$PM_{2.5}$ SIP

Appendix H

Alternative Modeling Demonstration for Buoyant Fugitives

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

AUG 16 2018

Karen Hacker, MD, MPH, Director, ACHD
Allegheny County Health Department
Air Quality Program
301 39th Street, Building #7
Pittsburgh, Pennsylvania 15201-1811

Dear Dr. Hacker:

Thank you for your letter dated July 27, 2018 regarding Allegheny County Health Department's request to use an alternative model to represent fugitive emissions from coke oven batteries at the U.S. Steel Mon Valley Works – Clairton plant located in Allegheny, Pennsylvania. EPA approval for the use of an alternative model is required under 40 CFR Part 51, Appendix W- Guideline on Air Quality Models, section 3.2. Allegheny County Health Department (ACHD) has requested 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, PA area and the 2010 1-hr SO_2 NAAQS nonattainment area SIP for the Allegheny, PA area which was submitted to EPA on October 3, 2017.

This alternative modeling approach involves a "hybrid" technique for the treatment of buoyant line sources that uses plume rises generated from the former EPA-preferred model, Buoyant Line and Point Source model (BLP), in conjunction with the current preferred model for near-field applications, American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD). This alternative model approach is referred to as the BLP/AERMOD Hybrid Approach. ACHD has sought approval for use of an alternative model under Appendix W, section 3.2.2 (b)(2) which states:

"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 in appendix A."

ACHD has sufficiently demonstrated, per section 3.2.2(b)(2), that the BLP/AERMOD Hybrid Approach performed better than the EPA's preferred model approach and other approaches tested for characterizing the fugitive emissions from the coke oven batteries at the Clairton Plant. ACHD also included additional weight-of-evidence statistical measures which support the results of their alternative model performance evaluation.

Technical staff in the Air Protection Division reviewed your submittal and forwarded a summary of your analysis to the Model Clearinghouse on August 7, 2018 requesting the Model Clearinghouse concur with the Regional Office's request that ACHD be granted approval to use the BLP/AERMOD Hybrid Approach.

On August 10, 2018, we received notice that the Model Clearinghouse has granted its concurrence[1] and we are now formally notifying you that your request to use BLP/AERMOD Hybrid Approach has been approved. If you have any questions regarding this matter please do not hesitate to contact me or have your staff contact Kinshasa Brown, EPA's Pennsylvania Liaison, at (215) 814-5404. For questions regarding this approval action, your staff may contact Cristina Fernandez, Director, Air Protection Division, at (215) 814-21785 or Tim Leon Guerrero of the Air Protection Division at (215) 814-2192

Sincerely,

Cosmo Servidio
Regional Administrator

cc: Jayme Graham, Air Program Manager, ACHD
Sandra Etzel, Section Chief, Planning and Data Analysis, Air Quality Program, ACHD
Jason Maranche, Engineer III, Planning and Data Analysis, Air Quality Program, ACHD
Kirit Dalal, Manager, Air Resource Management Division, PADEP
Randy Bordner, Manager, Stationary Sources Section, Air Resource Mgmt., PADEP

[1] https://cfpub.epa.gov/oarweb/MCHISRS/index.cfm?fuseaction=main.resultdetails&recnum=18-III-01

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

AUG 10 2018

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Model Clearinghouse Review of the BLP/AERMOD Hybrid Alternative Model Approach for Modeling Fugitive Emissions from Coke Oven Batteries at the U.S. Steel Mon Valley Works – Clairton Plant in Allegheny County, PA

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

TO: Timothy A. Leon Guerrero, Meteorologist
Office of Air Monitoring and Analysis, Air Protection Division, EPA Region 3

Alice Chow, Associate Director
Office of Air Monitoring and Analysis, Air Protection Division, EPA Region 3

INTRODUCTION

The U.S. Steel Mon Valley Works – Clairton Plant (Clairton Plant) in Allegheny County, PA is the country's largest coking facility with an annual capacity of 4.3 million tons. This plant is a tremendously complex coking facility with 708 ovens grouped into 10 operational batteries, comprised of 5 distinct battery lines, as a part of their coking operations. As noted by EPA Region 3 in its Concurrence Request Memorandum to the EPA's Model Clearinghouse,

> "coking facilities are complex emissions 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 that contributes to particulates and SO2 emissions when burned."

Adding to the complexity, the Clairton Plant is located in the Monongahela River Valley. The terrain surrounding the facility rises approximately 120 meters above the valley floor and contributes to terrain induced atmospheric temperature inversions. These temperature inversions are periods of diminished air dispersion out of the river valley and often episodes of poor air quality.

While many of the emissions sources at the Clairton Plant can be appropriately characterized by point, area, and/or volume source types for compliance demonstrations and State Implementation Plan (SIP) purposes, the coke oven batteries also produce a significant amount of fugitive emissions distributed along the length of the battery and are much more difficult to accurately characterize given a variety of factors and challenges, including accurate estimating fugitive emissions across each battery, sporadic nature of these emissions, extremely hot temperatures associated with these emissions releases, etc. Historically, coke oven fugitive emissions have been modeled as a type of buoyant line source using the Buoyant Line and Point Source (BLP) model. Traditionally created for modeling aluminum reduction facilities with much more uniform heat release profiles, the BLP model was intended to handle the unique dispersion from these types of facilities where plume rise and downwash effects from stationary line sources are important in simple terrain environments.

For coke oven batteries in complex terrain environments, a variety of alternative model approaches have been used in compliance demonstrations and SIP submittals over the past 40-years. Most commonly, some "hybrid" combination of the BLP model estimates of plume rise and initial vertical and/or lateral dispersion characteristics have been used to characterize coke oven battery emissions as volume sources within the Industrial Source Complex (ISC) model. In 2005, the American Meteorological Society/Environmental Protection Agency Model (AERMOD) replaced the ISC model as EPA's preferred near-field dispersion model. The BLP model was also replaced as an EPA preferred model with the release of AERMOD version 16216 and the 2016 revisions to the *Guideline on Air Quality Models* (Appendix W to 40 CFR Part 51, *Guideline*). AERMOD now incorporates the BLP model formulation algorithms as a "BUOYLINE" source option. However, there have not been any scientific formulations updates to the original BLP model formulations algorithms.

MODEL CLEARINGHOUSE REVIEW

From the EPA Region 3 Concurrence Request Memorandum, per the requirements of Section 3.2.2(b)(2) of the *Guideline*, the Allegheny County Health Department (ACHD) is seeking EPA approval to use an alternative model approach for their 2012 Annual Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standard (NAAQS) Nonattainment Area State Implementation Plan (SIP) and for their 2010 1-hr SO_2 NAAQS Nonattainment Area SIP for the respective Allegheny County, PA nonattainment area. Alternative models shall be evaluated from both a theoretical and a performance perspective before they are selected for regulatory use, specifically Section 3.2.2(b)(2) states,

> "2. If a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model in appendix A"

ACHD is seeking to use a combination of the BLP and AERMOD models to represent the fugitive emissions from coke oven batteries at the Clairton Plant as described in the ACHD technical support document, "BLP/AERMOD Hybrid Approach for Buoyant Fugitives in Complex Terrain." Specifically, estimates of emissions temperature and vertical velocity are used to compute buoyancy for input into BLP's plume rise module to yield estimated plume rise and subsequently derive initial vertical dispersion characteristics on an hourly varying basis as function of the plume height. The plume rise is then used to determine volume source characteristics for the fugitive emissions with AERMOD. Henceforth, this alternative model approach will be referred to as the "BLP/AERMOD Hybrid Approach." It should be noted that similar plume rise and calculated initial dispersion characteristics could have been generated from the BUOYLINE source group within AERMOD rather than the stand-alone BLP model for determining the fugitive emissions volume source characteristics in the alternative application of AERMOD, but the Model Clearinghouse does not anticipate that there would have been any discernable differences in the resulting alternative model demonstration.

For situations where it has been determined that an EPA preferred model is either not appropriate for the particular application or a more appropriate model or technique is available and applicable, the EPA Regional Administrators have the delegated authority to issue an alternative model approval under Section 3.2 of the *Guideline*, provided that such an approval is issued after consultation with the Model Clearinghouse. In this determination, the *Guideline* provides guidance to an objective and consistent evaluation protocol for the basis of the associated alternative model demonstration. The "Protocol for Determining the Best Performing Model" (EPA-454/R-92-025, NTIS No. PB 93-226082), also known as the Cox-Tikvart Protocol, provides a general framework for objective decision-making on the acceptability of an alternative model for a given regulatory application.

The Model Clearinghouse appreciates the efforts by EPA Region 3 to thoroughly review the ACHD technical support document and summarize their results in its Concurrence Request Memorandum. We find and agree with the EPA Region 3 assessment that ACHD applied the Cox-Tikvart Protocol using a network of facility representative ambient monitors and sufficiently demonstrated, per Section 3.2.2(b)(2) of the *Guideline*, that the BLP/AERMOD Hybrid Approach performed better than the EPA's preferred model approach and other approaches tested for characterizing the fugitive emissions from the coke oven batteries at the Clairton Plant. We also note that ACHD included additional weight-of-evidence statistical measures, as highlighted in Table 3 and Figure 7 of the Concurrence Request Memorandum and the associated information from the ACHD technical support document. The culmination of the recommended Cox-Tikvart Protocol approach and the additional weight-of-evidence statistics uniformly support the results of the ACHD alternative model performance evaluation.

The Model Clearinghouse concurrence is based on the assessment that is included in the EPA Region 3 Concurrence Request Memorandum and specifically refer readers Figure 8 and Figure 9 in the EPA Region 3 assessment and subsequently to the ACHD technical support document. As of this Model Clearinghouse Concurrence Response Memorandum, there has been only one other case-specific regulatory approval of a hybrid combination of information from the BLP model or the BUOYLINE source group as parameters for a volume source group within AERMOD. In that 2018 EPA Region 9 alternative model approval for a copper smelter in complex terrain, a statistical analysis following the Cox-Tikvart Protocol using a network of facility representative ambient monitors equally found that the BLP/AERMOD Hybrid Approach performed better than the preferred model approach in that specific case. For more information on this EPA Region 9 alternative model approval, please reference the record[1] in the Model Clearinghouse Information Storage and Retrieval System (MCHISRS) on the EPA's SCRAM website[2].

MODEL CLEARINGHOUSE CONCURRENCE SUMMARY

Per the request of EPA Region 3, the Model Clearinghouse has reviewed the ACHD alternative model demonstration and associated EPA Region 3 assessment for the use of the BLP/AERMOD Hybrid Approach for the assessment of the fugitive coke oven battery emissions at the Clairton Plant for the ACHD's 2012 Annual $PM_{2.5}$ NAAQS Nonattainment Area SIP and for the ACHD's 2010 1-hr SO_2 NAAQS Nonattainment Area SIP for the respective Allegheny County, PA nonattainment area. The Model Clearinghouse finds that the requirements and recommendations of Section 3.2 of the *Guideline* have been appropriately followed and hereby concur with EPA Region 3 on the alternative model approval. It is noted that all aspects of this Regional Office alternative model approval and Model Clearinghouse concurrence should be included in the SIP record and made available for comment during the appropriate public comment period.

The EPA has highlighted the need for further model development related to buoyancy in the AERMOD Development White Papers[3] initially released for the 2017 Regional, State, and Local Modelers' Workshop. More specifically, buoyancy related to elongated sources, such as coke oven batteries, was further discussed by the EPA at the 2018 Regional, State, and Local Modelers' Workshop[4]. The White Papers, which will be expanded in the EPA's forthcoming AERMOD Model Development and Update Plan, chart a pathway for further model development for addressing plume rise from many source types. It is expected that such development will better address model performance issues with sources like coke oven batteries. In the interim, the EPA has evaluated characterizing coke over batteries as a series of point sources in a manner that reasonably accounts for plume rise, downwash, and subsequent dispersion within the framework of the preferred model.

cc: Richard Wayland, C304-02
Anna Wood, C504-01
Tyler Fox, C439-01
Raj Rao, C504-01
EPA Air Program Managers
EPA Regional Modeling Contacts

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[1] https://cfpub.epa.gov/oarweb/MCHISRS/index.cfm?fuseaction=main.resultdetails&recnum=18-IX-01
[2] https://www.epa.gov/scram/air-quality-model-clearinghouse
[3] https://www3.epa.gov/ttn/scram/models/aermod/20170919_AERMOD_Development_White_Papers.pdf
[4] http://www.cleanairinfo.com/regionalstatelocalmodelingworkshop/archive/2018/Presentations/1-9_2018_RSL-White_Paper_Summaries.pdf

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 JF for
Office of Air Monitoring and Analysis, Air Protection Division, EPA Region 3

THRU: Alice H. Chow, Associate Director
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 SO_2 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 ($\mu g/m^3$) to 12.0 $\mu g/m^3$ (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 (SO_2) NAAQS, on June 22, 2010, EPA strengthened the primary NAAQS for SO_2 by establishing a new 1-hour standard at a level of 75 parts per billion (ppb) (2010 1-hour SO_2 NAAQS, 75 FR 35520). EPA designated a portion of Allegheny County, Pennsylvania as a nonattainment area[1] 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 51identifies 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 (SO_2). In 2016, the Clairton Plant emitted 550.3 tons of PM-10 and 889.9 tons of SO_2 placing it in the top five (5) emitters in Allegheny County for these pollutants[2].

Coking facilities are complex emission sources with multiple emission points and include numerous structures where building downwash can impact pollutant dispersion. Particulate and SO_2 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 SO_2 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

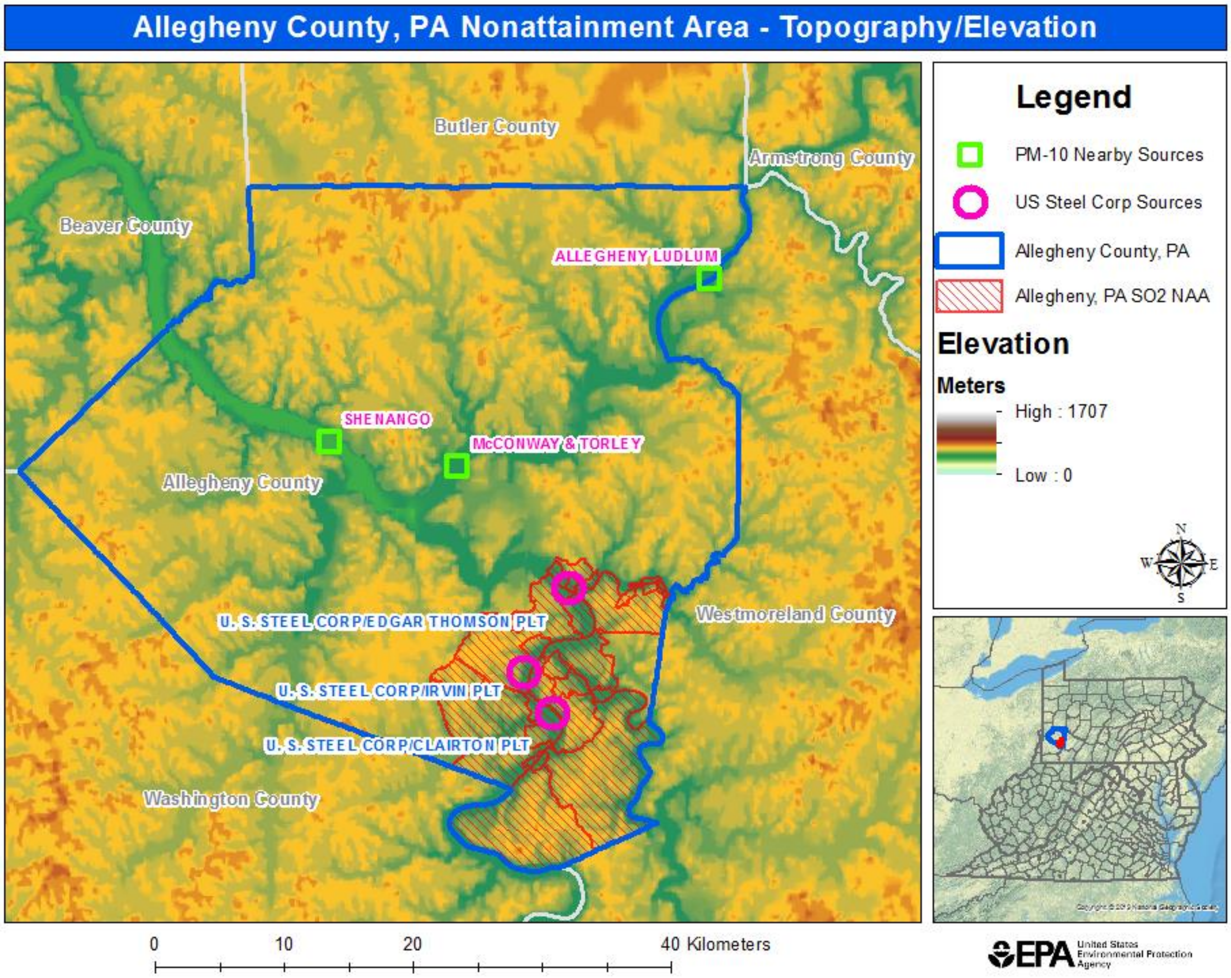
[2] See PA DEP eFACTS website for point source emission information for Allegheny County. https://www.ahs.dep.pa.gov/eFACTSWeb/criteria_facilityemissions.aspx

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 SO_2 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 quality[3].

[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 SO_2 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 SO_2 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 System[4]. 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 SO_2 SIP modeling demonstration[6].

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 SO_2 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 SO_2 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/SO_2 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 SO_2 SIP.

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[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 SO_2 SIP modeling demonstration and was described in Appendix A – Addendum of ACHD's SO_2 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 SO_2 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 SO_2 and PM-2.5 SIP modeling demonstrations. AERMOD treats both PM-10 and SO_2 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

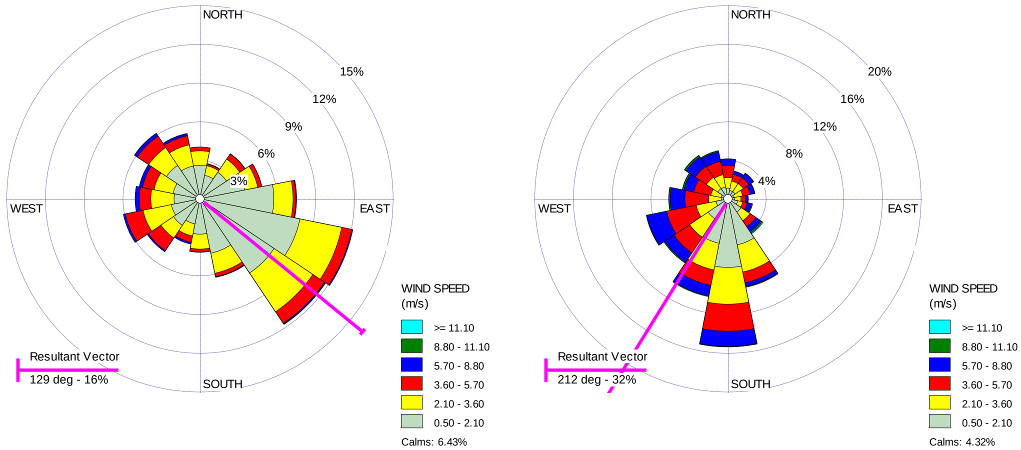
Facility	Point	PolyArea	Volume	Hybrid	BUOYLINE	Total
Allegheny Ludlum	40					40
McConway & Torley	10					10
Shenango	17					17
U. S. Steel Edgar Thomson	39		46			85
U. S. Steel Irvin	25		7			32
U. S. Steel Clairton (No Batteries)	53	2	56			111
U. S. Steel Clairton (Point Batteries)	117	2	56			175
U. 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 SO_2 SIP documentation and a MMIF evaluation in Appendix H of its 1-hour SO_2 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

10-m WRF Winds Clairton **50-m WRF Winds Clairton**

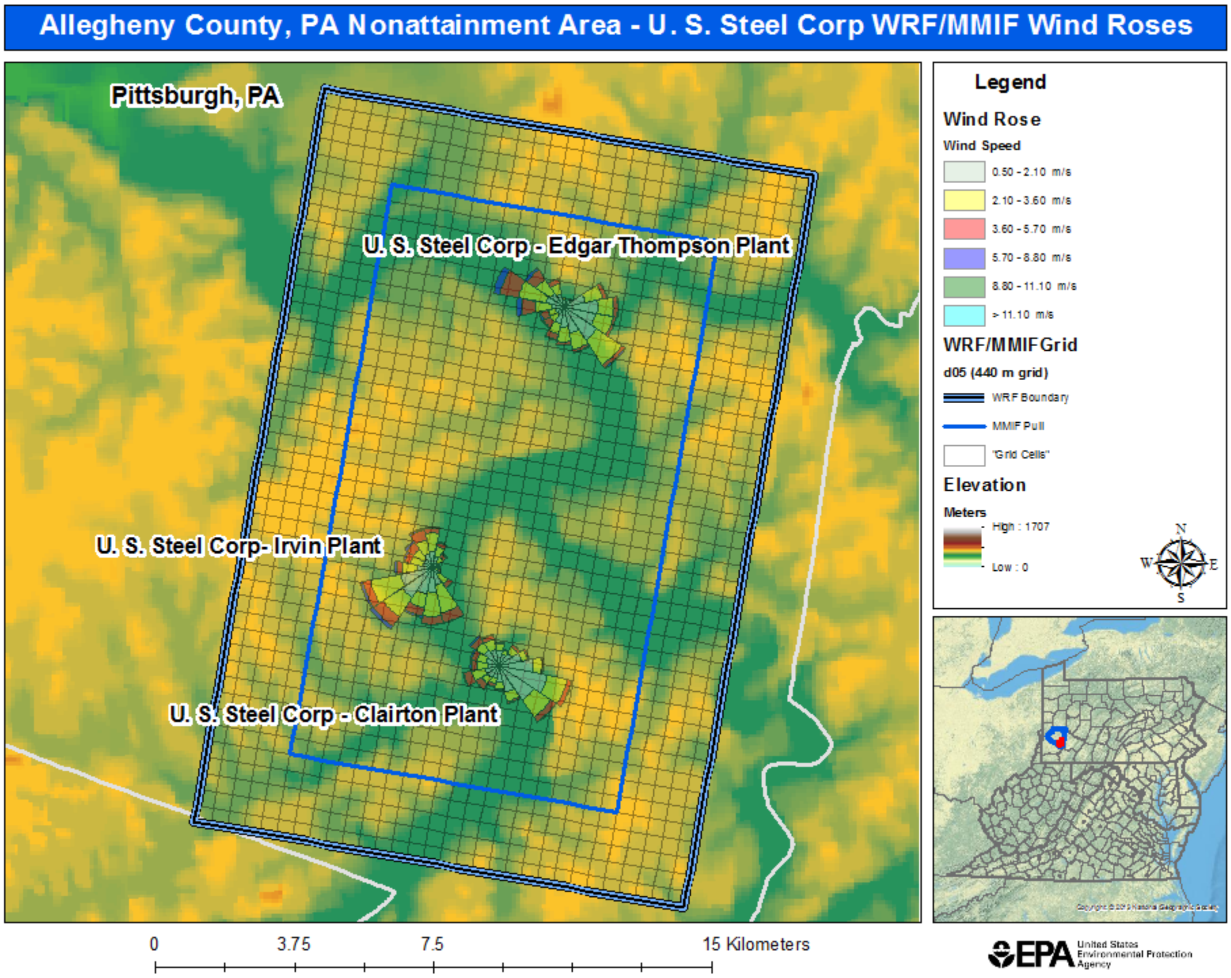


Building Downwash Parameterization: ACHD constructed detailed building information for the three (3) U. S. Steel Corporation sources as part of their 1-hr SO_2 SIP modeling analysis (see Appendix J of ACHD's 1-hour SO_2 SIP documentation). Since the modeling used for the statistical test predates the time period used for ACHD's 1-hour SO_2 SIP, there may be instances when some building structures and sources would need to be removed from their original 1-hour SO_2 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 µg/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 ≤ 1 µg/m^3 and < 0 µg/m^3 are all listed in the table for 2011.

Figure 4. PM-10 Monitor Locations

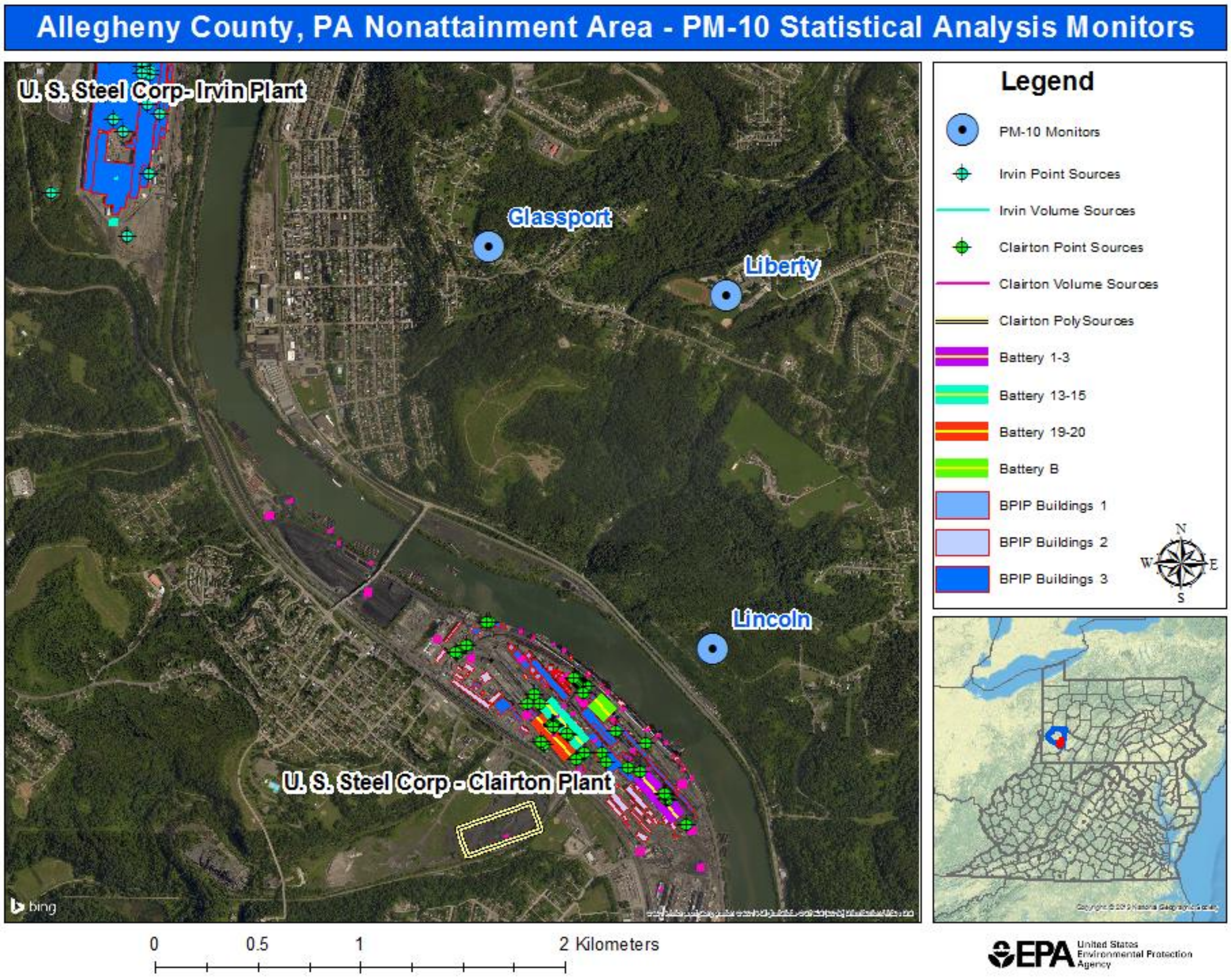


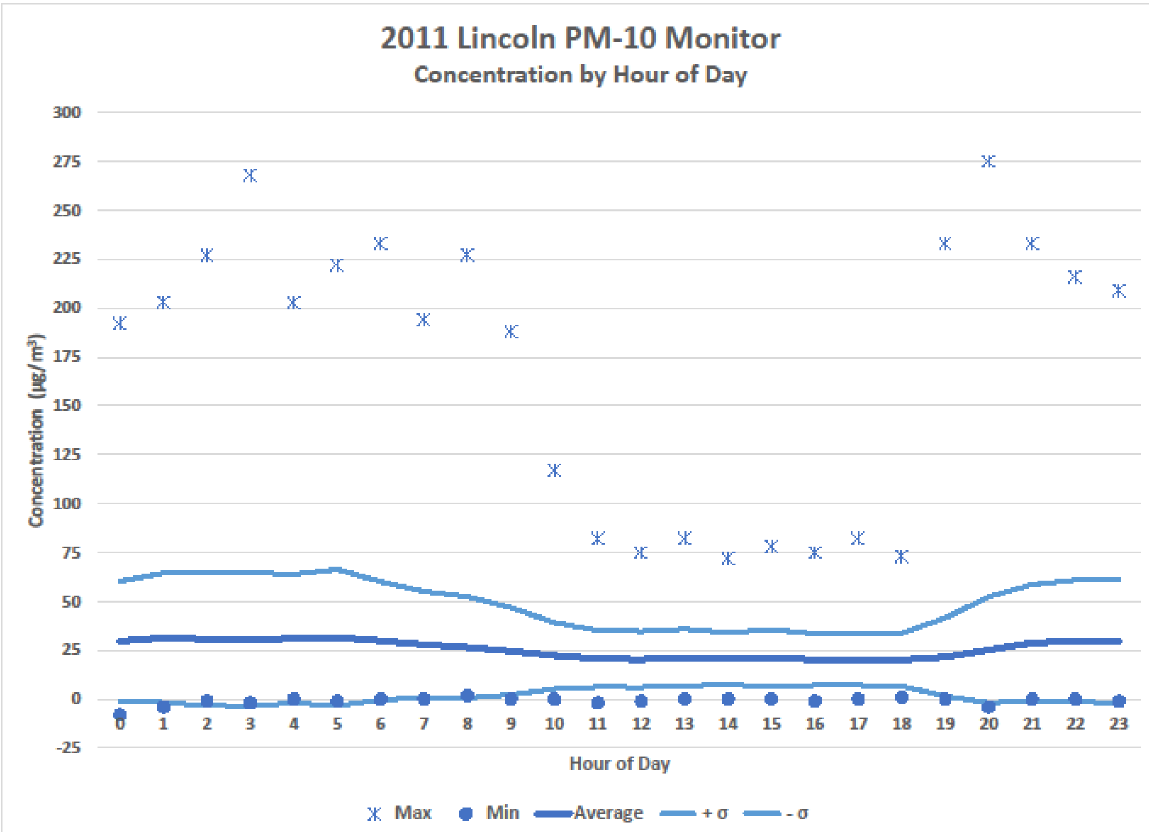
Table 2. AQS 2011 PM-10 Monitor Statistics (µg/m³)

	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 ≤ 1 µg/m³	87	331	295
Hours < 0 µg/m³	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 that 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 SO_2 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 SO_2 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 SO_2 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.

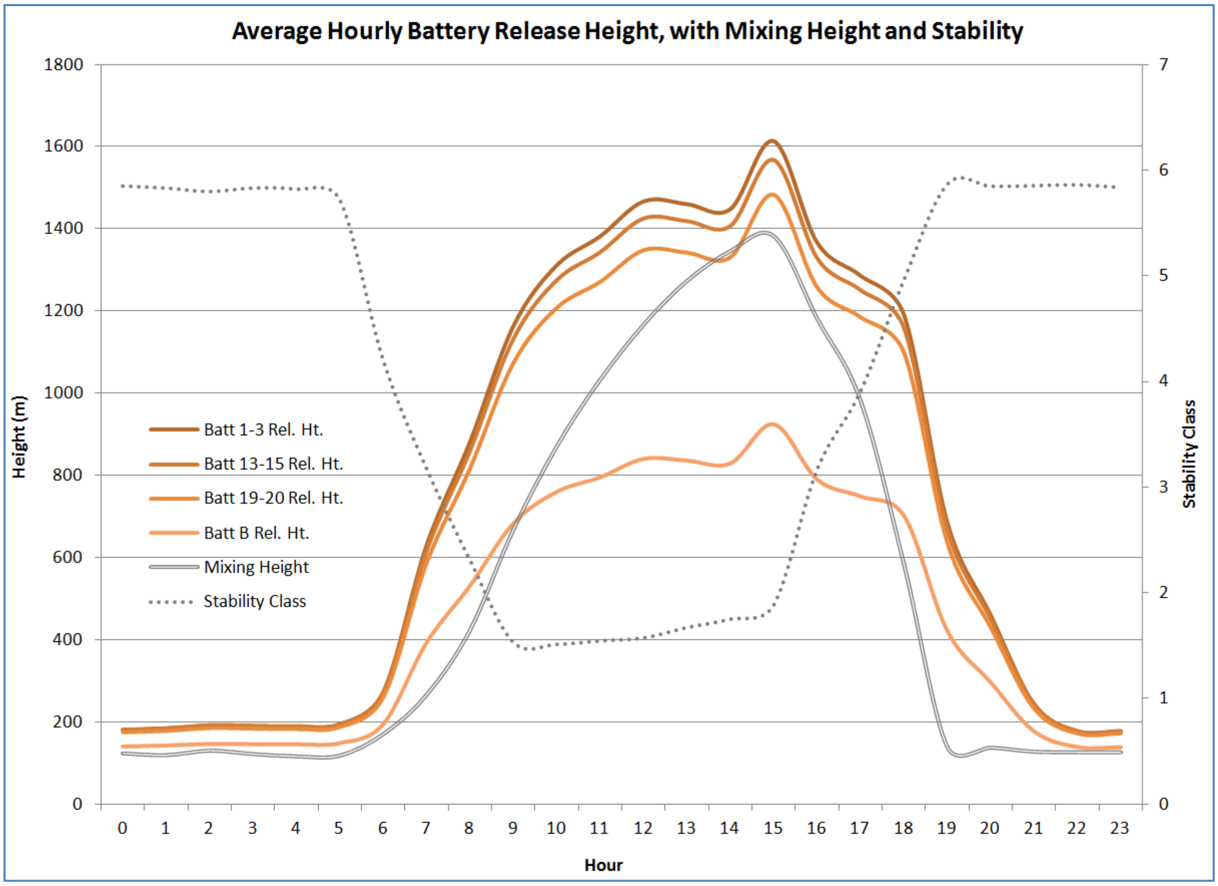
As noted previously, ACHD constructed a series of AERMOD simulations to create modeled concentrations for three (3) PM-10 monitors located near U. S. Steel Corporation's Irvin and Clairton plants. Meteorological and monitoring data from 2011 were constructed to develop the model to monitor database for 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 place model receptors surrounding the three (3) PM-10 monitoring sites. The model receptors were generated using 10-m resolution USGS NED data process using AERMAP version 18081 (AERMAP settings are listed in section 4.1.4 of ACHD's technical support document). A10-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 SO_2 SIP modeling demonstration. This approach was taken with proper EPA consultation and discussed in more detail in the 1-hour SO_2 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.

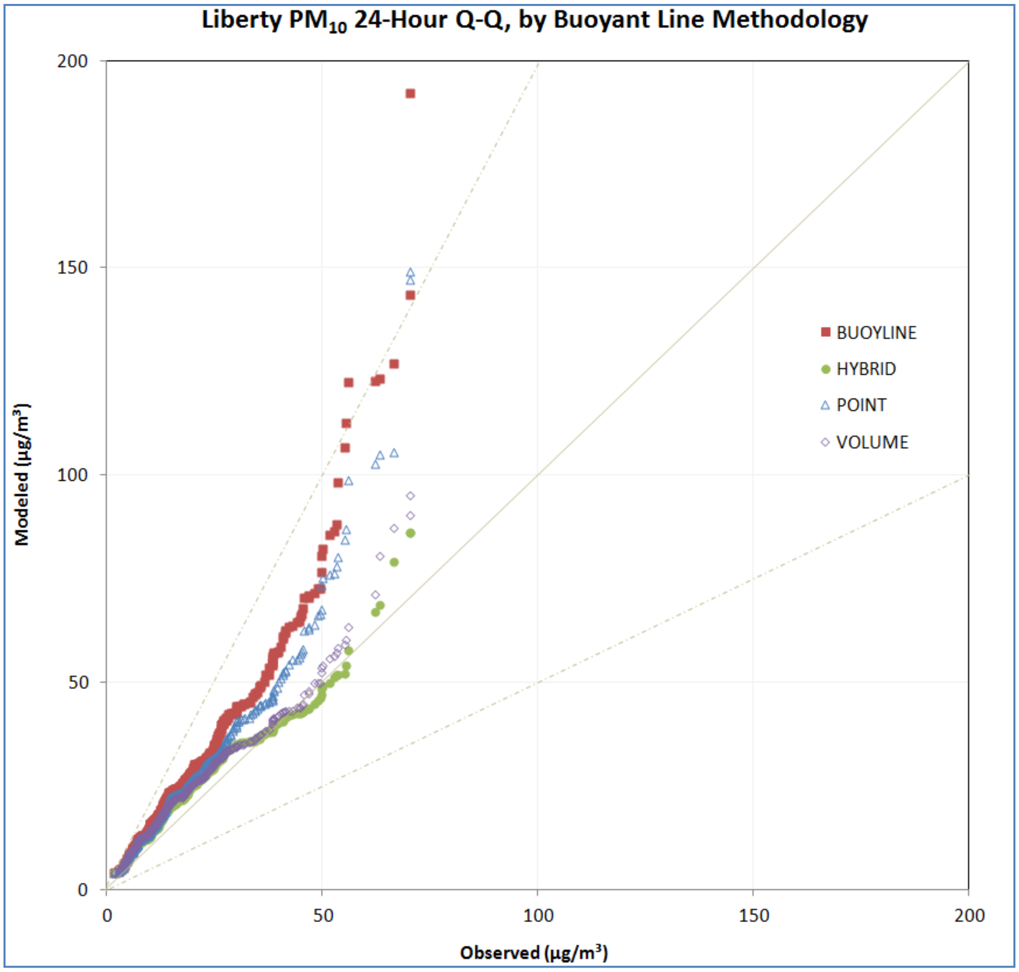
Several sets of statistical analyses were presented in ACHD's alternative model request. A swath of statistical tests was performed in accordance with PM-2.5 modeling guidance including a group of core statistical measures that were listed in Table 5-1 of ACHD's alternative model request. Results for 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

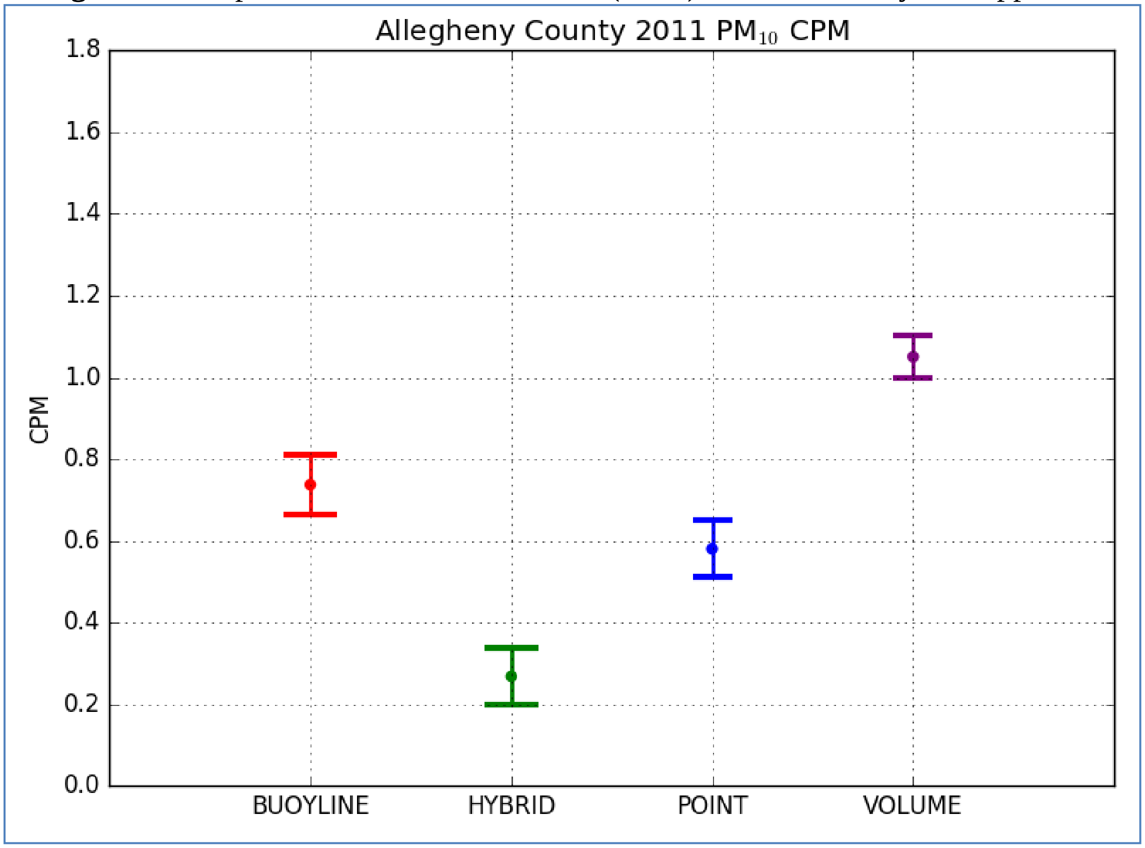
ACHD generated 1-hr, 3-hr and 24-hr Q-Q plots for the four (4) source characterization methods for monitor values. Figure 7 (taken from ACHD's alternative request technical support document) shows a 24-hr Q-Q plot for the Liberty monitor's model-monitor comparison; Q-Q plots show paired model/monitor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



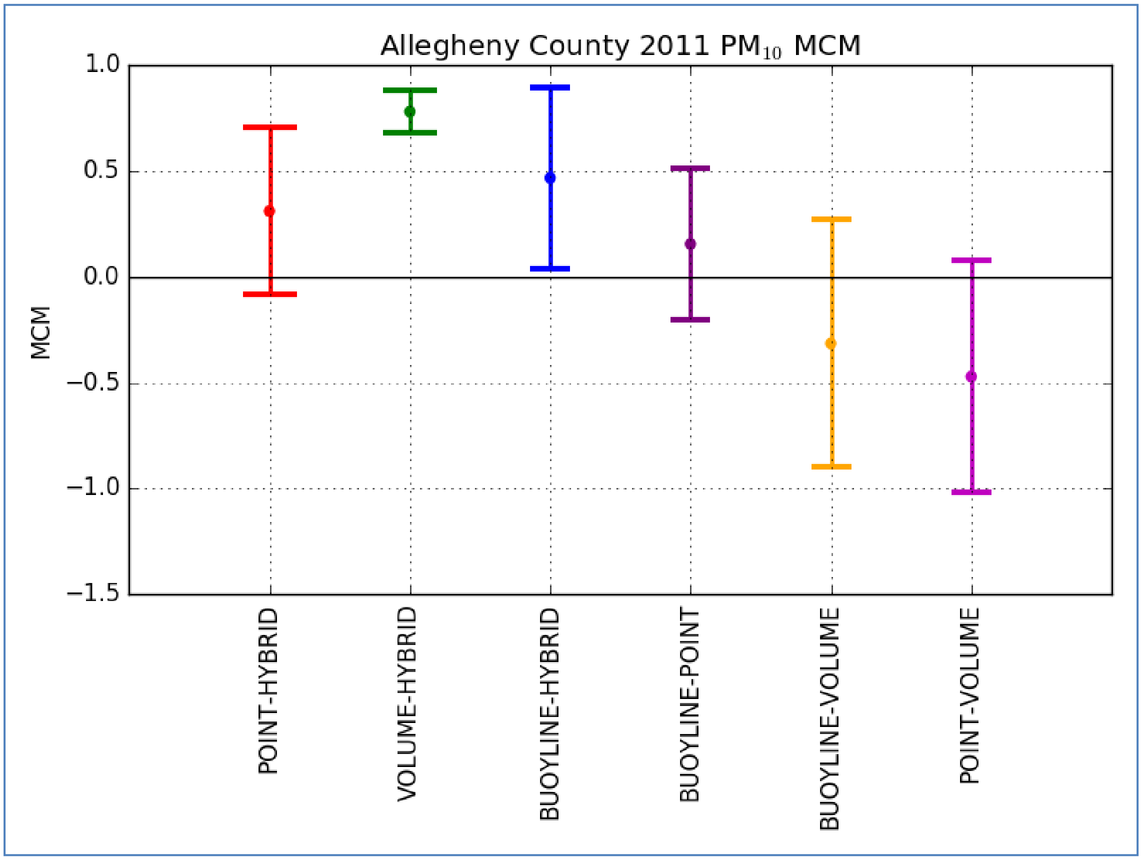
Additionally, ACHD constructed a model comparison measure (MCM) for each combination of models (six comparisons for the four different cases). These are shown in Figure 9 (Figure 5-14 from ACHD's technical support document). Model pairs are listed across the bottom axis of the figure. If the MCM confidence interval spans zero, performance differences are considered not statistically significant[7].

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 Plan[8]. 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.

