in the 1-hour SO₂ SIP documentation, which included specific comments and analysis from regional modeling staff. An additional description of this process is included in Appendix E of ACHD’s technical support document.

Statistical Analysis Results: Section 3.2.2(b)(2) of the Guideline on Air Quality Models outlines how an alternative modeling approach may be approvable if “a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model.” ACHD provided a statistical analysis summary from a series of modeling analyses using different modeling techniques to represent the fugitive coke oven emissions at the Clairton Plant, which were then compared to three (3) PM-10 monitors located near the U. S. Steel Corporation Clairton plant. Specifically, ACHD compared model results using AERMOD’s regulatory approach to modeling buoyant emissions (BUOYLINE) to the BLP/AERMOD Hybrid Approach. A more detailed discussion of the statistical analysis was included in Section 5 of ACHD’s technical support document to its alternative model request.

Several sets of statistical analyses were presented in ACHD’s alternative model request. A swath of statistical tests was performed in accordance with PM-2.5 modeling guidance including a group of core statistical measures that were listed in Table 5-1 of ACHD’s alternative model request. Results for the 24-hr PM-10 score statistics for the Liberty monitor (from Table 5-3 of ACHD’s technical support document) are presented in Table 3 below and show that the Hybrid methodology used to represent the Clairton Plant’s coke oven fugitives provides the best overall performance and offers a substantial improvement over the regulatory characterization using BUOYLINE, which generally provides overpredicted model results.

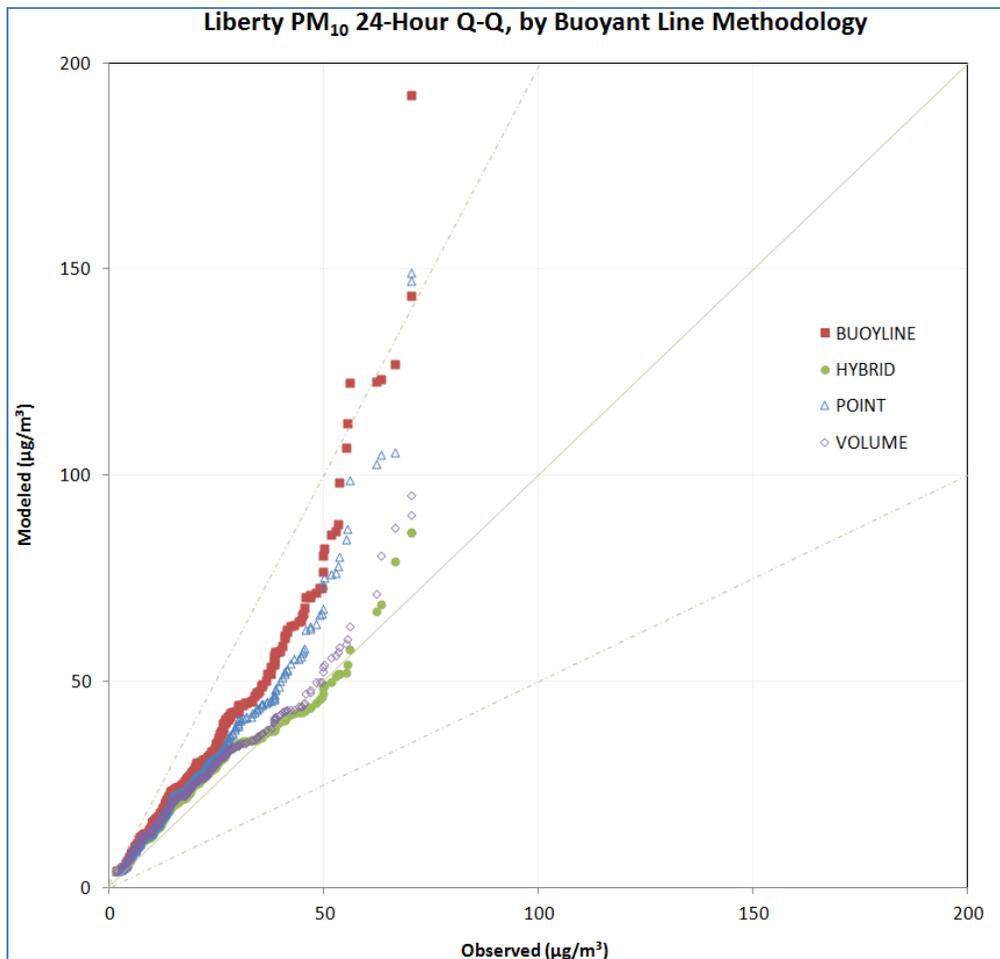
Table 3. Liberty 24-hr Core Statistics from ACHD’s Technical Support Document