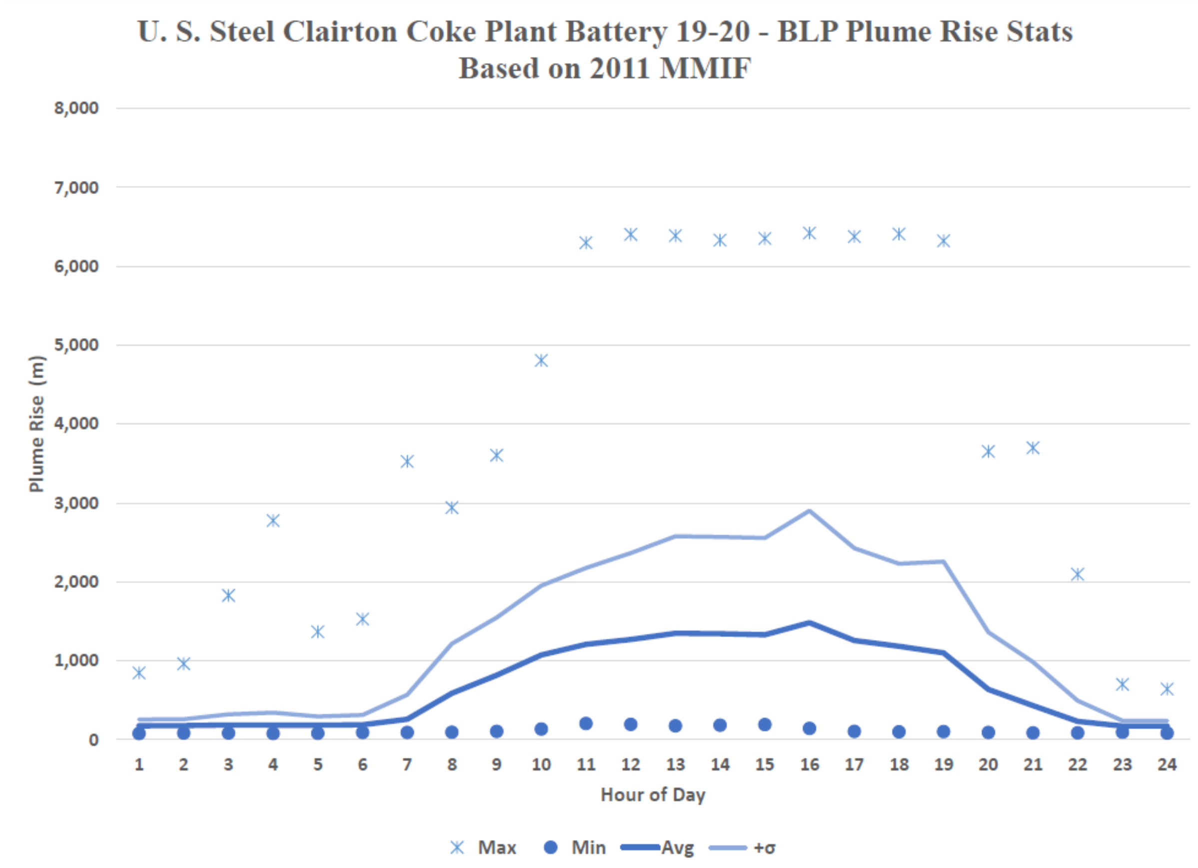
Table A-1. Clairton Plant Coke Oven Fugitive PM-10 Emissions by Battery

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



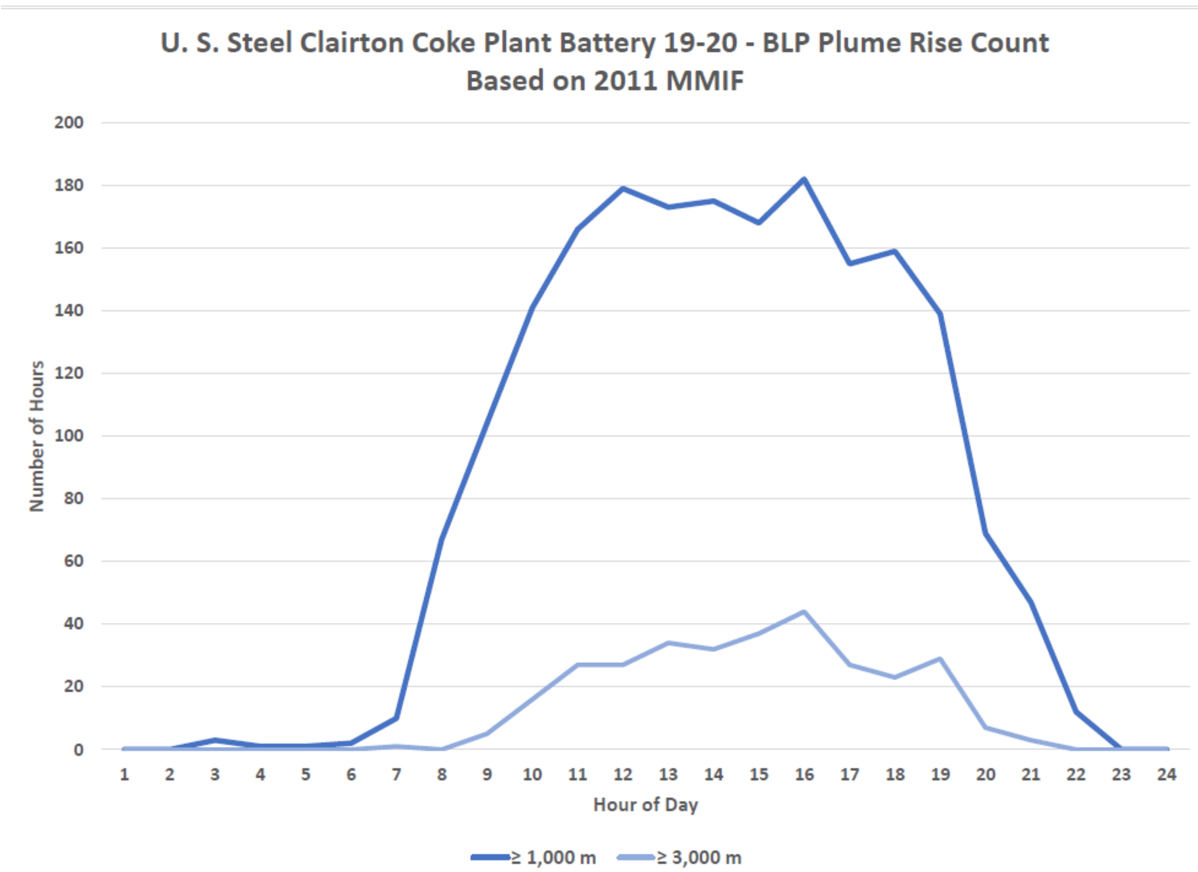
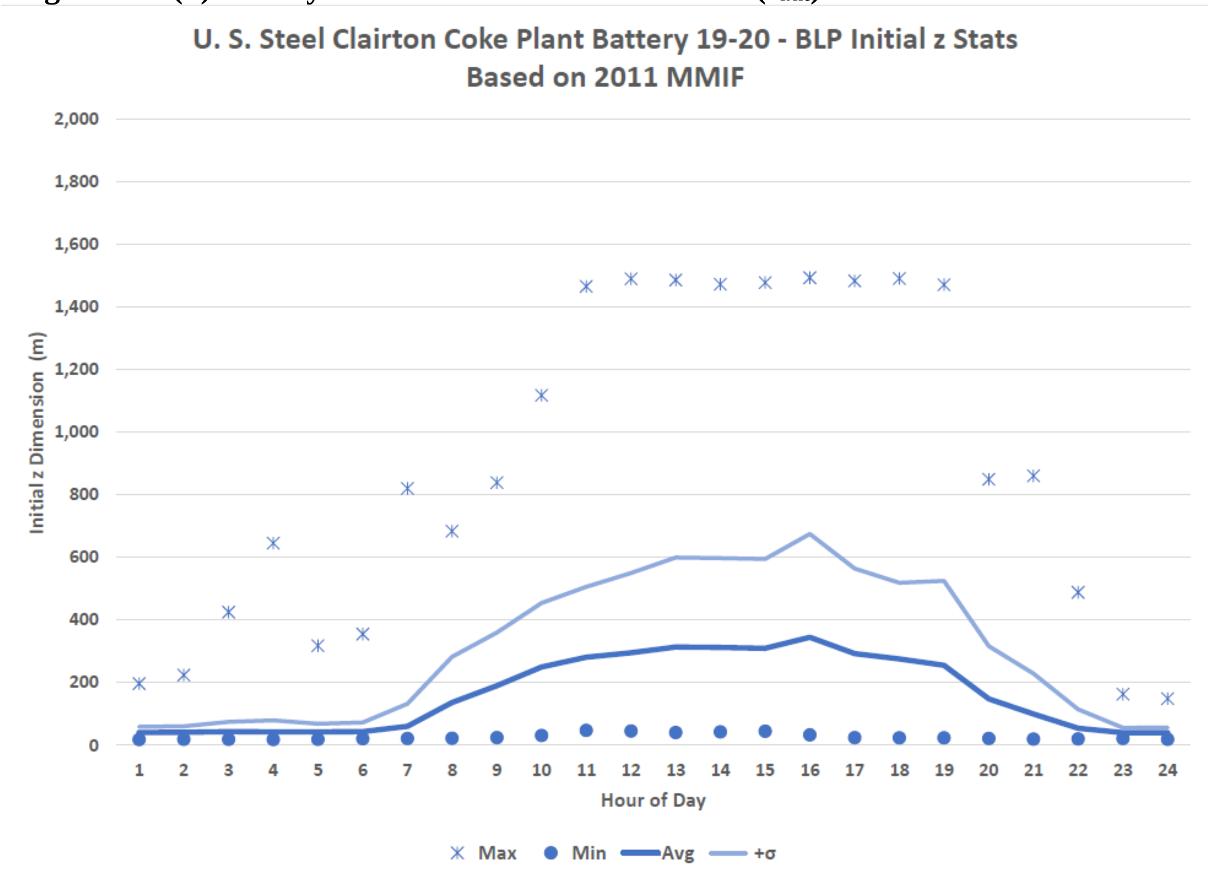


Figure A-1 (b) Battery 19-20 BLP Vertical Dimension (z_{init}) Statistics and Hour Counts



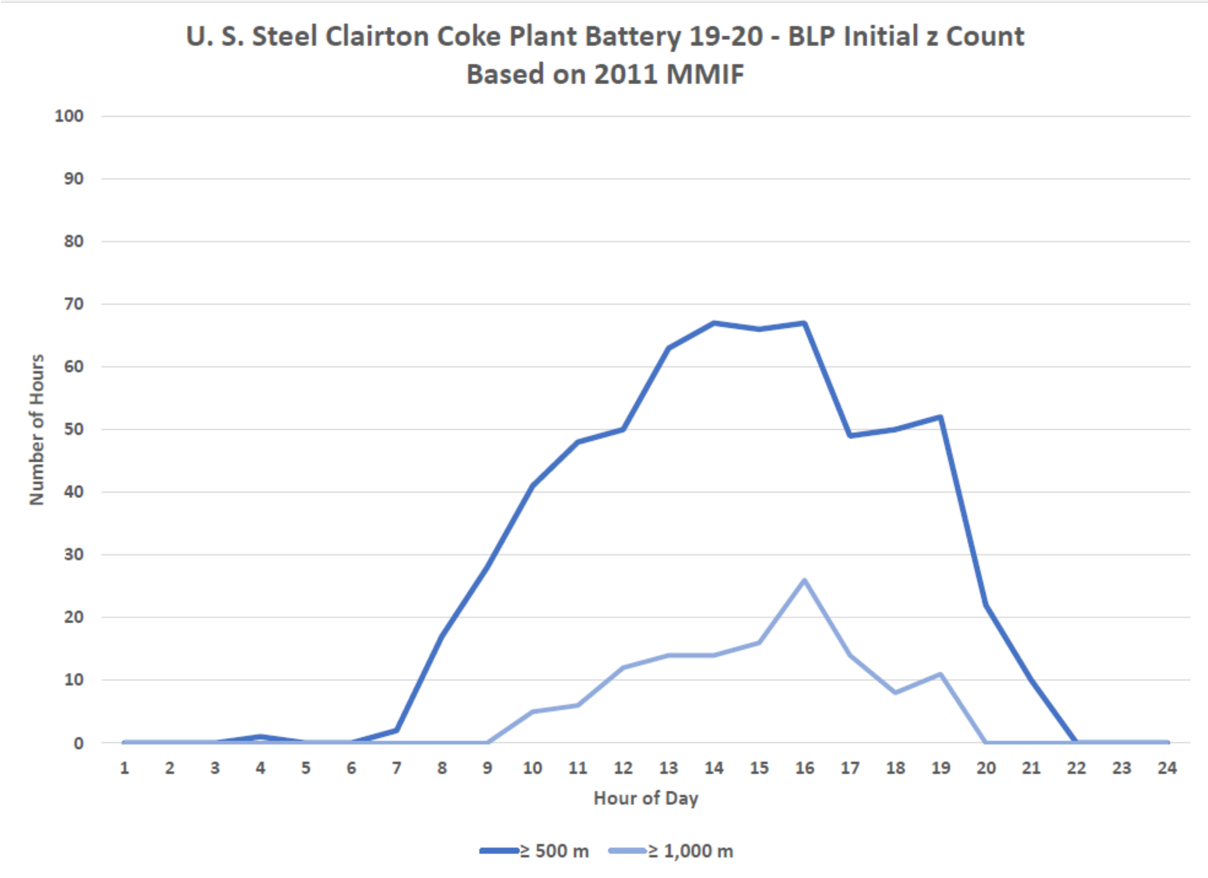
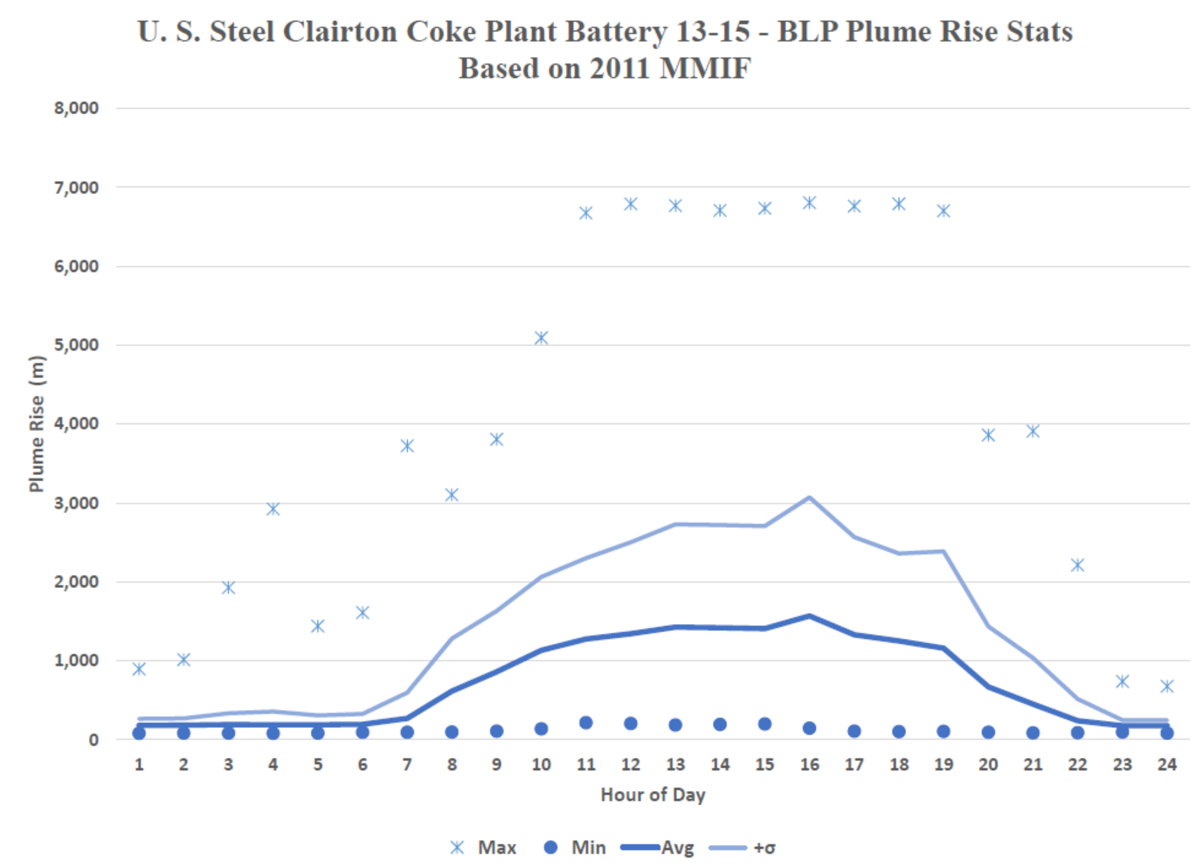


Figure A-2 (a) Battery 13-15 BLP Plume Rise (Model Release Heights) Statistics and Hour Counts



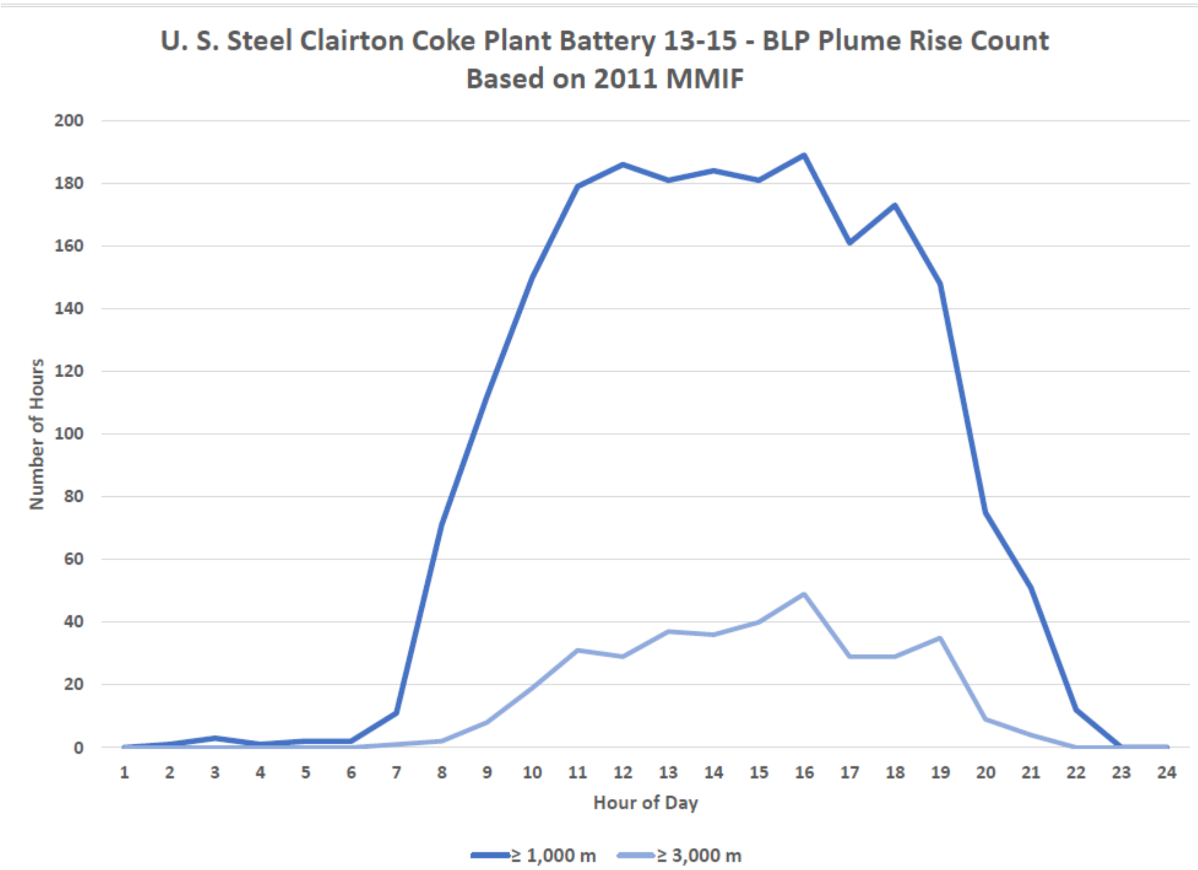
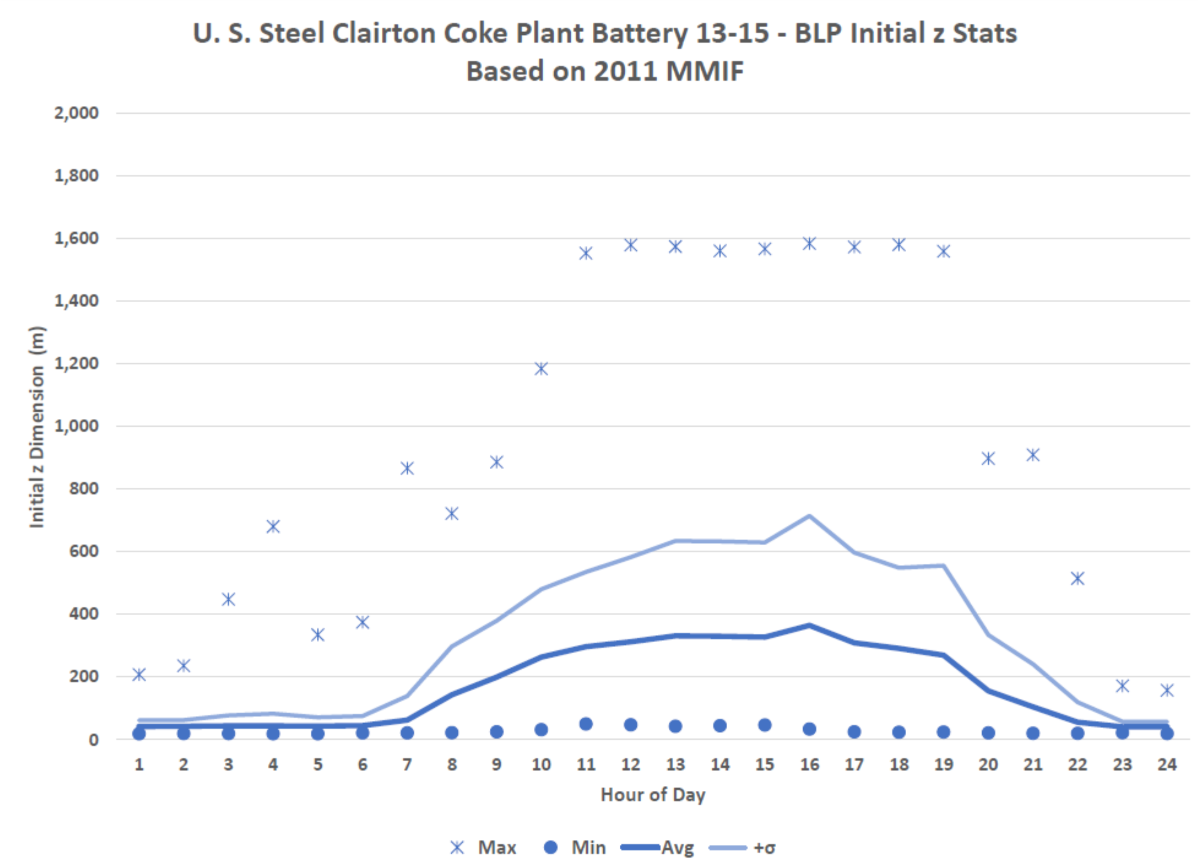
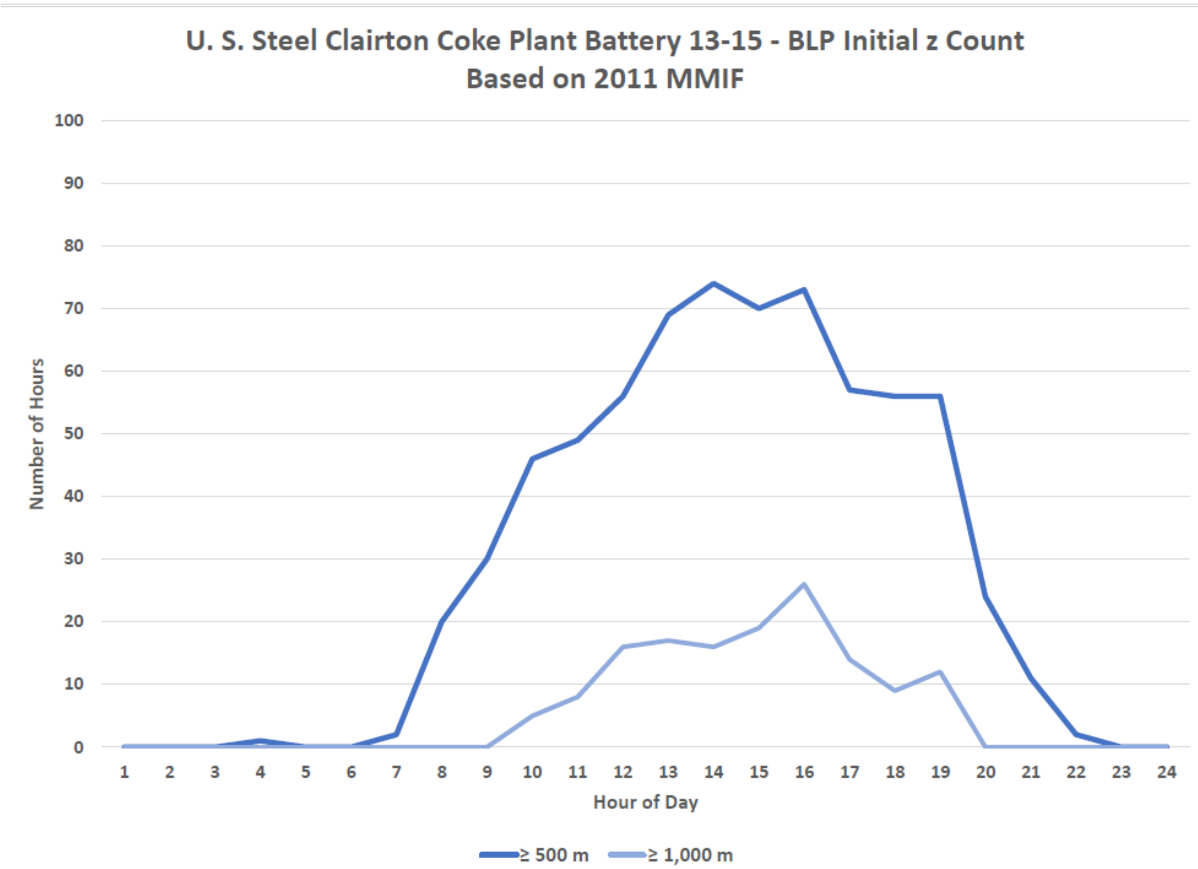


Figure A-2 (b) Battery 13-15 BLP Vertical Dimension (z_{init}) Statistics and Hour Counts





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July 27, 2018

Mr. Cosmo Servidio
Regional Administrator
U.S. Environmental Protection Agency, Region 3
1650 Arch Street, (Mail Code: 3RA00)
Philadelphia, PA 19103-2029

Dear Mr. Servidio:

The Allegheny County Health Department (ACHD) is pleased to submit an alternative air quality modeling demonstration for your review and approval. Use of an alternative modeling technique according to *40 CFR Part 51 Appendix W, Guideline on Air Quality Models ("Guideline")* requires approval from the regional U.S. Environmental Protection Agency (EPA) office as well as concurrence from the EPA Model Clearinghouse.

This alternative modeling approach involves a "hybrid" technique for the treatment of buoyant line sources that uses plume rises generated from the former EPA-preferred model, Buoyant Line and Point Source model (BLP), in conjunction with the current preferred model for near-field applications, American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD). Based on our findings, this BLP/AERMOD hybrid technique is the best possible method for the modeling of coke oven battery fugitives at the U. S. Steel Mon Valley Works Clairton Plant within complex terrain.

This technique has been used for our SO_2 State Implementation Plan (SIP) for the 2010 NAAQS, submitted to your office on Sept. 29, 2017 by the Pennsylvania Department of Environmental Protection (PA DEP). Upon approval and concurrence of this hybrid technique, it would also be used for our $PM_{2.5}$ SIP for the 2012 NAAQS.

According to Section 3.2.2 of the *Guideline*, 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 believes that the enclosed technical support document shows that the BLP/AERMOD hybrid approach performs better than any possible preferred technique based on a comprehensive comparison of modeled to monitored results. Modeling files and supporting documents are also included on the enclosed DVD.

The formulation of this hybrid approach is a result of several decades of air quality model evaluations, meteorological studies, and other analyses by ACHD and stakeholders. This same hybrid approach was also used in a recent alternative modeling demonstration in Arizona, approved by EPA Region 9 with concurrence from the EPA Model Clearinghouse.

We have worked closely with Region 3 staff in regard to this approach during the development of the SO_2 SIP and the $PM_{2.5}$ SIP. We request that the alternative demonstration be reviewed for appropriateness and anticipate that this approach can be deemed approvable for use in both of these SIP demonstrations.

If you have any questions, please call me at (412) 578-8103 or email me at Jayme.Graham@AlleghenyCounty.US.

Sincerely,

Jayme Graham, Manager
ACHD Air Quality Program

cc: Alice Chow, Associate Director, EPA Region 3
Tim Leon-Guerrero, Meteorologist, EPA Region 3
Kirit Dalal, Manager, Air Resource Management Division, PA DEP
Randy Bordner, Manager, Stationary Sources Section, Air Resource Mgmt., PA DEP
Sandra Etzel, Section Chief, Planning and Data Analysis, Air Quality Program, ACHD
Jason Maranche, Engineer III, Planning and Data Analysis, Air Quality Program, ACHD

Enclosures

- Alternative Modeling Technical Support Document: BLP/AERMOD Hybrid Approach for Buoyant Fugitives in Complex Terrain

- DVD: Alternative Modeling Files and Supporting Documents, ACHD, July 2018

Alternative Modeling Technical Support Document

BLP/AERMOD Hybrid Approach for Buoyant Fugitives in Complex Terrain

Allegheny County Health Department
Air Quality Program

July 27, 2018

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1 OVERVIEW

The Allegheny County Health Department (ACHD) is providing justification in this technical support document for the use of an alternative air quality model according to 40 CFR Part 51 Appendix W: Guideline on Air Quality Models ("Guideline", U.S. EPA, 2017). An alternative model requires approval from the regional U.S. Environmental Protection Agency (EPA) office as well as concurrence from the EPA Model Clearinghouse.

This alternative modeling approach involves a "hybrid" technique for the treatment of buoyant line sources, using plume rises generated by the former EPA-preferred Buoyant Line and Point Source (BLP) dispersion model in conjunction with the current preferred American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) for near-field applications.[1]

The BLP model was originally designed to model low-level, elongated emissions from aluminum reduction smelters, accounting for thermal buoyancy that can enhance the plume rises. These buoyancy algorithms can also be applicable to coke oven battery fugitive plumes, such as those at the U. S. Steel Mon Valley Works Clairton Plant in Allegheny County, Pennsylvania. However, BLP was recommended for simple terrain only, while the Clairton Plant is surrounded by complex terrain.[2]

With the release of version 15181 and subsequent versions of AERMOD, the BLP model code has been incorporated into AERMOD along with the new source type BUOYLINE. BLP has subsequently been removed from preferred status for regulatory applications according to the Guideline, with AERMOD as the sole preferred model for the simulation of buoyant line sources. AERMOD is also an all-terrain model that can accommodate for impacts in complex terrain.

ACHD has found that AERMOD, however, can greatly overpredict impacts when buoyant line sources are modeled with the BUOYLINE source type. Traditional source types such as point or volume sources (with fixed heights) also result in modeled overprediction when used for buoyant line sources. Based on the findings presented in this document, ACHD asserts that the BLP/AERMOD hybrid alternative technique is currently the best available method for modeling buoyant line sources in the complex terrain of Allegheny County.

ACHD also notes that this hybrid approach is a result of several decades of air quality model evaluation, meteorological studies, and other analyses. The hybrid approach has been used in both the ACHD SO_2 State Implementation Plan (SIP) for the 2010 National Ambient Air Quality Standards (NAAQS), already submitted to EPA Region 3, as well as the $PM_{2.5}$ SIP for the 2012 NAAQS (in development).

This demonstration may also be applicable to other modeling scenarios with buoyant sources in complex terrain. The BLP/AERMOD hybrid approach was recently used in an alternative modeling demonstration in Arizona, with approval by EPA Region 9 and concurrence from the EPA Model Clearinghouse.

[1] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models

[2] From the American Meteorological Society (AMS) glossary, complex terrain is a region having irregular topography, such as mountains or coastlines. For air dispersion modeling purposes, complex terrain is generally a region that includes elevations above emission release heights. Simple terrain is considered to be terrain below emission release heights.

2 PROBLEM STATEMENT

The U. S. Steel Mon Valley Works Clairton Plant in Allegheny County, PA is the largest producer of metallurgical coke in North America. The plant lies approximately 11 miles to the southeast of downtown Pittsburgh in the Monongahela River Valley (or "Mon Valley"). Several historical studies have been conducted that describe the intricacies of pollutant dispersion within the complex terrain and the micro-scale meteorological conditions of the river valley (DeNardo and McFarland, 1967; Cramer et al, 1975; Ludwig and Skinner, 1976; Sullivan, 1996).

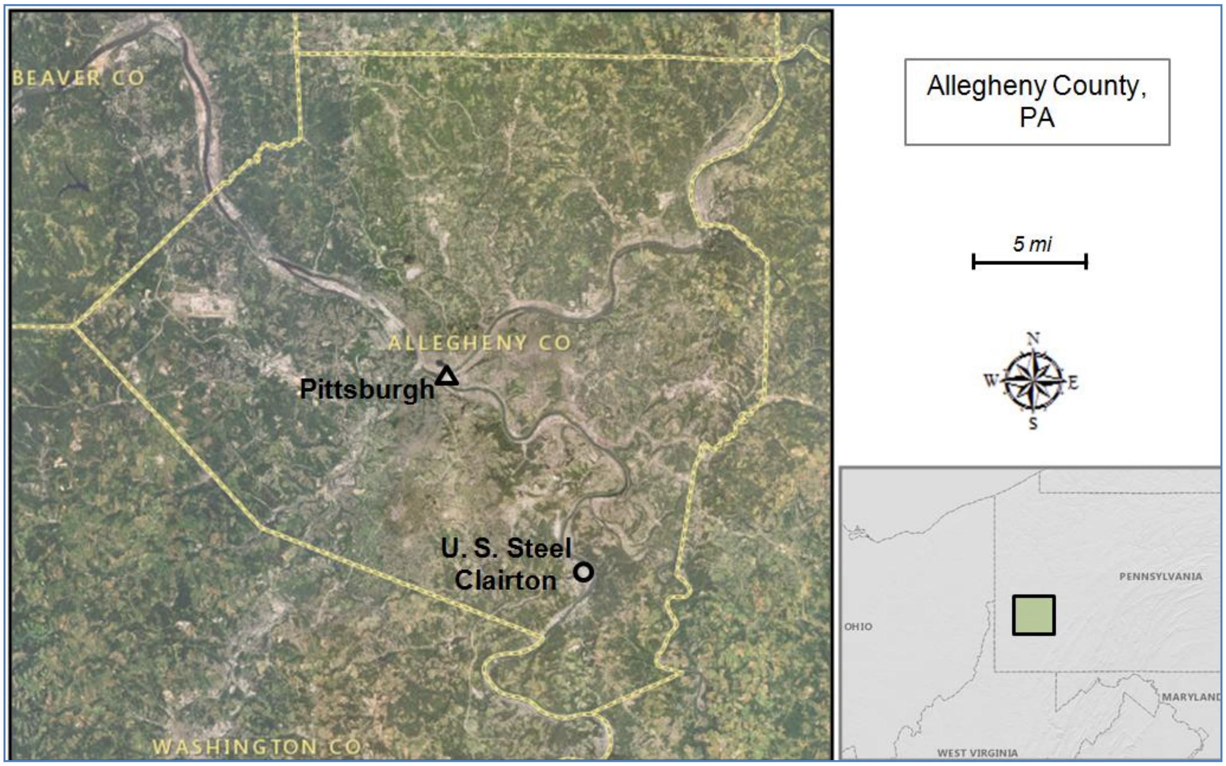

Figure 2-1. Map of Allegheny County, with the Location of the Clairton Plant

2.1 Battery Fugitive Characteristics

There are ten coke batteries in operation at the Clairton plant, comprising five distinct battery lines.[3] For stack-based releases from the plant, physical properties of the plumes have been well characterized via stack testing required by the Title V operating permit. For battery fugitives, which can represent a significant amount of primary pollutant emissions reported for the facility,[4] physical characterization of the plumes can be more difficult. These plumes cannot be easily measured by source testing methods, and they can be emitted from hundreds of points along each battery line on an intermittent basis. An illustration of a coke battery and associated releases are shown in Figure 2-2 (RTI, 2007).

[3] For this modeling demonstration, only nine of the batteries have been modeled due to the base year of 2011 selected for the modeling. The additional battery (C Battery) was not started until late 2012.

[4] For 2011 emissions, battery fugitives accounted for 37% of PM_{10} emissions, 27% of $PM_{2.5}$ emissions, and 12% of SO_2 emissions reported for the Clairton facility.

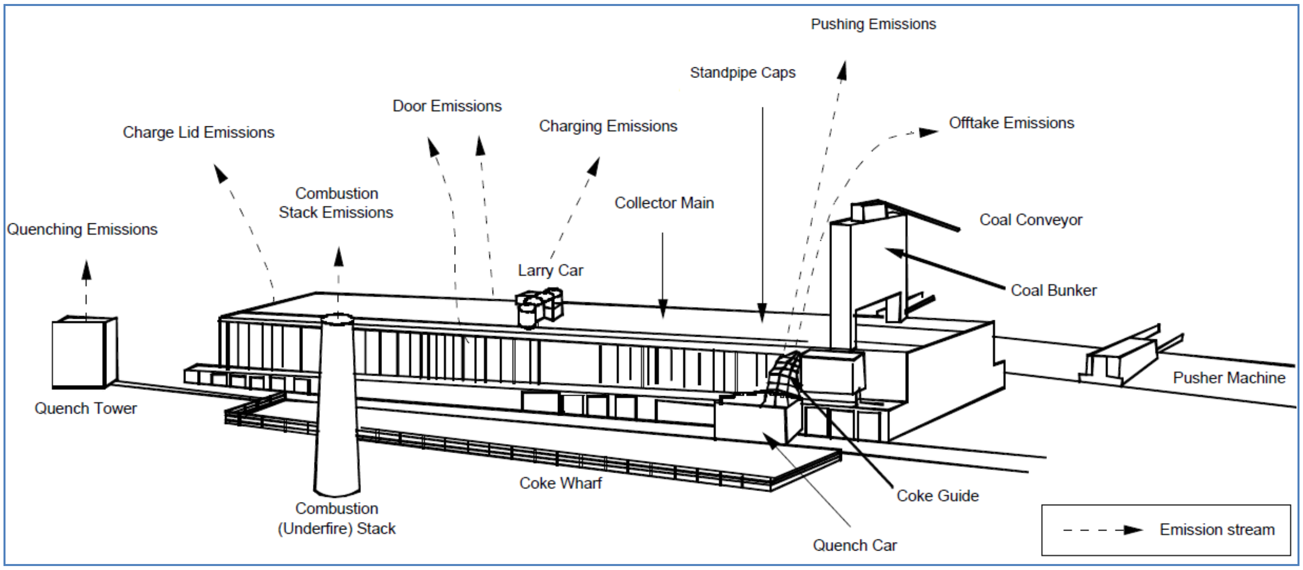

Figure 2-2. Typical Coke Battery Processes and Emissions

The coke batteries produce an extreme amount of heat that can enhance the vertical plume rise of the fugitive releases, as depicted in the cross-sectional view in Figure 2-3 (U.S. EPA, 2003). The BLP model was designed to specifically simulate these plume rises, dependent on stability conditions and wind speeds and directions. Winds along a buoyant line (i.e., parallel to) can also further enhance a plume, with an additive buoyancy effect as a plume moves along the line (Schulman and Scire, 1980).

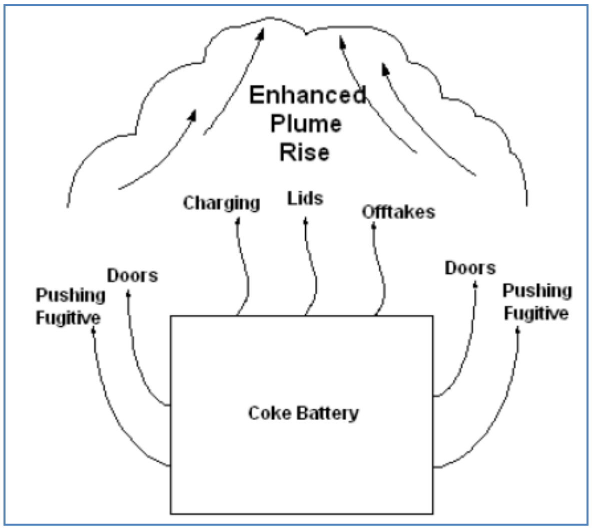

Figure 2-3. Thermally-Enhanced Coke Battery Fugitives

Any model configuration needs to properly account for both the thermal and physical characteristics of the battery sources as adequately as possible. The regulatory default source type for these sources in AERMOD is BUOYLINE.

2.2 Heat Island Effect

Studies in the Mon Valley have determined that an industrial heat island effect is evident at the Clairton plant in general, specifically near the coke batteries (Layland and Mersch, 1985; Sullivan, 1996). Analysis of surface brightness images have indicated a significant difference in surface temperatures above the coke batteries compared to the surrounding area in the range of 10-15 °F (ACHD, 2017; Warren et al., 2016). Additionally, a heat flux of 5573 W/m² has been calculated for areas near the batteries based on the amount of heat produced during coking and combustion operations (Sullivan, 2007), which would be appropriate for urban processing in AERMOD (Irwin, 1978).

Urban mode can be selected as an option in AERMOD for areas or sources with large amounts of heat flux, which adjusts the urban boundary layer for increased dispersion during stable conditions. Urban mode is usually associated with heat flux from a specified urban population, but an "effective" population can also be calculated for areas with high industrial heat flux.

However, test modeling by ACHD showed that even small effective populations for the coke battery sources can lead to underprediction of modeled impacts. In addition, settings with urban mode are arbitrary, with urban mode assigned to specific sources, assumptions made for the effective populations, etc. Furthermore, since urban mode affects the boundary layer, it can also lead to inconsistency in the meteorological data used for the domain.

ACHD presumes that the heat island effect is better characterized at the surface level, adding buoyancy to sources rather than modifying the boundary layers. Accounting for thermal buoyancy in this manner is likely the best approach for sources with localized industrial heat flux.

2.3 Complex Terrain and Non-Steady State

Additional issues that are crucial to the modeling of battery fugitives in Allegheny County are complex terrain and actual non-steady state conditions. The steep terrain of the Mon Valley can trap pollutants in the valley during extremely stagnant atmospheric conditions, which can be difficult to simulate with a steady-state model such as AERMOD. Figure 2-4 shows a contour map of the Mon Valley near the Clairton Plant, with elevations given in meters.

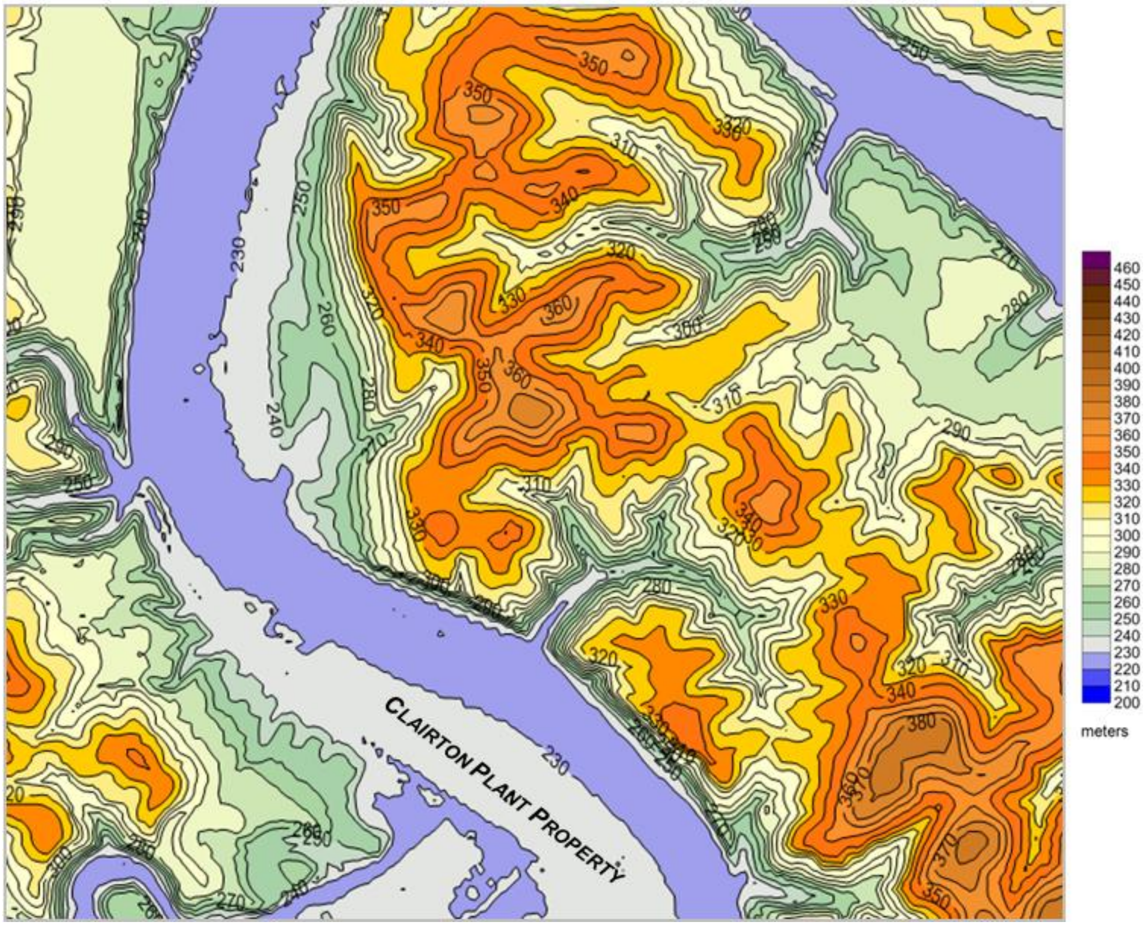

Figure 2-4. Shaded Contour Map of the Modeled Area

While AERMOD is designed to adequately account for complex terrain (Cimorelli et al., 2005; Perry et al., 2005), it can be somewhat limited in such terrain based on its handling of plumes. AERMOD formulation relies on critical hill height scales to determine the plume behavior (terrain-following or terrain-impacting) during specified atmospheric conditions for each hour. When a plume approaches a critical hill height, it can interact with terrain at that same elevation.

Figure 2-5 shows a cross-section of the area from the Clairton Plant to the Liberty monitoring site, dissecting the Lincoln ridge (see more discussion of the monitor sites in Section 4, Model Configuration). The Lincoln terrain can influence plumes originating at the Clairton plant, potentially "blocking" a plume from reaching the Liberty site if not modeled at an appropriate release height.

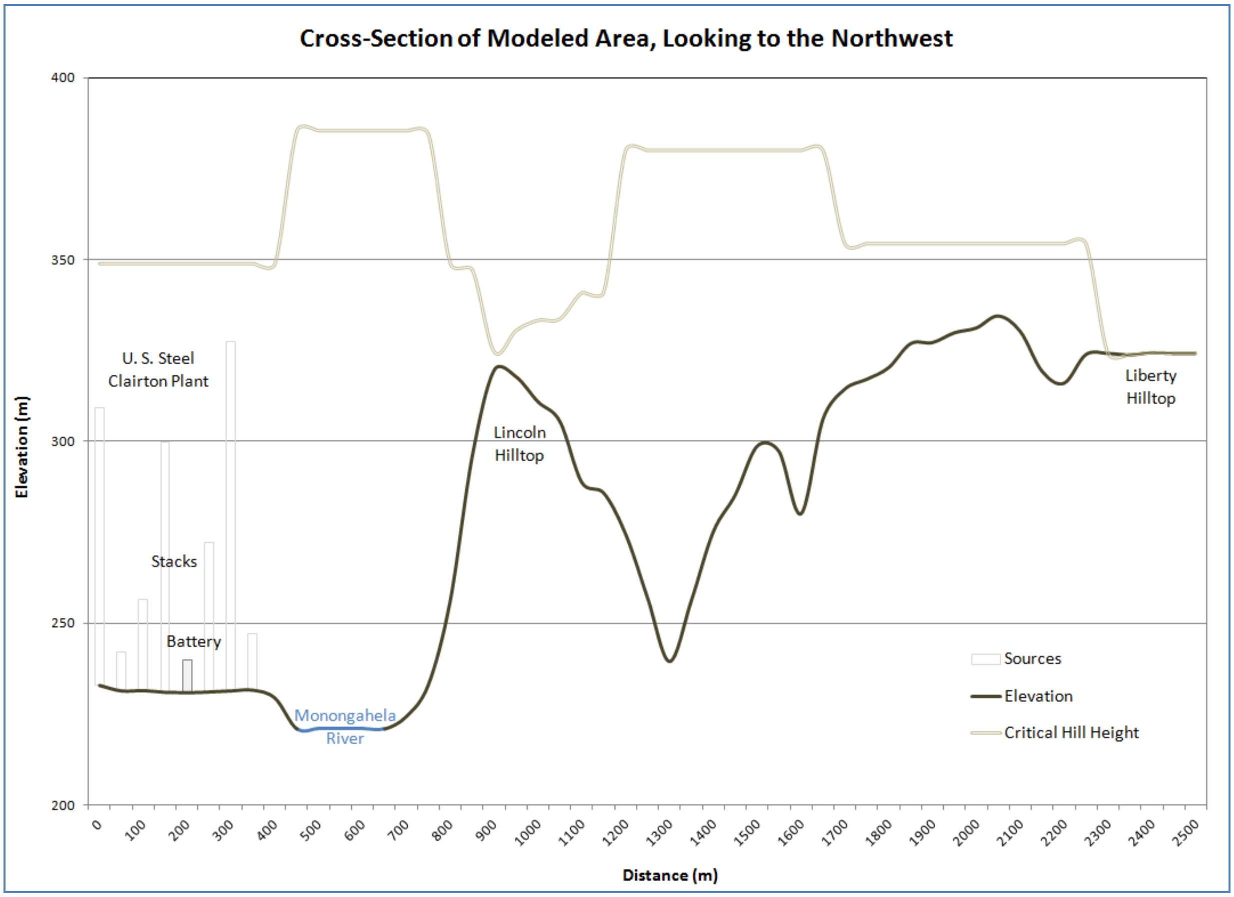

Figure 2-5. Cross-Section of Terrain in Modeled Area

The correct hourly release (or plume rise) height for each source is therefore pertinent to the correct dispersion in the area. In the case of battery fugitives, there is a "lift" from the actual release height that needs to be properly accounted for without under- or over-predicting plume rise and resulting impacts.

Little testing has been conducted with the BLP algorithms in complex terrain, as BLP was recommended for simple terrain modeling only (U.S. EPA, 2005). The CALPUFF model had previously incorporated the BLP algorithms and is a complex terrain model, but CALPUFF is no longer a preferred model and is also not recommended for near-field applications (U.S. EPA, 2008). AERMOD's BUOYLINE source type is essentially the first of its kind and may require further testing and review.

Additionally, battery fugitive emissions and river valley meteorology can often be non-steady state, with sub-hourly batch process emissions released during inhomogeneous winds and/or rapidly-changing meteorological conditions. AERMOD is designed for hourly-averaged emissions and meteorology (U.S. EPA, 2018d) and without the tracking of plumes from one hour to the next. Actual periods of high concentrations can occur during both isolated situations lasting less than an hour as well as persistent situations lasting for several hours in the valley. The proper source characterization and interpretation of modeled results in this area requires some "normalization" (or "smoothing") of steady-state probabilistic modeling to real-life non-steady state conditions.

3 BUOYANT LINE METHODOLOGIES

3.1 Buoyant Line Options

The buoyant line methodologies tested in this demonstration are listed below:

- BUOYLINE: default AERMOD source type for buoyant lines. Based on the original BLP code, requires line dimensions, average line parameters, and the buoyancy F' parameter.

- HYBRID: uses BLP-based plume rises to derive hourly release heights for varying-height line volume sources, with identical line parameters as the BUOYLINE method. Volume sources are created for AERMOD as elevated adjacent line volumes, with the number of volumes and lateral dimensions based on the dimensions of the battery. This is an alternative method based on the current preferred models and was originally developed for use in the ACHD PM_{10} SIP (ACHD, 1993; Weaver and Sullivan, 1995).

- POINT: uses point sources to represent battery fugitives, with a series of points at the same coordinates as the line volumes used for the hybrid method. This allows for temperature and flow for the fugitives, but the release heights are fixed for each hour.

- VOLUME: uses fixed-height line volume sources to represent battery fugitives, with a series of volumes at the same coordinates as the hybrid and point sources. No exit temperature or flow is associated with the volume releases. This is the regulatory approach for ambient-temperature line volume sources.

The buoyant line inputs were identical with BUOYLINE and BLP, based on the dimensions and parameters of the line (see Section 3.2 below). The following assumptions were made in the processing of the buoyant lines:

- Each line was modeled uniquely, with specific line parameters and with no additive buoyancy from parallel lines or point sources (and vice versa, buoyancy was not added to surrounding sources in any fashion).

- Emissions and line parameters were assumed to be constant for the line for each hour.

- Buoyancy was calculated from emissions-based heat flux only, with surface-based heat transfer not considered (due to potential double-counting).

- Transitional plume rise was not considered, with the final plume rise used for release heights (added to heights of the batteries, see Appendix B of this document).

All cases required post-processing due to the use of MMIF meteorology (see Model Configuration, Section 4), but BUOYLINE also required post-processing due to lines with different line parameters.[5] All other sources (points, area, non-buoyant volumes) are consistent for each case, with only the battery fugitive methodology differing for each model run.

[5] Various configurations were tested with BUOYLINE, including different size lines, parallel lines, etc. The effects were similar for all cases, with BUOYLINE leading to overprediction. With the current version of AERMOD, the modeling of several lines can also lead to modeled errors and requires considerable post-processing.

Other options that could be considered for buoyant lines might involve calculations of plume rise from AERMET/AERMOD variables, measurements of plume rise via instrumentation, or other techniques.

Figure 3-1 shows the location of each Clairton Plant buoyant line source (shown in red) modeled in this demonstration. The center coordinate of each corresponding volume/point source (used for the HYBRID, POINT, and VOLUME cases) are indicated by dots within the line.

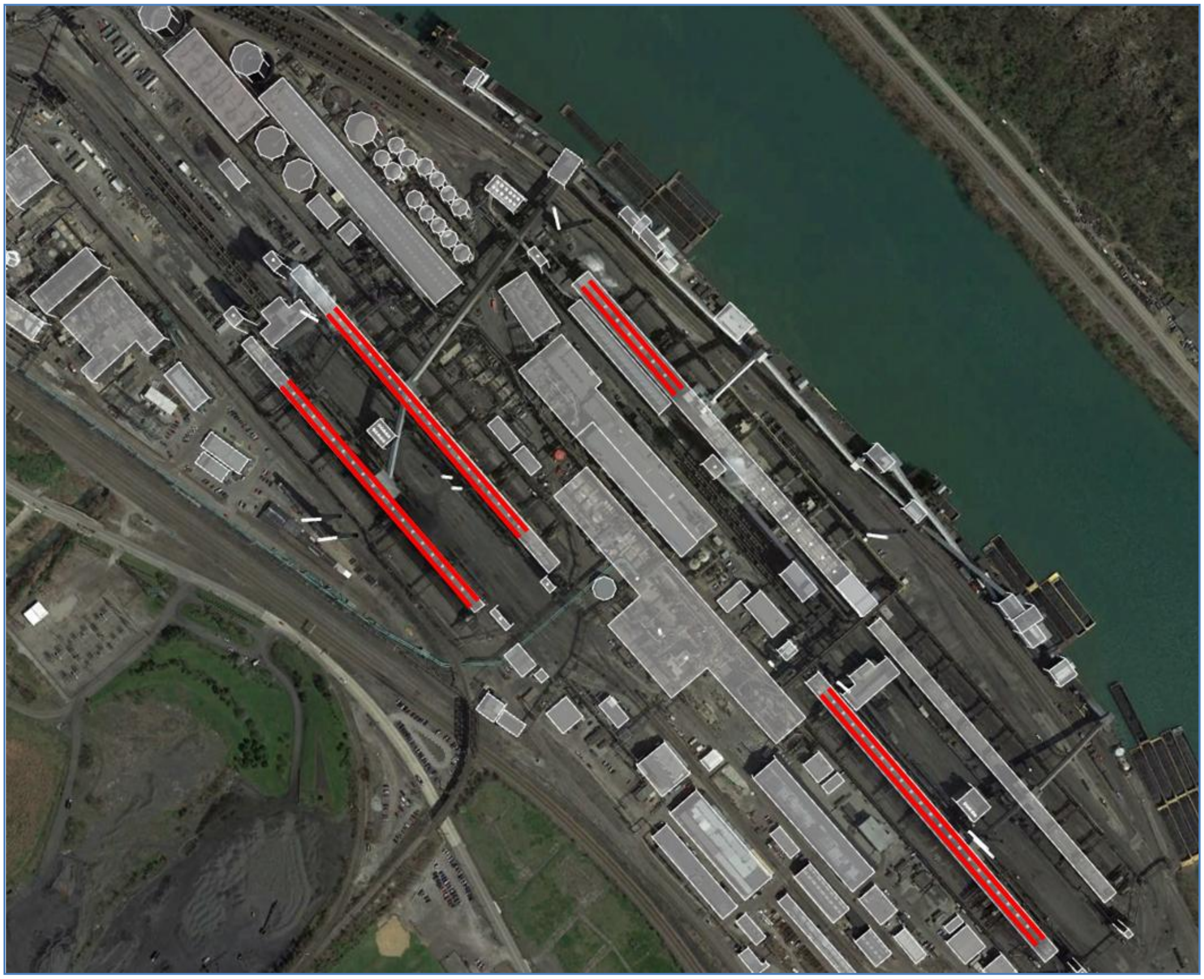

Figure 3-1. Clairton Plant Diagram and Battery Lines

3.2 Line Parameters

Line parameters were based on physical dimensions, flow, and temperatures of the line. The F' buoyancy term, based on the original BLP formulation, is given in Figure 3-2 (Schulman and Scire, 1980). Table 3-1 provides the parameters of each line modeled in this demonstration.

L	is the average building (line) length (m),
H_B	is the average building height (m),
W_M	is the average line source width (m),
W_B	is the average building width (m),
δ_x	is the average spacing between buildings (m), and
F'	is the average line source buoyancy parameter (m^4/s^3)

where

$$F' = \frac{g\ L\ W_M\ w\ (T_s - T_a)}{T_s}$$

and

g	is the gravitational acceleration (m/s^2),
w	is the exit velocity (m/s),
T_s	is the exit temperature (K), and
T_a	is the ambient air temperature (K)

Figure 3-2. BLP Buoyancy (F') Equation

Table 3-1. BUOYLINE/BLP Line Parameters

Buoyant Line Source	ID	Elev (m)	UTMx (m) nw	UTMy (m) nw	UTMx (m) se	UTMy (m) se
US STEEL CLAIRTON Batteries 1-3	CLBATT1_3	231	595732.52	4461976.88	595922.90	4461762.85
US STEEL CLAIRTON Batteries 13-15	CLBATT13_15	231	595271.42	4462323.03	595452.96	4462119.60
US STEEL CLAIRTON Batteries 19-20	CLBATT19_20	231	595229.60	4462254.53	595393.87	4462069.79
US STEEL CLAIRTON B Battery	CLBATTB	231	595515.79	4462338.59	595585.53	4462260.73
US STEEL CLAIRTON C Battery	CLBATTC	231	595663.04	4462173.24	595739.93	4462086.93
Buoyant Line Source (cont.)	ID	Avg Bldg (Line) Length (m)	Avg Bldg Ht (m)	Avg Bldg Width (m)	Avg Line Width (m)	Spacing (m)
US STEEL CLAIRTON Batteries 1-3	CLBATT1_3	287.0	8.5	13.7	1.0	0.0
US STEEL CLAIRTON Batteries 13-15	CLBATT13_15	273.0	8.8	14.0	1.0	0.0
US STEEL CLAIRTON Batteries 19-20	CLBATT19_20	247.0	10.5	14.0	1.0	0.0
US STEEL CLAIRTON B Battery	CLBATTB	106.0	15.1	16.7	1.0	0.0
US STEEL CLAIRTON C Battery	CLBATTC	115.0	15.1	16.7	1.0	0.0
Buoyant Line Source (cont.)	ID	Exit Temp (K)	Amb Temp (K)	Exit Vel (m/s)	Avg Line Buoyancy (m^4/s^3)	BUOYLINE Release Ht (m)
US STEEL CLAIRTON Batteries 1-3	CLBATT1_3	1184.83	284.27	3.05	6520.3	8.5
US STEEL CLAIRTON Batteries 13-15	CLBATT13_15	1184.83	284.27	3.05	6202.2	8.8
US STEEL CLAIRTON Batteries 19-20	CLBATT19_20	1184.83	284.27	3.05	5611.5	10.5
US STEEL CLAIRTON B Battery	CLBATTB	1184.83	284.27	3.05	2408.2	15.1
US STEEL CLAIRTON C Battery	CLBATTC	1184.83	284.27	3.05	2612.6	15.1

Battery height, length, and width are based on the actual physical dimensions of each battery. Line length is equal to the physical length of the line, while line width is based on an "equivalent" diameter of the various fugitive release points along the line (estimated as an average of 1.0 m). Exit velocity is based on calculated flows for each line (Layland and Mersch, 1985) along with observations of visible fugitive emissions (estimated as an average of 10 ft/s (3.05 m/s) collectively for the line emissions). Note that all values for the line parameters (and emissions) are considered to be constant for each hour, which assumes some "smoothing" for the line buoyancy calculations needed for steady-state modeling.

Ambient temperature is estimated as an average of year-round temperature for the Pittsburgh area (about 52 °F, or 284.27 K). Exit temperatures are based on the fugitive emission temperatures from all processes associated with the coking. The methodology for calculating the exit temperatures by process is described as follows:

- Charging and leaks (topside/door): calculated as the midpoint of the surface temperature (an average of 350 °F for door and top surfaces (Layland and Mersch, 1985)) and the temperature of hot coke 1800 °F (AISE, 1999), for an average of 1075 °F. It is assumed that that leaks are cooled by ambient air quicker than other processes (such as pushing, where the ovens and coke are exposed when the doors are off).

- For pushing (including pre-push, controlled (PEC), and uncontrolled pushing): a temperature of 1800 °F, equal to that of hot coke. The general range of coking is 1650-2000 °F, with a range of 1900-2000 °F for the actual skin of coke inside a coke oven chamber (AISE, 1999). It is assumed that that the 1800 °F temperature inherently includes some immediate heat loss and that pushing retains more heat from the oven and block of coke than other sources (such as leaks).

- For the hot cars (aka travel or quench cars): calculated as the midpoint of the temperature of "resting" coke in the car (1500 °F) (AISE, 1999) and the pushing temperature (1800 °F), for an average of 1650 °F during traveling from pushing to quenching.

- For soaking: calculated as the average of measured temperatures during stack testing (1273 °F) (ATS, 1995).

The calculated temperatures are then weighted by the corresponding fractions of each process to total battery fugitive emissions. For this demonstration, emissions for year 2011 were used (the base year for both the SO_2 and $PM_{2.5}$ SIPs). The percentages of battery fugitive PM_{10} emissions by process were as follows: charging/leaks (13%), pushing (73%), hot cars (10%), and soaking (4%).

The weighted average exit temperature was calculated as 1673 °F (1184.83 K) for PM_{10} (used collectively for PM, since $PM_{2.5}$ is a fraction of PM_{10}).[6]

[6] Using the same methodology for SO_2, the weighted temperature is calculated as 1587 °F. For the SO_2 SIP, a rounded value of 1600 °F was used for exit temperatures.

4 MODEL CONFIGURATION

The model configuration selected for this demonstration was based on the configuration of Allegheny County, PA $PM_{2.5}$ SIP for the 2012 NAAQS (under development at the time of this demonstration). The model design uses a combination of CAMx[7] for regional and secondary impacts and AERMOD for localized primary impacts for a base year of 2011 (see AERMOD Modeling Protocol for $PM_{2.5}$ (ACHD, 2018)).

The pollutant selected was PM_{10} (particulate matter, 10 microns or less), primarily due to the availability of monitored data from several sites surrounding the Clairton Plant for year 2011. PM_{10} may also be a more robust compound for this demonstration than a gaseous pollutant such as SO_2. Monitored PM can remain entrained in the atmosphere for longer periods than a gaseous plume, which can provide a better comparison to steady-state modeled values. Modeled background concentrations are also more specific to the area, using CAMx gridded model results in place of upwind/background monitored data.

While this demonstration is based on PM_{10} emissions and sources, a similar configuration was used for SO_2 SIP. The localized impacts of both pollutants are primary in nature (see Appendix A) and are attributed to the same sources.

PM and precursor emissions modeled were identical to those contained in the EPA 2011 National Emission Inventory (NEI)[8] inventory with the following exceptions:

- U. S. Steel Clairton Plant quench tower emissions were recalculated based on emission factors of lb/quench instead of lb/ton-coke, and with all mass from the EPA Method 5 stack test results used for the filterable component.
- Calgon Carbon (a distant source) Cooperite process emissions were revised for NH_3 based on updated stack test results.
- Emissions from small airfields and helipads that were closed as of 2011 were removed from the modeling inventory.

4.1 AERMOD Configuration

The AERMOD modeling system version 18081, including the latest versions of preprocessors and related programs, was used for the local source modeling.

4.1.1 Sources

Based on the design of the CAMx modeling, selected local major sources of primary PM emissions were tracked separately for hourly impacts. This allowed for local source modeling to be performed in combination with CAMx regional results without double-counting (see more in Section 4.2 below). These sources, referred to as local primary material (or "LPM") sources, are listed below:

- U. S. Steel Mon Valley Works
    - Clairton Plant
    - Irvin Plant
    - Edgar Thomson Plant

[7] Comprehensive Air Quality Model with extensions photochemical grid model.

[8] https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data

- Shenango
- ATI Allegheny Ludlum
- McConway & Torley

The U. S. Steel plants are an integrated steel mill, connected by pipeline and railroads throughout the Mon Valley. The Clairton Plant is the most important source for this demonstration, being the facility with the buoyant battery lines. (No other processes or sources were modeled in a non-regulatory manner.)

The Shenango, ATI Allegheny Ludlum, and McConway & Torley facilities are distant sources for this demonstration, located several miles away from the buoyant lines. They were included in the PM model design as LPM sources due to potential source/receptor impacts in other areas of the county, and they are included in this demonstration only to account for all possible contributions of primary PM.

Only primary filterable and condensable PM_{10} emissions were modeled. The source inventory used for the AERMOD sources is given in Appendix C.

4.1.2 Settings

AERMOD 18081 (U.S. EPA, 2018a) was run with the following settings:

- Calculate concentration values (CONC)
- Regulatory DEFAULT options:
  - Includes stack-tip downwash
  - Accounts for elevated terrain effects
  - Uses calms processing routine
  - Uses missing data processing routine
  - No exponential decay
- RURAL dispersion only (Auer, 1978)
- Pollutant type: OTHER (since specific processing routines were not needed, only hourly impacts)
- Time period: 1-hour averaging, for 8760 total hours for the period (year: 2011)
- Accepts FLAGPOLE receptor heights
- BPIPPRM building downwash parameters for POINT sources (U.S. EPA, 1993)
- No wet or dry depletion/deposition
- Meteorological data can include TEMP substitutions
- Multiple AERMOD runs, post-processed
- Source types:
  - POINT sources for stacks
  - VOLUME sources for non-buoyant fugitive sources
  - AREA sources for pile erosion
  - BUOYLINE for buoyant lines (BUOYLINE case only)
- HOUREMIS for buoyant line sources (HYBRID case only)
- Haul Road methodology (U.S. EPA, 2012) for road/vehicle emissions
- AERMET settings as listed below (Section 4.1.3)

4.1.3 Meteorology

The AERMOD meteorological preprocessor AERMET 18081 (U.S. EPA, 2018b) was run with the following settings:

- Meteorological year: 2011[9]
- MMIF version 3.4 (Brashers and Emery, 2016)[10] inputs for multiple facility locations
    - o 0.444 km resolution onsite, upper air, and surface characteristics inputs (U. S. Steel facility locations)
    - o 1.33 km resolution MMIF (all other source locations)
- Bulk Richardson low-level delta_T and solar radiation for stable boundary layer
- Low wind option ADJ_U* for stable boundary layer
- 0.0 m/s wind speed threshold, based on MMIF Guidance (U.S. EPA, 2018e)

MMIF was selected for this demonstration as the best available meteorological data, providing site-specific WRF-based data for each source location in the valley.[11] For more discussion on the MMIF inputs and configuration, see Appendix D of this document (also the SO_2 SIP (ACHD, 2017)).

4.1.4 Receptors

Monitored data from three PM_{10} sites were used for comparison to modeled results:

- Lincoln: a middle scale, highest-concentration site, in close proximity to Clairton Plant, or a "1st-tier" zone for primary pollutant impacts in the area

- Liberty: a neighborhood scale, population exposure site, located on the roof of a high school, or a "2nd-tier" zone for primary pollutant impacts in the area

- Glassport[12]: a neighborhood scale, population exposure, located on a similar "2nd-tier" zone hilltop like Liberty, but in a different wind direction

Based on the complex terrain and non-steady state issues discussed in Section 2 (Problem Statement), an "expanded-scale" approach was used for receptors to represent each monitor site in this demonstration (Maranche and Sadar, 2016). From 40 CFR Part 58 Appendix D, for pollutants in general, a "spatial scale of representativeness is described in terms of the physical dimensions of the air parcel nearest to a monitoring site throughout which actual pollutant concentrations are reasonably similar."

Middle and neighborhood monitor scales for PM_{10} are summarized as follows:

- Middle scale: concentrations typical of areas with dimensions ranging from about 100 meters to 0.5 kilometer. Much of the short-term public exposure to PM_{10} is on this scale or the neighborhood scale, including influences from stationary sources.

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[9] While 3 years of prognostic data are preferred for regulatory applications, only 1 year of data was available based on the $PM_{2.5}$ SIP configuration. ACHD deemed 2011 to be an appropriate year to represent typical meteorological conditions for the area.

[10] Note: the latest version 3.4 was used for this demonstration. The reference is for the most recent publically-available version (3.3).

[11] BUOYLINE was also tested with other available meteorological data (airport, local 10 m surface tower), showing the same tendency toward overestimation. Additionally, sodar and other multi-level data were used for evaluation of the MMIF data (see the SO_2 SIP for more details).

[12] The Glassport PM_{10} site is a different site than the former Glassport SO_2 site, which was located approximately 600 meters to the south in a "1st-tier" zone similar to Lincoln.

- Neighborhood scale: concentrations within some extended area with dimensions in the 0.5 to 4.0 kilometers range, representing reasonably homogenous conditions for PM_{10} concentrations as well as land use. Neighborhood scale PM_{10} sites often represent conditions where people live and work and can also provide larger-scale patterns for models relying on spatially-smoothed emission inputs.

Based on these monitor scales, 500-meter radius polar receptor grids were placed in the area, centered on each actual monitor site location as shown in Figure 4-1 below. The Clairton Plant configuration, located to the south and southwest of the sites, is shown by the gray structures within the yellow property fenceline.

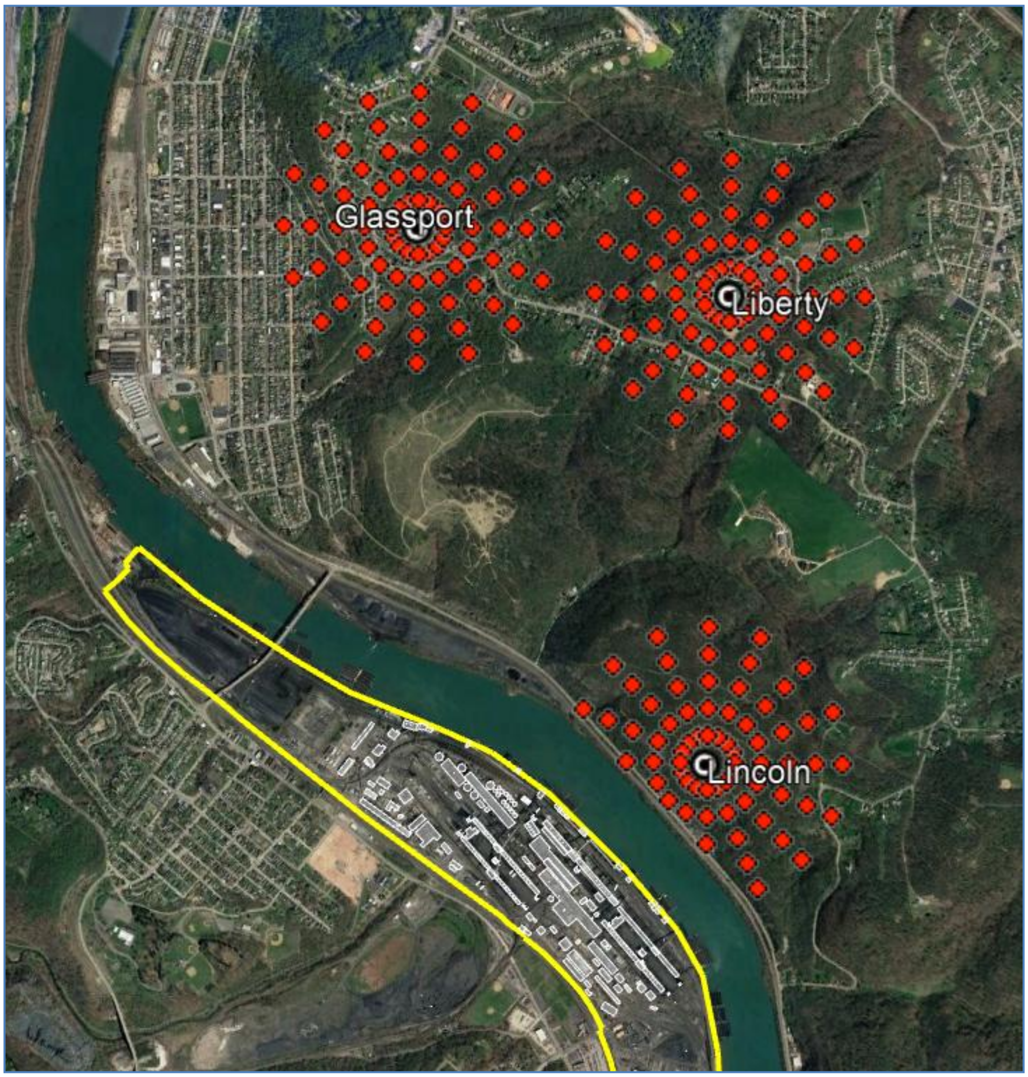

Figure 4-1. Receptors for PM_{10} Sites at 500-m Radius, in Relation to Clairton Plant

Receptors within 500 meters of Lincoln, but lying over the river and near the Clairton fenceline, were removed from the receptor grid. While these locations can be considered to be ambient air for some modeling applications, for the purposes of this demonstration they are considered to be unsuitable locations for comparison of modeled to monitored data.

While this expanded-scale receptor methodology may be somewhat unconventional for model performance demonstrations, ACHD deemed this method to be appropriate for the area for the following reasons:

- For a proper comparison of steady-state modeling to non-steady state conditions in complex terrain, there is a degree of forgiveness needed for both time and space. AERMOD is designed to produce straight-line concentrations on an hourly basis. In a sense, AERMOD may be too accurate for some non-steady state situations, leading to uncertainties in modeled impact locations.

- Based on $PM_{2.5}$ modeling guidance (U.S. EPA, 2014), an expanded-scale receptor approach is appropriate for localized PM, with several receptors placed near monitors in order to assess predicted concentration gradients. Modeling in the Mon Valley area can lead to large concentration gradients at receptors located only a few hundred meters apart.

- In addition to uncertainty with the model, there is a degree of uncertainty with meteorological data supplied to AERMOD (using both prognostic (MMIF) and measured data inputs). Inaccuracies in wind speeds or directions can lead to large variations in spatial impacts.

- Even with multiple MMIF data sets (and with multiple-level profiles), meteorological parameters are assumed to be constant for each hour from each starting point throughout the complex terrain. High-resolution wind fields (such as with a Lagrangian puff or computational fluid dynamic (CFD) model) may be more appropriate for this situation. (AERMOD with MMIF meteorology was chosen as the best-available regulatory approach at this time.)

- Merged plumes may be physically larger in real-life than modeled, especially in extremely stagnant conditions with elevated pollutant periods (lasting longer than an hour). A larger receptor grid can help to account for more wide-spread impacts near the monitor. (On this note, the use of BUOYLINE likely causes plumes that are too large within the river valley; the use of the expanded-scale receptor grids helps with the overall understanding of the modeled impacts in space.)

Coinciding with the expanded-scale receptor approach, a maximum-exposure basis was also used for the comparison of modeled to monitored data for each site. The highest hourly modeled concentration from any receptor in the expanded-scale grid was used as the hourly localized impact for each site, and corresponding 3-hour and 24-hour averages were based on composite averages of the maximum hourly concentrations.

The AERMOD terrain preprocessor AERMAP version 18081 (U.S. EPA, 2018c) was run with the following settings to generate the receptor grids:

- Domain
    - SW corner: 590000.0, 4457900.0
    - NE corner: 602100.0, 4469700.0
    - UTM zone 17, NAD83 datum
- Elevations based on 10 m resolution USGS NED data
- Total of 230 receptors (Lincoln: 68, Liberty: 81, Glassport: 81)

4.2 CAMx Configuration

The CAMx modeling used for this demonstration was configured with tracking for specific source groups, allowing for the apportionment of regional (wide-scale) and local primary contributions. The CAMx results used in combination with the AERMOD LPM results included emissions from all sources and sectors, for PM and all precursors, except for PM_{10} from the LPM sources given in Section 4.1. These "non-LPM" impacts from CAMx are essentially PM regional background for the area, without the localized primary excess.

4.2.1 Settings

CAMx version 6.30 (Ramboll Environ, 2016a) was run with the following settings:

- Modeled year: 2011
- Weather Research and Forecasting (WRF)[13] version 3.7.1 mesoscale meteorological inputs
- 36/12/4/1.33 km resolution nested grid structure
    - 1.33 km domain focused on Allegheny County
    - Additional 444 m resolution WRF grid (for MMIF only, at U. S. Steel locations)
- Particulate Source Appointment Technology (PSAT) for source group tracking
- Emissions based on 2011 MARAMA Alpha2[14] and NEI v6.2 Modeling Platform[15]
- Emissions modeling based on the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system[16]

More information can be found in the WRF and CAMx $PM_{2.5}$ modeling protocols and model performance evaluations (Ramboll Environ, 2016b; 2016c; 2017a; 2017b; 2018).

4.2.2 Combination of Impacts

Hourly impacts (for total regional PM_{10}, primary and secondary) from specific CAMx grid cells were combined with the hourly local AERMOD impacts for each model case and monitor location (expanded-scale receptor basis), paired in time. The CAMx grid cell corresponding to each monitor site was used for the regional (non-LPM) component. Figure 4-2 shows the numbered CAMx 1.33 km resolution grid cells[17] containing or surrounding each monitor location.

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13 https://www.mmm.ucar.edu/weather-research-and-forecasting-model

14 http://www.marama.org/technical-center/emissions-inventory/2011-inventory-and-projections

15 https://www.epa.gov/air-emissions-modeling/2011-version-6-air-emissions-modeling-platforms

16 https://www.cmascenter.org/smoke/

17 CAMx grid cells were numbered according to geographic x-y coordinates used by the model.

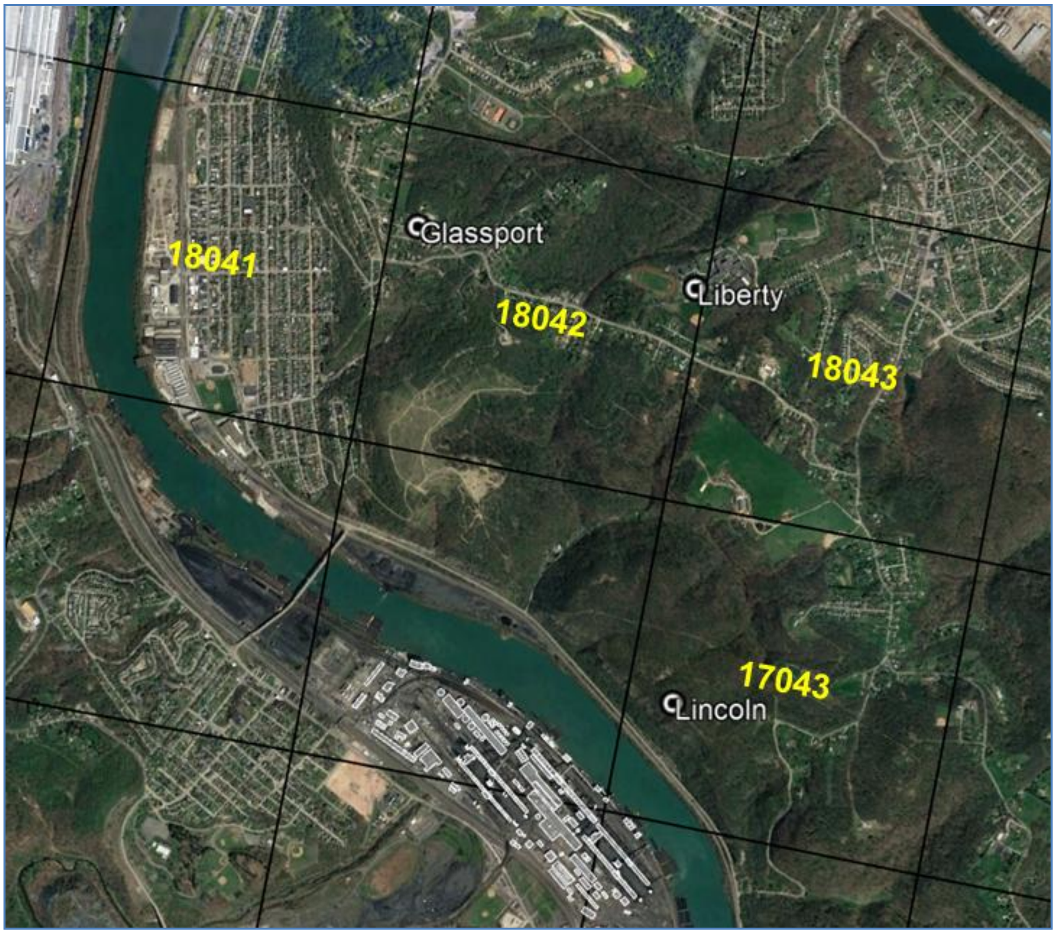

Figure 4-2. Numbered CAMx Grid Cells, 1.33 km Resolution

For the Lincoln monitor, since most receptors fall within the 17043 grid cell, hourly CAMx impacts from the 17043 cell were used in combination with the hourly AERMOD impacts. For the Liberty and Glassport sites, which both fall near the borders of CAMx grid cells, hourly averages of different grid cells were used in combination with AERMOD. (For Liberty, the hourly average of cells 18042 and 18043 was used; for Glassport, the hourly average of cells 18041 and 18042 was used.)

5 EVALUATION OF RESULTS

According to Section 3.2.2(b)(2) of the Guideline, 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." This section provides the model evaluation methodologies and results for the BLP/AERMOD hybrid approach compared to the preferred technique (BUOYLINE) and other methodologies.

5.1 Performance Evaluation Methodologies

Model performance is based on analysis of the modeled predictions for each case against available measurements at surrounding air quality monitors. Statistical measures and methods used in this analysis are similar to the techniques recommended by EPA and used in the evaluation of other model demonstrations (U.S. EPA, 2014; ENVIRON, 2012; ADEQ, 2018).

A comprehensive, multi-layered approach to model performance can include up to four components, viewed conceptually as follows:

- Operational: tests the ability of the model to estimate concentrations. This evaluation examines whether the measurements are properly represented by the model predictions but does not necessarily ensure that the model is getting "the right answer for the right reason";
- Diagnostic (or scientific): tests the ability of the model to get the right answer for the right reason;
- Mechanistic (or dynamic): tests the ability of the model to predict the response of concentrations to changes in variables such as emissions and meteorology; and
- Probabilistic: takes into account the uncertainties associated with model predictions and observations.

The operational component was the focus of the performance evaluation, while elements of the other components are also included in this demonstration. Table 5-1 lists a core set of statistical performance measures that can be used to evaluate model performance. Following Table 5-1 are additional statistical metrics used for the model evaluations, including a description of the composite performance measure (CPM) and model comparison measure (MCM) that can be used for direct comparison between models (U.S. EPA, 1992; Cox and Tikvart, 1990).

Table 5-1. Core Statistical Measures for Air Quality Model Evaluation

Statistical Measure	Mathematical Expression	Notes
Mean Bias (MB)	$\frac{1}{n}\sum_{1}^{n}(M-O)$	Reported as concentration (e.g., µg/m³)
Mean (Gross) Error (ME)	$\frac{1}{n}\sum_{1}^{n}\lvert M-O\rvert$	Reported as concentration, absolute values
Root Mean Square Error (RMSE)	$\sqrt{\frac{\sum_{1}^{n}(M-O)^2}{n}}$	Reported as concentration
Normalized Mean Bias (NMB)	$\frac{\sum_{1}^{n}(M-O)}{\sum_{1}^{n}(O)}$	Unitless
Normalized Mean Error (NME)	$\frac{\sum_{1}^{n}\lvert M-O\rvert}{\sum_{1}^{n}(O)}$	Unitless, absolute values
(Mean) Fractional Bias (FB)	$\frac{1}{n}\left(\frac{\sum_{1}^{n}(M-O)}{\sum_{1}^{n}\left(\frac{(M+O)}{2}\right)}\right)$	Unitless
(Mean) Fractional Error (FE)	$\frac{1}{n}\left(\frac{\sum_{1}^{n}\lvert M-O\rvert}{\sum_{1}^{n}\left(\frac{(M+O)}{2}\right)}\right)$	Unitless, absolute values
Standard Deviation (σ)	$\sqrt{\frac{1}{n}\sum_{1}^{n}(X-\overline{X})^2}$	Reported as concentration $\overline{X}$ = arithmetic average
Correlation Coefficient (r)	$\frac{1}{(n-1)}\sum_{1}^{n}\left(\left(\frac{O-\overline{O}}{\sigma_o}\right)*\left(\frac{M-\overline{M}}{\sigma_m}\right)\right)$	Unitless $\overline{M},\overline{O}$ = arithmetic averages

M = modeled (predicted) concentration at each time/location (1 through n)
O = observed (monitored) concentration at each time/location (1 through n)
X = modeled or observed concentration at each time/location (1 through n)
n = number of paired concentrations

Additional metrics used in the evaluation are described below.

Fractional factor of two (FF2): the ratio of the number of modeled concentrations within a factor of two of observed concentrations compared to the total number of modeled concentrations.

Geometric correlation coefficient (r_g): standard correlation coefficient computed using the natural log of the modeled and measured concentrations, calculated in equation (1):

$$r_g = \frac{\Sigma\left(ln(x) - \overline{ln\,(x)}\right)\left(ln(y) - \overline{ln\,(y)}\right)}{\sqrt{\Sigma\left(ln(x) - \overline{ln\,(x)}\right)^2}\sqrt{\Sigma\left(ln(y) - \overline{ln\,(y)}\right)^2}} \qquad (1)$$

Geometric mean (μ_g): the n^{th} root of the product of n numbers, calculated in equation (2). The geometric mean is used to evaluate a general expected value with dampened outlier influence.

$$\mu_g = \left(\prod_{i=1}^{n} c_i\right)^{1/n} \qquad (2)$$

Geometric mean variance (VG): a measure of the precision of the dataset. A perfect model would result in VG = 1. VG is calculated in equation (3), where c_o and c_p are the observed and predicted concentrations, respectively:

$$VG = e^{\left(\overline{\left(ln\left(\frac{c_o}{c_p}\right)\right)^2}\right)} \qquad (3)$$

Robust highest concentration (RHC): a comparison of modeled and observed concentrations at upper end of a frequency distribution, calculated using equation (4):

$$RHC = c_n + (\bar{c} - c_n)ln\left(\frac{3n-1}{2}\right) \qquad (4)$$

where c_n is the n^{th} highest concentration and $\bar{c}$ is the average of the (n-1) highest concentrations, and n is set to 26 as a threshold value

Composite performance measure (CPM): a single representative value for each model case, based on the calculation of both scientific and operational components using statistics from different averaging periods (1-hour, 3-hour, and 24-hour), meteorological conditions, and site locations. No model cases were screened out from CPM for this demonstration.

CPM is calculated on a network-wide basis, with the scientific component based on an average bias of all sites and meteorological scenarios on a 1-hour basis and the operational component based on peak network bias on 3-hour and 24-hour bases. The components are combined by averaging the scientific and operational components, with the operational component having more weight than the scientific component since it includes two averaging periods.

The scientific component of CPM assesses network-wide 1-hour concentrations during six specific meteorological conditions, as combinations of unstable, neutral, or stable conditions and wind speeds above or below 2.0 m/s.[18] For each model case, meteorological condition, and site location, the RHC is calculated for both observed and modeled data using equation (4). The absolute fractional bias (AFB) between the modeled and measured RHC is then calculated using equation (5):

$$AFB = \left| 2 \cdot \frac{(RHC_{measured} - RHC_{modeled})}{(RHC_{measured} + RHC_{modeled})} \right| \tag{5}$$

The operational component of CPM evaluates the peak 3-hour and 24-hour averages, independent of meteorology or spatial location. The absolute fractional bias between measured and modeled RHC is calculated in a similar manner as the scientific component, except that the values are on a network-wide maximum basis. For each model case (BUOYLINE, HYBRID, etc.), the maximum observation-based RHC from all three monitor locations and the maximum model-based RHC from all three locations is used to compute the AFB, calculated separately for the 3-hour and 24-hour bases.

CPM then combines the 1-hour, 3-hour, and 24-hour absolute fractional biases for both the scientific and operational components, for each model case, as shown in equation (6).

$$CPM = \frac{(average(AFB(i,j)\ + AFB(3)\ +\ AFB(24))}{3} \tag{6}$$

where AFB(i,j) is the absolute fractional bias for each meteorological condition and site (total of 18), AFB(3) is the absolute fractional bias for 3-hour averages (network-wide maximum basis), and AFB(24) is the absolute fractional bias for 24-hour averages (network-wide maximum basis)

CPM is lowest when there is a good agreement between measured and modeled RHC values. Comparing the magnitudes of the CPM values from different models using the same observational data provides insight into the model performance of each dispersion model in a relative sense.

A bootstrapping statistical technique was used to resample the observed and modeled data in 3-day blocks 1000 separate times in order to estimate the 95th percentile confidence intervals from standard deviations across the bootstrap iterations. Observed and modeled data from all three sites were used to estimate the CPM for each bootstrap.

Model comparison measure (MCM): a single representative value, calculated as the difference of the CPM values from one model case to another, along with confidence intervals similar to CPM. For four different model cases, there are a total of six comparisons (BUOYLINE minus HYBRID, HYBRID minus POINT, etc.) that can be generated. A positive value for MCM indicates that the first model case is inferior to the second model case (i.e., a higher CPM minus a lower CPM).

Additionally, if the confidence intervals do not span zero for a MCM, the model comparison is statistically significant. Otherwise, if the confidence intervals span zero, the model comparison is determined to be statistically insignificant, regardless of a negative or positive MCM value.

[18] For the meteorological conditions, data from the Clairton 444 m resolution MMIF were used. While the AERMOD demonstration also incorporated MMIF data sets from the other major source locations, the Clairton data was deemed to be most important for the buoyant line methodology comparisons and therefore used for CPM. The wind speed condition of below or above 2.0 m/s was based on the average surface reference wind speeds in the Clairton MMIF data.

Confidence intervals for MCM were calculated on a simultaneous basis by first calculating differences in the bootstrapped CPM results (1000 iterations) for different model case pairings along with a standard deviation across all of the bootstrapped model case differences. The bootstrapped differences by model pair were then subtracted from the non-bootstrapped MCM values (CPM of one model case minus CPM of another model case) and divided by the standard deviation. The confidence intervals were then calculated as the 95^{th} percentile of the above values for each model case pair.

Graphical displays also facilitate quantitative and qualitative comparisons between predictions and measurements. Graphical displays can include the following:

- Quantile-quantile (Q-Q) plots: a series of ranked pairings of predicted and observed concentration, where any rank of the predicted concentration is plotted against the same ranking of the observed concentration. Q-Q plots are used to evaluate a model's ability to represent the frequency distribution of the observed concentrations.

- Time series and scatter plots: concentrations matched in time for each monitoring location. Time series plots are helpful to understand the response of the model during specific measured time periods. Scatter plots show the correlation during all time periods between predicted and observed.

- Temporal distribution plots: concentrations shown by averages over selected time periods, such as hour of the day (diurnal), month, season, etc. Temporal plots show average patterns in time for groups of concentrations instead of for each concentration.

- Goal plots: provides a visual display of statistical metrics such as bias and error along with respective goals or criteria. For example, model results showing the least bias and/or error (within a box, or "goal") are the best performing cases.

5.2 Quantile-Quantile Plots by Site

Quantile-quantile (Q-Q) plots for each site and buoyant line methodology are given in Figures 5-1 through 5-9 below, by three different time-averaging periods: 1-hour (hourly), 3-hour, and 24-hour (daily). (Note: 3-hour and 24-hour averages are block averages, not rolling averages of any available period.)

For hours with missing monitored data (there are no missing periods from the modeled results), the monitored and modeled concentrations are first sorted on a time-paired basis, then hours with missing data were deleted. This excludes periods of unknown observed concentrations and also ensures the same number of samples for the comparisons.

Discussion of the results is given after the 24-hour Q-Q plot for each site. The 1:1 line is indicated by the solid diagonal line at 45° orientation, indicating a perfect relationship on a quantile-quantile basis, with the factor-of-two (over- or underprediction) lines indicated by the dotted lines. (Additional Q-Q plots by individual site/case are given in Appendix F of this document.)