Daily PM10 at Liberty					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	19.69	29.90	23.18	27.01	24.13
Mean Bias	--	10.21	3.49	7.32	4.44
Mean Error	--	14.73	8.56	11.50	9.35
Root Mean Square Error	--	22.55	11.41	17.61	12.66
Normalized Mean Bias	--	0.52	0.18	0.37	0.23
Normalized Mean Error	--	0.75	0.43	0.58	0.47
Fractional Bias	--	0.36	0.21	0.31	0.25
Fractional Error	--	0.55	0.42	0.47	0.44
Correlation Coefficient	--	0.50	0.66	0.58	0.61
Factor of Two	--	0.63	0.79	0.72	0.76
Geometric Correlation Coefficient	--	0.30	0.49	0.45	0.43
Geometric Mean	15.76	23.68	19.82	21.95	20.71
Geometric Mean Variance	--	1.80	1.36	1.49	1.43
Robust Highest Concentration (N=26)	74	155	78	137	92

ACHD generated 1-hr, 3-hr and 24-hr Q-Q plots for the four (4) source characterization methods for monitor values. Figure 7 (taken from ACHD’s alternative request technical support document) shows a 24-hr Q-Q plot for the Liberty monitor’s model-monitor comparison; Q-Q plots show paired model/monitor rankings with good model performance judged by how close the scatter plots fall along

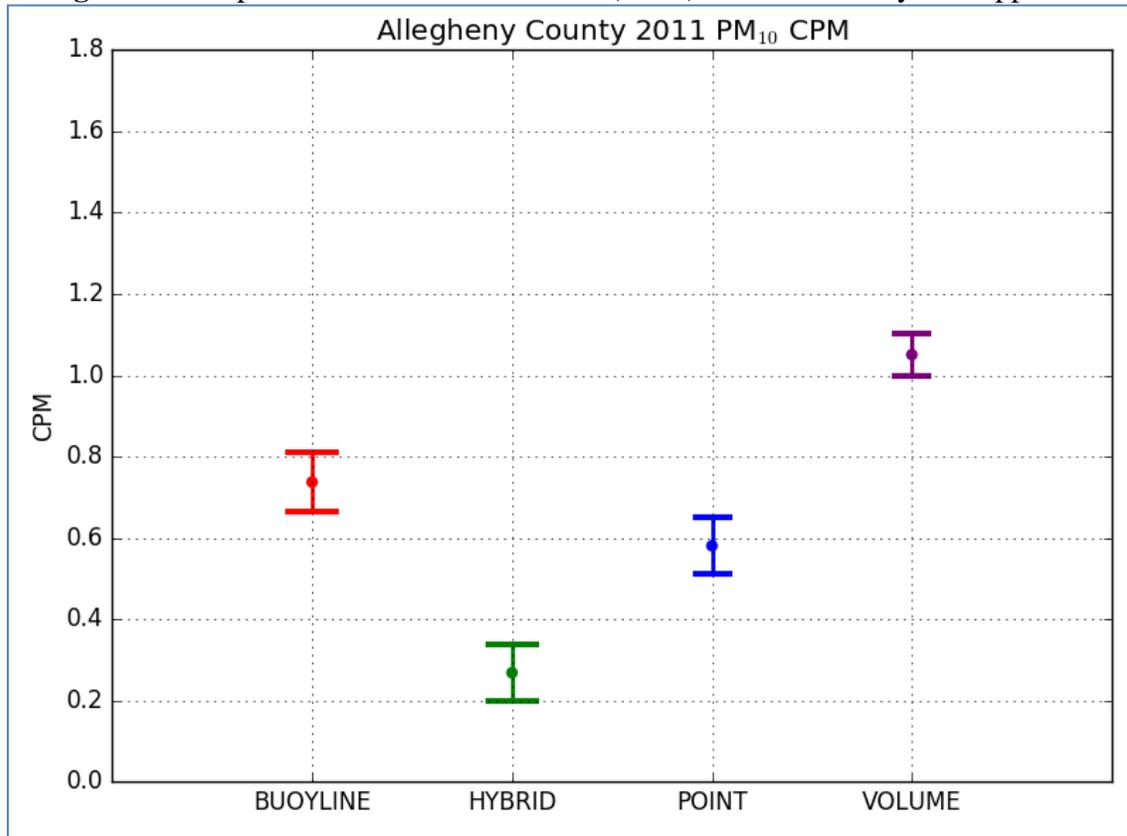
the 1-1 line. ACHD's results show that its Hybrid approach method for modeling Clairton's fugitive coke oven emissions falls closest to the 1-1 line. Using the regulatory source characterization (BUOYLINE) method produces model to monitor ratios that are over the 2-1 line indicating substantial model overprediction especially in the upper portion of the model-monitor distributions. This point is important since design value concentrations typically reside in the upper ranges of the monitor and model concentration distributions.