5.2.1 Lincoln Q-Q Plots

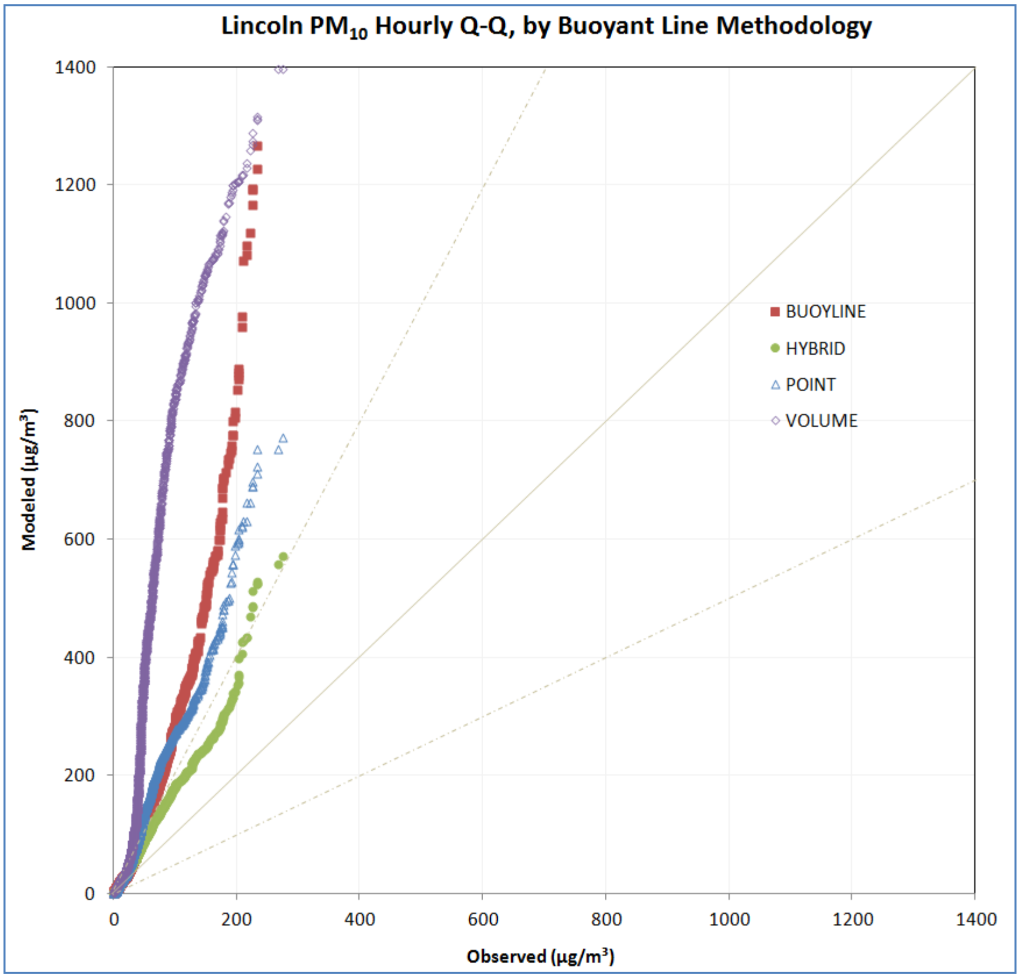

Figure 5-1. Lincoln 1-Hour Quantile-Quantile Plot

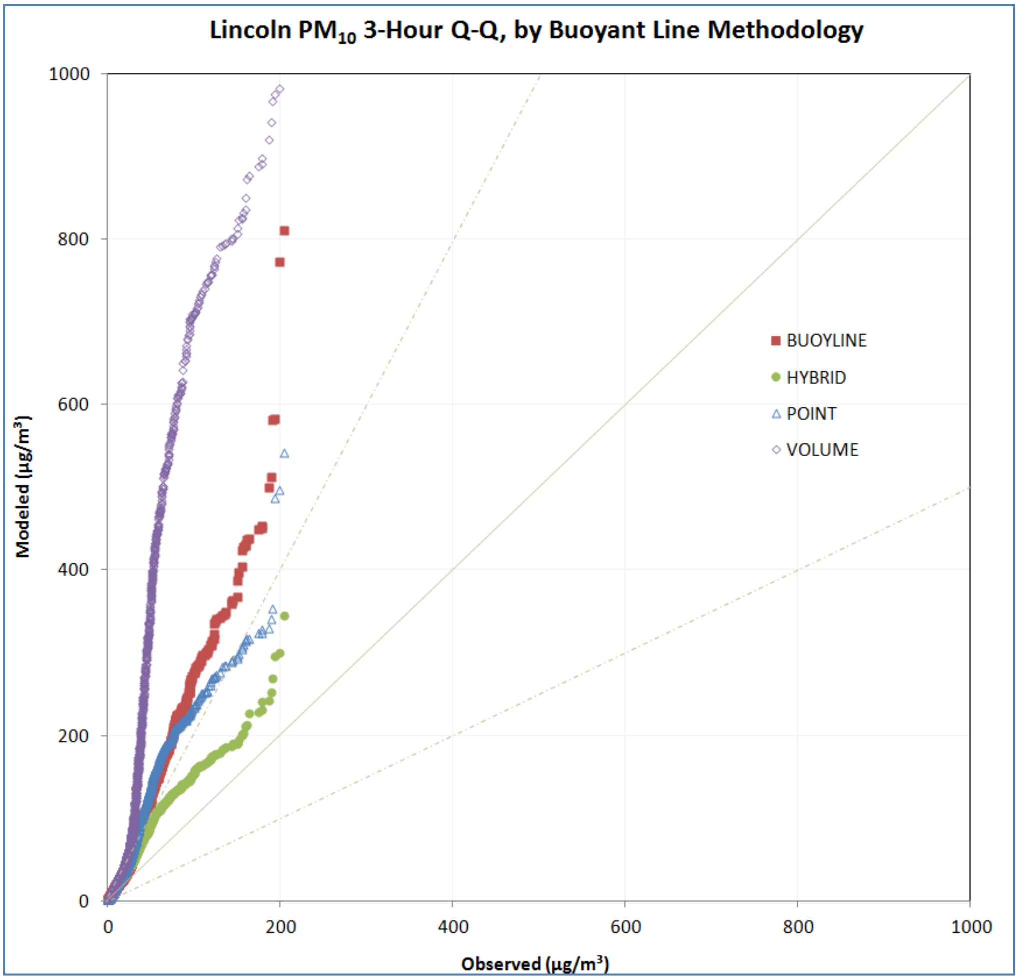

Figure 5-2. Lincoln 3-Hour Quantile-Quantile Plot

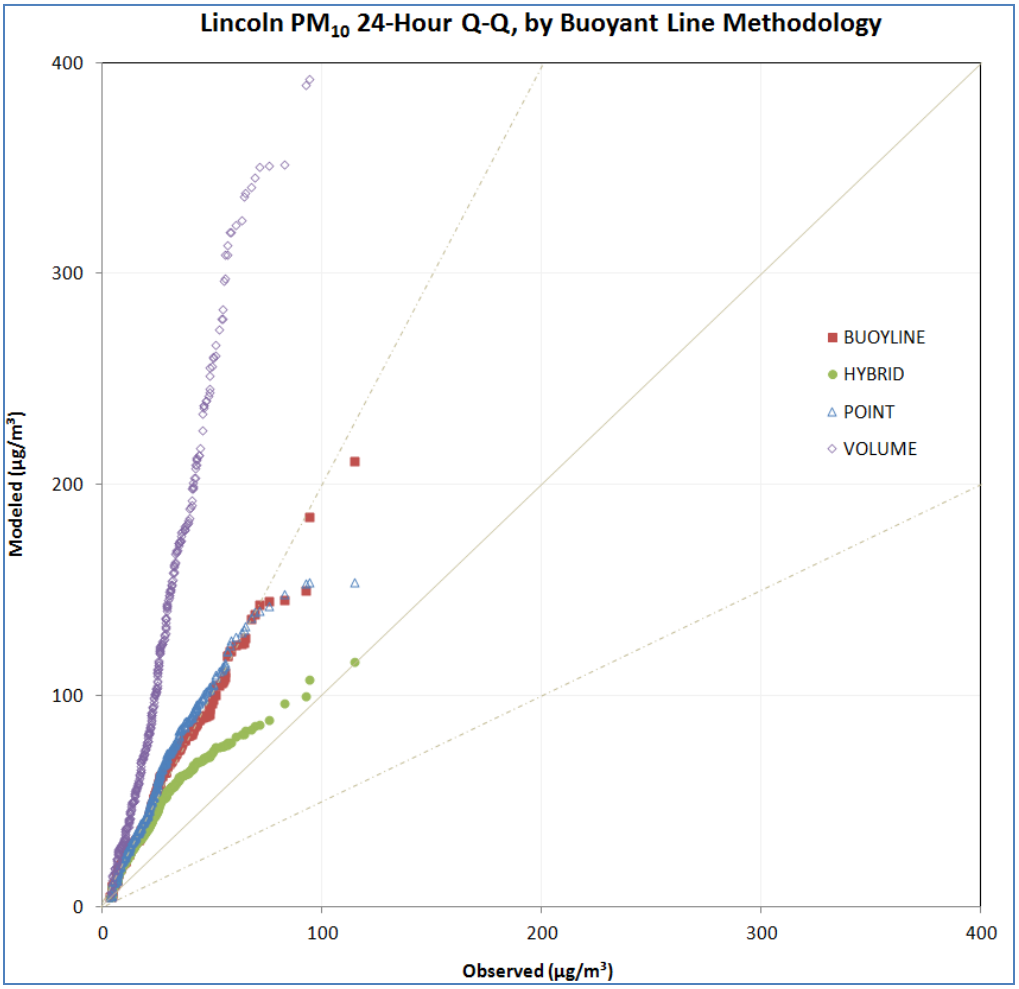

Figure 5-3. Lincoln 24-Hour Quantile-Quantile Plot

Overestimation is evident at Lincoln on an hourly basis, even with the hybrid case, likely due to the extreme near-field exposure of the site along with the use of the expanded-scale receptor grid. This may indicate that the expanded-scale approach is including too much of the area around the Lincoln site at middle scale. There may also be some overestimations due to all sources, including non-buoyant low-level volume and area sources such as road dust, coal/coke material handling, etc.

Overall, the hybrid case is the only case that stays consistently within a factor-of-two of the observations for all time periods, with the best results (closest to the 1:1 line) seen on a 24-hour basis. The volume source case is the worst performing case overall, with large overpredictions even on a 24-hour basis. This might be expected, based on the low release heights and lack of buoyancy associated with traditional non-buoyant volume sources. The point source case approximates the BUOYLINE method on a 24-hour basis.

5.2.2 Liberty Q-Q Plots

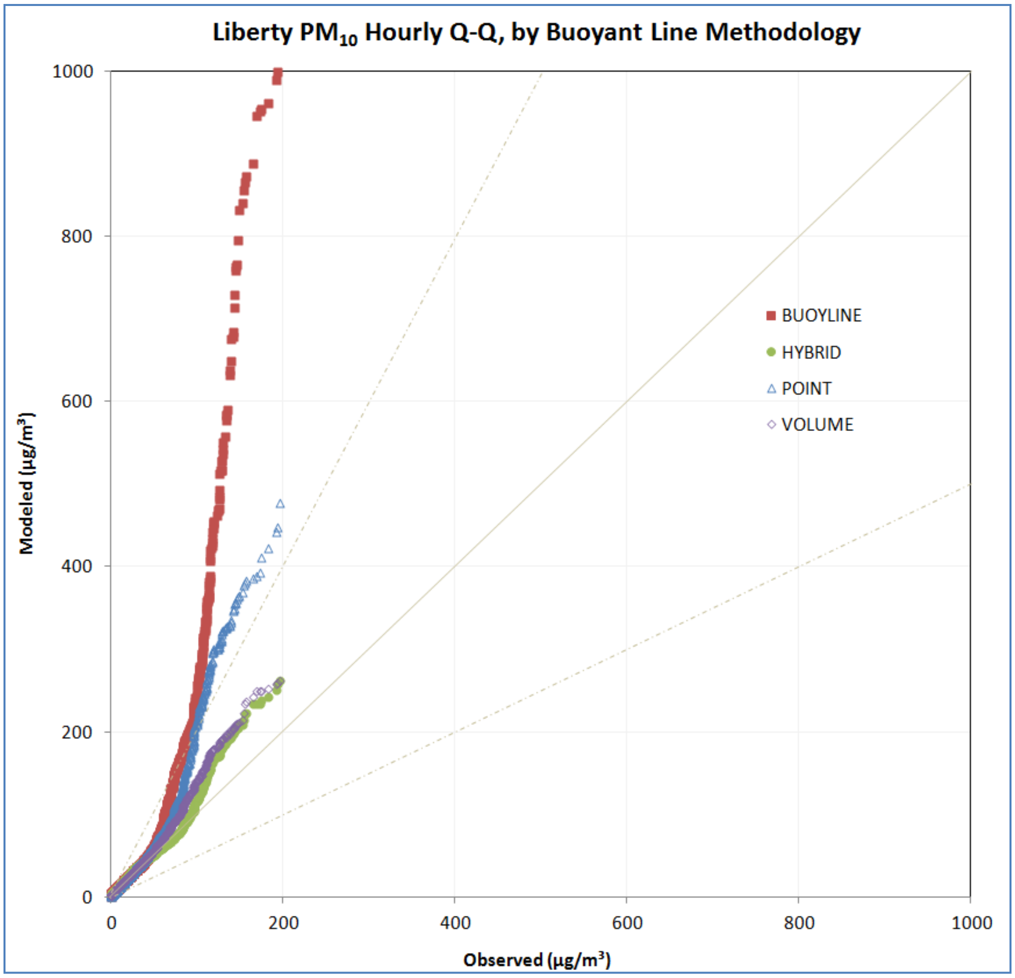

Figure 5-4. Liberty 1-Hour Quantile-Quantile Plot

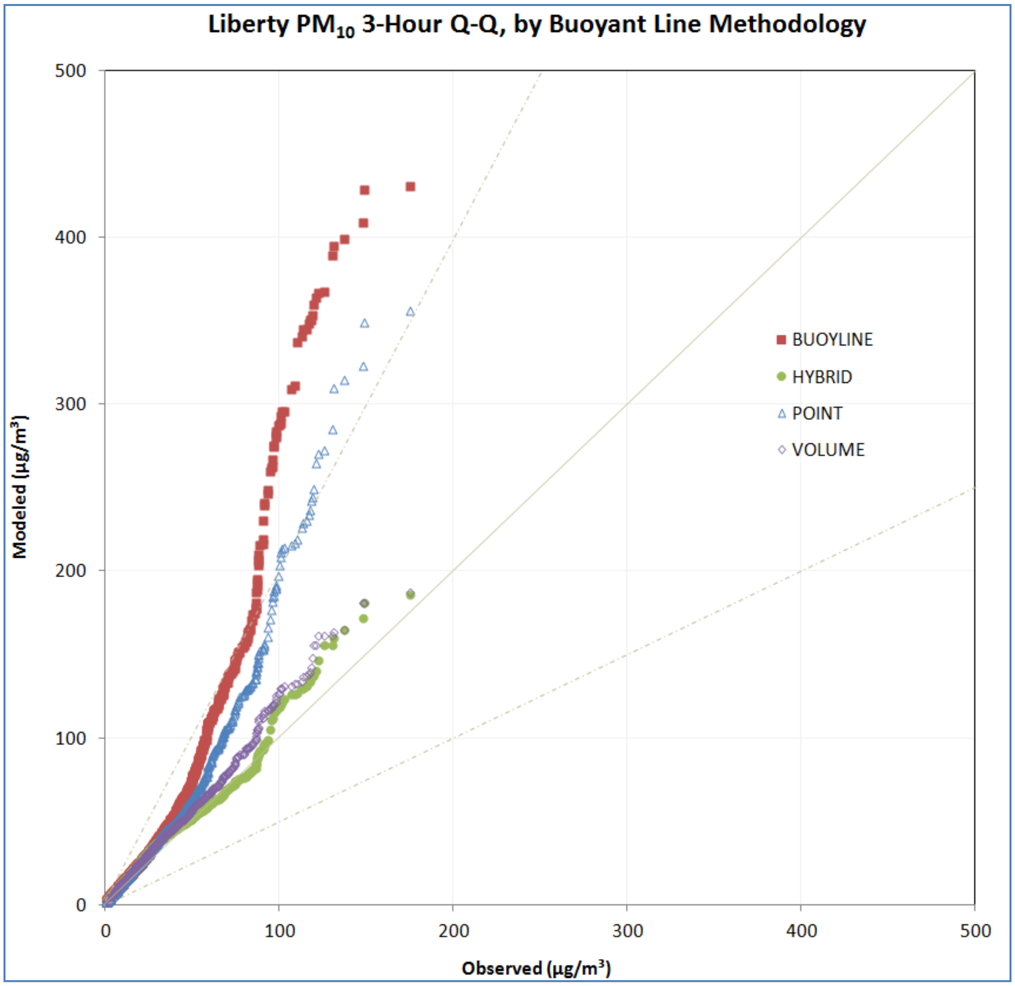

Figure 5-5. Liberty 3-Hour Quantile-Quantile Plot

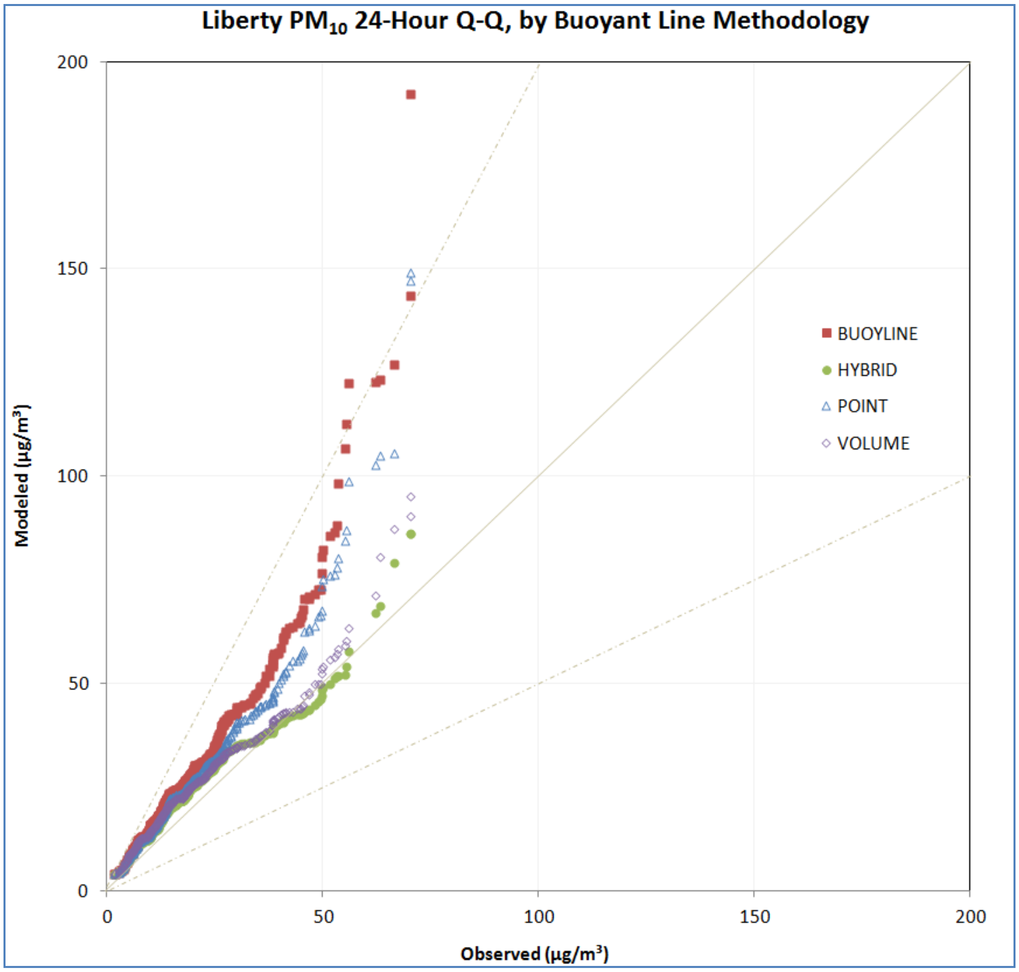

Figure 5-6. Liberty 24-Hour Quantile-Quantile Plot

The hybrid and volume cases show the best performance at Liberty for all time periods. However, due to the poor performance of the volume source method at Lincoln (a more source-oriented site), the volume source method is inappropriate for the entire modeling domain. The differences between Liberty and Lincoln also indicate the presence of significant concentration gradients throughout the modeled domain and the importance of examination of all possible locations for performance.

From a regulatory standpoint, Liberty is the most important of the three sites, since it has both SO_2 and $PM_{2.5}$ monitors that are showing nonattainment. (All sites tested have shown monitored attainment of PM_{10} for several years.)

5.2.3 Glassport Q-Q Plots

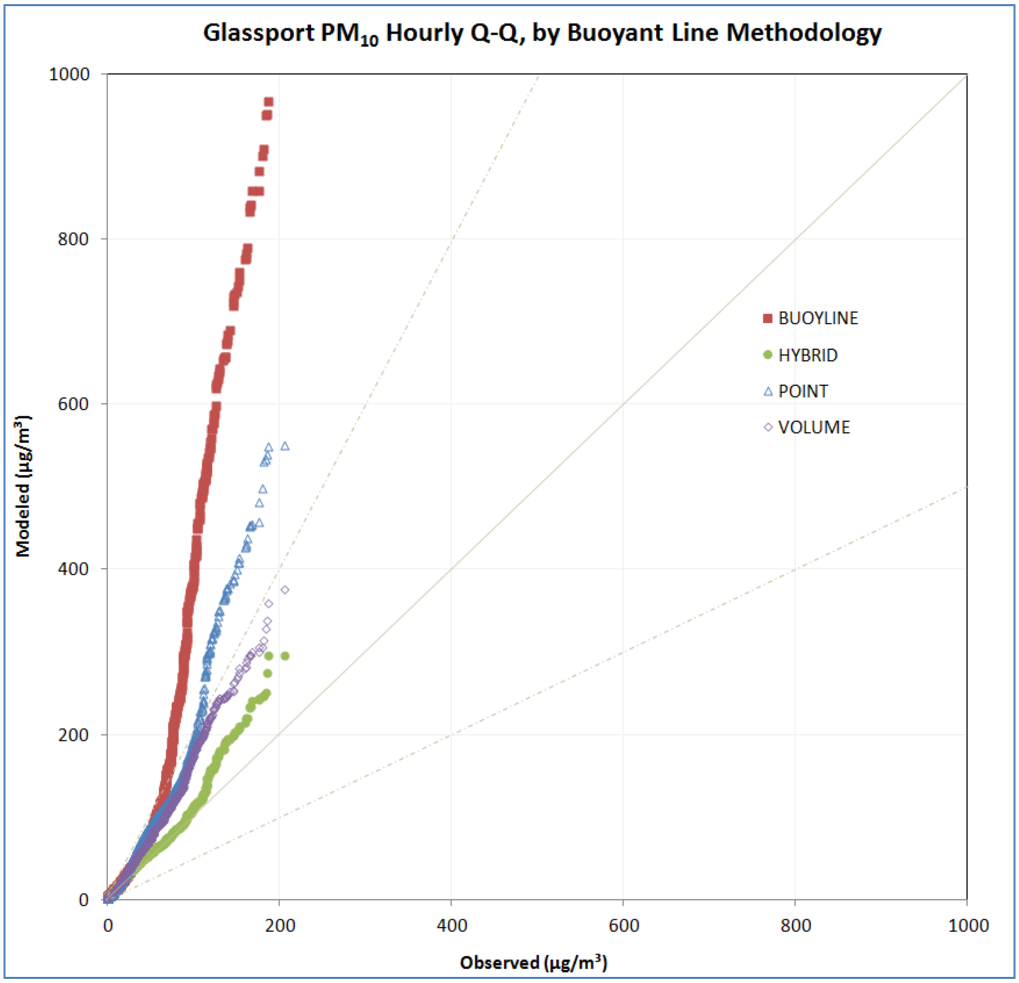

Figure 5-7. Glassport 1-Hour Quantile-Quantile Plot

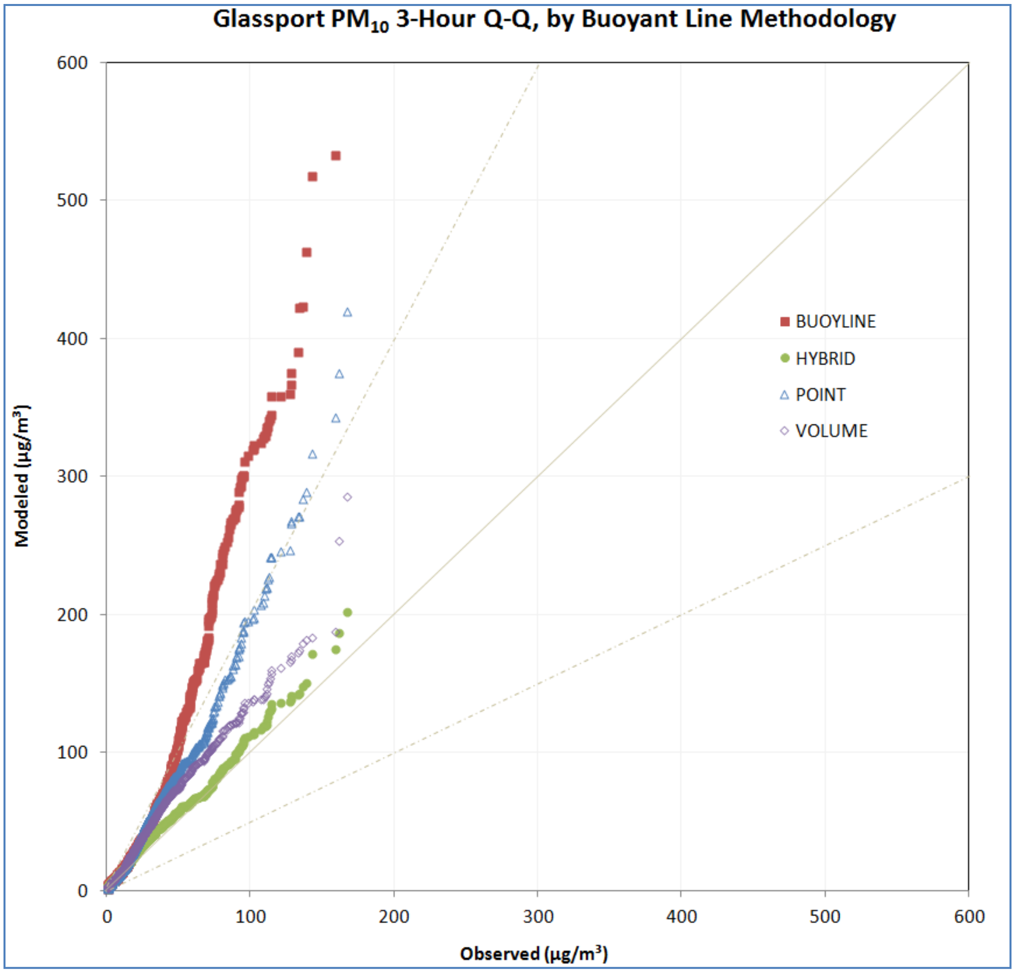

Figure 5-8. Glassport 3-Hour Quantile-Quantile Plot

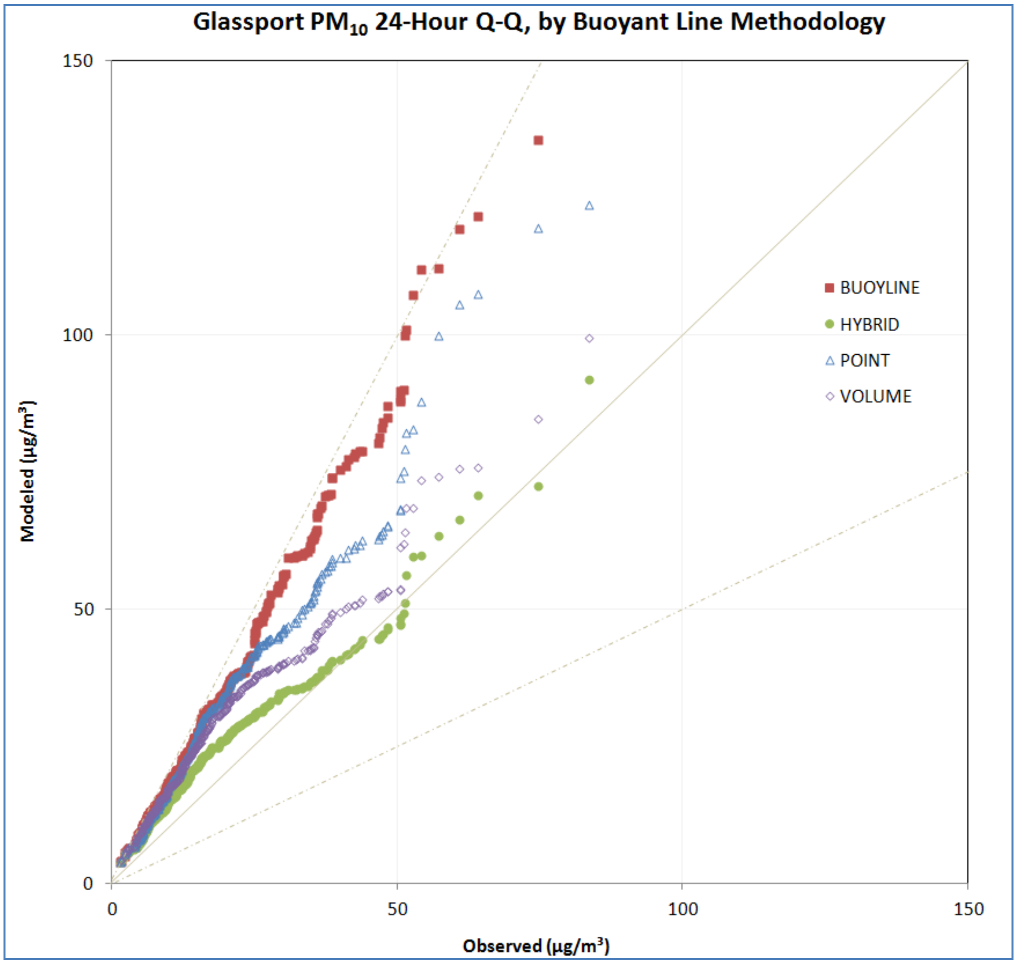

Figure 5-9. Glassport 24-Hour Quantile-Quantile Plot

Glassport shows results that are comparable to Liberty, but without the volume case showing similar results to the hybrid case. Glassport is the furthest away from the Clairton Plant, which lessens the impacts for some low-level sources (compare to Lincoln volume case).

The overall results from the Q-Q plots for each buoyant line case can be summarized as follows:

- BUOYLINE: overpredicts at locations/time periods
- HYBRID: best predictions compared to observed for all locations/periods
- POINT: overpredicts at all locations/periods, but with less overprediction than BUOYLINE
- VOLUME: overpredicts at sites closest to source, while showing reasonable results at some distance from source

5.3 Diurnal Plots

Figures 5-10 through 5-12 show the hourly average (diurnal) behavior of observed and modeled concentrations by buoyant line case for each site. Discussion of the results is given after Figure 5-12.

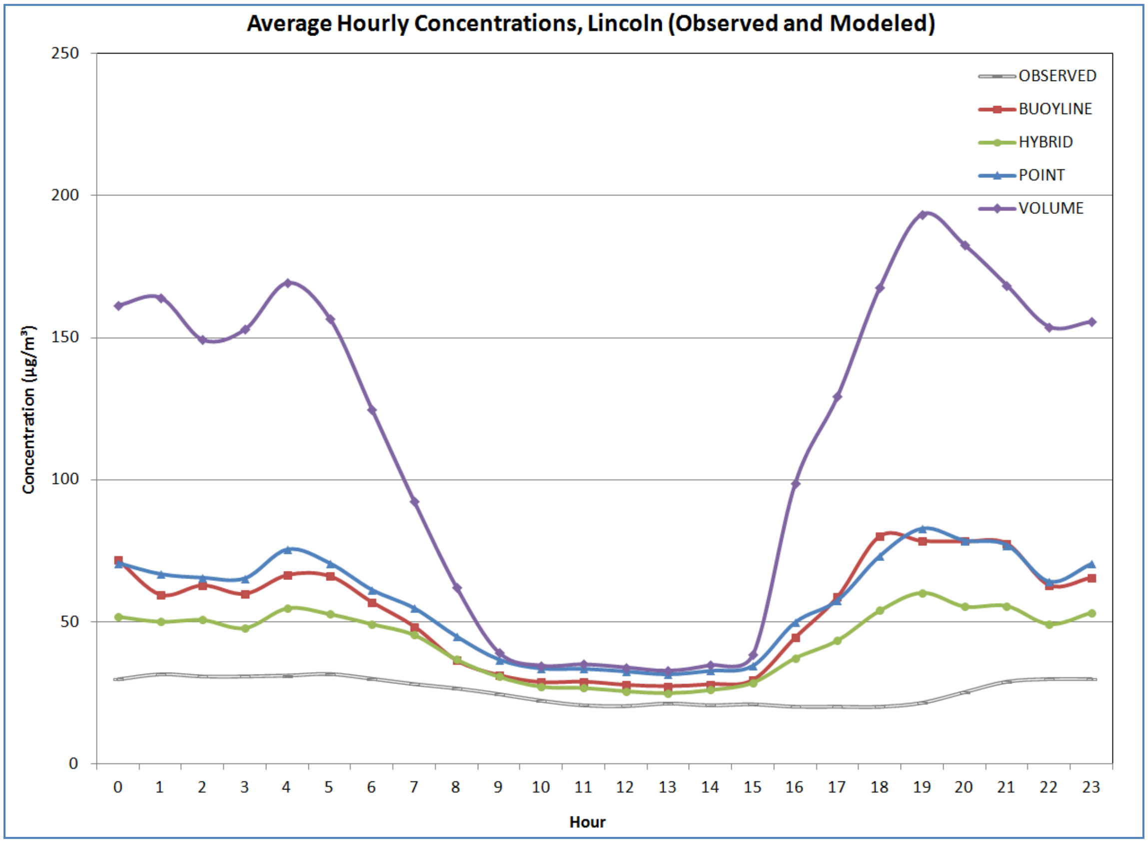

Figure 5-10. Hourly Averages, Modeled and Observed – Lincoln

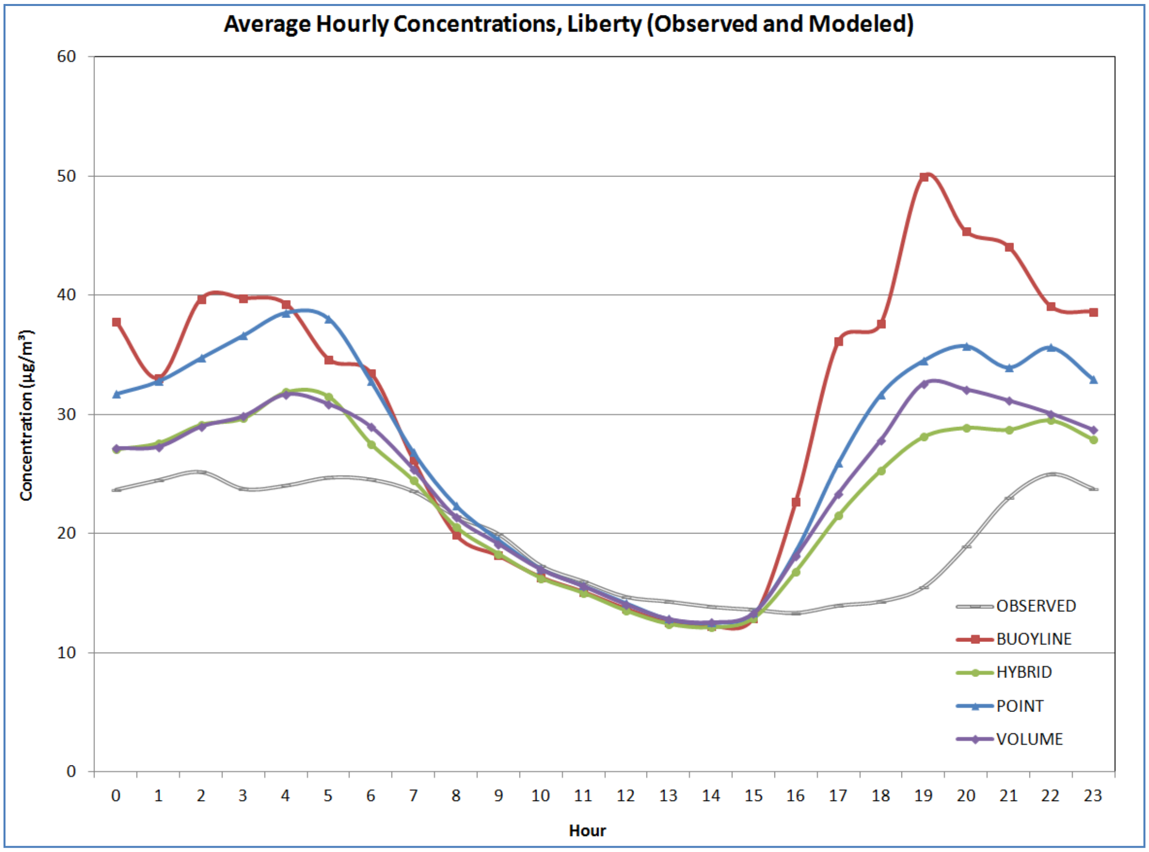

Figure 5-11. Hourly Averages, Modeled and Observed – Liberty

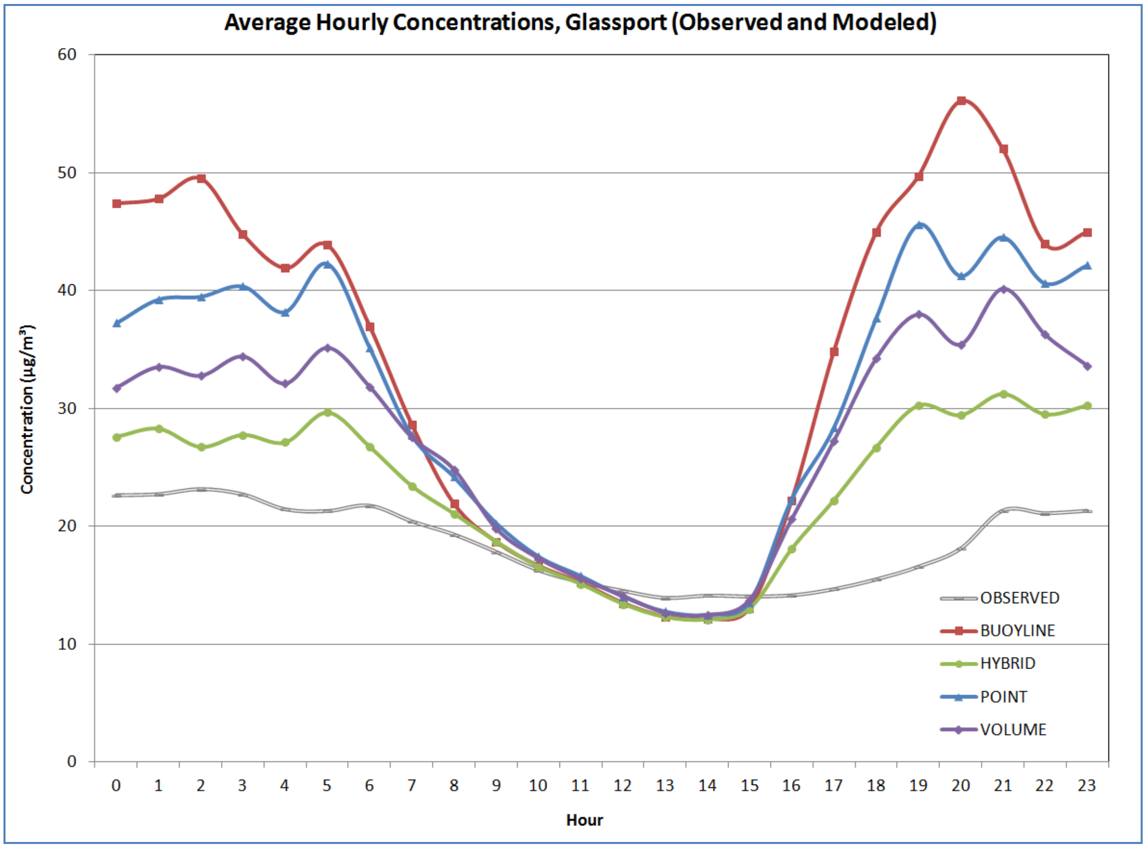

Figure 5-12. Hourly Averages, Modeled and Observed – Glassport

Figure 5-10 through 5-12 show that all model cases produce the same diurnal pattern of highest concentrations during nighttime stable conditions. The hybrid case shows the best averages for each site, with values closest to observed, with some overprediction. BUOYLINE shows the largest overpredictions compared to modeled at Liberty and Glassport, while the volume case shows the largest overpredictions at Lincoln.

5.4 Statistical Results by Site

Tables 5-2 through 5-4 provide statistical results for the different buoyant line methodologies for each site. A discussion of the results is included after Table 5-4.

Table 5-2. Statistical Results for Lincoln

Hourly PM10 at Lincoln					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	25.68	53.13	43.32	56.79	114.68
Mean Bias	--	27.45	17.65	31.12	89.01
Mean Error	--	39.37	28.74	41.35	97.64
Root Mean Square Error	--	94.90	52.46	79.49	220.77
Normalized Mean Bias	--	1.07	0.69	1.21	3.47
Normalized Mean Error	--	1.53	1.12	1.61	3.80
Fractional Bias	--	0.39	0.40	0.49	0.65
Fractional Error	--	0.73	0.69	0.77	0.87
Correlation Coefficient	--	0.11	0.15	0.16	0.13
Factor of Two	--	0.51	0.54	0.48	0.44
Geometric Correlation Coefficient	--	0.15	0.20	0.17	0.11
Geometric Mean	17.85	29.70	29.02	33.27	45.04
Geometric Mean Variance	--	3.91	3.10	4.40	12.30
Robust Highest Concentration (N=26)	269	1711	663	916	1387

N (Number of Data Points) 8535

3-Hour PM10 at Lincoln					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	25.68	53.34	43.47	56.98	115.30
Mean Bias	--	27.66	17.78	31.30	89.62
Mean Error	--	37.01	26.76	38.95	95.83
Root Mean Square Error	--	71.67	43.28	65.88	188.95
Normalized Mean Bias	--	1.08	0.69	1.22	3.49
Normalized Mean Error	--	1.44	1.04	1.52	3.73
Fractional Bias	--	0.46	0.44	0.55	0.75
Fractional Error	--	0.72	0.67	0.76	0.90
Correlation Coefficient	--	0.17	0.21	0.22	0.17
Factor of Two	--	0.53	0.55	0.49	0.42
Geometric Correlation Coefficient	--	0.19	0.24	0.21	0.12
Geometric Mean	18.64	33.08	31.36	36.74	52.89
Geometric Mean Variance	--	3.51	2.66	3.81	12.79
Robust Highest Concentration (N=26)	247	699	320	451	1035

N (Number of Data Points) 2823

Daily PM10 at Lincoln					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	25.62	53.03	43.17	56.61	114.82
Mean Bias	--	27.41	17.55	31.00	89.20
Mean Error	--	30.91	21.60	33.38	90.41
Root Mean Square Error	--	42.30	28.42	44.22	122.63
Normalized Mean Bias	--	1.07	0.69	1.21	3.48
Normalized Mean Error	--	1.21	0.84	1.30	3.53
Fractional Bias	--	0.63	0.52	0.69	1.07
Fractional Error	--	0.72	0.62	0.75	1.10
Correlation Coefficient	--	0.23	0.28	0.29	0.21
Factor of Two	--	0.47	0.58	0.42	0.22
Geometric Correlation Coefficient	--	0.17	0.25	0.23	0.09
Geometric Mean	21.01	43.49	37.53	46.78	84.61
Geometric Mean Variance	--	2.85	2.05	3.00	15.45
Robust Highest Concentration (N=26)	98	187	104	183	473

N (Number of Data Points) 354

Table 5-3. Statistical Results for Liberty

Hourly PM10 at Liberty					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	19.70	29.98	23.22	27.07	24.18
Mean Bias	--	10.28	3.52	7.37	4.48
Mean Error	--	21.32	13.97	17.85	15.31
Root Mean Square Error	--	64.20	24.28	38.64	27.73
Normalized Mean Bias	--	0.52	0.18	0.37	0.23
Normalized Mean Error	--	1.08	0.71	0.91	0.78
Fractional Bias	--	0.20	0.20	0.23	0.21
Fractional Error	--	0.64	0.62	0.64	0.63
Correlation Coefficient	--	0.19	0.42	0.34	0.35
Factor of Two	--	0.59	0.60	0.58	0.59
Geometric Correlation Coefficient	--	0.21	0.28	0.25	0.24
Geometric Mean	12.95	17.02	16.57	17.27	16.85
Geometric Mean Variance	--	2.80	2.26	2.55	2.43
Robust Highest Concentration (N=26)	208	1390	278	487	289

N (Number of Data Points) 8694

3-Hour PM10 at Liberty					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	19.74	30.08	23.28	27.14	24.24
Mean Bias	--	10.33	3.54	7.40	4.49
Mean Error	--	19.67	12.47	16.21	13.72
Root Mean Square Error	--	45.07	19.95	31.29	22.59
Normalized Mean Bias	--	0.52	0.18	0.37	0.23
Normalized Mean Error	--	1.00	0.63	0.82	0.69
Fractional Bias	--	0.23	0.20	0.24	0.22
Fractional Error	--	0.61	0.56	0.59	0.58
Correlation Coefficient	--	0.28	0.51	0.43	0.44
Factor of Two	--	0.62	0.64	0.61	0.63
Geometric Correlation Coefficient	--	0.25	0.36	0.32	0.31
Geometric Mean	13.78	18.45	17.26	18.30	17.76
Geometric Mean Variance	--	2.38	1.81	2.04	1.95
Robust Highest Concentration (N=26)	168	505	193	386	199

N (Number of Data Points) 2880

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

N (Number of Data Points) 364

Table 5-4. Statistical Results for Glassport

Hourly PM10 at Glassport					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	18.47	33.58	22.97	30.24	27.12
Mean Bias	--	15.12	4.51	11.77	8.65
Mean Error	--	24.52	14.22	20.01	17.64
Root Mean Square Error	--	75.62	24.97	43.09	34.41
Normalized Mean Bias	--	0.82	0.24	0.64	0.47
Normalized Mean Error	--	1.33	0.77	1.08	0.96
Fractional Bias	--	0.28	0.24	0.33	0.30
Fractional Error	--	0.67	0.64	0.68	0.67
Correlation Coefficient	--	0.19	0.36	0.32	0.28
Factor of Two	--	0.56	0.57	0.54	0.55
Geometric Correlation Coefficient	--	0.18	0.23	0.22	0.20
Geometric Mean	12.43	18.00	16.69	18.87	18.15
Geometric Mean Variance	--	3.08	2.34	2.88	2.76
Robust Highest Concentration (N=26)	226	1152	311	624	399

N (Number of Data Points) 8470

3-Hour PM10 at Glassport					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	18.49	33.53	23.03	30.33	27.19
Mean Bias	--	15.03	4.53	11.84	8.70
Mean Error	--	23.00	13.07	18.56	16.34
Root Mean Square Error	--	53.84	21.00	34.78	27.29
Normalized Mean Bias	--	0.81	0.25	0.64	0.47
Normalized Mean Error	--	1.24	0.71	1.00	0.88
Fractional Bias	--	0.33	0.25	0.37	0.33
Fractional Error	--	0.66	0.60	0.66	0.64
Correlation Coefficient	--	0.28	0.44	0.41	0.37
Factor of Two	--	0.56	0.60	0.55	0.57
Geometric Correlation Coefficient	--	0.20	0.28	0.27	0.24
Geometric Mean	12.94	19.66	17.32	20.07	19.34
Geometric Mean Variance	--	2.88	2.04	2.50	2.44
Robust Highest Concentration (N=26)	178	551	197	397	228

N (Number of Data Points) 2807

Daily PM10 at Glassport					
METRIC	OBSERVED	BUOYLINE	HYBRID	POINT	VOLUME
Arithmetic Mean	18.40	33.56	22.97	30.20	27.10
Mean Bias	--	15.16	4.57	11.80	8.70
Mean Error	--	18.05	9.26	13.83	11.82
Root Mean Square Error	--	26.96	12.28	19.56	16.02
Normalized Mean Bias	--	0.82	0.25	0.64	0.47
Normalized Mean Error	--	0.98	0.50	0.75	0.64
Fractional Bias	--	0.53	0.28	0.48	0.42
Fractional Error	--	0.64	0.47	0.57	0.54
Correlation Coefficient	--	0.47	0.60	0.59	0.53
Factor of Two	--	0.57	0.74	0.62	0.66
Geometric Correlation Coefficient	--	0.30	0.40	0.43	0.35
Geometric Mean	14.59	26.52	19.86	24.83	23.28
Geometric Mean Variance	--	2.22	1.49	1.82	1.76
Robust Highest Concentration (N=26)	78	139	78	116	87

N (Number of Data Points) 352

As can be seen by the results for nearly all measures, the performance of the hybrid approach is superior to that of the BUOYLINE, point, and volume methods. This positive performance can be seen in the bias and error metrics (mean, normalized, and fractional), where measures for hybrid are lower (better) than for the other techniques. The robust highest concentration (RHC) shows that the hybrid case produces outcomes that are close to observed values and without underprediction of impacts. (The daily RHC is an exact match for hybrid-to-observed for Glassport.)

Hybrid also shows the best means (arithmetic and geometric) with the least geometric mean variance. The correlation coefficients (standard (Pearson) and geometric), although low overall for pairing in time, are also best for the hybrid method in comparison to the other approaches. Additionally, the root mean square error (RMSE) – a performance statistic that indicates the average distance between each modeled and observed value – is smallest for the hybrid case.

There is some overprediction for each case and time period, which can be due to the expanded receptor scales as well as the proximity of Lincoln to the modeled sources (as discussed earlier). This can be viewed as favorable for the demonstration, with hybrid as the best performing case without a tendency toward underprediction.

5.5 Composite Performance and Model Comparison Measures

The composite performance measure (CPM) results for each buoyant line methodology are shown in Figure 5-13 below, with bars indicating the confidence intervals (from bootstrapping) for each CPM.