Figure 7. Q-Q plot for the 24-Hour Liberty Monitor-Model Results (from ACHD)



ACHD included a composite performance measure (CPM) analysis to examine overall model performance for the three (3) PM-10 monitors located near the Clairton Plant. The CPM combines multiple model-monitor statistics to gauge which model configuration best matches all of the monitoring information. Figure 8 is taken from ACHD's technical support document and shows the CPM for the BUOYLINE (regulatory), Hybrid, Point and Volume treatments of the fugitive coke oven emissions from the Clairton Plant. For CPM, the best performance is gauged by noting which approach has the lowest values. In this case the Hybrid approach best matches the PM-10 monitors closest to the Clairton Plant and therefore, as ACHD has noted, is the best approach to correctly capture the impacts of the coke oven battery fugitive emission.

Figure 8. Composite Performance Measure (CPM) from ACHD Hybrid Approach



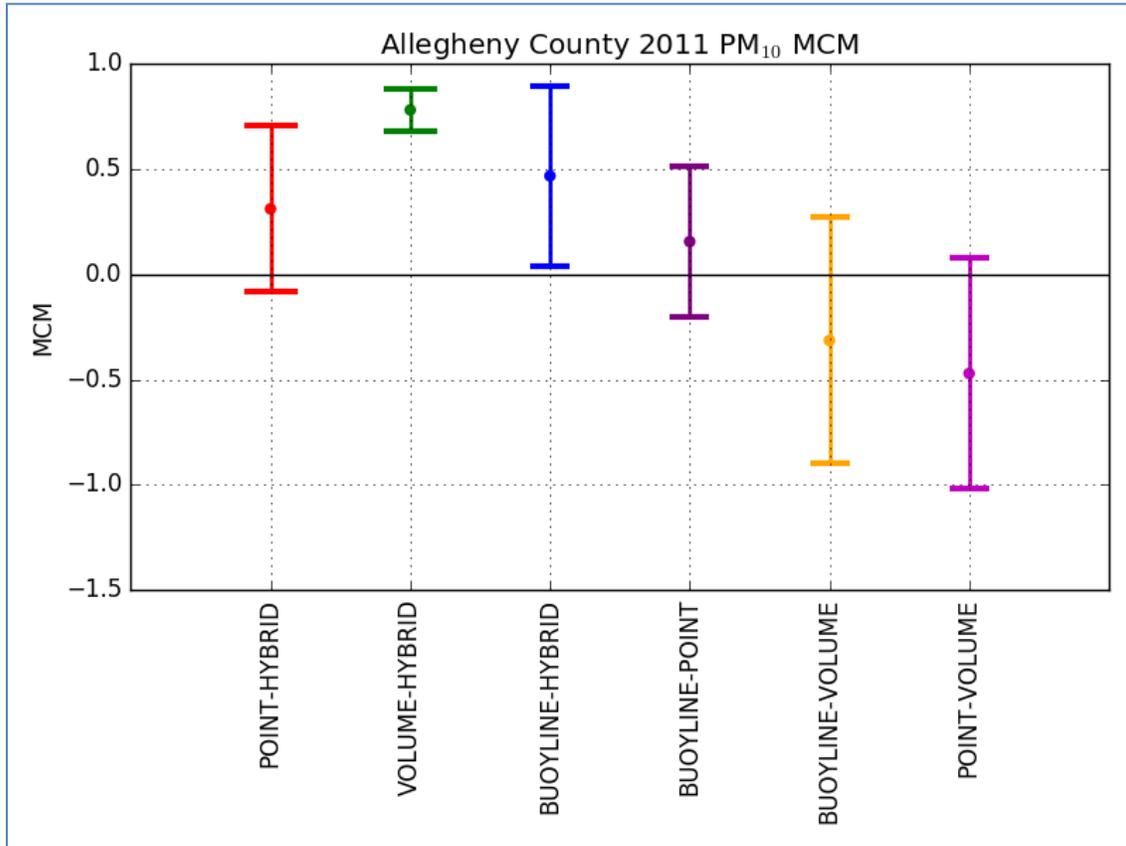
Additionally, ACHD constructed a model comparison measure (MCM) for each combination of models (six comparisons for the four different cases). These are shown in Figure 9 (Figure 5-14 from ACHD’s technical support document). Model pairs are listed across the bottom axis of the figure. If the MCM confidence interval spans zero, performance differences are considered not statistically significant⁷.

From ACHD’s technical support document:

“[T]he hybrid case is most superior case from the MCM analysis, showing positive values as the second model case (i.e., lower CPM values) as well as statistical significance (confidence intervals not spanning zero) when compared to the volume and BUOYLINE cases. The focus of this demonstration was the performance of the alternative hybrid case to the preferred BUOYLINE case, so this MCM is more relevant than the comparison of the hybrid case to the volume case. All other model case comparisons showed statistical insignificance (confidence intervals spanning zero).”

⁷ See Roger Brode presentation from 11th Modeling Conference (slide 15 of Proposed Updates to the AERMOD Modeling System presentation): <https://www3.epa.gov/ttn/scram/11thmodconfpres.htm>

**Figure 9. Model Comparison Measure (MCM) for ACHD PM-10 Modeling
(From ACHD Technical Support Document Figure 5-15)**



5. Conclusion

ACHD considers the BLP/AERMOD Hybrid Approach as the best available method for modeling the fugitive coke oven emissions from the Clairton Plant in lieu of using AERMOD’s BUOYLINE source characterization which is the preferred model listed in Appendix W for the current development of the PM-2.5 SIP Plan⁸. On July 27, 2018, ACHD sent a request to EPA Region 3’s Regional Administrator seeking approval to use this alternative model approach to characterize fugitive emissions from the coke oven batteries at the U.S. Steel – Clairton facility.

In support of this request, ACHD presented the results of their PM-10 modeling and statistical analysis to determine the best performing model for simulating the Clairton Plant’s fugitive coke oven emissions. These included a number of statistical measures to compare model-monitor concentrations. Overall the statistical analysis presented by the ACHD shows that the BLP/AERMOD Hybrid Approach most closely reproduces the observed monitor values that are nearest to the Clairton Plant. Utilizing the regulatory BUOYLINE option within AERMOD produces overestimations as does characterizing the

⁸ EPA has since approved AERMOD with a newly incorporated BLP algorithm as the preferred model for these sources, as part of revisions to Appendix W promulgated in 2017. See 82 FR 5182 (January 17, 2017). The effective date for Appendix W was later revised to May 22, 2017. See 82 FR 14324 (March 20, 2017).

fugitive coke oven emissions using the Point or Volume source characterizations. ACHD's statistical analysis, summarized in the previous section, included a host of core set statistical performance measures and a CPM analysis encompassing multiple statistics combining results for all monitors. Furthermore, a MCM analysis was presented showing the Hybrid approach's superior performance is statistically significant. Results of these statistical analyses indicate the Hybrid approach to modeling the Clairton Plant's coke oven fugitive emissions performs significantly better than the BUOYLINE regulatory approach given the meteorology and topography present in this section of Allegheny County, PA.