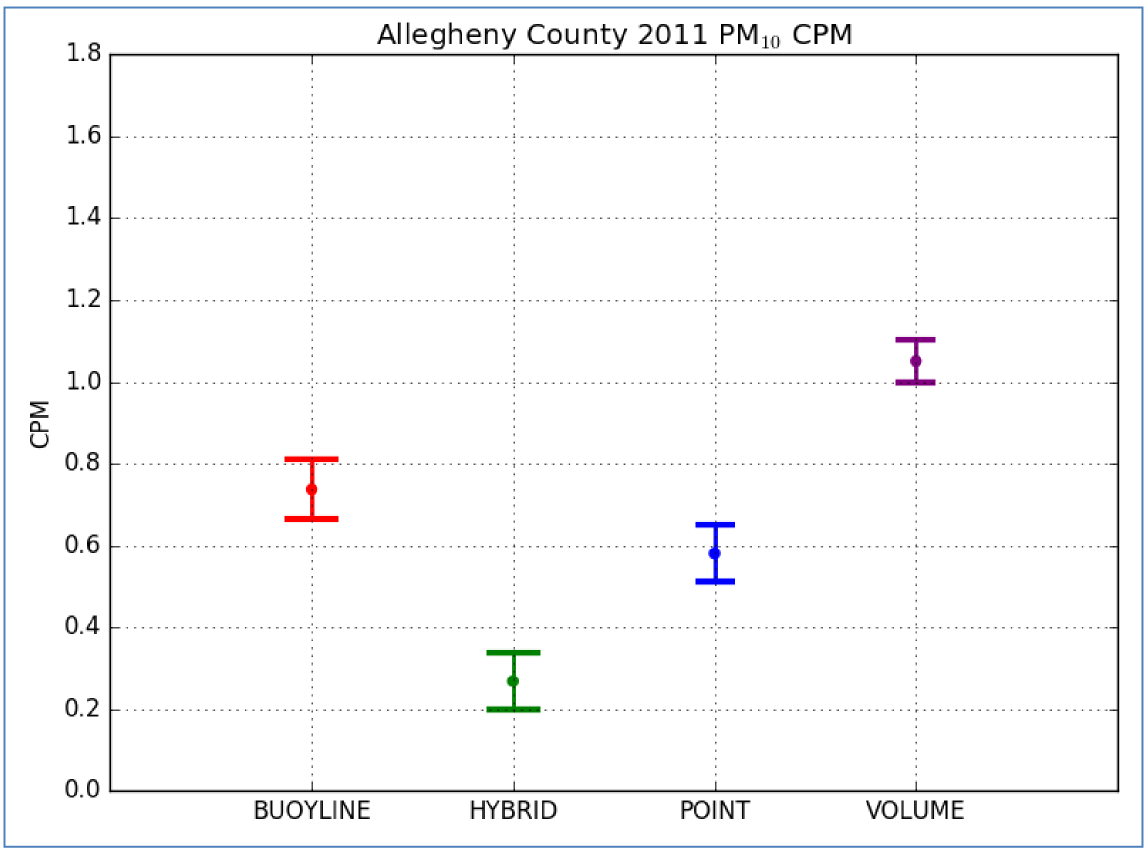

Figure 5-13. Composite Performance Measure (CPM) by Buoyant Line Methodology

The lowest values for CPM indicate the best performance between different model cases. Figure 5-13 indicates that the hybrid case is the best performing model case for the buoyant lines on a network-wide basis. The volume case shows the worst composite performance, primarily due to the large overpredictions at Lincoln with this model case.

The model comparison measure (MCM) results for each combination of models (six comparisons for the four different cases) are shown below in Figure 5-14.

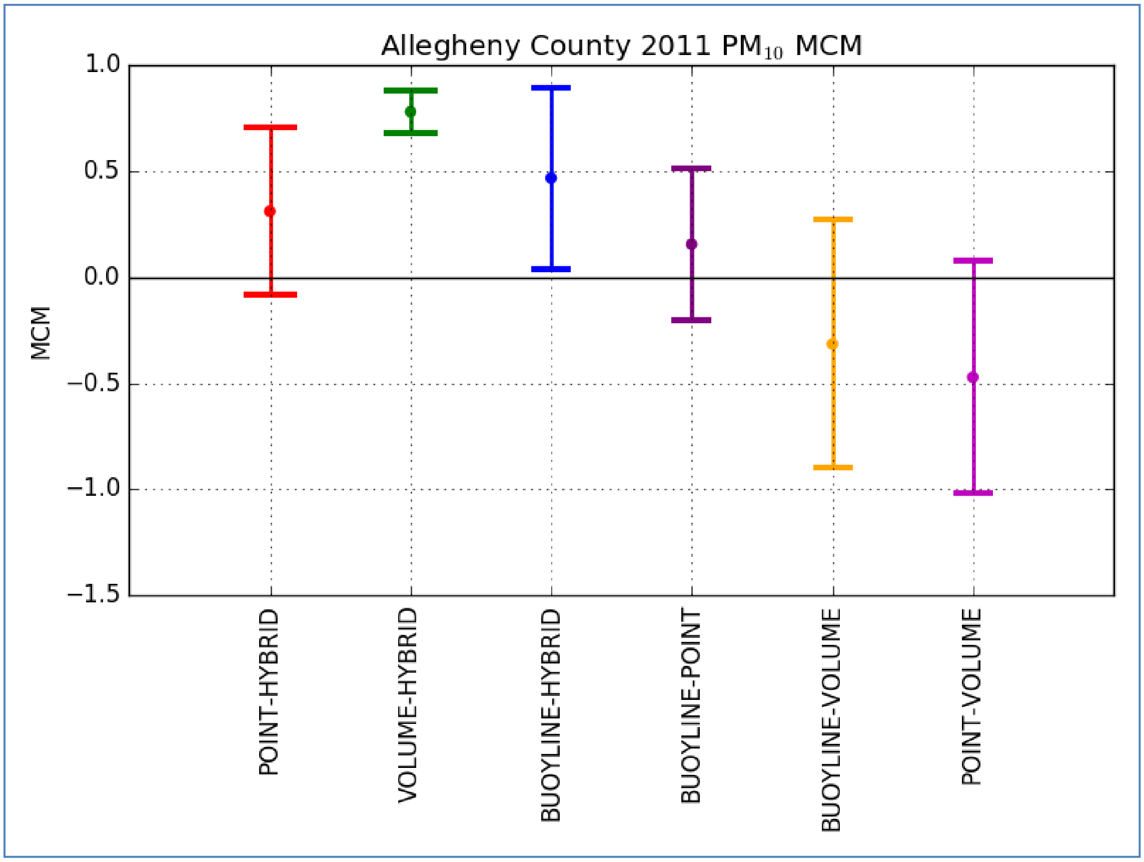

Figure 5-14. Model Comparison Measure (MCM) by Model Cases

The 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).

The results of the overall statistical performance evaluation indicate that the BLP/AERMOD hybrid approach performs better for the complex terrain conditions in Allegheny County, PA than any possible currently preferred technique, based on a comprehensive comparison of modeled to monitored results.

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&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL)

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APPENDICES

APPENDIX A – Monitored Data

The PM_{10} continuous monitors at Lincoln, Liberty, and Glassport are the same monitor type (EQPM-1090-079),[19] providing consistency for the hourly monitored data used in the analysis. The 2011 data for these monitors were fully quality-assured and certified according to EPA procedures.

Monitored data used in this analysis are identical to that available on EPA databases, except for minor data handling corrections for negative and zero concentrations. The method detection limit (MDL) for the TEOM is -10 µg/m³, and as a result, some negative hourly values are kept as valid raw data. However, from a modeling and statistical perspective, a negative concentration is not physically possible. Based on the CAMx modeling results, a minimum background value for PM_{10} was determined to be about 1 µg/m³. Therefore, negative and zero hourly values were corrected to a value of 1 µg/m³ prior to the model performance calculations.

For averaging periods longer than 1-hour, monitoring data completeness requirements (≥75%) were also applied to the monitored data. For 3-hour averages, only periods with 3 valid hours were used (after the negative/zero correction described above), and only 24-hour periods with more than 17 valid hours (midnight-to-midnight) were used for daily averages.

Additionally, due to the time difference between WRF/CAMx (UTC) and local time (EST), there are some missing modeled hours at the end of 2011. From the $PM_{2.5}$ SIP results, the last day (Dec. 31) was excluded from 24-hour averaging, and the last 5 hours of Dec. 30th were also missing from the hourly modeled data for this demonstration. As a result, there was a maximum of 8731 possible hours for model-to-monitor comparison. (The raw monitored PM_{10} concentrations during the missing modeled hours were inconsequential, with a maximum of 35 µg/m³ and a minimum of 0 µg/m³.)

Table A-1 below shows the statistics for the 2011 monitored data (based on the corrected hourly data) used for comparison to modeled data for this demonstration.

Table A-1. PM_{10} Monitored Data Statistics, 2011 (Corrected Methodology)

Statistic	Lincoln	Liberty	Glassport
Number of Hours	8535	8694	8470
Average	25.7	19.7	18.5
1-Hour Minimum	1.0	1.0	1.0
1-Hour Maximum	275.0	197.0	206.0
3-Hour Maximum	204.7	175.0	167.3
24-Hour Maximum	115.1	70.5	83.5

Lincoln shows the highest concentrations as a "1st-tier" impact location, with Liberty and Glassport showing lower concentrations in the "2nd-tier" zones. Liberty and Glassport are also similar to one

[19] Rupprecht & Patashnick Tapered Element Oscillating Microbalance (TEOM) Series 1400/1400a PM_{10} Monitor, Automated Equivalent Method: EQPM-1090-079. Liberty also includes PM_{10} filter-based monitors (different method type) that were not used for comparisons in this demonstration.

another for averages and extremes, with Glassport showing a slightly higher range for maximums and Liberty showing a higher average.

The long-term raw data trends with more recent data are similar to 2011, with Lincoln usually showing the highest hourly maximum and average values. Figures A-1 and A-2 show yearly PM_{10} hourly maximums and averages for each site for 2011-2017.

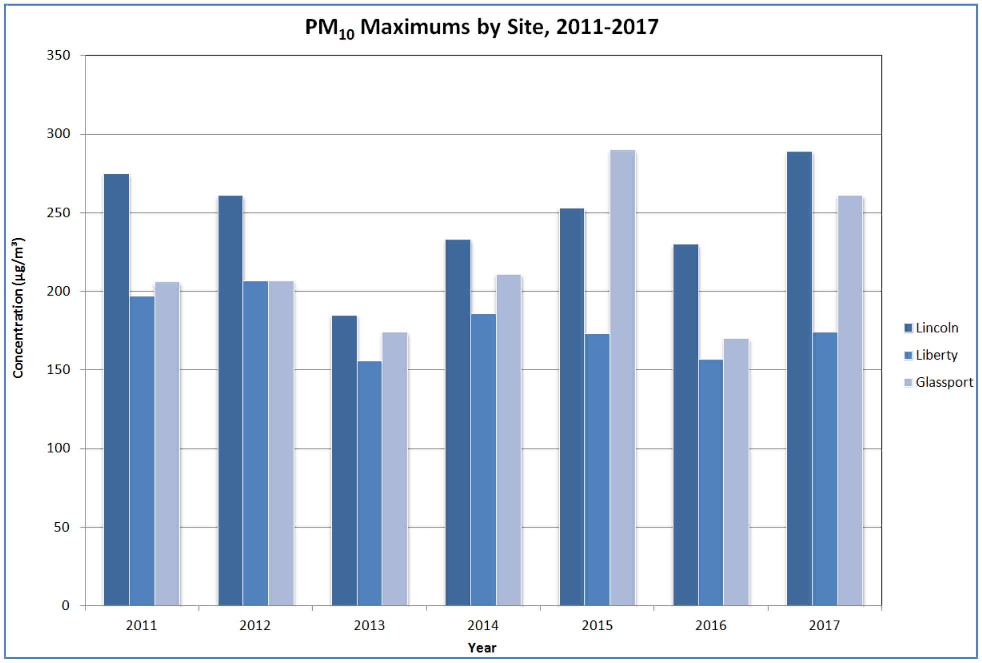


Figure A-1. PM_{10} Hourly Monitored Maximums by Site, 2011-2017

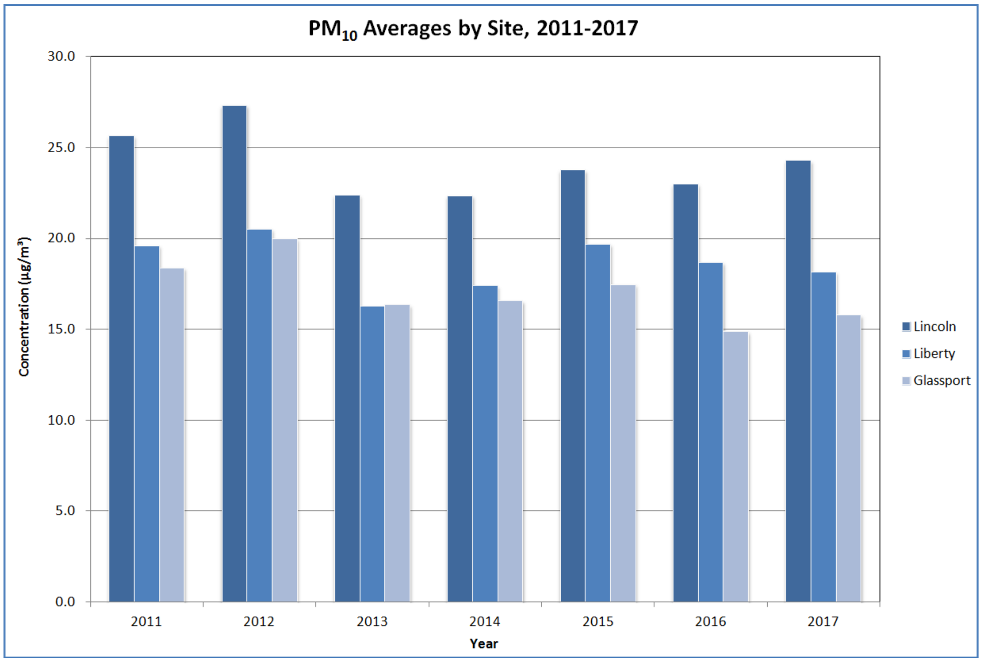


Figure A-2. PM_{10} Monitored Averages by Site, 2011-2017

While there are some differences from year-to-year, the overall trends for 2011-2017 are similar to 2011. Lincoln shows the highest maximums and averages, and Liberty and Glassport show values similar to one another. (As mentioned for the 2011 data, Glassport can show higher extremes than Liberty, and even higher than Lincoln in one year (2015).

A composite PM_{10} concentration ratio of Lincoln to the other sites is about 1.30 (calculated as an average of the hourly maximum and average ratios). This 1st-tier/2nd-tier zone ratio is similar to that of SO_2, which also shows an excess of localized primary impacts in the area. Analysis of long-term SO_2 data (1991-2005) for the former Glassport SO_2 site compared to Liberty showed an expected ratio of 1.26 on a 99th percentile basis.[20]

Furthermore, since this demonstration applies to both SO_2 and $PM_{2.5}$ SIP modeling, a direct comparison of multi-pollutant data at Liberty was also conducted. Figure A-3 below shows a scatter plot of Liberty PM_{10} vs. SO_2, by daily maximum 1-hour values, for 2011-2017.

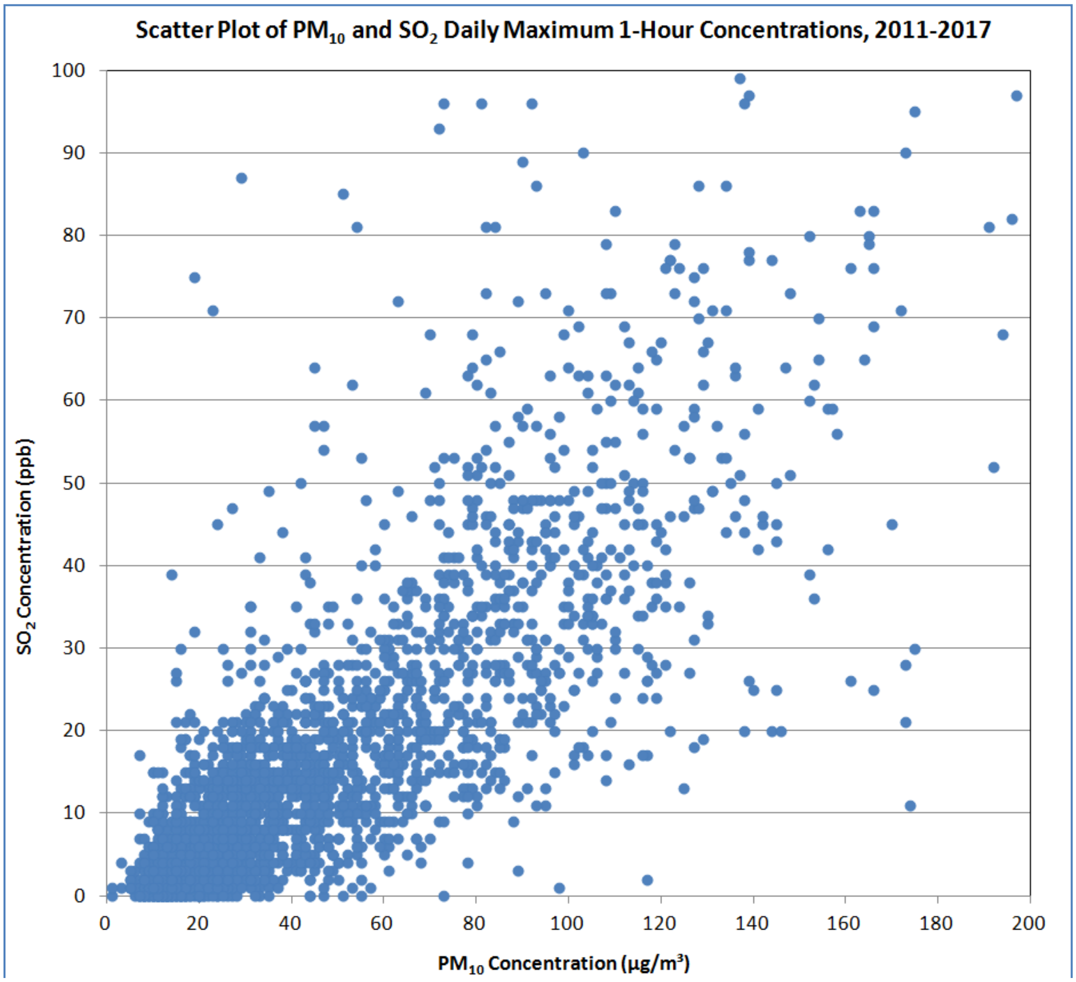


Figure A-3. Liberty PM_{10} vs. SO_2, Daily 1-Hour Maximums, 2011-2017

Note: some values >axis maximums were excluded from the figure

[20] As mentioned in Section 4, the former Glassport SO_2 site is a different site than the Glassport PM_{10} site. The Glassport SO_2 site was a "1st-tier" impact location, similar to Lincoln for PM_{10}. See the SO_2 SIP for more details.

A correlation coefficient (r) of 0.71 was calculated for the long-term PM_{10} and SO_2 daily 1-hour maximums. While this is not a perfect relationship, it indicates similar behavior for PM_{10} and SO_2 on a daily maximum basis.

Average hourly PM_{10} and SO_2 were next examined for diurnal patterns. Figure A-4 below shows hourly averages of PM_{10} and SO_2 at Liberty for 2011-2017.

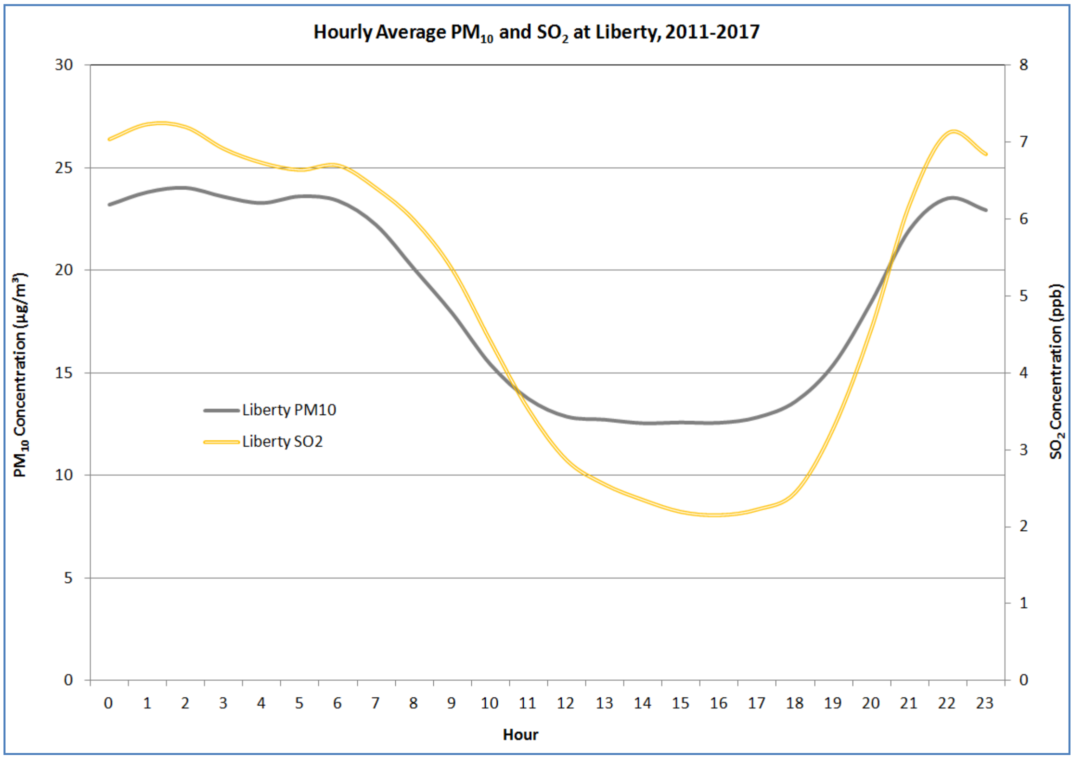


Figure A-4. Liberty PM_{10} and SO_2 Hourly Averages, 2011-2017

The diurnal behavior is similar for PM_{10} and SO_2, with the highest average values occurring during nighttime hours, driven by stable meteorological conditions. SO_2 shows a deeper trough during unstable/daytime conditions, suggesting that PM_{10} has a higher background (or daytime component) than SO_2 for the area.

Additionally, exceedance threshold values were also examined for daily 1-hour maximum SO_2 and 24-hour FRM[21] $PM_{2.5}$ concentrations. Table A-2 shows statistics for days when the pollutants exceeded the standards[22] over the 2011-2017 timeframe.

[21] Federal Reference Method

[22] 75 ppb for 1-hour SO_2; 35 µg/m³ for 24-hour $PM_{2.5}$

Table A-2. Exceedance Day Statistics, SO_2 and $PM_{2.5}$, 2011-2017

Exceedance Condition	Value
Number of total SO_2 exceedance days	67
Number of total $PM_{2.5}$ exceedance days	59
Number of days with both SO_2 and $PM_{2.5}$ exceedances	16
SO_2 average (ppb) during $PM_{2.5}$ exceedance days	71.1
$PM_{2.5}$ average (µg/m³) during SO_2 exceedance days	28.9

The exceedance day statistics show a strong relationship between elevated SO_2 and $PM_{2.5}$ levels for 2011-2017. The SO_2 average during $PM_{2.5}$ exceedances is within 95% of the SO_2 standard, and the $PM_{2.5}$ average during SO_2 exceedances is within 83% of the $PM_{2.5}$ standard. About 1 exceedance day out of every 4 features an exceedance of both pollutants.

APPENDIX B – BLP Plume Rise Methodology

This appendix describes the methodology used to generate plume rises from BLP for use in AERMOD.

Note that AERMOD's BUOYLINE code contains the identical algorithms as BLP for plume rise, and the model evaluation of AERMOD/BLP shows equivalent results from both models (Paumier, 2016). However, plume rises cannot be directly extracted from AERMOD using the DEBUGOPT option, and the AERMOD code would need to be modified in order to generate plume rises for buoyant line sources.

The steps taken to use BLP plume rises for AERMOD volume sources were as follows:

1. Modify the BLP code so that plume rises are explicitly generated as hourly output data. Changes to the BLP code did not alter the line source algorithms, only adding the output of plume rise data as a model option.

2. Reformat the MMIF meteorological data corresponding to the facility with buoyant line sources into PCRAMMET ASCII format (the format used by BLP). This follows the procedure outlined in the AERMOD/BLP technical support document (Paumier, 2016). For this demonstration, only the Clairton Plant battery fugitives were characterized as buoyant line volumes.

    a. Convert stability conditions (based on Monin-Obukhov lengths and surface roughness) into Pasquill-Gifford stability classes (1 through 6, or A through F). This conversion was based on the AERMOD subroutine LTOPG (LSTAB).
    b. Convert wind directions to flow vectors (wind flowing toward).
    c. For mixing height, use the maximum of the convective and mechanical heights for each hour as both the urban and rural mixing height for BLP.
    d. Since BLP cannot accept missing data, fill any missing hours using interpolation, persistence, and professional judgment. (With the current low wind speed handling procedures for MMIF, there are no calms/missing hours with MMIF.)

3. Run the modified BLP code (named "BLPRISE" by ACHD) for the buoyant line sources. The BLP inputs include line dimensions, exit velocity, and buoyancy parameter F'. Only the plume rises generated by BLP are utilized after this step.

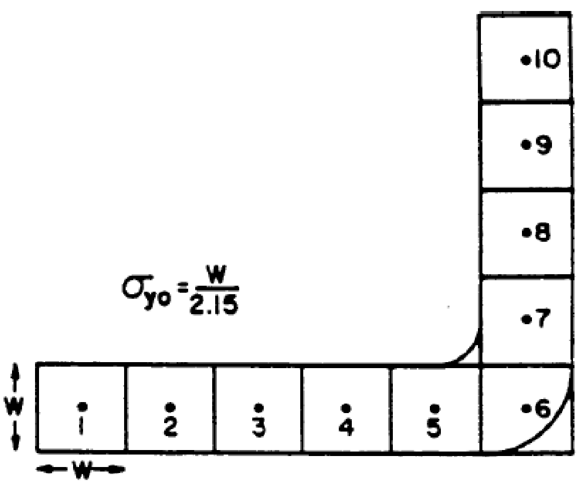
4. Using the generated plume rises for each line, calculate hourly release heights as plume rises added to the building height. Equidistant (adjacent, or exact) line volume sources were created to represent segments of the line, and each volume source was then assigned the hourly release heights. An HOUREMIS file was used for the height-varying data for the buoyant volume sources.

Initial lateral dimensions (σ_{yo}) and initial vertical dimensions (σ_{zo}) for each volume source were based on the suggested procedures for volume and line sources, from Table 3-2 of the AERMOD User's Guide (U.S. EPA, 2018a), shown below:

Type of Source		Procedure for Obtaining Initial Dimension
(a) Initial Lateral Dimension (σ_{yo})		
Single Volume Source	σ_{yo} =	length of side divided by 4.3
Line Source Represented by Adjacent Volume Sources (see Figure 1-8 (a) in EPA, 1995a)	σ_{yo} =	length of side divided by 2.15
Line Source Represented by Separated Volume Sources (see Figure 1-8(b) in EPA, 1995a)	σ_{yo} =	center to center distance divided by 2.15
(b) Initial Vertical Dimension (σ_{zo})		
Surface-Based Source (h_e ~ 0)	σ_{zo} =	vertical dimension of source divided by 2.15
Elevated Source (h_e > 0) on or Adjacent to a Building	σ_{zo} =	building height divided by 2.15
Elevated Source (h_e > 0) not on or Adjacent to a Building	σ_{zo} =	vertical dimension of source divided by 4.3

Initial lateral dimensions were constant for each hour, based on the width of the battery divided by 2.15. Initial vertical dimensions varied by hour, based on the hourly-varying released heights divided 4.3.

The locations used for the volumes were based on the adjacent (or exact) representation of a line source by multiple volume sources, from Figure 1-8 from Section 1.2.2 of the ISC Model User's Guide, Volume II (U.S. EPA, 1995), shown below:



Several transitional plume rises and distances are created with each hour of plume rise data from BLPRISE. Final plume rise can occur very close to the line or a few kilometers from the line, depending on stability and wind conditions. Terrain could be theoretically impacted during transitional plume rises before final plume rise is reached (but BLP was a simple-terrain model).

However, after examination of the transitional plume rises in relation to the sources and terrain for this demonstration, the use of final plume rise is appropriate. Hours with little plume rise generally reach final plume rise over a short distance (within the property fenceline), and hours with elevated plume rise quickly reach heights above surrounding terrain over short transitional distances. Additionally, the highest rises and distances occur during convective unstable/neutral conditions, with good dispersion and low monitored concentrations. Some of these plume rises may seem unrealistic, but they may also be considered as measures of atmospheric conditions, analogous to extremely low Monin-Obukhov lengths or mixing heights.

Figure B-1 below shows the hourly average (diurnal) release heights from BLPRISE for each line, along with hourly average mixing heights and stability classes. Stability classes are shown with a different y-axis, cycling from very stable conditions (class=6) to very unstable conditions (class=1), with neutral conditions (class=4) occurring during the day/night transitions.

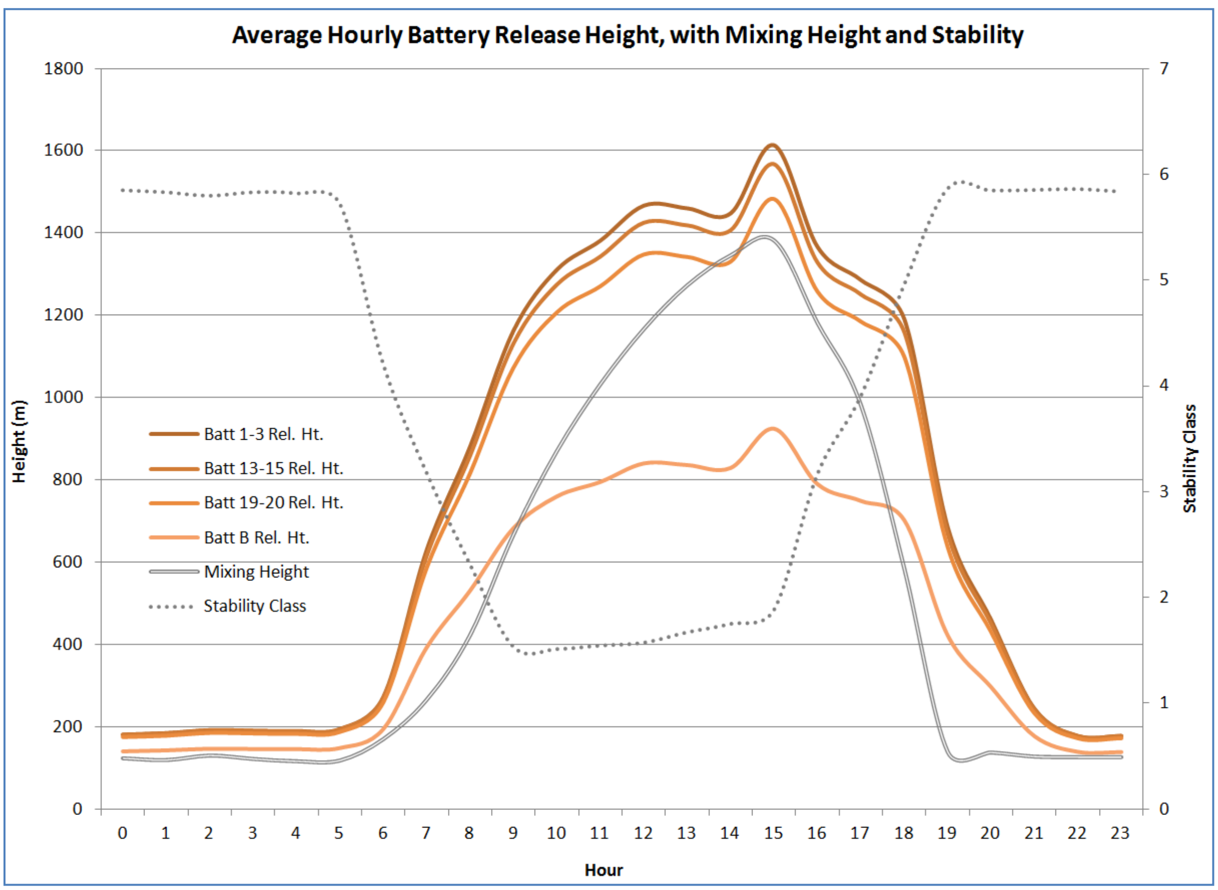


Figure B-1. Average Hourly Height (Battery Release Height, Mixing Height) and Stability Class

Plume rises from BLPRISE are a function of stabilities and mixing heights for each hour. On an average basis, the thermal buoyancy of each line is effectively forcing the modeled plumes upward and into the mixing layer. As a result, AERMOD is provided with more appropriate starting heights for the dispersion of battery fugitives in complex terrain.

Additive buoyancy from parallel lines was not used for this demonstration, with each line modeled separately for the hybrid method (the same was done using BUOYLINE) and corresponding impacts combined via post-processing. (See Appendix E of this document.)

The BLPRISE code is included in Appendix G of this document, with modifications from the BLP code highlighted in yellow. The code was modified only to generate output that was not automatically created by BLP version 99176.

APPENDIX C – AERMOD Source Parameters

This appendix provides the source parameters used for the sources modeled with AERMOD for each facility/process and model ID.

Below is a key of the abbreviations used in the tables, with a description of each parameter and the corresponding unit.

Parameter	**Description**	**Unit**
UTMx	UTM x-coordinate	meters
UTMy	UTM y-coordinate	meters
ELEV	Elevation	meters
HEIGHT	Stack height	meters
TEMP	Stack exit velocity	meters/second
VEL	Stack exit temperature	Kelvin
DIAM	Stack diameter	meters
BLDG	Building downwash parameters included (yes/no)	n/a
REL HEIGHT	Release height above ground (volume or area)	meters
INIT SY	Initial lateral dimension of volume (σ_y)	meters
INIT SZ	Initial vertical dimension of volume (σ_z)	meters
EMIS RATE	Emission rate	grams/second

U. S. Steel Clairton Plant point and volume source parameters are given in Tables C-1 and C-2, respectively. These sources were consistent for each model test case using different buoyant line methodologies.

Table C-1. U. S. Steel Clairton Point Sources

SOURCE	ID	UTMx	UTMy	ELEV	HEIGHT	TEMP	VEL	DIAM	BLDG	EMIS RATE
US STEEL CLAIRTON Quench Tower 1	CLQNCH1	595964.00	4461731.00	231	30.48	358.49	3.54	6.80	YES	1.676500
US STEEL CLAIRTON Quench Tower 5	CLQNCH5	595472.00	4462078.00	231	30.48	358.49	3.54	7.10	YES	0.684070
US STEEL CLAIRTON Quench Tower 7	CLQNCH7	595430.00	4462047.00	231	37.18	362.77	2.99	8.81	YES	1.973100
US STEEL CLAIRTON Quench Tower B	CLQNCHB	595460.00	4462374.00	231	41.15	368.55	4.30	9.51	YES	1.313800
US STEEL CLAIRTON PEC Baghouse 1-3, Module 1	CLPEC1A	595865.80	4461872.20	231	24.99	324.83	18.81	0.91	YES	0.014322
US STEEL CLAIRTON PEC Baghouse 1-3, Module 2	CLPEC1B	595861.10	4461877.20	231	24.99	324.83	18.81	0.91	YES	0.014322
US STEEL CLAIRTON PEC Baghouse 1-3, Module 3	CLPEC1C	595856.40	4461882.40	231	24.99	324.83	18.81	0.91	YES	0.014322
US STEEL CLAIRTON PEC Baghouse 1-3, Module 4	CLPEC1D	595863.60	4461874.40	231	24.99	324.83	18.81	0.91	YES	0.014322
US STEEL CLAIRTON PEC Baghouse 1-3, Module 5	CLPEC1E	595858.80	4461879.70	231	24.99	324.83	18.81	0.91	YES	0.014322
US STEEL CLAIRTON PEC Baghouse 13-15, Module 1	CLPEC13A	595324.70	4462210.50	231	24.99	324.83	18.23	0.91	YES	0.018603
US STEEL CLAIRTON PEC Baghouse 13-15, Module 2	CLPEC13B	595320.30	4462215.50	231	24.99	324.83	18.23	0.91	YES	0.018603
US STEEL CLAIRTON PEC Baghouse 13-15, Module 3	CLPEC13C	595315.90	4462220.40	231	24.99	324.83	18.23	0.91	YES	0.018603
US STEEL CLAIRTON PEC Baghouse 13-15, Module 4	CLPEC13D	595317.90	4462218.00	231	24.99	324.83	18.23	0.91	YES	0.018603
US STEEL CLAIRTON PEC Baghouse 13-15, Module 5	CLPEC13E	595322.60	4462212.80	231	24.99	324.83	18.23	0.91	YES	0.018603
US STEEL CLAIRTON PEC Baghouse 19-20, Module 1	CLPEC19A	595320.00	4462206.40	231	24.99	304.83	17.94	0.91	YES	0.021549
US STEEL CLAIRTON PEC Baghouse 19-20, Module 2	CLPEC19B	595315.50	4462211.30	231	24.99	304.83	17.94	0.91	YES	0.021549
US STEEL CLAIRTON PEC Baghouse 19-20, Module 3	CLPEC19C	595311.00	4462216.50	231	24.99	304.83	17.94	0.91	YES	0.021549
US STEEL CLAIRTON PEC Baghouse 19-20, Module 4	CLPEC19D	595313.00	4462214.00	231	24.99	304.83	17.94	0.91	YES	0.021549
US STEEL CLAIRTON PEC Baghouse 19-20, Module 5	CLPEC19E	595317.70	4462208.80	231	24.99	304.83	17.94	0.91	YES	0.021549
US STEEL CLAIRTON PEC Baghouse B, Module 1	CLPECBA	595439.60	4462430.50	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 2	CLPECBB	595435.90	4462433.40	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 3	CLPECBC	595420.80	4462445.60	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 4	CLPECBD	595432.50	4462436.10	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 5	CLPECBE	595428.60	4462439.30	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 6	CLPECBF	595424.50	4462442.60	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 7	CLPECBG	595436.00	4462425.70	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 8	CLPECBH	595432.20	4462428.70	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 9	CLPECBI	595428.70	4462431.50	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 10	CLPECBJ	595424.30	4462435.10	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 11	CLPECBK	595420.30	4462438.20	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON PEC Baghouse B, Module 12	CLPECBL	595416.80	4462441.30	231	15.54	324.83	13.79	1.22	YES	0.031759
US STEEL CLAIRTON Battery 1 Underfiring	CLCOMB1	595871.00	4461845.00	231	68.58	526.49	7.59	2.44	YES	0.193390
US STEEL CLAIRTON Battery 2 Underfiring	CLCOMB2	595866.00	4461852.00	231	68.58	534.27	7.71	2.44	YES	0.355090
US STEEL CLAIRTON Battery 3 Underfiring	CLCOMB3	595742.00	4461989.00	231	68.58	539.27	7.38	2.44	YES	0.263510
US STEEL CLAIRTON Battery 13 Underfiring	CLCOMB13	595389.00	4462164.00	231	68.58	535.38	4.48	3.05	YES	0.240440
US STEEL CLAIRTON Battery 14 Underfiring	CLCOMB14	595380.00	4462174.00	231	68.58	536.49	4.30	3.05	YES	0.232390
US STEEL CLAIRTON Battery 15 Underfiring	CLCOMB15	595253.00	4462318.00	231	68.58	541.49	4.48	3.05	YES	0.443470
US STEEL CLAIRTON Battery 19 Underfiring	CLCOMB19	595273.00	4462117.00	231	76.20	519.27	3.72	4.72	YES	0.352180
US STEEL CLAIRTON Battery 20 Underfiring	CLCOMB20	595258.00	4462134.00	231	76.20	542.05	4.27	4.72	YES	0.375440
US STEEL CLAIRTON B Battery Underfiring	CLCOMBB	595477.00	4462406.00	231	96.01	515.38	5.06	4.95	YES	0.262840
US STEEL CLAIRTON Boiler 1	CLBLR1	595004.00	4462714.00	231	57.91	457.60	29.56	2.67	YES	0.630450
US STEEL CLAIRTON Boiler 2	CLBLR2	594989.00	4462717.00	231	57.91	437.05	21.94	2.13	YES	0.264840
US STEEL CLAIRTON Boiler R1	CLBLRR1	594892.00	4462604.00	231	50.29	524.27	7.47	2.59	YES	0.018834
US STEEL CLAIRTON Boiler R2	CLBLRR2	594892.00	4462604.00	231	50.29	524.27	7.47	2.59	YES	0.013097
US STEEL CLAIRTON Boiler T1	CLBLRT1	594845.00	4462563.00	231	26.52	544.27	9.05	1.46	YES	0.036560
US STEEL CLAIRTON Boiler T2	CLBLRT2	594837.00	4462569.00	231	26.52	543.16	9.05	1.46	YES	0.035409
US STEEL CLAIRTON SCOT Incinerator	CLSCOT	595575.00	4462036.00	231	45.72	638.16	17.43	1.17	YES	0.079646
US STEEL CLAIRTON Misc. Flaring	CLFLARE	595554.00	4462083.00	231	8.26	1273.00	20.00	0.63	NO	0.000003

Table C-2. U. S. Steel Clairton Volume Sources

SOURCE	ID	UTMx	UTMy	ELEV	REL HEIGHT	INIT SY	INIT SZ	EMIS RATE
US STEEL CLAIRTON COOLING TOWER, Fan 1	CLCOOL1	595464.20	4462313.20	231	44.20	5.02	10.28	0.697400
US STEEL CLAIRTON COOLING TOWER, Fan 2	CLCOOL2	595457.60	4462322.70	231	44.20	5.02	10.28	0.697400
US STEEL CLAIRTON COOLING TOWER, Fan 3	CLCOOL3	595451.20	4462331.50	231	44.20	5.02	10.28	0.697400
US STEEL CLAIRTON COOLING TOWER, Fan 4	CLCOOL4	595444.70	4462340.40	231	44.20	5.02	10.28	0.697400
US STEEL CLAIRTON COOLING TOWER, Fan 5	CLCOOL5	595438.30	4462349.10	231	44.20	5.02	10.28	0.697400
US STEEL CLAIRTON #1 Pulverizers	CLPULV1	595943.00	4461998.00	231	9.00	2.33	8.37	0.000397
US STEEL CLAIRTON #2 Pulverizers	CLPULV2	595579.00	4462373.00	231	3.65	2.33	3.40	0.000072
US STEEL CLAIRTON Blasting - Black Beauty	CLBLKBTY	595835.00	4461406.00	231	6.10	2.33	5.67	0.016708
US STEEL CLAIRTON Boom Conveyor, Segment 1	CLBOOM1	594267.00	4463101.00	231	5.50	2.33	2.56	0.000311
US STEEL CLAIRTON Boom Conveyor, Segment 2	CLBOOM2	594421.00	4463005.00	231	5.50	2.33	2.56	0.000311
US STEEL CLAIRTON Coke Pile, Load/Unload	CLCOKEP	595085.00	4461671.00	231	6.10	2.33	2.84	0.002086
US STEEL CLAIRTON Coal Bins/Bunkers, Segment 1	CLBUNK1	595858.00	4461835.00	231	18.25	2.33	8.48	0.000065
US STEEL CLAIRTON Coal Bins/Bunkers, Segment 2	CLBUNK2	595334.00	4462256.00	231	18.40	2.33	8.56	0.000065
US STEEL CLAIRTON Coal Bins/Bunkers, Segment 3	CLBUNK3	595313.00	4462162.00	231	21.25	2.33	9.88	0.000065
US STEEL CLAIRTON Coal Bins/Bunkers, Segment 4	CLBUNK4	595606.00	4462239.00	231	28.55	2.33	13.28	0.000065
US STEEL CLAIRTON Ball Mill 1-3	CLBALL1	595858.00	4461835.00	231	18.25	2.33	8.48	0.000118
US STEEL CLAIRTON Ball Mill 13-15	CLBALL13	595334.00	4462256.00	231	18.40	2.33	8.56	0.000150
US STEEL CLAIRTON Ball Mill 19-20	CLBALL19	595313.00	4462162.00	231	21.25	2.33	9.88	0.000167
US STEEL CLAIRTON Ball Mill B	CLBALLB	595606.00	4462239.00	231	28.55	2.33	13.28	0.000083
US STEEL CLAIRTON Continuous Unloading #1	CLUNLD1	595826.00	4462163.00	231	10.00	2.33	4.65	0.003607
US STEEL CLAIRTON Continuous Unloading #2	CLUNLD2	595365.00	4462576.00	231	10.00	2.33	4.65	0.004551
US STEEL CLAIRTON Pedestal Crane Unloader	CLPED	595153.00	4462670.00	231	6.10	2.33	2.84	0.000316
US STEEL CLAIRTON Clamshell Unloader	CLCLAM	594032.00	4463306.00	231	6.10	2.33	2.84	0.000250
US STEEL CLAIRTON Screen Station 1 (1-3)	CLSCR1	595768.00	4461988.00	231	7.50	2.33	3.49	0.012341
US STEEL CLAIRTON Screen Station 2 (13-15, 19-20)	CLSCR2	595229.00	4462312.00	231	12.40	2.33	5.77	0.033105
US STEEL CLAIRTON Screen Station 3 (B)	CLSCR3	595685.00	4462051.00	231	7.50	2.33	3.49	0.062783
US STEEL CLAIRTON Coal Transfer, Tower 1	CLCOALT1	595988.00	4461954.00	231	9.00	2.33	4.19	0.001631
US STEEL CLAIRTON Coal Transfer, Tower 2	CLCOALT2	595770.00	4462190.00	231	9.00	2.33	4.19	0.001631
US STEEL CLAIRTON Coal Transfer, Tower 3	CLCOALT3	595655.00	4462289.00	231	9.00	2.33	4.19	0.001631
US STEEL CLAIRTON Coal Transfer, Tower 4	CLCOALT4	595480.00	4462454.00	231	9.00	2.33	4.19	0.001631
US STEEL CLAIRTON Coal Transfer, Tower 5	CLCOALT5	595215.00	4462632.00	231	9.00	2.33	4.19	0.001631
US STEEL CLAIRTON Coke Transfer 1-3, B - Segment 1	CLCOKET1	595844.00	4461883.00	231	6.10	2.33	2.84	0.019002
US STEEL CLAIRTON Coke Transfer 1-3, B - Segment 2	CLCOKET2	595596.00	4462200.00	231	6.10	2.33	2.84	0.019002
US STEEL CLAIRTON Coke Transfer 13-15, 19-20	CLCOKET3	595331.00	4462196.00	231	6.10	2.33	2.84	0.046306
US STEEL CLAIRTON By-Product, Tar/Liquor/Pitch - Segment 1	CLTAR1	595411.00	4462269.00	231	6.10	2.33	2.84	0.034024
US STEEL CLAIRTON By-Product, Tar/Liquor/Pitch - Segment 2	CLTAR2	595514.00	4462136.00	231	6.10	2.33	2.84	0.034024
US STEEL CLAIRTON By-Product (Cooler/Pumphouse Sumps)	CLSUMP	595364.00	4462306.00	231	6.10	2.33	2.84	0.015879
US STEEL CLAIRTON By-Product (Tar Storage Tanks)	CLTANK	595356.00	4462436.00	231	8.10	3.26	3.77	0.000262
US STEEL CLAIRTON Aeration Basins - WWTP	CLAERBN	595158.00	4462533.00	231	7.50	5.35	3.49	0.034232
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 1	CLROAD1	595738.00	4461596.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 2	CLROAD2	595795.00	4461036.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 3	CLROAD3	596031.00	4461518.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 4	CLROAD4	595989.00	4461695.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 5	CLROAD5	595943.00	4461926.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 6	CLROAD6	595390.00	4462452.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 7	CLROAD7	594913.00	4462537.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 8	CLROAD8	595185.00	4462261.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 9	CLROAD9	595437.00	4461976.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 10	CLROAD10	594747.00	4462629.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 11	CLROAD11	594409.00	4462859.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Motor Vehicles and Roads, Segment 12	CLROAD12	593930.00	4463233.00	231	2.55	6.98	2.37	0.021614
US STEEL CLAIRTON Tug Boat Exhaust, Segment 1	CLTUG1	594222.00	4463159.00	231	3.05	2.33	1.42	0.039818
US STEEL CLAIRTON Tug Boat Exhaust, Segment 2	CLTUG2	595312.00	4462606.00	231	3.05	2.33	1.42	0.039818
US STEEL CLAIRTON Tug Boat Exhaust, Segment 3	CLTUG3	595863.00	4462126.00	231	3.05	2.33	1.42	0.039818

U. S. Steel Clairton Plant buoyant line (battery) source coordinates, elevations, and emission rates are given in Table C-3 for all buoyant line test cases except BUOYLINE. (See Table 3-1 in Section 3 for the BUOYLINE parameters.)

For the HYBRID, POINT, and VOLUME test cases, batteries were modeled by segments of each battery line, by adjacent line volume source methodology (equidistant segments). The number segments for each line is as follows:

- Batteries 1-3: 21 segments
- Batteries 13-15: 19 segments
- Batteries 19-20: 18 segments
- B Battery: 6 segments

Additional parameters, specific to each segment, were assigned as follows, by buoyant line methodology:

HYBRID (volumes):

- Release height: varying by hour (based on BLP-based plume rises + battery height)
- Initial lateral dimension (σ_y): based on width of building by segment
    - Batteries 1-3: 6.70 m
    - Batteries 13-15: 6.51 m
    - Batteries 19-20: 6.51 m
    - B Battery: 7.77 m
- Initial vertical dimension (σ_z): varying by hour, release height/4.3

POINT:

- Stack height: battery height (see Table 3-1)
- Stack temperature: 1199.83 K (1800 °F, the temperature used for pushing)
- Stack exit velocity: 3.05 m/s
- Stack diameter: 1.0 m

VOLUME:

- Release height: battery height (same as POINT case)
- Initial lateral dimension (σ_y): based on width of building by segment (same as HYBRID case)
- Initial vertical dimension (σ_z): battery height/2.15

Table C-3. U. S. Steel Clairton Buoyant Line Sources (non-BUOYLINE)

SOURCE	ID	UTMx	UTMy	ELEV	EMIS RATE
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 1	CLB01S01	595737.10	4461971.80	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 2	CLB01S02	595746.20	4461961.50	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 3	CLB01S03	595755.30	4461951.30	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 4	CLB01S04	595764.40	4461941.00	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 5	CLB01S05	595773.50	4461930.80	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 6	CLB01S06	595782.60	4461920.60	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 7	CLB01S07	595791.70	4461910.30	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 8	CLB01S08	595800.80	4461900.10	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 9	CLB01S09	595809.90	4461889.90	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 10	CLB01S10	595819.00	4461879.60	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 11	CLB01S11	595828.10	4461869.40	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 12	CLB01S12	595837.20	4461859.20	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 13	CLB01S13	595846.30	4461848.90	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 14	CLB01S14	595855.40	4461838.70	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 15	CLB01S15	595864.60	4461828.50	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 16	CLB01S16	595873.70	4461818.20	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 17	CLB01S17	595882.80	4461808.00	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 18	CLB01S18	595891.90	4461797.70	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 19	CLB01S19	595901.00	4461787.50	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 20	CLB01S20	595910.10	4461777.30	231	0.080361
US STEEL CLAIRTON Batteries 1-3 Fugitives Seg 21	CLB01S21	595919.20	4461767.00	231	0.080361
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 1	CLB13S01	595276.10	4462317.80	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 2	CLB13S02	595285.40	4462307.40	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 3	CLB13S03	595294.70	4462296.90	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 4	CLB13S04	595304.10	4462286.50	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 5	CLB13S05	595313.40	4462276.00	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 6	CLB13S06	595322.70	4462265.60	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 7	CLB13S07	595332.00	4462255.10	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 8	CLB13S08	595341.30	4462244.70	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 9	CLB13S09	595350.70	4462234.20	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 10	CLB13S10	595360.00	4462223.80	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 11	CLB13S11	595369.30	4462213.30	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 12	CLB13S12	595378.60	4462202.90	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 13	CLB13S13	595387.90	4462192.50	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 14	CLB13S14	595397.30	4462182.00	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 15	CLB13S15	595406.60	4462171.60	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 16	CLB13S16	595415.90	4462161.10	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 17	CLB13S17	595425.20	4462150.70	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 18	CLB13S18	595434.60	4462140.20	231	0.108650
US STEEL CLAIRTON Batteries 13-15 Fugitives Seg 19	CLB13S19	595443.90	4462129.80	231	0.108650

Table C-3. U. S. Steel Clairton Buoyant Line Sources (non-BUOYLINE) – continued

SOURCE	ID	UTMx	UTMy	ELEV	EMIS RATE
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 1	CLB19S01	595234.20	4462249.30	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 2	CLB19S02	595243.60	4462238.80	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 3	CLB19S03	595252.90	4462228.40	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 4	CLB19S04	595262.20	4462217.90	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 5	CLB19S05	595271.50	4462207.50	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 6	CLB19S06	595280.80	4462197.00	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 7	CLB19S07	595290.10	4462186.50	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 8	CLB19S08	595299.40	4462176.10	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 9	CLB19S09	595308.70	4462165.60	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 10	CLB19S10	595318.00	4462155.10	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 11	CLB19S11	595327.30	4462144.70	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 12	CLB19S12	595336.60	4462134.20	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 13	CLB19S13	595345.90	4462123.80	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 14	CLB19S14	595355.20	4462113.30	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 15	CLB19S15	595364.50	4462102.80	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 16	CLB19S16	595373.80	4462092.40	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 17	CLB19S17	595383.10	4462081.90	231	0.143640
US STEEL CLAIRTON Batteries 19-20 Fugitives Seg 18	CLB19S18	595392.40	4462071.40	231	0.143640
US STEEL CLAIRTON B Battery Fugitives Seg 1	CLBBS01	595521.40	4462332.40	231	0.108640
US STEEL CLAIRTON B Battery Fugitives Seg 2	CLBBS02	595532.50	4462319.90	231	0.108640
US STEEL CLAIRTON B Battery Fugitives Seg 3	CLBBS03	595543.70	4462307.50	231	0.108640
US STEEL CLAIRTON B Battery Fugitives Seg 4	CLBBS04	595554.80	4462295.00	231	0.108640
US STEEL CLAIRTON B Battery Fugitives Seg 5	CLBBS05	595565.90	4462282.60	231	0.108640
US STEEL CLAIRTON B Battery Fugitives Seg 6	CLBBS06	595577.10	4462270.20	231	0.108640

U. S. Steel Clairton Plant area source parameters are given in Table C-4 below. These sources were consistent for each model test case using different buoyant line methodologies.

Table C-4. U. S. Steel Clairton Area Sources

SOURCE	ID	UTMx	UTMy	CORNER	ELEV	REL HEIGHT	EMIS RATE (per m²)
US STEEL CLAIRTON Coke Storage/Erosion (Peters Creek)	CLEROS1	594891.00	4461579.00	1	231	6.1	0.00000027985
		594847.00	4461711.00	2			
		595204.00	4461836.00	3			
		595249.00	4461705.00	4			
US STEEL CLAIRTON Coke Storage/Erosion (South Yard)	CLEROS2	595726.00	4460737.00	1	231	6.1	0.00000091571
		595781.00	4460960.00	2			
		595848.00	4460943.00	3			
		595794.00	4460722.00	4			

Tables C-5 through C-8 show the point and volume source parameters used for the U. S. Steel Edgar Thomson and Irvin Plants. These facilities, while part of the same integrated mill as the Clairton Plant (U. S. Steel Mon Valley Works), are some distance away from the Clairton Plant. (Irvin is about 2 km to the NNW, while Edgar Thomson is about 9 km to the NNE.)

Table C-5. U. S. Steel Edgar Thomson Point Sources

SOURCE	ID	UTMx	UTMy	ELEV	HEIGHT	TEMP	VEL	DIAM	BLDG	EMIS RATE
US STEEL EDGAR THOMSON Riley Boiler 1	ETRB1	597057.00	4471990.00	225	49.17	672.04	7.86	4.22	YES	2.648300
US STEEL EDGAR THOMSON Riley Boiler 2	ETRB2	597042.00	4471996.00	225	49.17	672.04	7.86	4.22	YES	2.733100
US STEEL EDGAR THOMSON Riley Boiler 3	ETRB3	597027.00	4472001.00	225	49.17	672.04	7.86	4.22	YES	2.497800
US STEEL EDGAR THOMSON Blast Furnace 1 Stoves	ETBF1STV	597180.00	4472051.00	225	79.42	464.82	7.97	3.28	YES	1.684100
US STEEL EDGAR THOMSON Casthouse Baghouse (4 comps)	ETCASTB	597131.00	4471997.00	225	27.43	394.26	10.00	3.60	YES	0.054306
US STEEL EDGAR THOMSON Blast Furnace 3 Stoves	ETBF3STV	597014.00	4472084.00	225	57.05	522.59	9.84	2.59	YES	1.735200
US STEEL EDGAR THOMSON BFG Flare	ETBFGF	597166.00	4471984.00	225	66.00	1273.00	20.00	0.92	YES	0.307290
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 1	ETMIX1	596463.30	4472314.50	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 2	ETMIX2	596466.00	4472313.70	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 3	ETMIX3	596462.30	4472311.60	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 4	ETMIX4	596465.20	4472310.80	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 5	ETMIX5	596461.40	4472308.70	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 6	ETMIX6	596464.40	4472307.80	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 7	ETMIX7	596460.70	4472305.80	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 8	ETMIX8	596463.50	4472304.90	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 9	ETMIX9	596459.70	4472302.90	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 10	ETMIX10	596462.70	4472302.10	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 11	ETMIX11	596459.20	4472300.00	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Mixer Baghouse, Module 12	ETMIX12	596462.00	4472299.20	228	21.64	327.44	22.91	0.73	YES	0.010427
US STEEL EDGAR THOMSON BOP Vessel F&R Scrubber, Stack 1	ETSCRB1	596571.90	4472271.80	228	55.17	321.88	17.54	3.05	YES	2.007900
US STEEL EDGAR THOMSON BOP Vessel F&R Scrubber, Stack 2	ETSCRB2	596588.30	4472257.70	228	55.17	321.88	17.54	3.05	YES	2.007900
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 1	ETSEC1	596411.10	4472401.50	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 2	ETSEC2	596411.00	4472398.00	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 3	ETSEC3	596411.10	4472394.70	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 4	ETSEC4	596410.90	4472391.20	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 5	ETSEC5	596410.90	4472387.50	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 6	ETSEC6	596410.90	4472384.10	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 7	ETSEC7	596410.80	4472380.20	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 8	ETSEC8	596410.80	4472376.70	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 9	ETSEC9	596410.70	4472373.30	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Secondary Baghouse, Mod. 10	ETSEC10	596410.70	4472369.60	228	14.63	322.10	10.00	3.60	YES	0.017418
US STEEL EDGAR THOMSON BOP Railcar Unloading Baghouse	ETUNLD	596443.30	4472403.60	228	12.19	294.27	10.00	0.70	YES	0.012827
US STEEL EDGAR THOMSON BOP Transfer Tower Baghouse	ETTRAN	596422.50	4472201.20	228	32.61	294.27	10.00	1.60	YES	0.006415
US STEEL EDGAR THOMSON LMF Baghouse, Module 1	ETLMFB1	596603.20	4472432.30	229	20.42	351.97	10.94	0.73	YES	0.005003
US STEEL EDGAR THOMSON LMF Baghouse, Module 2	ETLMFB2	596596.50	4472433.90	229	20.42	351.97	10.94	0.73	YES	0.005003
US STEEL EDGAR THOMSON LMF Baghouse, Module 3	ETLMFB3	596604.20	4472435.70	229	20.42	351.97	10.94	0.73	YES	0.005003
US STEEL EDGAR THOMSON LMF Baghouse, Module 4	ETLMFB4	596597.30	4472437.20	229	20.42	351.97	10.94	0.73	YES	0.005003
US STEEL EDGAR THOMSON LMF Baghouse, Module 5	ETLMFB5	596605.10	4472439.20	229	20.42	351.97	10.94	0.73	YES	0.005003
US STEEL EDGAR THOMSON LMF Baghouse, Module 6	ETLMFB6	596598.20	4472440.60	229	20.42	351.97	10.94	0.73	YES	0.005003

Table C-6. U. S. Steel Edgar Thomson Volume Sources

SOURCE	ID	UTMx	UTMy	ELEV	REL HEIGHT	INIT SY	INIT SZ	EMIS RATE
US STEEL EDGAR THOMSON BF1 Material/Slag Handling	ETBF1SLG	597224.00	4472002.00	228	6.10	2.33	2.84	0.081349
US STEEL EDGAR THOMSON BF1 Casthouse (Roof + Fume) Seg a	ETCAST1A	597195.60	4472010.10	225	27.13	7.07	12.62	0.565180
US STEEL EDGAR THOMSON BF1 Casthouse (Roof + Fume) Seg b	ETCAST1B	597190.40	4471995.90	225	27.13	7.07	12.62	0.565180
US STEEL EDGAR THOMSON BF1 Breakdown	ETBF1BRK	597206.50	4472031.40	226	52.50	1.86	24.42	0.112710
US STEEL EDGAR THOMSON BF3 Material/Slag Handling	ETBF3SLG	597095.20	4472077.20	228	6.10	1.86	2.84	0.070628
US STEEL EDGAR THOMSON BF3 Casthouse (Roof + Fume) Seg a	ETCAST3A	597072.80	4472065.30	225	30.78	6.13	14.32	0.562330
US STEEL EDGAR THOMSON BF3 Casthouse (Roof + Fume) Seg b	ETCAST3B	597078.30	4472046.30	225	30.78	6.13	14.32	0.562330
US STEEL EDGAR THOMSON BF3 Breakdown	ETBF3BRK	597066.50	4472083.80	226	43.80	2.74	19.30	0.112710
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 1	ETBOP1	596533.90	4472311.00	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 2	ETBOP2	596536.90	4472321.60	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 3	ETBOP3	596539.90	4472332.10	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 4	ETBOP4	596543.00	4472342.70	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 5	ETBOP5	596546.00	4472353.30	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 6	ETBOP6	596549.10	4472363.90	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 7	ETBOP7	596552.10	4472374.40	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON BOP Process Fuel Use (Roof Monitor) Seg 8	ETBOP8	596555.10	4472385.00	228	53.11	5.12	24.70	0.028078
US STEEL EDGAR THOMSON Continuous Casting/LMF (Roof Mon) Seg 1	ETCCLMF1	596609.70	4472367.60	228	51.16	4.79	23.79	0.001991
US STEEL EDGAR THOMSON Continuous Casting/LMF (Roof Mon) Seg 2	ETCCLMF2	596612.40	4472377.50	228	51.16	4.79	23.79	0.001991
US STEEL EDGAR THOMSON Continuous Casting/LMF (Roof Mon) Seg 3	ETCCLMF3	596615.00	4472387.50	228	51.16	4.79	23.79	0.001991
US STEEL EDGAR THOMSON Continuous Casting/LMF (Roof Mon) Seg 4	ETCCLMF4	596617.70	4472397.50	228	51.16	4.79	23.79	0.001991
US STEEL EDGAR THOMSON Continuous Casting/LMF (Roof Mon) Seg 5	ETCCLMF5	596620.30	4472407.40	228	51.16	4.79	23.79	0.001991
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 1	ETBFMC1	597248.00	4471879.00	225	18.00	5.74	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 2	ETBFMC2	596873.90	4472180.30	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 3	ETBFMC3	596891.70	4472174.10	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 4	ETBFMC4	596909.40	4472167.90	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 5	ETBFMC5	596927.20	4472161.70	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 6	ETBFMC6	596945.00	4472155.50	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 7	ETBFMC7	596962.80	4472149.30	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 8	ETBFMC8	596980.60	4472143.10	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 9	ETBFMC9	596998.40	4472136.90	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 10	ETBFMC10	597016.10	4472130.70	228	18.00	8.76	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 11	ETBFMC11	597091.90	4472159.30	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 12	ETBFMC12	597109.60	4472152.80	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 13	ETBFMC13	597127.40	4472146.40	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 14	ETBFMC14	597145.20	4472139.90	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 15	ETBFMC15	597163.00	4472133.50	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 16	ETBFMC16	597180.80	4472127.10	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 17	ETBFMC17	597198.60	4472120.60	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 18	ETBFMC18	597216.40	4472114.20	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON BF Fugitives (Misc. Comb.) Seg 19	ETBFMC19	597234.20	4472107.80	228	18.00	8.80	8.37	0.004479
US STEEL EDGAR THOMSON Cooling Tower / BFCE Recycle	ETCOOL1	596485.10	4472243.70	228	20.42	2.11	9.50	0.011311
US STEEL EDGAR THOMSON Cooling Tower / BOP	ETCOOL2	596575.10	4472241.00	228	15.24	1.52	7.09	0.014231
US STEEL EDGAR THOMSON Cooling Tower / Caster	ETCOOL3	596761.20	4472390.90	228	15.24	1.05	7.09	0.006478
US STEEL EDGAR THOMSON Cooling Tower / WSAC (Mold Water)	ETCOOL4	596979.00	4472046.00	228	9.14	0.82	4.25	0.074842
US STEEL EDGAR THOMSON Roads & Misc. Combustion	ETROAD	596941.90	4472066.80	225	2.55	6.98	2.37	0.539570
US STEEL EDGAR THOMSON Storage Piles	ETSTOR	597037.40	4472151.30	225	6.10	7.94	2.84	0.031859

Table C-7. U. S. Steel Irvin Point Sources

SOURCE	ID	UTMx	UTMy	ELEV	HEIGHT	TEMP	VEL	DIAM	BLDG	EMIS RATE
US STEEL IRVIN Boiler #1	IRBLR1	593149.00	4465476.00	287	19.50	635.38	10.23	1.10	YES	0.052257
US STEEL IRVIN Boiler #2	IRBLR2	593171.00	4465165.00	287	21.94	537.05	8.00	1.28	YES	0.061408
US STEEL IRVIN Boilers #3-4	IRBLR3	593419.00	4465596.00	287	22.86	644.26	9.70	1.42	YES	0.033067
US STEEL IRVIN 80" Mill Reheat Furnace 1	IR80IN1	593177.00	4465871.00	287	20.00	710.38	29.43	1.98	YES	0.134160
US STEEL IRVIN 80" Mill Reheat Furnace 2	IR80IN2	593178.00	4465884.00	287	20.00	710.38	29.43	1.98	YES	0.133530
US STEEL IRVIN 80" Mill Reheat Furnace 3	IR80IN3	593179.00	4465896.00	287	20.00	710.38	29.43	1.98	YES	0.125190
US STEEL IRVIN 80" Mill Reheat Furnace 4	IR80IN4	593180.00	4465909.00	287	20.00	710.38	29.43	1.98	YES	0.203680
US STEEL IRVIN 80" Mill Reheat Furnace 5	IR80IN5	593181.00	4465923.00	287	20.00	710.38	29.43	1.98	YES	0.184520
US STEEL IRVIN 80" Mill Reheat Waste Stack 6	IR80INW	593243.00	4465922.00	287	28.34	710.38	29.43	1.82	YES	0.196440
US STEEL IRVIN #1 Galv Line Preheat	IRGALV1	593352.00	4465406.00	287	25.30	944.26	9.48	1.42	YES	0.014944
US STEEL IRVIN #2 Galv Line Preheat	IRGALV2	593350.00	4465386.00	287	26.82	944.26	2.66	1.37	YES	0.010730
US STEEL IRVIN HPH Annealing Furnaces (seg a)	IRHPH_A	593328.60	4465585.50	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN HPH Annealing Furnaces (seg b)	IRHPH_B	593325.20	4465553.50	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN HPH Annealing Furnaces (seg c)	IRHPH_C	593321.80	4465521.60	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN HPH Annealing Furnaces (seg d)	IRHPH_D	593318.40	4465489.80	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN HPH Annealing Furnaces (seg e)	IRHPH_E	593315.30	4465457.80	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN HPH Annealing Furnaces (seg f)	IRHPH_F	593311.60	4465425.90	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN HPH Annealing Furnaces (seg g)	IRHPH_G	593308.20	4465394.00	287	21.33	527.60	10.00	0.76	YES	0.008644
US STEEL IRVIN Open Coil Annealing	IROCA	593335.00	4465243.00	287	21.33	310.94	10.52	2.96	YES	0.035800
US STEEL IRVIN Continuous Annealing	IRCONTA	593341.00	4464903.00	287	36.57	513.72	10.52	1.07	YES	0.015991
US STEEL IRVIN Peach Tree Flare A&B	IRPTF	592868.00	4464808.00	333	18.28	1273.00	20.00	0.63	NO	0.024474
US STEEL IRVIN COG Flares 1-3	IRCOGF	593237.00	4464601.00	287	8.99	1273.00	20.00	0.63	NO	0.014798
US STEEL IRVIN 64" Pickling Line (Descaler)	IR64PKL	593213.00	4465111.00	287	15.54	328.15	12.41	0.76	YES	0.005787
US STEEL IRVIN 84" Pickling Line (Descaler)	IR84PKL	593130.10	4465287.60	287	35.05	327.59	10.36	1.37	YES	0.015871
US STEEL IRVIN Cold Reduction Mill	IRCOLD	593397.00	4465193.00	287	26.82	312.04	12.71	6.86	YES	0.870700

Table C-8. U. S. Steel Irvin Volume Sources

SOURCE	ID	UTMx	UTMy	ELEV	REL HEIGHT	INIT SY	INIT SZ	EMIS RATE
US STEEL IRVIN Cooling Tower HPH	IRCOOL1	593359.00	4465916.00	287	10.06	1.60	4.68	0.002275
US STEEL IRVIN Cooling Tower North Water Treatment	IRCOOL2	593006.00	4465719.00	293	10.36	1.30	4.82	0.002157
US STEEL IRVIN Miscellaneous NG Combustion (segment 1)	IRMISC1	593181.00	4464880.00	287	17.00	2.33	7.91	0.009603
US STEEL IRVIN Miscellaneous NG Combustion (segment 2)	IRMISC2	593230.00	4465326.00	287	17.00	2.33	7.91	0.009603
US STEEL IRVIN Miscellaneous NG Combustion (segment 3)	IRMISC3	593275.00	4465778.00	287	17.00	2.33	7.91	0.009603
US STEEL IRVIN Roads/Vehicles (segment 1)	IRROAD1	593146.00	4466074.00	287	2.55	6.98	2.37	0.002654
US STEEL IRVIN Roads/Vehicles (segment 2)	IRROAD2	593167.00	4464665.00	287	2.55	6.98	2.37	0.002654

Table C-9 shows the point source parameters used for the distant sources for this demonstration (Allegheny Ludlum, McConway & Torley, Shenango). These sources are several kilometers away from the Clairton Plant and the PM_{10} monitors used for the model comparison. They were included in the AERMOD modeling in order to account for all background primary PM_{10} impacts, since they were tracked as local primary (LPM) sources separately from the CAMx regional sources (see Model Configuration, Section 4).

Source characterization for the distant sources was not as “refined” as the U. S. Steel sources and did not include the use of volume or area sources, building downwash parameters, etc. All source parameters were identical to the CAMx inputs, with some smaller sources aggregated into one source (such as plant-wide fugitives, cooling towers, etc.)

The Cheswick power plant is an additional large source of primary pollutants located in the northeastern portion of Allegheny County (about 9 kilometers to the southwest of Allegheny Ludlum). It was not included in the local source AERMOD modeling but was included in the CAMx regional modeling. Since emissions are from a tall stack (550 ft) and not near the immediate impact zone of any surrounding PM monitor, Cheswick was not selected for local source tracking. Screening results for this source show minimal effects in southeastern Allegheny County (see the SO_2 SIP for more information).

Table C-9. Distant Sources

FACILITY	SOURCE	ID	UTMx	UTMy	ELEV	HEIGHT	TEMP	VEL	DIAM	EMIS RATE
ALLEGHENY LUDLUM	#1 A&P LINE, SHOTBLAST / #1 A&P, SHOT BLAST	LUD01	607692.80	4496079.50	233	3.05	295.37	10.06	0.91	0.097519
ALLEGHENY LUDLUM	#1-2 A&P ANNEALING FCE	LUD02	607323.90	4495839.90	233	19.81	295.37	0.03	0.03	0.018411
ALLEGHENY LUDLUM	#2 A&P LINE, KOLENE DESC. / #2 A&P, KOLENE DESCALING	LUD03	607692.80	4496079.50	233	16.76	313.71	3.05	1.31	0.007767
ALLEGHENY LUDLUM	#3 B&P LINE PREHEATER NG / #3 B&P LINE PREHEATER, NG	LUD04	607692.80	4496079.50	233	15.24	295.37	0.03	0.03	0.004027
ALLEGHENY LUDLUM	#3 B&P LINE, SHOTBLAST / #3 B&P, NEW SHOT BLAST	LUD05	607692.80	4496079.50	233	3.05	295.37	9.33	0.49	0.207410
ALLEGHENY LUDLUM	#3 DEPT. BOILERS / #3 DEPT. BOILERS, NG	LUD06	607692.80	4496079.50	233	6.10	449.82	5.70	2.13	0.012945
ALLEGHENY LUDLUM	1-3 PICKLE,ACID SCRUBBING / #1-3 PICKLE ACID SCRUBBER	LUD07	607601.30	4496027.10	233	21.30	310.99	15.20	1.22	0.050054
ALLEGHENY LUDLUM	AMER. HORIZ LADLE PREHEAT / AMER HORIZ PREHEAT 1-3 NG	LUD08	607692.80	4496079.50	233	12.19	295.37	0.03	0.03	0.000015
ALLEGHENY LUDLUM	AOD / AOD - CANOPY BAGHOUSE	LUD09	607692.80	4496079.50	233	22.55	366.48	3.41	3.05	0.158790
ALLEGHENY LUDLUM	AOD / AOD - UNCAPTURED	LUD10	607692.80	4496079.50	233	22.55	295.37	0.03	0.03	0.004890
ALLEGHENY LUDLUM	AOD MOLD PREHEATERS 1-24	LUD11	607724.80	4496265.40	233	39.62	295.37	0.03	0.03	0.000299
ALLEGHENY LUDLUM	AOD VESSEL PREHEATER / AOD VESSEL PRHTR NG	LUD12	607692.80	4496079.50	233	12.19	295.37	0.03	0.03	0.000748
ALLEGHENY LUDLUM	BELL ANNEAL FCES. 1-6 / NG	LUD13	607380.40	4495853.00	233	23.42	295.37	0.03	0.03	0.000748
ALLEGHENY LUDLUM	BLOOM HORIZ PREHEATERS	LUD14	607760.10	4496220.40	233	42.00	295.37	0.03	0.03	0.006904
ALLEGHENY LUDLUM	CASTER TUNDISH PREHEAT / TUNDISH PREHEATERS 1,2 NG	LUD15	607692.80	4496079.50	233	22.55	366.48	3.41	3.05	0.000898
ALLEGHENY LUDLUM	CONTINUOUS CASTER / TORCH CUT-OFF BAGHOUSE	LUD16	607692.80	4496079.50	233	22.55	366.48	11.19	3.05	0.001536
ALLEGHENY LUDLUM	EAF 1 - CANOPY / AOD CANOPY BAGHOUSE	LUD17	607702.70	4496090.80	233	22.86	366.99	2.54	5.18	1.099200
ALLEGHENY LUDLUM	EAF 1 - CANOPY / EAF 1 CANOPY - UNCAPTURED	LUD18	607702.70	4496090.80	233	3.05	295.37	0.03	0.03	0.046890
ALLEGHENY LUDLUM	EAF 1 - MELTING-33&34DEC / MELTING - DEC BAGHOUSE	LUD19	607715.70	4496072.10	233	22.86	366.99	2.54	5.18	0.030780
ALLEGHENY LUDLUM	EAF 2 - CANOPY / CANOPY BAGHOUSE	LUD20	607646.00	4496273.10	233	18.59	366.99	3.41	3.05	0.098957
ALLEGHENY LUDLUM	EAF 2 - CANOPY / CANOPY UNCAPTURED	LUD21	607646.00	4496273.10	233	3.05	295.37	0.03	0.03	0.176170
ALLEGHENY LUDLUM	EAF 2 -- MELTING(31&32DEC) / MELTING - DEC BAGHOUSE	LUD22	607694.20	4496098.40	233	25.60	366.99	2.76	4.27	0.039123
ALLEGHENY LUDLUM	HORIZ EAF LADLE PREHEATER / HORIZ EAF LADLE PRHT NG	LUD23	607692.80	4496079.50	233	12.19	295.37	0.03	0.03	0.000748
ALLEGHENY LUDLUM	HOT BAND NORMALIZER / HOT BAND NORMALIZER NG	LUD24	607702.70	4496090.80	233	2.30	1393.99	3.56	1.83	0.017548
ALLEGHENY LUDLUM	HOT STRIP UNIVERSAL MILL / HOT STRIP UNIV MILL STACK	LUD25	607692.80	4496079.50	233	21.34	338.71	15.24	2.44	0.291920
ALLEGHENY LUDLUM	LOFTUS SOAK PITS / LOFTUS SOAK PITS 13-16 NG	LUD26	607254.90	4495754.50	233	38.10	810.99	3.46	1.22	0.012082
ALLEGHENY LUDLUM	LOFTUS SOAK PITS / LOFTUS SOAK PITS 17-20 NG	LUD27	607236.40	4495746.50	233	38.10	810.99	3.46	1.22	0.012082
ALLEGHENY LUDLUM	LOFTUS SOAK PITS / LOFTUS SOAK PITS 21-23 NG	LUD28	607211.10	4495738.40	233	38.10	810.99	2.57	1.22	0.009781
ALLEGHENY LUDLUM	LOFTUS SOAK PITS / LOFTUS SOAK PITS 9-12, NG	LUD29	607277.60	4495761.50	233	38.10	810.99	3.43	1.22	0.012082
ALLEGHENY LUDLUM	MISC FUGS, COOLING TWRS, STRIP DRYING	LUD30	607692.80	4496079.50	233	3.05	295.37	0.03	0.03	0.745400
ALLEGHENY LUDLUM	NO. 3 DEPT WET GRINDER / NO. 3 DEPT. WET GRINDER	LUD31	607692.80	4496079.50	233	10.67	293.15	15.24	0.91	0.005466
ALLEGHENY LUDLUM	PLATE BURNERS / TORCH CUTTERS	LUD32	607692.80	4496079.50	233	12.19	294.26	15.24	1.22	0.042172
ALLEGHENY LUDLUM	RUST REHEAT FURNACE, NG	LUD33	607341.60	4495841.30	233	38.10	810.92	16.52	1.52	0.158790
ALLEGHENY LUDLUM	SALEM REHEAT FURNACE, NG	LUD34	607411.10	4495839.00	233	38.10	810.92	15.64	2.44	1.207300
ALLEGHENY LUDLUM	SLAB GRINDERS	LUD35	607692.80	4496079.50	233	12.19	310.93	19.60	1.22	0.759730
ALLEGHENY LUDLUM	TANDEM MILL / 56 INCH TANDEM MILL	LUD36	607626.40	4495913.50	233	12.19	294.26	30.48	1.22	1.455000
ALLEGHENY LUDLUM	TANDEM MILL PREHEATER NG	LUD37	607692.80	4496079.50	233	15.24	295.37	0.03	0.03	0.000748
ALLEGHENY LUDLUM	UNITED MILL / UNITED MILL	LUD38	607692.80	4496079.50	233	12.19	294.26	30.48	1.22	0.285260
ALLEGHENY LUDLUM	VERT. EAF LADLE PREHEATRS NG	LUD39	607692.80	4496079.50	233	12.19	295.37	0.03	0.03	0.000374
ALLEGHENY LUDLUM	Z MILL / Z MILL	LUD40	607692.80	4496079.50	233	10.67	294.26	15.24	0.91	0.066065
McCONWAY & TORLEY	CLEANING AND FINISHING / AIR ARC TABLES BAGHOUSE	MC01	588111.00	4481386.90	224	12.80	293.15	8.99	1.52	0.008156
McCONWAY & TORLEY	CLEANING AND FINISHING / SHOT BLAST BAGHOUSE	MC02	588111.00	4481386.90	224	10.06	293.15	13.35	1.16	0.018007
McCONWAY & TORLEY	CORE MAKING / H-80 AND A-12 CORE MACH	MC03	588111.00	4481386.90	224	4.88	295.37	2.04	1.37	0.029227
McCONWAY & TORLEY	MISC FUGS, CORE MAKING, CLEANING, HANDLING	MC04	588111.00	4481386.90	224	3.05	295.37	0.03	0.03	0.395610
McCONWAY & TORLEY	MOLD AND SAND HANDLING / CASTING SHAKEOUT	MC05	588111.00	4481386.90	224	8.53	293.15	12.19	1.01	0.066731
McCONWAY & TORLEY	MOLD AND SAND HANDLING / SAND HANDLING AND PREP	MC06	588111.00	4481386.90	224	8.53	293.15	33.22	1.01	0.010414
McCONWAY & TORLEY	MOLD AND SAND HANDLING / SAND RECLAIM	MC07	588111.00	4481386.90	224	9.45	293.15	18.44	1.35	0.017260
McCONWAY & TORLEY	STEEL MAKING / ELECTRIC ARC FURNACE-BH3A	MC08	587992.70	4481463.70	224	7.62	367.39	19.05	0.84	0.074132
McCONWAY & TORLEY	STEEL MAKING / ELECTRIC ARC FURNACE-BH7	MC09	588043.70	4481527.60	224	5.49	426.39	11.69	1.14	0.332920
McCONWAY & TORLEY	STEEL MAKING / STOPPER ROD / LADLE PREHEAT	MC10	588111.00	4481386.90	224	4.88	295.37	6.71	1.37	2.131400

Table C-9. Distant Sources – continued

FACILITY	SOURCE	ID	UTMx	UTMy	ELEV	HEIGHT	TEMP	VEL	DIAM	EMIS RATE
SHENANGO	#1-4 PACKAGE BOILERS	SHEN01	578300.90	4483067.80	220	15.24	449.66	20.33	0.91	0.367350
SHENANGO	BATTERY S1 FUGITIVES	SHEN02	578075.60	4483295.20	220	10.36	644.26	3.05	0.46	0.044741
SHENANGO	BATTERY S1 FUGITIVES / BATTERY S-1 SOAKING	SHEN03	578075.60	4483295.20	220	12.50	1366.48	6.10	0.46	0.001254
SHENANGO	BATTERY S-1 UNDERFIRE / BATTERY S-1 UNDERFIRE	SHEN04	578137.20	4483244.80	220	76.20	590.21	9.02	2.59	0.714560
SHENANGO	COAL HANDLING & EROSION	SHEN05	578127.00	4483228.40	220	15.24	294.26	3.05	0.27	0.068666
SHENANGO	COKE HANDLING & COKE/COAL EROSION	SHEN06	578127.00	4483228.40	220	7.62	294.26	3.05	0.27	0.074923
SHENANGO	COOLING TOWERS / WET SURFACE COOLER #1	SHEN07	578127.00	4483228.40	220	9.14	294.26	3.05	0.27	0.028275
SHENANGO	EMERGENCY FLARE / COG RELEASES UNFLARED	SHEN08	578091.10	4483271.00	220	14.02	295.37	4.39	0.58	0.001689
SHENANGO	EMERGENCY FLARE / EMGNCY FLARE-COG FLARING	SHEN09	578091.10	4483271.00	220	14.02	1272.99	20.00	0.58	0.059232
SHENANGO	LIGHT OIL TRUCK AND BARGE	SHEN10	578127.00	4483228.40	220	6.10	294.26	3.05	0.27	0.000006
SHENANGO	MAIN (BLEEDER) FLARE	SHEN11	578211.40	4483202.30	220	30.48	1272.99	20.00	0.61	0.001144
SHENANGO	MISC FUGS, COOLING TWRS	SHEN12	578127.00	4483228.40	220	3.05	294.26	0.03	0.03	0.527150
SHENANGO	PEC BAGHOUSE	SHEN13	578118.00	4483380.00	220	45.72	295.37	19.41	3.05	0.109910
SHENANGO	QUENCH TOWER, BATTERY S-1	SHEN14	578162.70	4483238.40	220	17.07	338.55	4.33	4.57	1.209100
SHENANGO	S-1 PUSHING FUGITIVES / S-1 PUSHING FUGITIVES	SHEN15	578082.40	4483300.80	220	10.36	1033.15	1.59	1.59	0.057168
SHENANGO	SULFEROX VENT / SULFEROX VENT	SHEN16	578080.10	4483114.30	220	17.68	329.10	14.54	0.20	0.043384
SHENANGO	TAR DECANTER SLUDGE RECYL	SHEN17	578127.00	4483228.40	220	7.62	294.26	3.05	0.27	0.000009

APPENDIX D – MMIF Configuration

MMIF meteorological data was used for this demonstration as the most appropriate available data. MMIF version 3.4 was used for the extractions of the WRF data, as prepared for the $PM_{2.5}$ SIP. MMIF Guidance includes recommendations for some settings for MMIF, while allowing for user selection for other settings (Brashers and Emery, 2016). See the SO_2 SIP for a detailed analysis of MMIF for regulatory modeling (ACHD, 2017).

<u>MMIF Output Mode</u>

AERMET-ready output files were selected for the MMIF processing. As such, MMIF data are used for onsite, upper air, and surface characteristic inputs, processed through AERMET to generate AERMOD-ready meteorological files. This is the recommended approach and allows for other options such as ADJ_U*.

<u>MMIF Vertical Layers</u>

ACHD selected the following vertical layers for MMIF, with TOP structure:

20 30 40 60 80 100 125 150 175 200 250 300 350 400 450 500 600 700 800 900 1000 1500 2000 2500 3000 3500 4000 5000

These layers are slightly different than the recommended lowest layers up to 100 m but allow for more characterization in-valley, specifically for the 10 m level winds.

<u>Mixing Height</u>

The user has three different options for mixing heights supplied by MMIF:

- WRF (no recalculation of mixing heights)
- MMIF (MMIF-recalculated mixing heights)
- AERMET (allow AERMET to calculate mixing heights)

The AERMET option was selected for mixing height, allowing for AERMET calculation of mixing height along with ADJ_U* processing. (Note: ADJ_U* can affect several interdependent variables in the boundary layer parameters file (.sfc), including mixing height. Also, turbulence parameters are not included with MMIF, so ADJ_U* is appropriate for use.) The use of AERMET-based mixing heights was deemed to be the best complement for MMIF to AERMOD, more consistent with the overall methodology for the AERMOD modeling system.

<u>MMIF Upper Levels</u>

Based on comparisons to measured sodar and multi-level tower data, wind speeds at upper levels (above 50 m) were found to contain a high bias. This is based on airport/plateau wind speeds built into the WRF and not translating into lower wind speeds to represent localized in-valley flow. (See more details in the SO_2 SIP.)

To eliminate this bias, only surface wind speeds up to the 50 m layer were used from the supplied MMIF ONSITE data. This technique forces AERMOD, which extrapolates hourly data based on any/all supplied measurements, to more realistically calculate the upper levels wind speeds. This may also be a more AERMET-like approach for wind speed, putting more emphasis on AERMET than WRF for vertical profiles.

Wind Speed Threshold

A wind speed threshold of 0.0 m/s was selected for Stage 1 AERMET processing of MMIF data, as recommend by the MMIF Guidance. This allows for all wind speeds generated by the WRF model to be used in the profile (.pfl) file, but a minimum speed of 0.28 m/s is substituted for any hour below this minimum in the boundary layer parameters file (.sfc). The use of MMIF therefore contains no missing or calms data for any hour.

Note: for the SO_2 SIP, a threshold of 0.5 m/s was used for Stage 1 AERMET processing. Overall results with/without a threshold are similar, with some source impacts increasing while others show decreases in impacts. The use of lower thresholds did not affect the highest range (99^{th} percentile) concentrations predicted with the SO_2 attainment modeling.

Post-Processing

As mentioned throughout this document, the use of multiple meteorological data sets requires post-processing. CALPOST was used for the post-processing (see Appendix E).

MMIF Cells

The MMIF cells used for site-specific meteorology for each facility modeled in the demonstration are shown geographically in Figure D-1. The U. S. Steel locations lie within the 444 m resolution WRF grid, while the others fall within the 1.33 km resolution grid.

Figure D-1. MMIF Locations used for the Modeling

APPENDIX E – Post-Processing

For post-processing results from different runs (e.g., using different MMIF cells or different BUOYLINE results), the CALPUFF modeling system post-processors were used.

This required three steps/programs:

- AER2CAL (version 1.21): converts AERMOD post files to CALPUFF format. The AERMOD post files (using the POSTFILE keyword) are in unformatted binary format, with the 1-hour averages for each discrete receptor.

- CALSUM (version 7.0.0): sums the hourly impacts from different runs, matched in time/space.

- CALPOST (version 7.1.0): processes the impacts, generates the selected rank(s) for the impact totals in summary and plot formats.

AER2CAL and CALSUM are related programs with no regulatory status. CALPOST is no longer part of a preferred modeling system (with CALPUFF), but there is no preferred post-processer available with AERMOD. These CALPUFF tools are publicly available and show equivalent results to AERMOD.

To test the equivalence of the default AERMOD processing to the CALPOST post-processing, individual test sources were run in AERMOD and then post-processed and summed with CALPOST. Results were identical between AERMOD (with all sources in one run) and CALPOST, except for some slight differences (±0.01 $\mu g/m^3$) due to CALPOST rounding the impacts to five significant figures, while AERMOD keeps five decimal places.

APPENDIX F – Additional Model Performance Figures

Figures F-1 through F-9 provide individual Q-Q plots by buoyant line methodology for each site and averaging period, shown in logarithmic scale.