After careful consideration, review and summary of the information that was submitted, including a thorough statistical analysis presented as part of ACHD's formal request for use of an alternative model under section 3.2.2 (b)(2) of Appendix X, EPA Region 3 believes that ACHD has fully demonstrated that the alternative model (BLP/AERMOD Hybrid Approach) provides superior results over the regulatory (BUOYLINE) model and therefore should be approved. Region 3 seeks Model Clearinghouse Concurrence with its conclusion in accordance with section 3.2.2 (a) of Appendix W.

Appendix – BLP Plume Rise and Initial Vertical Dimension Calculations

The Hybrid modeling approach used by the ACHD to more correctly simulate the buoyant fugitive emissions from the Clairton Plant’s coke ovens utilized a modified BLP Plume Rise algorithm to generate hourly varying release heights and initial plume dimensions for input into AERMOD. These values are calculated based on average temperature and vertical velocity information and hourly atmospheric conditions taken from the prognostic meteorological model (WRF). Final plume rises and initial plume dimensions from BLP Plume Rise are fed into AERMOD as an hourly varying volume source.

EPA has noted that this procedure can produce plume rise calculations that occasionally exceed 3,000 m along with initial vertical plume dimensions in excess of 500 m. Both of these values could be considered excessive. This section presents additional information regarding BLP Plume Rise generated plume rise and initial vertical plume dimension as pulled from the AERMOD hourly emission file.

ACHD’s modeling analysis included the model files used in its alternative model statistical analysis. Only the Hybrid case utilized an hourly varying emission file. The Clairton Coke plant is comprised of four (4) main coke oven batteries; Clairton currently has five (5) batteries but only four (4) were active for the 2011 model simulation. PM-10 emissions from each battery were unique as were battery dimensions that were fed into the buoyancy calculations (F') and thus each battery has its own hourly plume rise (model release heights) and initial plume dimension. Specific plume rise calculation methodologies are outline in Appendix B (and G) of ACHD’s technical support document.

Combined coke oven battery fugitive emission rates are summarized in Table A-1. Battery 19-20 is the largest PM-10 fugitive emission source in ACHD’s model simulation. The next largest fugitive emission source is Battery 13-15. Both batteries generate over 50% of the modeled fugitive PM-10 emissions in ACHD’s modeling analysis. Battery B, a more recently constructed coke oven battery, has substantially lower emissions than the other older coke oven batteries. Newer coke ovens generally have fewer leaks and have better designed/functioning control equipment.

Table A-1. Clairton Plant Coke Oven Fugitive PM-10 Emissions by Battery

Clairton Battery	PM-10 (lbs/hr)	PM-10 (tpy)	Battery Flow Rates (m ³ /s)
Battery 1-3	13.39	58.66	875.35
Battery 13-15	16.38	71.76	832.65
Battery 19-21	20.52	89.88	753.35
Battery B	5.17	22.66	323.30
Total Modeled		242.97	

Figures showing modeled hourly release heights and initial vertical dimensions from the AERMOD Hybrid simulations are presented for Battery 19-20 and Battery 13-15 on the following pages (Figure A-1 and A-2). These figures are broken down by hour of day and show hourly plume rise and vertical dimension statistics and the number of hours during the simulation period plume rises exceed 1,000 m and 3,000 m and initial vertical dimensions exceeded 500 m and 1,000 m.

Potentially excessive plume rise and initial vertical dimension occur almost exclusively during the daytime hours when the atmosphere is expected to be well mixed, and monitor concentrations are low. The highest monitor concentrations that are used in determining compliance with the NAAQS (design values) typically occur during the overnight hours. Differences between the overnight and daytime release heights may be due to differences in the F' calculations for stable versus neutral or above stability categories in the BLP Plume Rise equations.