<u>Lincoln Hourly</u>

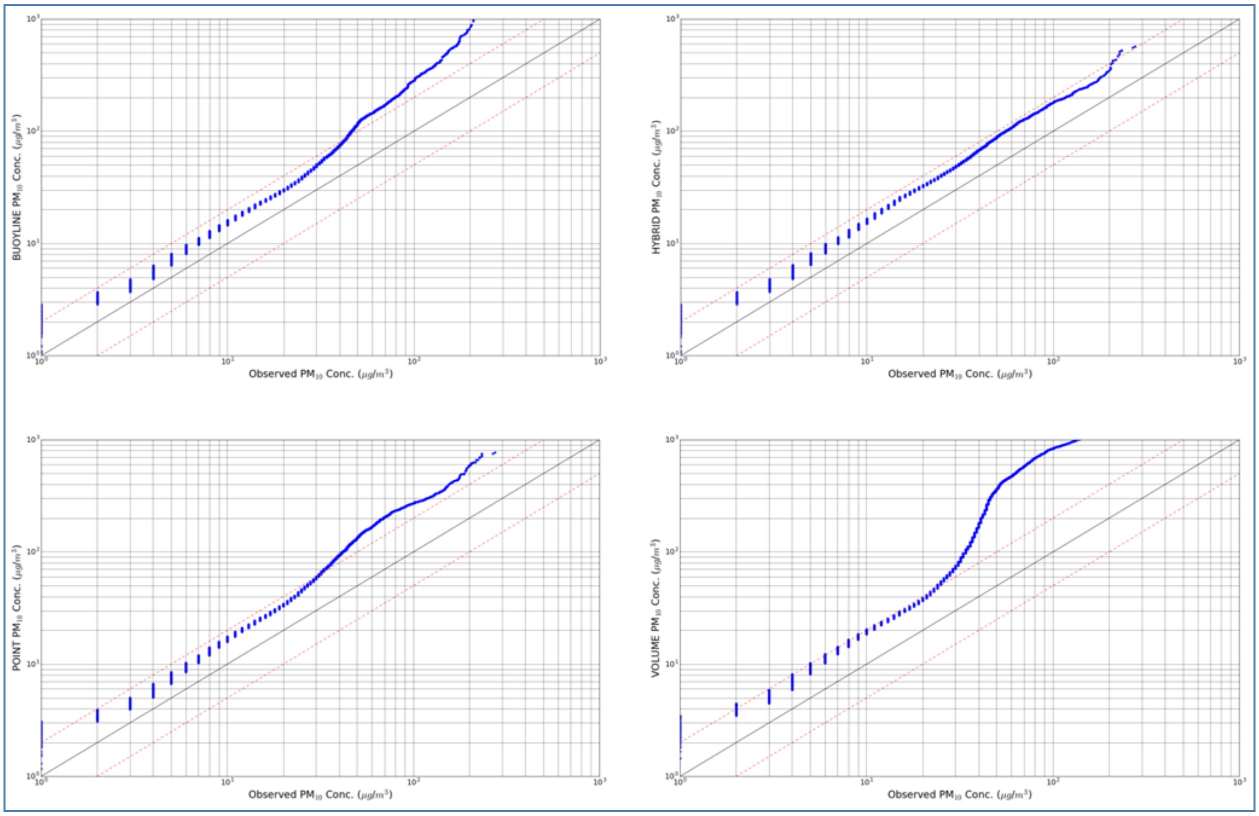


Figure F-1. Lincoln 1-Hour Q-Q Plots, by Buoyant Line Methodology

Lincoln 3-Hour

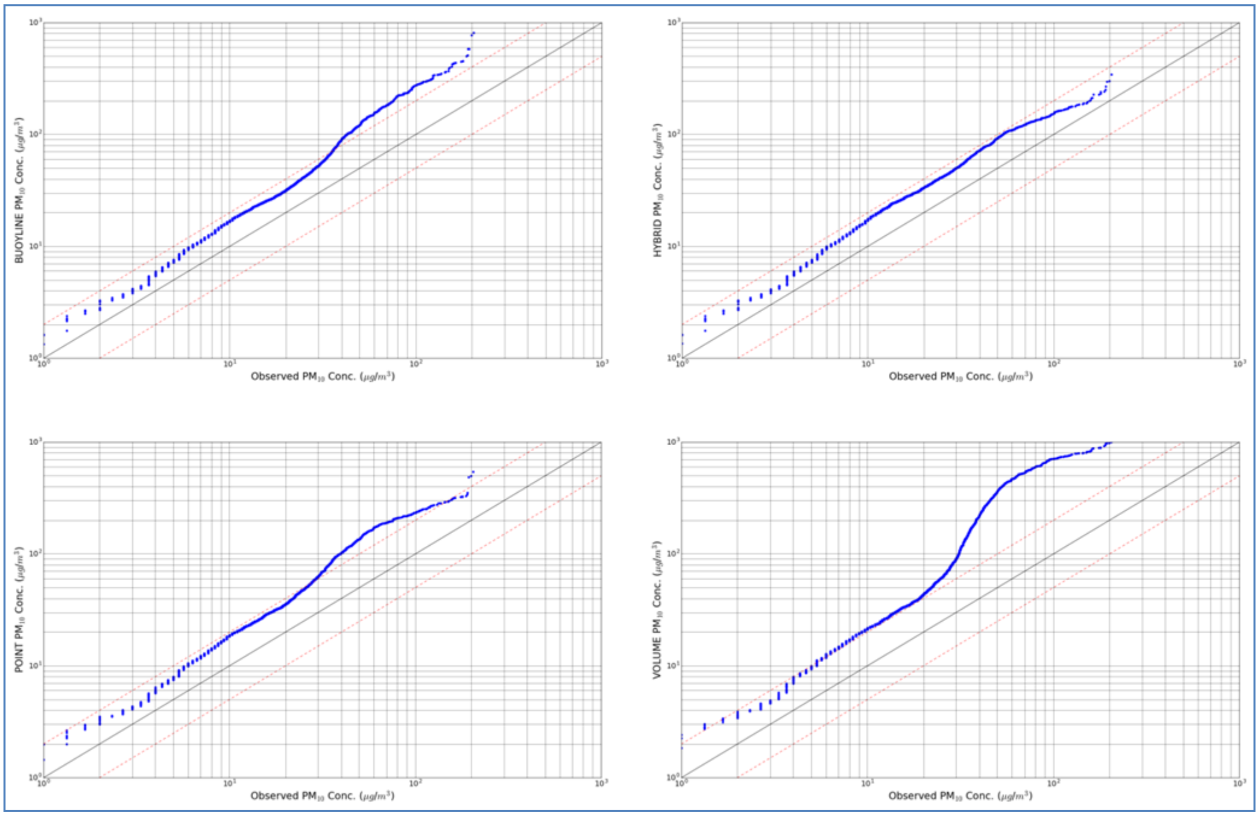


Figure F-2. Lincoln 3-Hour Q-Q Plots, by Buoyant Line Methodology

Lincoln Daily

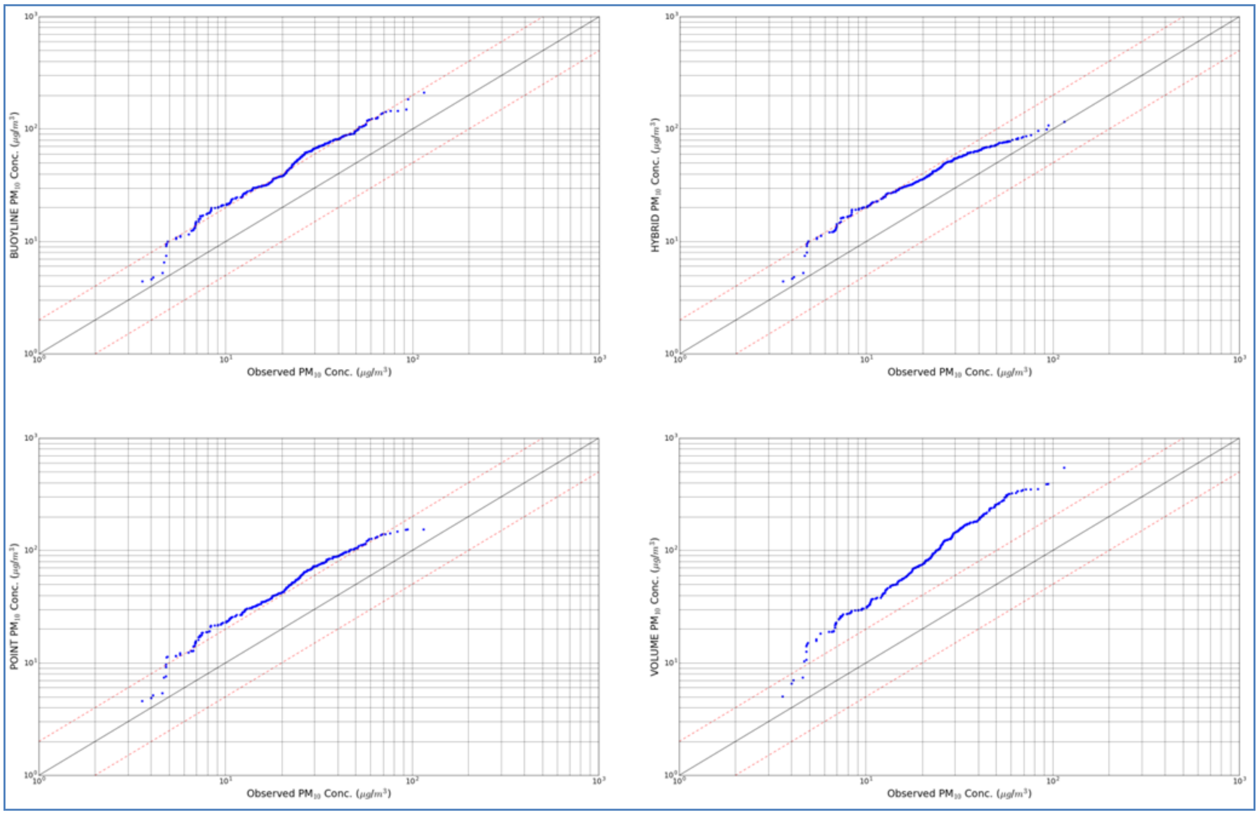


Figure F-3. Lincoln 24-Hour Q-Q Plots, by Buoyant Line Methodology

Liberty Hourly

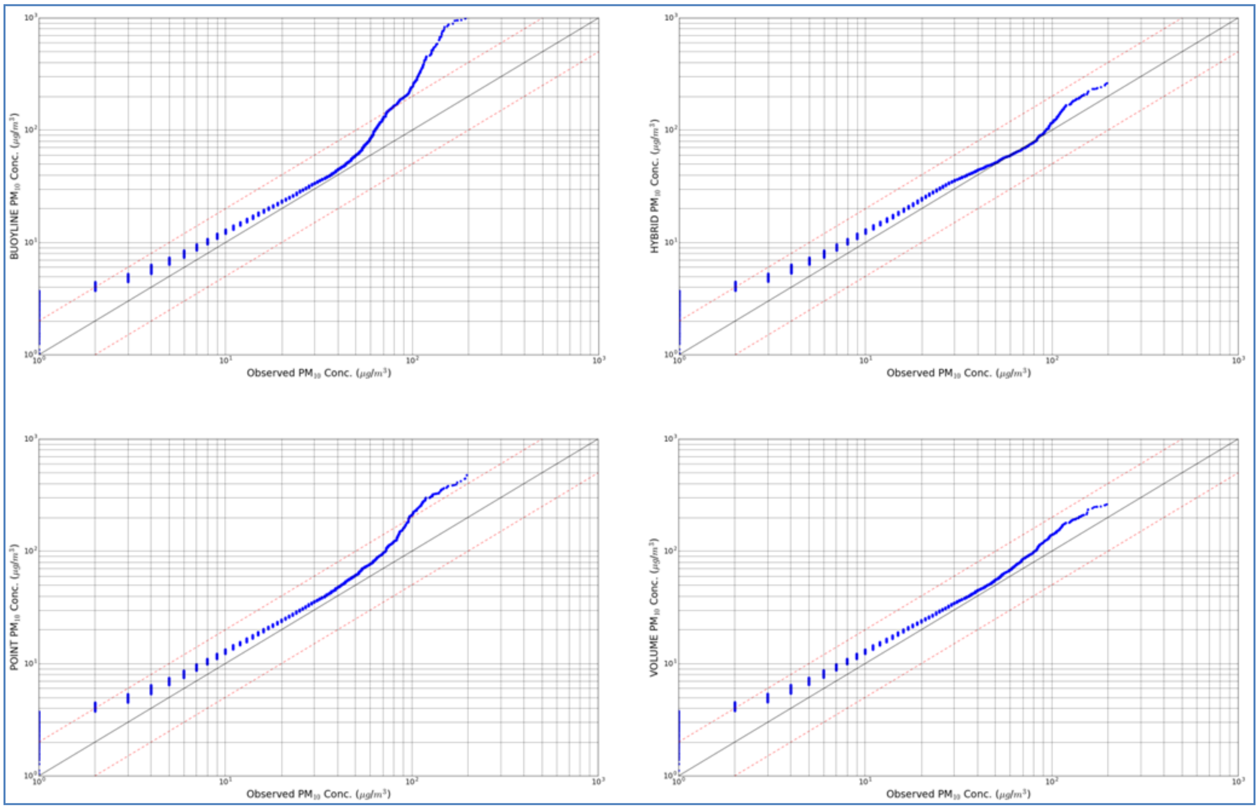


Figure F-4. Liberty 1-Hour Q-Q Plots, by Buoyant Line Methodology

Liberty 3-Hour

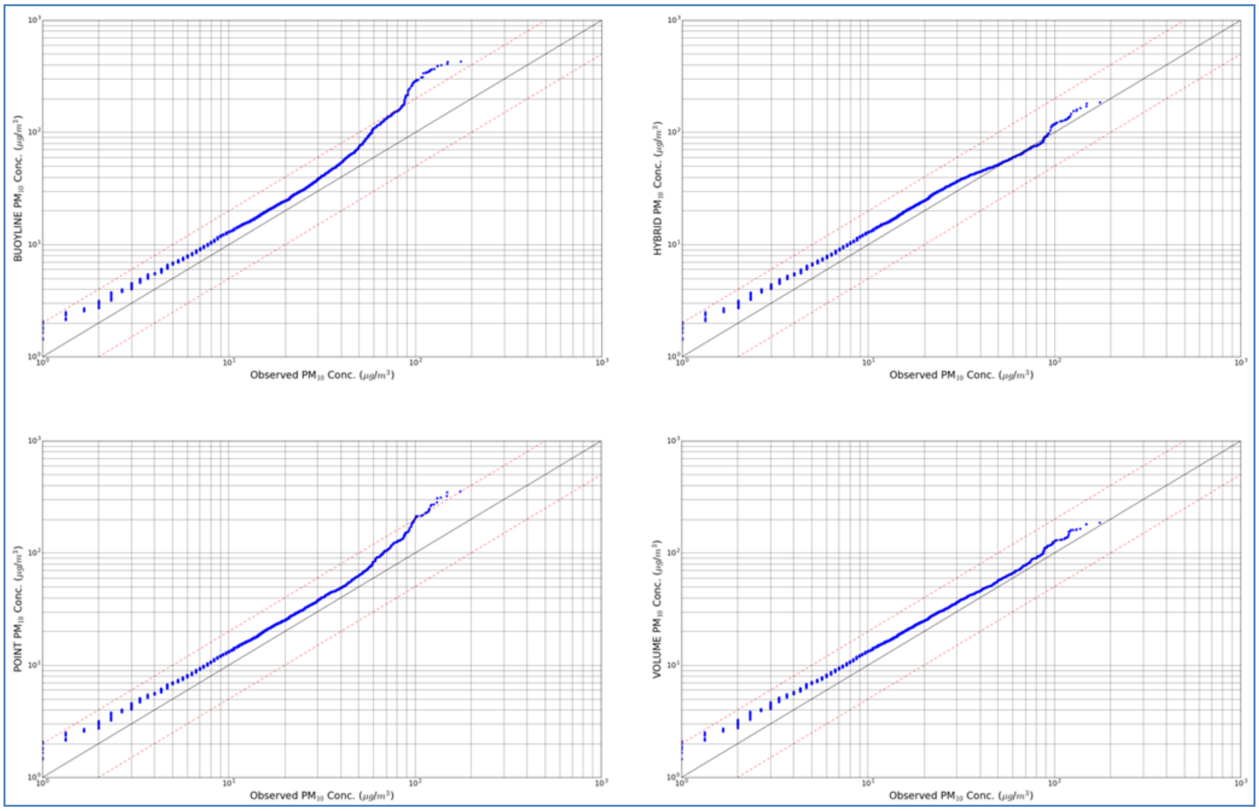


Figure F-5. Liberty 3-Hour Q-Q Plots, by Buoyant Line Methodology

Liberty Daily

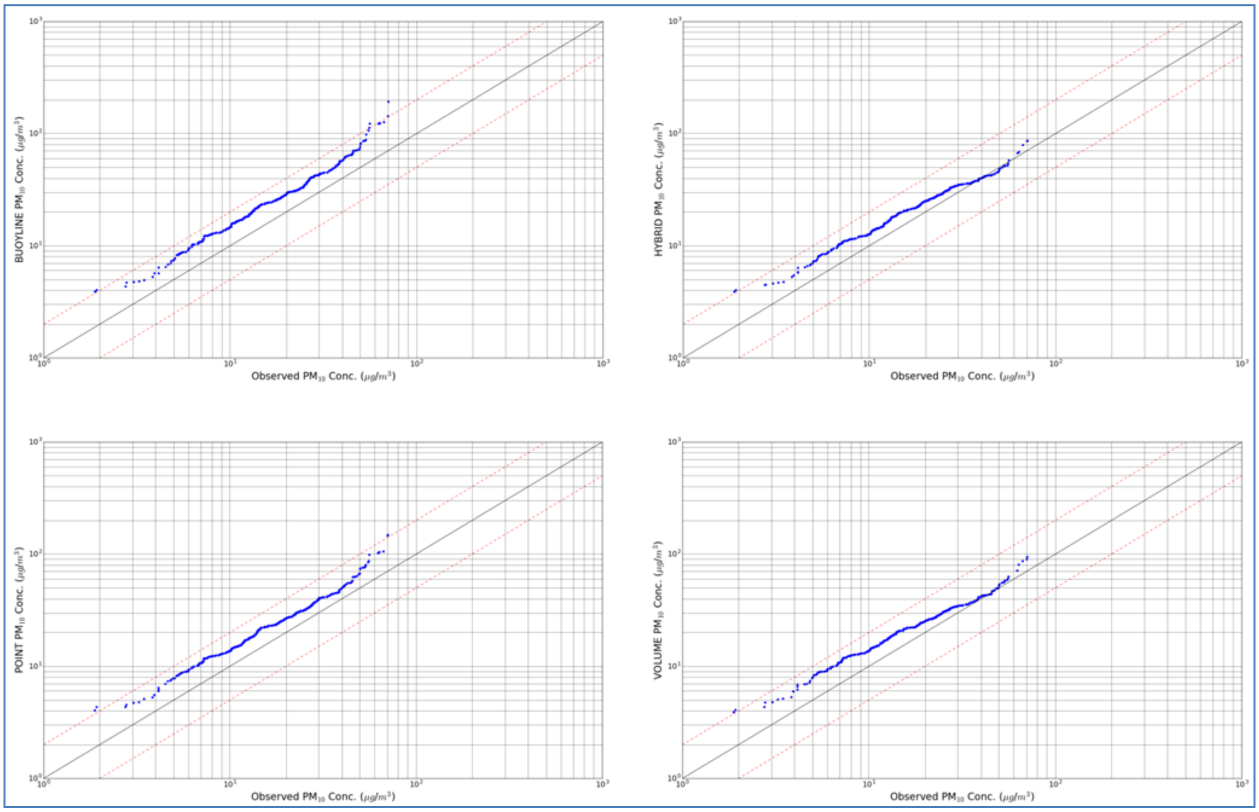


Figure F-6. Liberty 24-Hour Q-Q Plots, by Buoyant Line Methodology

Glassport Hourly

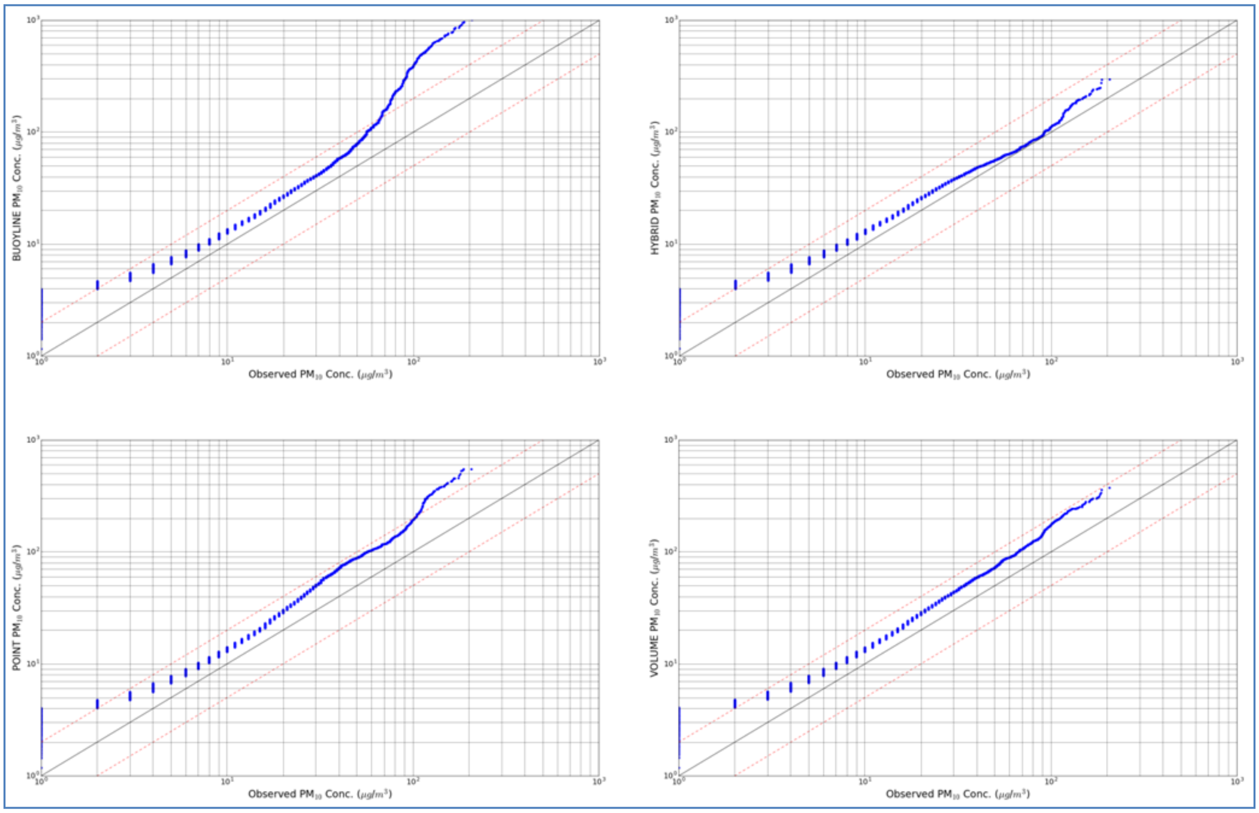


Figure F-7. Glassport 1-Hour Q-Q Plots, by Buoyant Line Methodology

Glassport 3-Hour

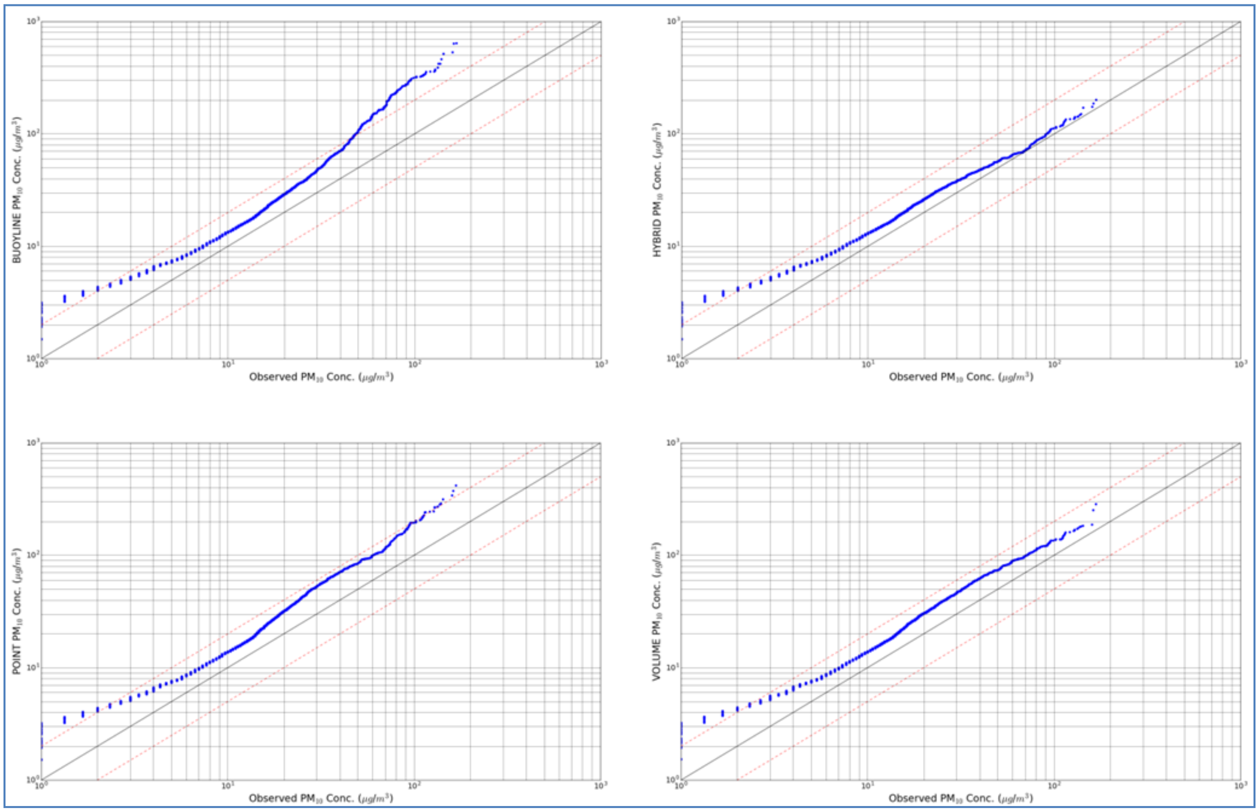


Figure F-8. Glassport 3-Hour Q-Q Plots, by Buoyant Line Methodology

Glassport Daily

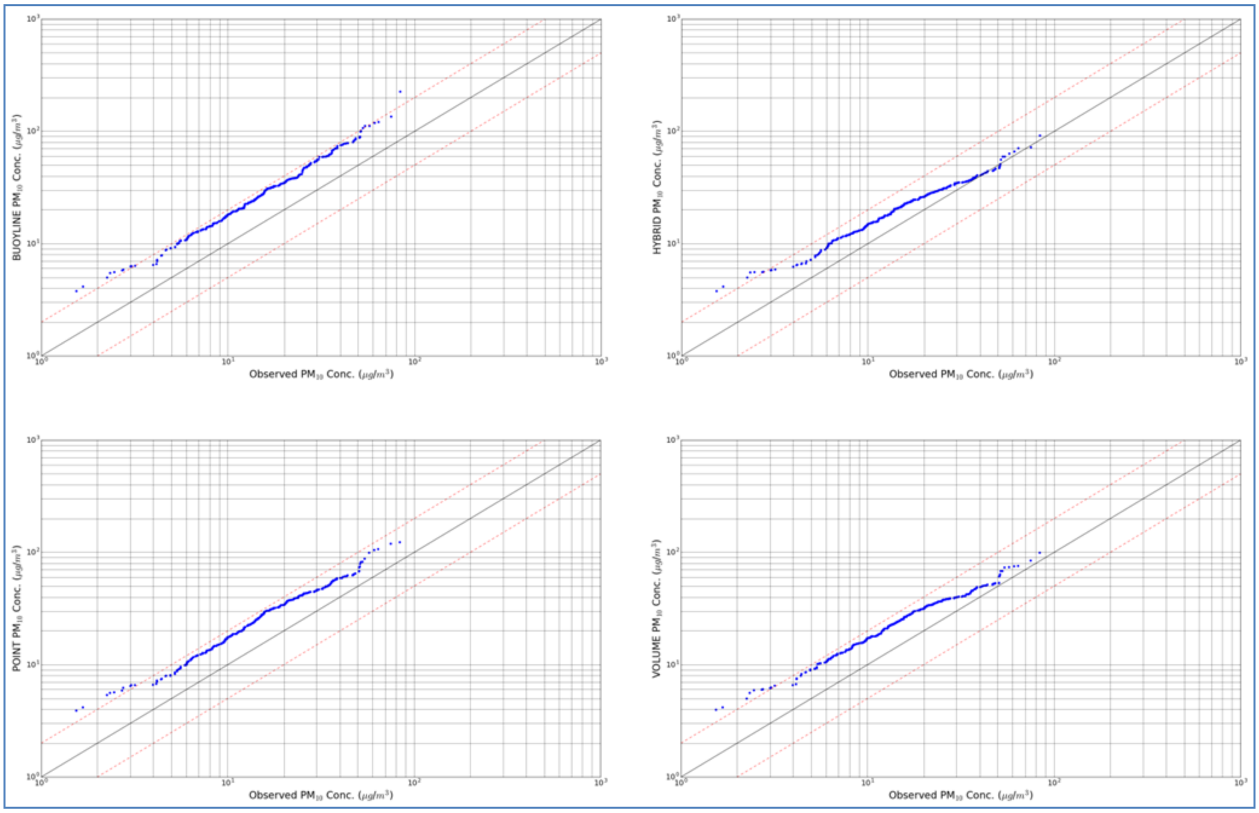


Figure F-9. Glassport 24-Hour Q-Q Plots, by Buoyant Line Methodology

APPENDIX G – Modified BLP Code

(Modifications highlighted in yellow)

```
C***********************************************************************BLP00005
C                                                                       BLP00006
C                          BLP (DATED 99176)                            BLP00010
C                                                                       BLP00060
C             *** SEE BLP MODEL CHANGE BULLETIN MCB#3 ***               BLP00061
C                                                                       BLP00062
C    ON THE SUPPORT CENTER FOR REGULATORY AIR MODELS BULLETIN BOARD     BLP00063
C                                                                       BLP00064
C                             919-541-5742                              BLP00065
C                                                                       BLP00066
C***********************************************************************BLP00070
C                                                                       BLP00080
C      BLP -- MULTIPLE BUOYANT LINE AND POINT SOURCE                    BLP00090
C      DISPERSION MODEL                                                 BLP00100
C                                                                       BLP00110
C                                                                       BLP00120
C                                                                       BLP00130
C      DEVELOPED BY:                                                    BLP00140
C                                                                       BLP00150
C      JOE SCIRE AND LLOYD SCHULMAN                                     BLP00160
C      ENVIRONMENTAL RESEARCH AND TECHNOLOGY                            BLP00170
C      696 VIRGINIA ROAD                                                BLP00180
C      CONCORD, MASSACHUSETTS  01742                                    BLP00190
C                                                                       IBM
C                                                                       BLP00200
C***********************************************************************BLP00210
C
C      MODIFIED BY:
C
C      ROGER W. BRODE
C      PACIFIC ENVIRONMENTAL SERVICES, INC.
C      5001 S. MIAMI BLVD, SUITE 300
C      P.O. BOX 12077
C      RESEARCH TRIANGLE PARK, NC  27709
C
C      June 25, 1999
C
C      Modified to read meteorological data from an ASCII data file,
C      rather than an unformatted data file, using the default ASCII
C      format for ISCST3 generated by PCRAMMET and MPRM.  Also modified
C      to get filenames from the command line using the Lahey LF90
C      GETCL function (based on the ISCST3 model code), and to write
C      the model run date and time to the main output file.  Version
C      date used for output is now defined once in BLOCK DATA as
C      CHARACTER*5 VERSN.  Also modified for Y2K compliance using a
C      date window of 1950 to 2049.
C
C***********************************************************************
C
C
C      ADDITIONAL MODIFICATION BY:
C
C      Jason Maranche, Allegheny County Health Department (ACHD)
C
C      November 2013
C
C      Modified by ACHD in order to generate plume rise output
C      for use in AERMOD.  Original algorithms were developed by
C      Larry Simmons of E2M for the ACHD PM10 SIP workgroup in 1993.
C
C      Code changes indicated by 'ACHDXXXX' at line number.
C
C
C***********************************************************************
C                                                                       BLP00220
C                                                                       BLP00220
      CHARACTER*4 TITLE(20)                                             BLP00230
```

```
      REAL L,LEFF,LD,LELEV                                              BLP00240
      LOGICAL RINPUT,LSHEAR,RDOWNW,RUTMS                                BLP00250
      LOGICAL LMETIN,LMETOT,LTRANS                                      BLP00260
      LOGICAL RCOMPR                                                    BLP00270
      COMMON/SOURCE/NLINES,XLBEG(10),XLEND(10),DEL(10),YSCS(10),QT(10), BLP00280
     1 HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),                 BLP00290
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),     BLP00300
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)      BLP00310
      COMMON/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY,XRSCS(100),          BLP00320
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC                 BLP00330
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP00340
     1 LTRANS                                                           BLP00350
      COMMON/PRLS/XFB,LEFF,LD,R0,XFINAL,XFS                             BLP00360
      COMMON/RINTP/XDIST(7),DH(7)                                       BLP00370
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR BLP00380
      COMMON/METD24/KST(24),SPEED(24),RANDWD(24),HMIX(24),TEMP(24),     BLP00390
     1 DTHTA(2),PEXP(6),IDELS,IDSURF,IYSURF,IDUPER,IYUPER,TERAN(6),     BLP00400
     2 IRU,IHRMAX,LMETIN,LMETOT,IDAYS(366)                              BLP00410
      COMMON/PBLDAT/TWOPBL,PBL1P6                                       BLP00420
      COMMON/OUTPT/IPCL(11),IPCP(51)                                    BLP00430
      COMMON/PARM/CRIT,TER1,DECFAC,XBACKG,CONST2,CONST3,MAXIT           BLP00440
C     COMMON/QA/VERSON,LEVEL                                            BLP00450
      DATA PI/3.1415927/                                                BLP00460
CPES  Begin PES Code Changes

C     Declare ILEN_FLD Parameter, which controls length of filenames.
C     Also declare variables for input and output filenames, version date
C     and model run time and date.
      INTEGER, PARAMETER :: ILEN_FLD = 80
      CHARACTER (LEN=ILEN_FLD) :: INPFIL, OUTFIL, METFIL, CNCFIL
      COMMON/IOFILE/ INPFIL, OUTFIL, METFIL, CNCFIL
      CHARACTER RUNDAT*8, RUNTIM*8, VERSN*5
      COMMON/DATETIME/ RUNDAT, RUNTIM, VERSN

C     Get Date and Time using system-specific functions     ---   CALL DATIME
      CALL DATIME (RUNDAT, RUNTIM)

C     Retrieve Input and Output File Names From Command Line,
C                                                           ---   CALL GETCOM
      CALL GETCOM ('  BLP   ',ILEN_FLD,INPFIL,OUTFIL,CNCFIL,METFIL)

C     Open Input and Output Files                           ---   CALL FILOPN
      CALL FILOPN (ILEN_FLD,INPFIL,OUTFIL,CNCFIL,METFIL)

      WRITE (6,1234) VERSN, RUNDAT, RUNTIM
 1234 FORMAT ('1',21X,'BLP              (DATED ',A5,')',71X,A8/123X,A8/)

CPES  End PES Code Changes
C                                                                       BLP00580
C     READ INPUTS                                                       BLP00590
C                                                                       BLP00600
      CALL INPUT(RINPUT,RDOWNW,TITLE,RUTMS,RCOMPR)                      BLP00610
      IF(.NOT.RINPUT)CALL RECEPT(RUTMS)                                 BLP00620
C
C     WRITE HEADERS FOR PLUME RISE HEIGHTS AND DISTANCES                ACHD0621
      IF(.NOT.LMETOT)THEN                                               ACHD0622
      WRITE(6,2222)                                                     ACHD0623
2222  FORMAT(1X,'PLUME RISE HEIGHTS AND DISTANCES OUTPUT'//             ACHD0624
     1 3X,'YR',1X,'JDAY',2X,'HR',5X,'DH1',5X,'DH2',5X,'DH3',5X,'DH4',   ACHD0625
     2 5X,'DH5',5X,'DH6',5X,'DH7',5X,'XF1',5X,'XF2',5X,'XF3',5X,'XF4',  ACHD0626
     3 5X,'XF5',5X,'XF6',5X,'XF7',7X,'XFB',5X,'XFS')                    ACHD0627
      END IF                                                            ACHD0628
C
C                                                                       BLP00630
C     WRITE RUN INFORMATION TO RECORD #1 OF OUTPUT FILE (20)            BLP00640
C                                                                       BLP00650
      CALL OUTITL(TITLE,NREC,NPTS,NLINES,IPCL,IPCP,IYR,IDAYS,RCOMPR)    BLP00660
      IF(NLINES.LT.1)GO TO 21                                           BLP00670
      DO 20 I=1,NLINES                                                  BLP00680
20    DEL(I)=XLEND(I)-XLBEG(I)                                          BLP00690
21    CONTINUE                                                          BLP00700
```

```
      IF(NPTS.LE.0)GO TO 520                                            BLP00710
C                                                                       BLP00720
C     IF THE POINT SOURCE DOWNWASH OPTION IS REQUESTED,                 BLP00730
C     DEFINE THE RECTANGLE OF INFLUENCE (IN SCS COORDINATES)            BLP00740
C     FOR THE DOWNWASH CALCULATIONS                                     BLP00750
C                                                                       BLP00760
      IF(.NOT.RDOWNW)GO TO 520                                          BLP00770
      THREHB=3.*HB                                                      BLP00780
      TWOHB=2.*HB                                                       BLP00790
      HALFWB=WB/2.                                                      BLP00800
      XAMIN=-TWOHB                                                      BLP00810
      XAMAX=L+TWOHB                                                     BLP00820
      YAMIN=-HALFWB-TWOHB                                               BLP00830
      YAMAX=(NLINES-1)*(DX+WB)+HALFWB+TWOHB                             BLP00840
C     FOR THOSE POINTS WITHIN THE REGION OF BUILDING DOWNWASH           BLP00850
C     EFFECTS AND WITH STACK HEIGHTS < 3*HB, SET                        BLP00860
C     IDOWNW (POINT #) = 1                                              BLP00870
      DO 505 I=1,NPTS                                                   BLP00880
      IF(PHS(I).GE.THREHB)GO TO 505                                     BLP00890
      IF(XPSCS(I).LT.XAMIN.OR.XPSCS(I).GT.XAMAX)GO TO 505               BLP00900
      IF(YPSCS(I).LT.YAMIN.OR.YPSCS(I).GT.YAMAX)GO TO 505               BLP00910
      IDOWNW(I)=1                                                       BLP00920
505   CONTINUE                                                          BLP00930
520   CONTINUE                                                          BLP00940
      IF(LMETIN)GO TO 1212                                              BLP00950
C     READ STATION CODES AND YEAR OF METEOROLOGICAL DATA                BLP00960
CPES  Begin PES Code Changes

      READ(2,*)IDS,IYS,IDU,IYU

CPES  End PES Code Changes
      IF(IDS.EQ.IDSURF.AND.IYS.EQ.IYSURF.AND.IDU.EQ.IDUPER.AND.         BLP00980
     1 IYU.EQ.IYUPER)GO TO 1212                                         BLP00990
      WRITE(6,1211)IDSURF,IYSURF,IDS,IYS,IDUPER,IYUPER,IDU,IYU          BLP01000
1211  FORMAT('1','REQUESTED STATION ID OR YEAR DOES NOT MATCH ',        BLP01010
     1 'THAT READ FROM THE MET. DATA FILE -- RUN TERMINATED'/           BLP01020
     2 '0',2X,'REQUESTED SURFACE DATA: ID = ',I5,3X,'YEAR = ',I4/       BLP01030
     3 10X,'MET. DATA READS: ID = ',I5,3X,'YEAR = ',I4/                 BLP01040
     4 '0','REQUESTED UPPER AIR DATA: ID = ',I5,3X,'YEAR = ',I4/        BLP01050
     5 10X,'MET. DATA FILE READS: ID = ',I5,3X,'YEAR = ',I4)            BLP01060
C     CALL WAUDIT
      STOP                                                              BLP01070
1212  CONTINUE                                                          BLP01080
C     CALCULATE DISTANCE (FROM XFB) TO FINAL NEUTRAL PLUME RISE         BLP01090
C     ASSUMING PLUMES INTERACT BEFORE REACHING TERMINAL RISE            BLP01100
      FBRG=N*FPRIME/PI                                                  BLP01110
      IF(FBRG.GT.55.)GO TO 10                                           BLP01120
C     THE CONSTANT 49 = 3.5*14.                                         BLP01130
      XFINAL=49.*FBRG**0.625                                            BLP01140
      GO TO 15                                                          BLP01150
10    XFINAL=3.5*CONST3*FBRG**0.4                                       BLP01160
15    CONTINUE                                                          BLP01170
      XMATCH=XFINAL                                                     BLP01180
C                                                                       BLP01190
C     ENTER MAIN LOOP                                                   BLP01200
C                                                                       BLP01210
      ISTART=1                                                          BLP01220
      DO 135 I=1,366                                                    BLP01230
      II=367-I                                                          BLP01240
      IF(IDAYS(II).NE.1)GO TO 135                                       BLP01250
      LASTDY=II                                                         BLP01260
      GO TO 137                                                         BLP01270
135   CONTINUE                                                          BLP01280
      WRITE(6,136)                                                      BLP01290
136   FORMAT(///'0','EXECUTION TERMINATING -- NO ELEMENTS OF ',         BLP01300
     1 'IDAYS ARRAY ARE EQUAL TO ONE')                                  BLP01310
C     CALL WAUDIT
      STOP                                                              BLP01320
137   CONTINUE                                                          BLP01330
      IF(LMETIN)LASTDY=1                                                BLP01340
      WRITE(6,1401)                                                     BLP01350
```

```
1401  FORMAT('1')                                                       BLP01360
      DO 1002 IDAY=ISTART,LASTDY                                        BLP01370
CPES  Begin PES Code Changes

C     READ METEOROLOGICAL DATA AND RETURN JULIAN DAY (JDAY) FROM DATA FILE

      CALL MET(JDAY)

C     Check for Proper Date Sequence
      IF (IDAY .NE. JDAY) THEN
         WRITE(*,*) 'MET DATA SEQUENCE ERROR AT JDAY = ',JDAY
         WRITE(6,*) 'MET DATA SEQUENCE ERROR AT JDAY = ',JDAY
         STOP
      END IF

CPES  End PES Code Changes
      IF(IDAYS(IDAY).NE.1)GO TO 1002                                    BLP01410
C                                                                       BLP01420
      DO 1000 IHR=1,IHRMAX                                              BLP01430
C                                                                       BLP01440
      IHOUR=IHR                                                         BLP01450
      ISTAB=KST(IHR)                                                    BLP01460
      TER1=1.-TERAN(ISTAB)                                              BLP01470
      P=PEXP(ISTAB)                                                     BLP01480
      TDEGK=TEMP(IHR)                                                   BLP01490
      IF(ISTAB.GT.4)S=9.80616*DTHTA(ISTAB-4)/TDEGK                      BLP01500
      WS=SPEED(IHR)                                                     BLP01510
      WD=RANDWD(IHR)                                                    BLP01520
C     CONVERT WD (FROM PREPROCESSOR) TO WD IN THE REGULAR               BLP01530
C     METEOROLOGICAL SENSE (I.E., 0=NORTH WIND,90=EAST WIND,            BLP01540
C     180=SOUTH WIND,270=WEST WIND)                                     BLP01550
      WD1=WD+180.                                                       BLP01560
      WD1=AMOD(WD1,360.)                                                BLP01570
      THETA=360.-(WD1+TCOR)                                             BLP01580
      IF(THETA.LT.0.0)THETA=360.+THETA                                  BLP01590
      THETA=AMOD(THETA,360.)                                            BLP01600
      DPBL=HMIX(IHR)                                                    BLP01610
      TWOPBL=2.*DPBL                                                    BLP01620
      PBL1P6=1.6*DPBL                                                   BLP01630
      CALL COORD(THETA)                                                 BLP01640
      CALL CONTRB(RCOMPR)                                               BLP01650
1000  CONTINUE                                                          BLP01660
1002  CONTINUE                                                          BLP01670
      WRITE(6,1005)JDAY                                                 BLP01680
1005  FORMAT(/////'0',30X,'LAST DAY PROCESSED = ',I3)                   BLP01690
C
C     CALL WAUDIT
      STOP                                                              BLP01700
      END                                                               BLP01710
CPES  Begin PES Code Changes

      SUBROUTINE GETCOM (MODEL,LENGTH,INPFIL,OUTFIL,CNCFIL,METFIL)
C***********************************************************************
C
C        ADAPTED FROM PCCODE Module of ISC2 Short Term Model - ISCST2
C
C        PURPOSE: Controls Retrieving Input and Output File Names From
C                 the Command Line for PCs
C
C        PROGRAMMER: Roger Brode
C
C        DATE:    March 2, 1992
C
C        MODIFIED:   To use ILEN_FLD (passed in as LENGTH) to define
C                    the length of the INPFIL and OUTFIL variables,
C                    and to specify length of the command line as
C                    a PARAMETER, initially set to 150.  Also set up
C                    conditional compilation statements (commented out)
C                    to facilitate compilation by DEC Visual Fortran.
C                    R.W. Brode, PES, Inc. - 12/2/98
C
```

```
C        MODIFIED:   Jayant Hardikar, PES, Inc.
C                    - Length of command line for Lahey version changed
C                      from 80 to 120 characters - 4/19/93
C                    - Adapted for DEPMET/PMERGE - 7/29/94
C
C        INPUTS:  Command Line
C
C        OUTPUTS: Input Runstream File Name
C                 Output Print File Name
C
C        CALLED FROM:   MAIN
C***********************************************************************
C
C     Variable Declarations
      IMPLICIT NONE

      INTEGER LENGTH
      CHARACTER (LEN=LENGTH) :: INPFIL, OUTFIL, CNCFIL, METFIL
      CHARACTER (LEN=8)      :: MODEL
C     Declare the COMLIN Variable to Hold Contents of Command Line for Lahey
      INTEGER , PARAMETER :: LENCL = 150
      CHARACTER (LEN=LENCL) :: COMLIN
      INTEGER LOCB(LENCL), LOCE(LENCL), I, IFCNT
      LOGICAL INFLD

      COMLIN = ' '
      METFIL = ' '

C*************************************************************LAHEY START
C     Use Lahey Function GETCL To Retrieve Contents of Command Line.
C     Retrieve Input and Output File Names From the COMLIN Variable.
      CALL GETCL(COMLIN)
      INFLD = .FALSE.
      IFCNT = 0
      DO I = 1, LENCL
         IF (.NOT.INFLD .AND. COMLIN(I:I) .NE. ' ') THEN
            INFLD = .TRUE.
            IFCNT = IFCNT + 1
            LOCB(IFCNT) = I
         ELSE IF (INFLD .AND. COMLIN(I:I) .EQ. ' ') THEN
            INFLD = .FALSE.
            LOCE(IFCNT) = I - 1
         END IF
      END DO
      IF (IFCNT .LT. 3 .OR. IFCNT .GT. 4) THEN
C        Error on Command Line.  Write Error Message and STOP
         WRITE(*,660) MODEL
         STOP
      END IF
      INPFIL = COMLIN(LOCB(1):LOCE(1))
      OUTFIL = COMLIN(LOCB(2):LOCE(2))
      CNCFIL = COMLIN(LOCB(3):LOCE(3))
C     Check for Optional Argument for Preprocessed Met Data File
      IF (IFCNT .EQ. 4) THEN
         METFIL = COMLIN(LOCB(4):LOCE(4))
      END IF

C*************************************************************LAHEY STOP

  660 FORMAT (' COMMAND LINE ERROR: ',A8,' input_file output_file',
     &        ' concen_file [metdata_file]')

      RETURN
      END


      SUBROUTINE DATIME ( DCALL, TCALL )
C***********************************************************************
C                 DATIME Module
C
C        PURPOSE: Obtain the system date and time
```

```
C
C        PROGRAMMER: Jim Paumier, PES, Inc.
C
C        DATE:    April 15, 1994
C
C        MODIFIED:   Uses Fortran 90 DATE_AND_TIME routine.
C                    R.W. Brode, PES, 8/14/98
C
C        INPUTS:  none
C
C        OUTPUTS: Date and time in character format
C
C        CALLED FROM:  RUNTIME
C***********************************************************************
C
C     Variable Declarations
      IMPLICIT NONE

      CHARACTER DCALL*8, TCALL*8
      CHARACTER CDATE*8, CTIME*10, CZONE*5
      INTEGER  :: IDATETIME(8)
      INTEGER  :: IPTYR, IPTMON, IPTDAY, IPTHR, IPTMIN, IPTSEC

      DCALL = ' '
      TCALL = ' '

C     Call date and time routine
      CALL DATE_AND_TIME (CDATE, CTIME, CZONE, IDATETIME)

C     Convert year to two digits and store array variables
      IPTYR  = IDATETIME(1) - 100 * INT(IDATETIME(1)/100)
      IPTMON = IDATETIME(2)
      IPTDAY = IDATETIME(3)
      IPTHR  = IDATETIME(5)
      IPTMIN = IDATETIME(6)
      IPTSEC = IDATETIME(7)

C     Write Date and Time to Character Variables, DCALL & TCALL
      WRITE(DCALL, '(2(I2.2,"/"),I2.2)' ) IPTMON, IPTDAY, IPTYR
      WRITE(TCALL, '(2(I2.2,":"),I2.2)' ) IPTHR, IPTMIN, IPTSEC

      RETURN
      END

      SUBROUTINE FILOPN (LENGTH,INPFIL,OUTFIL,CNCFIL,METFIL)
C***********************************************************************
C                 FILOPN Module
C
C        PURPOSE: Opens Input and Output Files
C
C        PROGRAMMER: Roger Brode, PES, Inc.
C
C        DATE:    December 6, 1994
C
C        INPUTS:  Input filename, INPFIL
C                 Output filename, OUTFIL
C                 Concentration filename, CNCFIL
C                 Met Data filename, METFIL
C
C        OUTPUTS: Openned files
C
C        CALLED FROM:  MAIN
C
C        ERROR HANDLING:   Checks errors opening files
C***********************************************************************
C
C     Variable Declarations
      IMPLICIT NONE

      INTEGER LENGTH
      CHARACTER (LEN=LENGTH) :: INPFIL, OUTFIL, CNCFIL, METFIL
```

```
      CHARACTER DUMMY*8

      SAVE

C     OPEN Input Runstream File, Unit = 5
      DUMMY = 'RUN-STRM'
      OPEN (UNIT=5,FILE=INPFIL,ERR=99,STATUS='OLD')

C     OPEN Print Output File, Unit = 6
      DUMMY = 'OUTPUT'
CLF90 The CARRIAGECONTROL specifier in the following statement is a
CLF90 non-standard Lahey language extension (also supported by DEC VF),
CLF90 and may need to be removed for portability of the code.
      OPEN (UNIT=6,FILE=OUTFIL,CARRIAGECONTROL='FORTRAN',
     &      ERR=99,STATUS='UNKNOWN')

C     OPEN Output Concentration Data File, Unit = 20
      DUMMY = 'CONCDATA'
      OPEN (UNIT=20,FILE=CNCFIL,FORM='UNFORMATTED',ERR=99,
     &      STATUS='UNKNOWN')

      IF (METFIL .NE. ' ') THEN
C        OPEN Meteorological Data File, Unit = 2
         DUMMY = 'METDATA'
         OPEN (UNIT=2,FILE=METFIL,ERR=99,STATUS='OLD')
      END IF

      GO TO 1000

C     WRITE Error Message:  Error Opening File
 99   WRITE(*,*) 'Error Opening File: ', DUMMY
      STOP

 1000 CONTINUE

      RETURN
      END

CPES  End PES Code Changes
C
      SUBROUTINE INPUT(RINPUT,RDOWNW,TITLE,RUTMS,RCOMPR)                BLP01720
C                                                                       BLP01730
C                                                                       BLP01740
      REAL*8 RXBEG,RYBEG,RXEND,RYEND,XBASE,YBASE,XCOORD,YCOORD          BLP01750
      REAL*8 XLBEG,XLEND,YLBEG,YLEND                                    BLP01760
      REAL*8 ANGRD,SINT,COST,XB1,XE1,YB1,YE1,EX,EY                      BLP01770
      REAL*8 YLBS,YLES                                                  BLP01780
      REAL YLBEG1(10),YLEND1(10)                                        BLP01790
      REAL L,LELEV                                                      BLP01800
      REAL DIAM(50)                                                     BLP01810
      LOGICAL RINPUT,LINPUT,LUTMS,LPART,LSHEAR,RDOWNW,LDOWNW,LFALSE     BLP01820
      LOGICAL LMETOT,LMETIN,LTRANS,RUTMS                                BLP01830
      LOGICAL LCOMPR,RCOMPR                                             BLP01840
      CHARACTER*4 TITLE(20)
      CHARACTER*4 ALPYES,ALP1,ALP2,ALP3,ALP4,ALP5,ALP6
C                                                                       BLP01850
C     COMMON BLOCKS                                                     BLP01860
C                                                                       BLP01870
      COMMON/SOURCE/NLINES,XLBEG1(10),XLEND1(10),DEL(10),YSCS(10),      BLP01880
     1 QT(10),HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),          BLP01890
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),     BLP01900
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)      BLP01910
      COMMON/RCEPT/RXBEG1,RYBEG1,RXEND1,RYEND1,RDX,RDY,XRSCS(100),      BLP01920
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC                 BLP01930
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP01940
     1 LTRANS                                                           BLP01950
      COMMON/OUTPT/IPCL(11),IPCP(51)                                    BLP01960
      COMMON/PARM/CRIT,TER1,DECFAC,XBACKG,CONST2,CONST3,MAXIT           BLP01970
      COMMON/METD24/KST(24),SPEED(24),RANDWD(24),HMIX(24),TEMP(24),     BLP01980
     1 DTHTA(2),PEXP(6),IDELS,IDSURF,IYSURF,IDUPER,IYUPER,TERAN(6),     BLP01990
     2 IRU,IHRMAX,LMETIN,LMETOT,IDAYS(366)                              BLP02000
```

```
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR
C     COMMON/QA/VERSON,LEVEL
CPES  Begin PES Code Changes

      CHARACTER RUNDAT*8, RUNTIM*8, VERSN*5
      COMMON/DATETIME/ RUNDAT, RUNTIM, VERSN

CPES  End PES Code Changes
C
C     NAMELIST STATEMENTS
C
      NAMELIST/GEN/NLINES,NPTS,NREC,LINPUT,LUTMS,LPART,LDOWNW,LSHEAR,
     1 LTRANS,TCOR,LCOMPR
      NAMELIST/RISE/L,HB,WB,WM,FPRIME,DX
      NAMELIST/METIN/ZMEAS,DTHTA,PEXP,IDSURF,IYSURF,IDUPER,IYUPER,
     1 IDELS,IRU,IDAYS,LMETIN,LMETOT
      NAMELIST/CALC/CRIT,TERAN,DECFAC,XBACKG,CONST2,CONST3,MAXIT
      NAMELIST/OUTPUT/IPCL,IPCP
      NAMELIST/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY
C
      DATA LINPUT/.FALSE./,LUTMS/.FALSE./,LPART/.FALSE./
      DATA LDOWNW/.TRUE./,LFALSE/.FALSE./,LCOMPR/.FALSE./
      DATA ALPYES/'YES'/,ALP1/'NO'/
      DATA ALP2/'NO'/,ALP3/'NO'/,ALP4/'NO'/,ALP5/'NO'/,ALP6/'NO'/
      DATA RAD/0.017453293/
      DATA MAXL/10/,MAXP/50/,MAXR/100/
      DATA TEN6/1.E6/
C
C     READ TITLE CARD
C
      READ(5,7)TITLE
7     FORMAT(20A4)
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM
1400  FORMAT('1',11X,'BLP -- MULTIPLE BUOYANT LINE AND POINT ',
     1'SOURCE DISPERSION MODEL     SCRAM VERSION (DATED ',A5,')',17X,A8,
     2/,123X,A8 / ' ',13('**********'))

CPES  End PES Code Changes
      WRITE(6,8)TITLE
8     FORMAT(/'0',20A4)
C
C     READ NUMBER OF SOURCES AND FORMAT OF INPUTS (GEN NAMELIST)
C
      READ(5,GEN)
      WRITE(6,GEN)
      N=NLINES
      RINPUT=LINPUT
      RUTMS=LUTMS
      RCOMPR=LCOMPR
      IF(NLINES.LE.0)LDOWNW=LFALSE
      RDOWNW=LDOWNW
      IF(NLINES.GT.MAXL)GO TO 700
      IF(NPTS.GT.MAXP)GO TO 702
      IF(NREC.GT.MAXR)GO TO 704
C
C     READ PARAMETERS USED IN LINE SOURCE PLUME RISE
C     CALCULATIONS (RISE NAMELIST)
C
      IF(NLINES.LT.1)GO TO 49
      READ(5,RISE)
      WRITE(6,RISE)
C
C     READ RECEPTOR INFORMATION (RCEPT NAMELIST)
C
C     IF LINPUT (RINPUT) = .TRUE., INPUT COORDINATES OF EACH RECEPTOR
C     OTHERWISE, INPUT RECEPTOR GRID BOUDARIES AND SPACING AND A
C     RECTANGULAR RECEPTOR GRID WILL BE GENERATED (UP TO 100 RECEPTORS)
49    CONTINUE
      IF(RINPUT)GO TO 25
```

```
      READ(5,RCEPT)                                                     BLP02620
      WRITE(6,RCEPT)                                                    BLP02630
      XBASE=0.0                                                         BLP02640
      YBASE=0.0                                                         BLP02650
      IF(.NOT.LUTMS)GO TO 61                                            BLP02660
      XBASE=RXBEG                                                       BLP02670
      YBASE=RYBEG                                                       BLP02680
61    CONTINUE                                                          BLP02690
      RXBEG1=RXBEG-XBASE                                                BLP02700
      RYBEG1=RYBEG-YBASE                                                BLP02710
      RXEND1=RXEND-XBASE                                                BLP02720
      RYEND1=RYEND-YBASE                                                BLP02730
25    CONTINUE                                                          BLP02740
C                                                                       BLP02750
C     READ MET. DATA PARAMETERS (METIN NAMELIST)                        BLP02760
C                                                                       BLP02770
      READ(5,METIN)                                                     BLP02780
      WRITE(6,METIN)                                                    BLP02790
      IF(IYSURF.EQ.IYUPER)GO TO 55                                      BLP02800
      WRITE(6,56)IYSURF,IYUPER                                          BLP02810
56    FORMAT('1','RUN TERMINATED -- YEAR REQUESTED FOR SURFACE AND ',   BLP02820
     1 'UPPER AIR MET. DATA DO NOT MATCH'/'0','IYSURF = ',I4,           BLP02830
     2 5X,'IYUPER = ',I4)                                               BLP02840
C     CALL WAUDIT
      STOP                                                              BLP02850
55    CONTINUE                                                          BLP02860
      IYR=IYSURF                                                        BLP02870
      IF(LMETIN)IDAYS(1)=1                                              BLP02880
      IF(MOD(IYSURF,4).NE.0)IDAYS(366)=0                                BLP02890
C                                                                       BLP02900
C     READ DECAY RATE, TERRAIN CORRECTION FACTOR, CONVERGENCE           BLP02910
C     CRITERION, ITERATION LIMIT (CALC NAMELIST)                        BLP02920
C                                                                       BLP02930
      READ(5,CALC)                                                      BLP02940
      WRITE(6,CALC)                                                     BLP02950
C                                                                       BLP02960
C     READ WHICH SOURCES (IF ANY) TO HAVE PARTIAL                       BLP02970
C     CONCENTRATION OUTPUT (OUTPUT NAMELIST)                            BLP02980
C                                                                       BLP02990
      IF(.NOT.LPART)GO TO 118                                           BLP03000
      READ(5,OUTPUT)                                                    BLP03010
      WRITE(6,OUTPUT)                                                   BLP03020
118   CONTINUE                                                          BLP03030
C                                                                       BLP03040
C     READ COORDINATES OF USER SPECIFIED RECEPTORS                      BLP03050
C                                                                       BLP03060
      IF(.NOT.RINPUT)GO TO 40                                           BLP03070
      IF(LUTMS)GO TO 36                                                 BLP03080
C     READ RECEPTOR COORDINATES IN SCS UNITS                            BLP03090
      DO 27 I=1,NREC                                                    BLP03100
27    READ(5,28)XRSCS(I),YRSCS(I),RELEV(I)                              BLP03110
28    FORMAT(3F10.1)                                                    BLP03120
      XBASE=0.0                                                         BLP03130
      YBASE=0.0                                                         BLP03140
      GO TO 40                                                          BLP03150
C     READ RECEPTOR COORDINATES IN UTM UNITS                            BLP03160
36    READ(5,28)XBASE,YBASE,RELEV(1)                                    BLP03170
      XRSCS(1)=0.0                                                      BLP03180
      YRSCS(1)=0.0                                                      BLP03190
      IF(NREC.LE.1)GO TO 40                                             BLP03200
      DO 37 I=2,NREC                                                    BLP03210
      READ(5,28)XCOORD,YCOORD,RELEV(I)                                  BLP03220
      XRSCS(I)=XCOORD-XBASE                                             BLP03230
      YRSCS(I)=YCOORD-YBASE                                             BLP03240
37    CONTINUE                                                          BLP03250
40    CONTINUE                                                          BLP03260
C                                                                       BLP03270
C     READ LINE SOURCE PARAMETERS USED IN DISPERSION CALCULATIONS       BLP03280
C                                                                       BLP03290
      IF(NLINES.LT.1)GO TO 59                                           BLP03300
      DO 46 I=1,NLINES                                                  BLP03310
```

```
      READ(5,48)XLBEG,YLBEG,XLEND,YLEND,HS(I),QT(I),LELEV(I)            BLP03320
48    FORMAT(4F10.1,2F10.4,F10.1)                                       BLP03330
C     NEGATIVE EMISSIONS CANNOT BE USED WHEN ARRAY COMPRESSION          BLP03340
C     OPTION IS USED                                                    BLP03350
      IF(.NOT.RCOMPR.OR.QT(I).GE.0.0)GO TO 936                          BLP03360
      WRITE(6,934)I,QT(I)                                               BLP03370
934   FORMAT(//'0','EXECUTION TERMINATING -- NEGATIVE EMISSIONS ',      BLP03380
     1 'CANNOT BE USED WHEN ARRAY COMPRESSION OPTION (LCOMPR) IS ',     BLP03390
     2 'USED'/'0','LINE SOURCE: ',I2,3X,'EMISSION RATE = ',F12.2)       BLP03400
C     CALL WAUDIT
      STOP                                                              BLP03410
936   CONTINUE                                                          BLP03420
C     CHANGE EMISSION RATE TO MICROGRAMS/SECOND                         BLP03430
      QT(I)=QT(I)*TEN6                                                  BLP03440
      IF(XLBEG.GT.XLEND)GO TO 706                                       BLP03450