Figure A-1 (a) Battery 19-20 BLP Plume Rise (Model Release Heights) Statistics and Hour Counts

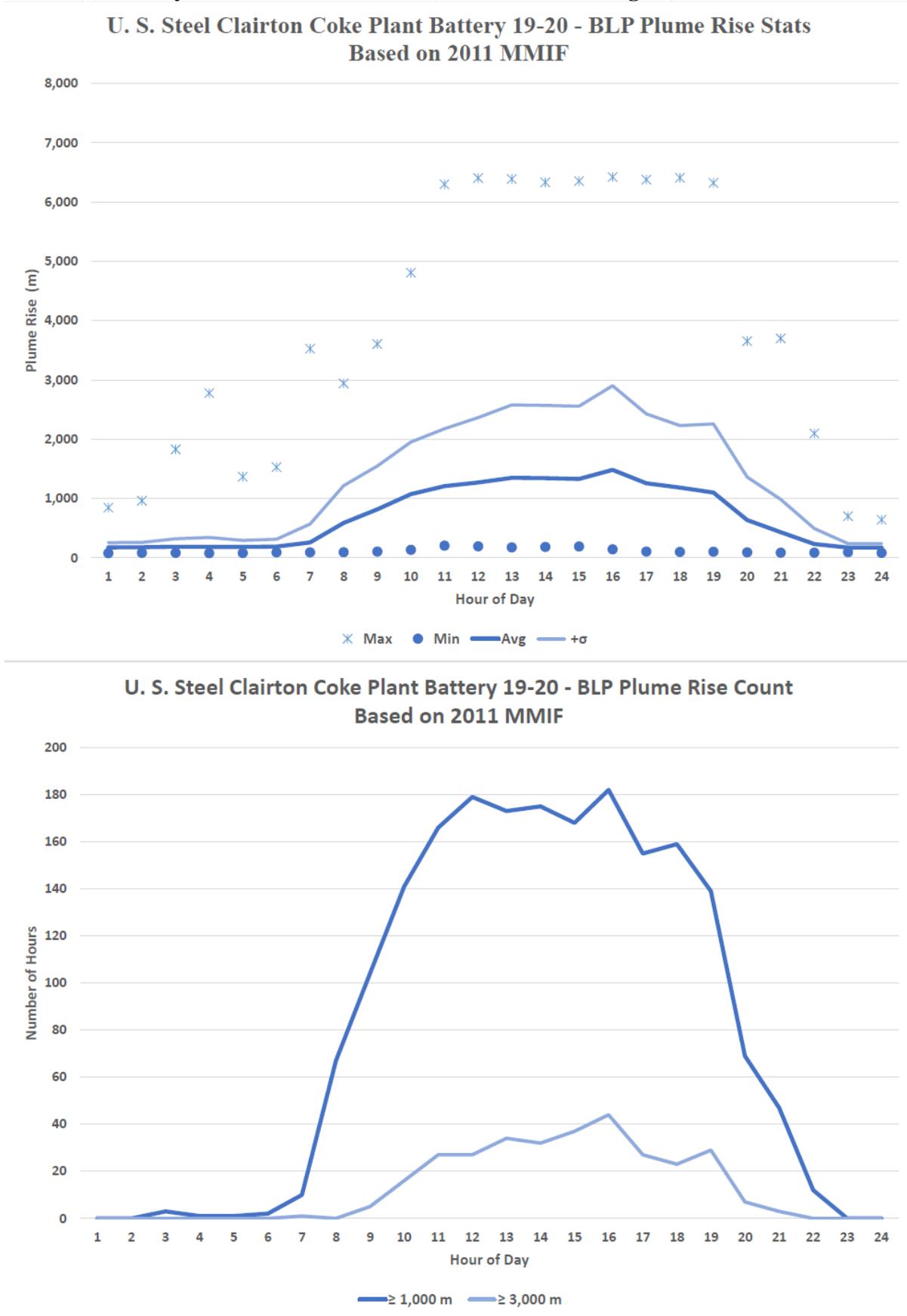


Figure A-1 (b) Battery 19-20 BLP Vertical Dimension (z_{init}) Statistics and Hour Counts



Figure A-2 (a) Battery 13-15 BLP Plume Rise (Model Release Heights) Statistics and Hour Counts

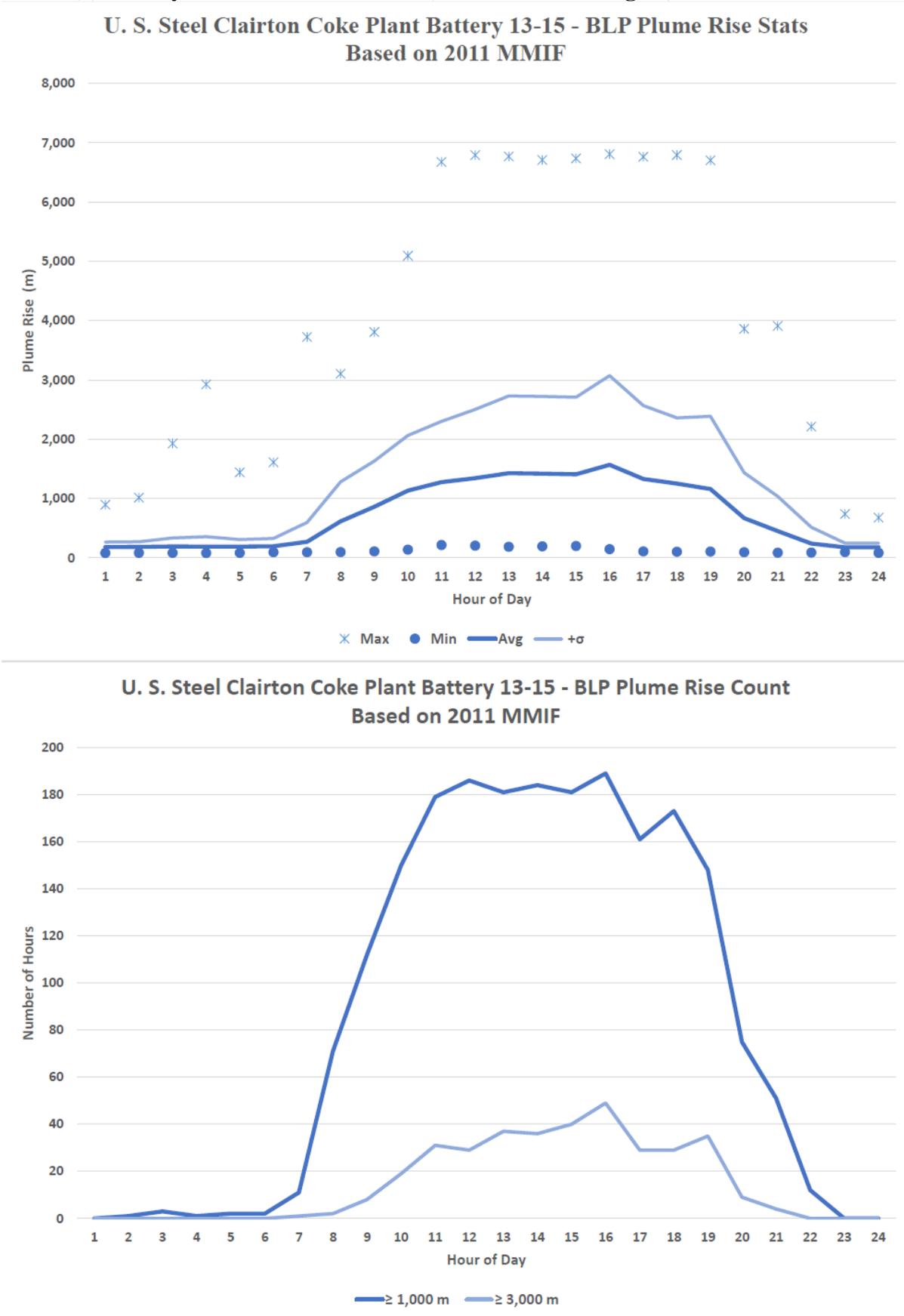


Figure A-2 (b) Battery 13-15 BLP Vertical Dimension (z_{init}) Statistics and Hour Counts