C     VERIFY LINE SOURCE COORDINATES ARE                                BLP03460
C     INPUT CORRECTLY - SCS COORDINATE SYSTEM                           BLP03470
      IF(LUTMS)GO TO 946                                                BLP03480
      IF(I.NE.1)GO TO 940                                               BLP03490
      YLBS=YLBEG                                                        BLP03500
      YLES=YLEND                                                        BLP03510
C     SCS COORDINATES OF BEGINNING OF FIRST LINE SOURCE                 BLP03520
C     SHOULD BE (0.0,0.0)                                               BLP03530
      IF(XLBEG.EQ.0.0.AND.YLBEG.EQ.0.0)GO TO 940                        BLP03540
      WRITE(6,708)XLBEG,YLBEG                                           BLP03550
708   FORMAT('1','THE ORIGIN OF THE SCS COORDINATE SYSTEM MUST BE ',    BLP03560
     1 'LOCATED AT THE BEGINNING OF '/3X,'LINE SOURCE NO. 1 -- I.E.,',  BLP03570
     2 '(XLBEG,YLBEG) FOR LINE NO. 1 MUST BE (0.0,0.0)'/'0','VALUES ',  BLP03580
     3 'OF (XLBEG,YLBEG) INPUT BY USER ARE (',F10.1,',',F10.1,')')      BLP03590
C     CALL WAUDIT
      STOP                                                              BLP03600
940   CONTINUE                                                          BLP03610
C     X-AXIS IN THE SCS COORDINATE SYSTEM MUST BE PARALLEL TO           BLP03620
C     THE LINE SOURCES                                                  BLP03630
      IF(YLBEG.EQ.YLEND)GO TO 941                                       BLP03640
      WRITE(6,709)I,YLBEG,YLEND                                         BLP03650
709   FORMAT('1','IN SCS COORDINATE SYSTEM, THE X-AXIS IS ALIGNED ',    BLP03660
     1 'PARALLEL TO THE LINE SOURCES -- I.E., THE Y COORDINATES '/3X,   BLP03670
     2 'OF THE BEGINNING AND END OF EACH LINE SOURCE MUST BE THE SAME'/ BLP03680
     3 '0','VALUES INPUT BY THE USER FOR LINE ',I2,' ARE YLBEG = ',     BLP03690
     4 F10.1,3X,'YLEND = ',F10.1)                                       BLP03700
C     CALL WAUDIT
      STOP                                                              BLP03710
941   CONTINUE                                                          BLP03720
      IF(I.EQ.1)GO TO 946                                               BLP03730
      IF(YLBEG.GT.YLBS.AND.YLEND.GT.YLES)GO TO 942                      BLP03740
      IM1=I-1                                                           BLP03750
      WRITE(6,710)IM1,YLBS,YLES,I,YLBEG,YLEND                           BLP03760
710   FORMAT('1','IN SCS COORDINATE SYSTEM, LINE SOURCES MUST BE ',     BLP03770
     1 'INPUT IN ORDER OF INCREASING Y -- I.E., YLBEG (YLEND) OF LINE ',BLP03780
     2 'NO. N'/3X,'MUST BE GREATER THAN YLBEG (YLEND) OF LINE NO. (N-1)'BLP03790
     3 /'0','VALUES INPUT BY THE USER FOR LINE ',I2,' ARE YLBEG = ',    BLP03800
     4 F10.1,3X,'YLEND = ',F10.1/29X,'LINE ',I2,3X,'YLBEG = ',F10.1,3X, BLP03810
     5 'YLEND = ',F10.1)                                                BLP03820
C     CALL WAUDIT
      STOP                                                              BLP03830
942   CONTINUE                                                          BLP03840
      YLBS=YLBEG                                                        BLP03850
      YLES=YLEND                                                        BLP03860
946   CONTINUE                                                          BLP03870
      XLBEG1(I)=XLBEG-XBASE                                             BLP03880
      YLBEG1(I)=YLBEG-YBASE                                             BLP03890
      XLEND1(I)=XLEND-XBASE                                             BLP03900
      YLEND1(I)=YLEND-YBASE                                             BLP03910
      YSCS(I)=YLBEG1(I)                                                 BLP03920
46    CONTINUE                                                          BLP03930
59    CONTINUE                                                          BLP03940
C                                                                       BLP03950
C     READ POINT SOURCE INFORMATION                                     BLP03960
C                                                                       BLP03970
      IF(NPTS.LT.1)GO TO 22                                             BLP03980
```

```
      DO 15 I=1,NPTS
      READ(5,14)XCOORD,YCOORD,PHS(I),PQ(I),D,W,TSTACK(I),PELEV(I)
14    FORMAT(2F10.1,5F10.4,F10.1)
C     NEGATIVE EMISSIONS CANNOT BE USED WHEN ARRAY COMPRESSION
C     OPTION IS USED
      IF(.NOT.RCOMPR.OR.PQ(I).GE.0.0)GO TO 1936
      WRITE(6,1934)I,PQ(I)
1934  FORMAT(//'0','EXECUTION TERMINATING -- NEGATIVE EMISSIONS ',
     1 'CANNOT BE USED WHEN ARRAY COMPRESSION OPTION (LCOMPR) IS ',
     2 'USED'/'0','POINT SOURCE: ',I2,3X,'EMISSION RATE = ',F12.2)
C     CALL WAUDIT
      STOP
1936  CONTINUE
C     CHANGE EMISSION RATE TO MICROGRAMS/SECOND
      PQ(I)=PQ(I)*TEN6
      XPSCS(I)=XCOORD-XBASE
      YPSCS(I)=YCOORD-YBASE
C     CONSTANT 2.45154 = G/4. (9.80616/4.)
      APTS(I)=2.45154*D*D*W/TSTACK(I)
C     WHEN MULTIPLIED BY THE AMBIENT TEMPERATURE, BPTS GIVES 3. * FM
C     CONSTANT 0.75 = 3./(2.*2.)
      BPTS(I)=0.75*W*W*D*D/TSTACK(I)
      VEXIT(I)=W
      DIAM(I)=D
15    CONTINUE
22    CONTINUE
C
C     WRITE INPUT PARAMETERS
C
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM

CPES  End PES Code Changes
      WRITE(6,8)TITLE
      NDYS=0
      DO 135 I=1,366
135   NDYS=NDYS+IDAYS(I)
      WRITE(6,136)NDYS,IDAYS
136   FORMAT(//'0','TOTAL NUMBER OF DAYS INCLUDED IN THIS RUN: ',I3//
     1 1X,'(0=NOT INCLUDED,1=INCLUDED)'//
     2 3('0',10(10I1,3X)/),'0',6(10I1,3X),6I1)
      NT=NPTS+NLINES
      WRITE(6,112)NT,NLINES,NPTS
112   FORMAT(//'0','TOTAL NUMBER OF SOURCES: ',I3//12X,'LINE SOURCES: ',
     1 I3/11X,'POINT SOURCES: ',I3)
      IF(LPART)ALP1=ALPYES
      WRITE(6,113)ALP1
113   FORMAT(/'0','PARTIAL CONCENTRATIONS REQUESTED FOR ANY LINE OR ',
     1 'POINT SOURCES ? ',A3)
      IF(LDOWNW)ALP2=ALPYES
      WRITE(6,1110)ALP2
1110  FORMAT('0','POINT SOURCE BUILDING DOWNWASH OPTION REQUESTED ? ',
     1 A3)
      IF(LSHEAR)ALP3=ALPYES
      WRITE(6,1111)ALP3
1111  FORMAT('0','VERTICAL WIND SHEAR (IN PLUME RISE) REQUESTED ? ',A3)
      IF(LTRANS)ALP5=ALPYES
      WRITE(6,1212)ALP5
1212  FORMAT('0','TRANSITIONAL POINT SOURCE PLUME RISE REQUESTED ? ',A3)
      IF(LMETOT)ALP4=ALPYES
      WRITE(6,1112)ALP4
1112  FORMAT('0','OUTPUT OF METEOROLOGICAL DATA REQUESTED ? ',A3)
      IF(RCOMPR)ALP6=ALPYES
      WRITE(6,1113)ALP6
1113  FORMAT('0','OPTION TO COMPRESS OUTPUT CONCENTRATION ARRAYS ',
     1 'REQUESTED ? ',A3)
C
C     WRITE THE LINE SOURCE PLUME RISE PARAMETERS
C
      IF(NLINES.LT.1)GO TO 122
```

```
      DXM=DX+WB                                                         BLP04650
      WRITE(6,50)HB,WB,L,DX,DXM,WM,FPRIME                               BLP04660
50    FORMAT(//'0','PARAMETERS USED IN THE LINE SOURCE PLUME RISE ',    BLP04670
     1 'CALCULATIONS'/                                                  BLP04680
     1 '0','BUILDING DIMENSIONS:  HEIGHT = ',F7.2,1X,'(M)'/             BLP04690
     2 24X,'WIDTH = ',F7.2,1X,'(M)'/                                    BLP04700
     3 23X,'LENGTH = ',F7.2,1X,'(M)'/                                   BLP04710
     4 '0',9X,'BUILDING SEPARATION = ',F7.2,1X,'(M)'/                   BLP04720
     5 '0',6X,'LINE SOURCE SEPARATION = ',F7.2,1X,'(M)'/                BLP04730
     6 '0',11X,'LINE SOURCE WIDTH = ',F7.2,1X,'(M)'/                    BLP04740
     7 '0','BUOYANCY FLUX PER LINE (FPRIME) = ',F7.1,1X,'(M**4/S**3)')  BLP04750
122   CONTINUE                                                          BLP04760
C                                                                       BLP04770
C     WRITE THE METEOROLOGICAL PARAMETERS                               BLP04780
C                                                                       BLP04790
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM

CPES  End PES Code Changes
      WRITE(6,1120)                                                     BLP04810
1120  FORMAT(/'0','METEOROLOGICAL PARAMETERS')                          BLP04820
      WRITE(6,1121)ZMEAS,PEXP,DTHTA                                     BLP04830
1121  FORMAT(/'0','MEAN WIND SPEED MEASUREMENT HEIGHT = ',F4.1,' (M)'/  BLP04840
     1 '0','WIND SPEED POWER LAW EXPONENTS (STABILITIES 1-6) =  ',      BLP04850
     2 6(F4.2,2X)/'0','VERTICAL POTENTIAL TEMPERATURE GRADIENT =  ',    BLP04860
     3 F5.3,1X,'DEG K/M  (STABILITY 5)',5X,F5.3,1X,'DEG K/M  ',         BLP04870
     4 '(STABILITY 6)')                                                 BLP04880
      IF(LMETIN)WRITE(6,1122)                                           BLP04890
1122  FORMAT('0','METEOROLOGICAL DATA -- FORMATTED USER INPUT')         BLP04900
      IF(.NOT.LMETIN)WRITE(6,1123)IDELS,IRU,IDSURF,IYSURF,IDUPER,IYUPER BLP04910
1123  FORMAT('0','METEOROLOGICAL DATA -- PREPROCESSOR FORMAT'/          BLP04920
     1 '0','STABILITY CLASS VARIATION RESTRICTED TO ',I1,' CLASSES/',   BLP04930
     2 'HOUR'/'0',1X,'MIXING HEIGHTS USED: ',I1,2X,'(1=RURAL,2=URBAN)'/ BLP04940
     3 '    SURFACE STATION ID: ',I5,5X,'YEAR: ',I2/                    BLP04950
     4 1X,'UPPER AIR STATION ID: ',I5,5X,'YEAR: ',I2)                   BLP04960
C                                                                       BLP04970
C     WRITE THE COMPUTATIONAL PARAMETERS                                BLP04980
C                                                                       BLP04990
      WRITE(6,1130)CRIT,MAXIT                                           BLP05000
1130  FORMAT(///'0','COMPUTATIONAL PARAMETERS'//'0','CONVERGENCE ',     BLP05010
     1 'THRESHOLD FOR LINE SOURCE CALCULATIONS = ',F6.3,1X,             BLP05020
     2 /                                                                BLP05030
     3 '0','MAXIMUM NUMBER OF ITERATIONS IN LINE SOURCE CALCULATIONS = 'BLP05040
     4,I2)                                                              BLP05050
      IF(.NOT.LSHEAR)WRITE(6,1131)CONST2                                BLP05060
1131  FORMAT('0','STABLE POINT SOURCE PLUME RISE CONSTANT (CONST2) = ', BLP05070
     1 F4.2)                                                            BLP05080
      WRITE(6,11131)CONST3                                              BLP05090
11131 FORMAT('0','FINAL NEUTRAL PLUME RISE CONSTANT (CONST3) = ',       BLP05100
     1 F5.2)                                                            BLP05110
      WRITE(6,1132)XBACKG,DECFAC,TERAN                                  BLP05120
1132  FORMAT('0','BACKGROUND CONCENTRATION = ',F8.2,1X,'(MICROGRAMS/',  BLP05130
     1 'M**3)'/'0','POLLUTANT DECAY FACTOR = ',E12.5,1X,' (1/SEC)'/     BLP05140
     2 '0','TERRAIN ADJUSTMENT FACTORS (STABILITIES 1-6) =  ',          BLP05150
     3 6(F4.2,2X))                                                      BLP05160
C                                                                       BLP05170
C     WRITE THE RECEPTOR INFORMATION                                    BLP05180
C                                                                       BLP05190
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM

CPES  End PES Code Changes
      IF(RINPUT)GO TO 85                                                BLP05210
      WRITE(6,114)                                                      BLP05220
114   FORMAT(/'0','RECEPTOR LOCATIONS GENERATED FROM USER DEFINED ',    BLP05230
     1 'RECEPTOR RECTANGLE')                                            BLP05240
      WRITE(6,70)RXBEG,RYEND,RXEND,RYEND,RXBEG,RYBEG,RXEND,RYBEG,RDX,RDYBLP05250
70    FORMAT(//'0',10X,'RECEPTOR NETWORK DEFINED BY THE FOLLOWING ',    BLP05260
     1 'RECTANGLE'/                                                     BLP05270
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     2 '0',10X,'(',F10.1,',',F10.1,')',5X,'(',F10.1,',',F10.1,')'/      BLP05280
     3 '0',10X,'(',F10.1,',',F10.1,')',5X,'(',F10.1,',',F10.1,')'/      BLP05290
     4 '0',10X,'X GRID SPACING = ',F7.2/                                BLP05300
     5 '0',10X,'Y GRID SPACING = ',F7.2)                                BLP05310
      GO TO 99                                                          BLP05320
85    WRITE(6,115)NREC                                                  BLP05330
115   FORMAT(/'0','ALL RECEPTOR LOCATIONS SPECIFIED BY THE USER -- ',   BLP05340
     1 'TOTAL NUMBER OF RECEPTOR: ',I3)                                 BLP05350
      WRITE(6,89)NREC                                                   BLP05360
89    FORMAT(//'0',10X,'RECEPTOR NETWORK (USER INPUT)'/                 BLP05370
     1 '0','NUMBER OF RECEPTORS: ',I4///1X,'RECEPTOR NUMBER',10X,       BLP05380
     2 'X',14X,'Y',10X,'ELEVATION'/25X,'(M)',12X,'(M)',12X,'(M)'/)      BLP05390
      DO 92 I=1,NREC                                                    BLP05400
      XCOORD=XRSCS(I)+XBASE                                             BLP05410
      YCOORD=YRSCS(I)+YBASE                                             BLP05420
92    WRITE(6,93)I,XCOORD,YCOORD,RELEV(I)                               BLP05430
93    FORMAT(7X,I3,11X,F10.1,5X,F10.1,2X,F10.1)                         BLP05440
99    CONTINUE                                                          BLP05450
      IF(.NOT.LUTMS)WRITE(6,116)TCOR                                    BLP05460
116   FORMAT('0','SOURCE AND RECEPTOR LOCATIONS SPECIFIED IN SCS ',     BLP05470
     1 'COORDINATES -- TCOR = ',F6.2,' DEGREES')                        BLP05480
      IF(LUTMS)WRITE(6,117)                                             BLP05490
117   FORMAT('0','SOURCE AND RECEPTOR LOCATIONS SPECIFIED IN UTM ',     BLP05500
     1 'COORDINATES')                                                   BLP05510
C                                                                       BLP05520
C     WRITE THE LINE SOURCE  PARAMETERS                                 BLP05530
C                                                                       BLP05540
      IF(NLINES.LT.1)GO TO 1133                                         BLP05550
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM

CPES  End PES Code Changes
      WRITE(6,60)NLINES                                                 BLP05570
60    FORMAT(/'0','LINE SOURCE PARAMETERS'///'0','NUMBER OF LINES: ',I4 BLP05580
     1 //1X,'LINE NUMBER',4X,'X START',6X,'Y START',9X,'X END',9X,      BLP05590
     2 'Y END',11X,'Q',10X,'HEIGHT',5X,'ELEVATION'/                     BLP05600
     3 18X,'(M)',10X,'(M)',12X,'(M)',11X,'(M)',8X,'(GM/SEC)',9X,        BLP05610
     4 '(M)',9X,'(M)')                                                  BLP05620
      DO 65 I=1,NLINES                                                  BLP05630
      XLBEG=XLBEG1(I)+XBASE                                             BLP05640
      YLBEG=YLBEG1(I)+YBASE                                             BLP05650
      XLEND=XLEND1(I)+XBASE                                             BLP05660
      YLEND=YLEND1(I)+YBASE                                             BLP05670
      QGMS=QT(I)/TEN6                                                   BLP05680
65    WRITE(6,62)I,XLBEG,YLBEG,XLEND,YLEND,QGMS,HS(I),LELEV(I)          BLP05690
62    FORMAT(4X,I3,7X,4(F10.1,4X),2X,F7.2,6X,F7.2,1X,F10.1)             BLP05700
      WRITE(6,212)                                                      BLP05710
212   FORMAT(//'0','SOURCE CONTRIBUTIONS FROM THE FOLLOWING ',          BLP05720
     1 'LINE SOURCES ARE AVAILABLE: '/'0','(0=NOT AVAILABLE; ',         BLP05730
     2 '1=AVAILABLE)'/'0','LINE SOURCE NUMBER',5X,'AVAILABILITY')       BLP05740
      DO 219 I=1,NLINES                                                 BLP05750
      WRITE(6,215)I,IPCL(I)                                             BLP05760
215   FORMAT('0',7X,I2,19X,I1)                                          BLP05770
219   CONTINUE                                                          BLP05780
      WRITE(6,216)NLINES,IPCL(11)                                       BLP05790
216   FORMAT('0',5X,'1 - ',I2,17X,I1)                                   BLP05800
1133  CONTINUE                                                          BLP05810
C                                                                       BLP05820
C     WRITE THE POINT SOURCE PARAMETERS                                 BLP05830
C                                                                       BLP05840
      IF(NPTS.LT.1)GO TO 127                                            BLP05850
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM

CPES  End PES Code Changes
      WRITE(6,160)NPTS                                                  BLP05870
160   FORMAT(/'0','POINT SOURCE PARAMETERS'///'0','NUMBER OF POINTS: ', BLP05880
     1 I4//1X,'POINT NUMBER',8X,'X',14X,'Y',11X,'Q',10X,'HEIGHT',4X,    BLP05890
     2 'DIAM.',4X,'EXIT VEL.',4X,'STACK TEMP.',3X,'ELEVATION'/          BLP05900
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     3 20X,'(M)',12X,'(M)',6X,'(GM/SEC)',9X,'(M)',6X,'(M)',7X,
     4 '(M/S)',8X,'(DEG K)',8X,'(M)')
      DO 132 I=1,NPTS
      XCOORD=XPSCS(I)+XBASE
      YCOORD=YPSCS(I)+YBASE
      QGMS=PQ(I)/TEN6
132   WRITE(6,133)I,XCOORD,YCOORD,QGMS,PHS(I),DIAM(I),VEXIT(I),
     1 TSTACK(I),PELEV(I)
133   FORMAT(5X,I3,8X,F10.1,5X,F10.1,4X,F7.2,6X,F7.2,2X,F7.2,4X,F7.2,
     1 8X,F6.1,2X,F10.1)
      WRITE(6,222)
222   FORMAT(//'0','SOURCE CONTRIBUTIONS FROM THE FOLLOWING ',
     1 'POINT SOURCES ARE AVAILABLE: '/'0','(0=NOT AVAILABLE; ',
     2 '1=AVAILABLE)'/'0','POINT SOURCE NUMBER',5X,'AVAILABILITY')
      DO 239 I=1,NPTS
      WRITE(6,235)I,IPCP(I)
235   FORMAT('0',8X,I2,19X,I1)
239   CONTINUE
      WRITE(6,236)NPTS,IPCP(51)
236   FORMAT('0',6X,'1 - ',I2,17X,I1)
127   CONTINUE
C
C     CALCULATE SCS COORDINATES FROM UTM COORDINATES
C
      IF(.NOT.LUTMS)RETURN
      IF(NLINES.LE.0)RETURN
      XOR=XLBEG1(1)
      YOR=YLBEG1(1)
      DDX=XLEND1(1)-XOR
      DDY=YLEND1(1)-YOR
      ANGRAD=ATAN2(DDY,DDX)
      ANGRD=ANGRAD
      TCOR=90.+ANGRAD/RAD
      SINT=DSIN(ANGRD)
      COST=DCOS(ANGRD)
      WRITE(6,189)
189   FORMAT('1')
C
C     TRANSLATE ORIGIN AND ROTATE COORDINATES
C
C     LINE SOURCE COORDINATES
      DO 260 I=1,NLINES
      XLBEG1(I)=XLBEG1(I)-XOR
      XLEND1(I)=XLEND1(I)-XOR
      YLBEG1(I)=YLBEG1(I)-YOR
      YLEND1(I)=YLEND1(I)-YOR
      XB1=XLBEG1(I)
      XE1=XLEND1(I)
      YB1=YLBEG1(I)
      YE1=YLEND1(I)
      YB1=-XB1*SINT+YB1*COST
      YLBEG1(I)=YB1
      XB1=(XB1+YB1*SINT)/COST
      XLBEG1(I)=XB1
      YE1=-XE1*SINT+YE1*COST
      YSCS(I)=YE1
      YLEND1(I)=YE1
      XE1=(XE1+YE1*SINT)/COST
      XLEND1(I)=XE1
260   CONTINUE
      DO 266 I=1,NLINES
C     VERIFY LINE SOURCE COORDINATES ARE
C     INPUT CORRECTLY - UTM COORDINATES
      IF(I.NE.1)GO TO 242
      YLBSAV=YLBEG1(I)
      YLESAV=YLEND1(I)
      GO TO 266
242   CONTINUE
      IF(YLBEG1(I).GT.YLBSAV.AND.YLEND1(I).GT.YLESAV)GO TO 243
      IM1=I-1
      WRITE(6,217)IM1,YLBSAV,YLESAV,I,YLBEG1(I),YLEND1(I)
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217   FORMAT('1','LINE SOURCE COORDINATES INPUT IN INCORRECT ',         BLP06620
     1 'ORDER -- WHEN USING UTM COORDINATES '/3X,                       BLP06630
     2 'LINE SOURCE COORDINATES MUST BE INPUT SUCH THAT WHEN ',         BLP06640
     3 'COORDINATES ARE CONVERTED TO SCS COORDINATES '/3X,              BLP06650
     4 'YLBEG (YLEND) OF LINE NO. N MUST BE GREATER THAN ',             BLP06660
     5 'YLBEG (YLEND) OF LINE NO. (N-1)'/'0','CURRENT SCS VALUES ',     BLP06670
     6 'FOR ',2('LINE ',I2,' ARE YLBEG = ',F10.1,3X,'YLEND = ',         BLP06680
     7 F10.1/24X))                                                      BLP06690
C     CALL WAUDIT
      STOP                                                              BLP06700
243   CONTINUE                                                          BLP06710
      YLBSAV=YLBEG1(I)                                                  BLP06720
      YLESAV=YLEND1(I)                                                  BLP06730
266   CONTINUE                                                          BLP06740
C     POINT SOURCE COORDINATES                                          BLP06750
      IF(NPTS.LT.1)GO TO 275                                            BLP06760
      DO 270 I=1,NPTS                                                   BLP06770
      XPSCS(I)=XPSCS(I)-XOR                                             BLP06780
      YPSCS(I)=YPSCS(I)-YOR                                             BLP06790
      EX=XPSCS(I)                                                       BLP06800
      EY=YPSCS(I)                                                       BLP06810
      EY=-EX*SINT+EY*COST                                               BLP06820
      YPSCS(I)=EY                                                       BLP06830
      EX=(EX+EY*SINT)/COST                                              BLP06840
      XPSCS(I)=EX                                                       BLP06850
270   CONTINUE                                                          BLP06860
275   CONTINUE                                                          BLP06870
C     TRANSLATE BUT DO NOT ROTATE RECEPTOR RECTANGLE COORDINATES        BLP06880
      IF(LINPUT)GO TO 290                                               BLP06890
      RXBEG1=RXBEG1-XOR                                                 BLP06900
      RXEND1=RXEND1-XOR                                                 BLP06910
      RYBEG1=RYBEG1-YOR                                                 BLP06920
      RYEND1=RYEND1-YOR                                                 BLP06930
      GO TO 299                                                         BLP06940
290   DO 295 I=1,NREC                                                   BLP06950
      XRSCS(I)=XRSCS(I)-XOR                                             BLP06960
      YRSCS(I)=YRSCS(I)-YOR                                             BLP06970
      EX=XRSCS(I)                                                       BLP06980
      EY=YRSCS(I)                                                       BLP06990
      EY=-EX*SINT+EY*COST                                               BLP07000
      YRSCS(I)=EY                                                       BLP07010
      EX=(EX+EY*SINT)/COST                                              BLP07020
      XRSCS(I)=EX                                                       BLP07030
295   CONTINUE                                                          BLP07040
299   CONTINUE                                                          BLP07050
      RETURN                                                            BLP07060
700   WRITE(6,701)NLINES,MAXL                                           BLP07070
701   FORMAT('1','NUMBER OF LINE SOURCES INPUT EXCEEDS MAXIMUM NUMBER ',BLP07080
     1 'ALLOWED'/'0','NUMBER OF LINE SOURCES INPUT (NLINES): ',I5/      BLP07090
     2 '0','MAXIMUM NUMBER OF LINE SOURCES ALLOWED: ',I5)               BLP07100
C     CALL WAUDIT
      STOP                                                              BLP07110
702   WRITE(6,703)NPTS,MAXP                                             BLP07120
703   FORMAT('1','NUMBER OF POINT SOURCES INPUT EXCEEDS MAXIMUM ',      BLP07130
     1 'NUMBER ALLOWED'/'0','NUMBER OF POINT SOURCES INPUT (NPTS): ',I5/BLP07140
     2 '0','MAXIMUM NUMBER OF POINT SOURCES ALLOWED: ',I5)              BLP07150
C     CALL WAUDIT
      STOP                                                              BLP07160
704   WRITE(6,705)NREC,MAXR                                             BLP07170
705   FORMAT('1','NUMBER OF RECEPTORS INPUT EXCEEDS MAXIMUM NUMBER ',   BLP07180
     1 'ALLOWED'/'0','NUMBER OF RECEPTORS INPUT (NREC): ',I5/           BLP07190
     2 '0','MAXIMUM NUMBER OF RECEPTORS ALLOWED: ',I5)                  BLP07200
C     CALL WAUDIT
      STOP                                                              BLP07210
706   WRITE(6,707)XLBEG,XLEND                                           BLP07220
707   FORMAT('1','ENTER COORDINATES OF THE LINE SOURCE ENDPOINTS FROM ',BLP07230
     1 'WEST TO EAST -- '/1X,'I.E., XLBEG MUST BE LESS THAN OR EQUAL ', BLP07240
     2 'TO XLEND'/'0','XLBEG INPUT AS ',F10.1/'0','XLEND INPUT AS ',    BLP07250
     3 F10.1)                                                           BLP07260
C     CALL WAUDIT
      STOP                                                              BLP07270
```

```
      END                                                               BLP07280
C
C
      SUBROUTINE RECEPT(LUTMS)                                          BLP07290
C                                                                       BLP07300
C                                                                       BLP07310
      REAL*8 EX,EY,SINT,COST,ANGRAD                                     BLP07320
      REAL LELEV                                                        BLP07330
      LOGICAL LUTMS                                                     BLP07340
      COMMON/SOURCE/NLINES,XLBEG(10),XLEND(10),DEL(10),YSCS(10),QT(10), BLP07350
     1 HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),                 BLP07360
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),     BLP07370
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)      BLP07380
      COMMON/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY,XRSCS(100),          BLP07390
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC                 BLP07400
C     COMMON/QA/VERSON,LEVEL                                            BLP07410
CPES  Begin PES Code Changes

      CHARACTER RUNDAT*8, RUNTIM*8, VERSN*5
      COMMON/DATETIME/ RUNDAT, RUNTIM, VERSN

CPES  End PES Code Changes
      DATA RAD/57.29578/                                                BLP07420
      IF(NLINES.LE.0)GO TO 151                                          BLP07430
      YLMAX=YSCS(1)                                                     BLP07440
      YLMIN=YSCS(NLINES)                                                BLP07450
      XLMAX=XLEND(1)                                                    BLP07460
      XLMIN=XLBEG(1)                                                    BLP07470
      DO 5 I=1,NLINES                                                   BLP07480
      XLMIN=AMIN1(XLMIN,XLBEG(I))                                       BLP07490
      XLMAX=AMAX1(XLMAX,XLEND(I))                                       BLP07500
      YLMIN=AMIN1(YLMIN,YSCS(I))                                        BLP07510
      YLMAX=AMAX1(YLMAX,YSCS(I))                                        BLP07520
5     CONTINUE                                                          BLP07530
C     DEFINE THE SOURCE RECTANGLE                                       BLP07540
      WRITE(6,105)XLMIN,YLMAX,XLMAX,YLMAX,XLMIN,YLMIN,XLMAX,YLMIN       BLP07550
105   FORMAT('0','THE SOURCE RECTANGLE IS DEFINED BY THE FOLLOWING ',   BLP07560
     1 'POINTS (IN SCS COORDINATES):'                                   BLP07570
     2 /'0','(',F10.2,',',F10.2,')',10X,'(',F10.2,',',F10.2,')'         BLP07580
     3 /'0','(',F10.2,',',F10.2,')',10X,'(',F10.2,',',F10.2,')')        BLP07590
      GO TO 161                                                         BLP07600
C     IF THERE ARE NO LINE SOURCES, SOURCE RECTANGLE IS                 BLP07610
C     UNDEFINED -- ASSIGN VALUES TO XLMIN,XLMAX,YLMIN,YLMAX             BLP07620
C     SUCH THAT NO RESTRICTION IS PLACED ON THE LOCATIONS OF            BLP07630
C     RECEPTORS                                                         BLP07640
151   CONTINUE                                                          BLP07650
      XLMIN=1.E10                                                       BLP07660
      XLMAX=-1.E10                                                      BLP07670
      YLMIN=1.E10                                                       BLP07680
      YLMAX=-1.E10                                                      BLP07690
161   CONTINUE                                                          BLP07700
      IF(.NOT.LUTMS)GO TO 550                                           BLP07710
      ANGRAD=(TCOR-90.)/RAD                                             BLP07720
      SINT=DSIN(ANGRAD)                                                 BLP07730
      COST=DCOS(ANGRAD)                                                 BLP07740
550   CONTINUE                                                          BLP07750
      NRINX=(RXEND-RXBEG)/RDX+1.01                                      BLP07760
      NRINY=(RYEND-RYBEG)/RDY+1.01                                      BLP07770
C     NTHTOT IS THE NUMBER OF RECEPTORS BEFORE ELIMINATING              BLP07780
C     THOSE IN THE SOURCE RECTANGLE                                     BLP07790
      NTHTOT=NRINX*NRINY                                                BLP07800
      NREC=0                                                            BLP07810
      DO 10 I=1,NRINX                                                   BLP07820
      DO 10 J=1,NRINY                                                   BLP07830
      RXSAVE=RXBEG+(I-1)*RDX                                            BLP07840
      RYSAVE=RYBEG+(J-1)*RDY                                            BLP07850
      IF(.NOT.LUTMS)GO TO 560                                           BLP07860
      EX=RXSAVE                                                         BLP07870
      EY=RYSAVE                                                         BLP07880
      EY=-EX*SINT+EY*COST                                               BLP07890
      RYSAVE=EY                                                         BLP07900
```

```
      EX=(EX+EY*SINT)/COST
      RXSAVE=EX
560   CONTINUE
C     IF A RECEPTOR IS OUTSIDE THE SOURCE RECTANGLE, RECORD ITS
C     X AND Y COORDINATES, OTHERWISE, IGNORE IT
      IF(RYSAVE.GT.YLMAX.OR.RYSAVE.LT.YLMIN)GO TO 9
      IF(RXSAVE.GT.XLMAX.OR.RXSAVE.LT.XLMIN)GO TO 9
      GO TO 10
9     NREC=NREC+1
      IF(NREC.GT.100)GO TO 200
      XRSCS(NREC)=RXSAVE
      YRSCS(NREC)=RYSAVE
10    CONTINUE
CPES  Begin PES Code Changes

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM
1400  FORMAT('1',11X,'BLP -- MULTIPLE BUOYANT LINE AND POINT ',
     1'SOURCE DISPERSION MODEL     SCRAM VERSION (DATED ',A5,')',17X,A8,
     2/,123X,A8 / ' ',13('**********'))

CPES  End PES Code Changes
      WRITE(6,26)
26    FORMAT(//'0','RECEPTOR NO.',11X,'LOCATION',19X,'RECEPTOR NO.',11X,
     1 'LOCATION'/16X,'X',16X,'Y',32X,'X',16X,'Y')
      IH=NREC/2
      DO 30 I=1,IH
      IP=IH+I
      WRITE(6,29)I,XRSCS(I),YRSCS(I),IP,XRSCS(IP),YRSCS(IP)
29    FORMAT(3X,I3,10X,F6.0,10X,F6.0,13X,I3,10X,F6.0,10X,F6.0)
30    CONTINUE
      IEVEN=MOD(NREC,2)
      IF(IEVEN.NE.0)WRITE(6,33)NREC,XRSCS(NREC),YRSCS(NREC)
33    FORMAT(51X,I3,10X,F6.0,10X,F6.0)
      WRITE(6,35)NTHTOT,NREC
35    FORMAT(////1X,'NUMBER OF POSSIBLE RECEPTOR LOCATIONS = ',I5/
     1 '0','NUMBER OF ACTUAL RECEPTOR LOCATIONS = ',I5)
      WRITE(6,37)
37    FORMAT(/'0','GENERATED RECEPTOR LOCATIONS IN SCS COORDINATES')
      RETURN
200   WRITE(6,205)RXBEG,RYBEG,RXEND,RYEND,RDX,RDY
205   FORMAT('0','TOO MANY RECEPTOR LOCATIONS REQUESTED.'/'0',
     1 'RECEPTORS AT: (',E13.6,',',E13.6,')',2X,'TO  (',E13.6,',',
     2 E13.6,')',10X,'WITH (DX,DY) = (',E13.6,',',E13.6,')')
C     CALL WAUDIT
      STOP
      END
C
      SUBROUTINE OUTITL(TITLE,NREC,NPTS,NLINES,IPCL,IPCP,IYR,IDAYS,
     1 RCOMPR)
C
C
      CHARACTER*4 TITLE(20)
      INTEGER IPCL(11),IPCP(51)
      DIMENSION IDAYS(366)
      LOGICAL RCOMPR
C
C     THIS SUBROUTINE WRITES THE TITLE CARD AND OTHER RUN
C     INFORMATION TO RECORD #1 OF THE OUTPUT FILE (UNIT 20)
C
C     THOUSANDS PLACE OF NNREC IS CODED TO INDICATE IF ARRAY
C     COMPRESSION OPTION IS USED
C     IF NNREC > 1000, OUTPUT ARRAYS ARE COMPRESSED
C     IF NNREC < 1000, OUTPUT ARRAYS ARE NOT COMPRESSED
      NNREC=NREC
      IF(RCOMPR)NNREC=NNREC+1000
      WRITE(20)TITLE,NNREC,NPTS,NLINES,IPCL,IPCP,IYR,IDAYS
      RETURN
      END
C
CPES  Begin PES Code Changes
```

```
      SUBROUTINE MET(JDAY)

C     The routine has been modified to read meteorological data from
C     an ASCII-formatted file rather than an unformatted file.  It also
C     returns the Julian day (JDAY) determined from the date in the file.
C     Simple error checks for proper date sequence have also been added.
C     Modified by R.Brode, PES, Inc. - 6/25/99

CPES  End PES Code Changes
C                                                                       BLP08540
C                                                                       BLP08550
      LOGICAL LMETIN,LMETOT                                             BLP08560
CPES  Beging PES Code Changes

      DIMENSION HLH(2,24)

CPES  End PES Code Changes
      COMMON/METD24/KST(24),SPEED(24),RANDWD(24),HMIX(24),TEMP(24),     BLP08600
     1 DTHTA(2),PEXP(6),IDELS,IDSURF,IYSURF,IDUPER,IYUPER,TERAN(6),     BLP08610
     2 IRU,IHRMAX,LMETIN,LMETOT,IDAYS(366)                              BLP08620
      COMMON/QA/VERSON,LEVEL                                            BLP08630
CPES  Beging PES Code Changes

      CHARACTER RUNDAT*8, RUNTIM*8, VERSN*5
      COMMON/DATETIME/ RUNDAT, RUNTIM, VERSN

CPES  End PES Code Changes
      DATA KSTOLD/5/                                                    BLP08640
C                                                                       BLP08650
C     READ PROCESSED UNFORMATTED METEOROLOGICAL DATA                    BLP08660
C                                                                       BLP08670
      IF(LMETIN)GO TO 185                                               BLP08680
CPES  Begin PES Code Changes

      DO I = 1, 24
C        Read Hourly Records from Formatted ASCII File
         READ(2,9500,END=999,ERR=99) IYR, IMO, IDAY, IHR,
     &        RANDWD(I), SPEED(I), TEMP(I), KST(I),
     &        HLH(1,I), HLH(2,I)
9500     FORMAT(4I2,2F9.4,F6.1,I2,2F7.1)
         IF (I .NE. IHR) THEN
            WRITE(*,*) 'MET DATA SEQUENCE ERROR AT ',IYR,IMO,IDAY,IHR
            WRITE(6,*) 'MET DATA SEQUENCE ERROR AT ',IYR,IMO,IDAY,IHR
            STOP
         END IF

         CYCLE

99       CONTINUE

         WRITE(*,*) 'ERROR READING MET DATA FILE AT ',IYR,IMO,IDAY,IHR
         WRITE(6,*) 'ERROR READING MET DATA FILE AT ',IYR,IMO,IDAY,IHR
         STOP

999      CONTINUE

         WRITE(*,*) 'PREMATURE END OF FILE REACHED FOR MET DATA'
         WRITE(6,*) 'PREMATURE END OF FILE REACHED FOR MET DATA'
         STOP

      END DO

C     Convert Year to 4-Digit Value (IYEAR) Using Date Windowing
      IF (IYR .GE. 50 .AND. IYR .LE. 99) THEN
         IYEAR = 1900 + IYR
      ELSE IF (IYR .LT. 50) THEN
         IYEAR = 2000 + IYR
      ELSE
C        Input IYR must be 4-digit:  Save to IYEAR and convert to 2-digit
         IYEAR = IYR
         IYR   = IYEAR - 100 * (IYEAR/100)
```

```
      END IF

C     Calculate Julian Day Using 4-Digit Year
      CALL JULIAN(IYEAR,IMO,IDAY,JDAY)

C     Write Status Message to the Screen
      WRITE(*,909) JDAY, IYEAR
 909  FORMAT('+','Now Processing Data For Day No. ',I4,' of ',I4)

CPES  End PES Code Changes
C     IRU=1 FOR RURAL MIXING HEIGHTS, IRU=2 FOR URBAN MIXING HEIGHTS    BLP08800
      DO 5 I=1,24                                                       BLP08810
      HMIX(I)=HLH(IRU,I)                                                BLP08820
5     CONTINUE                                                          BLP08830
C                                                                       BLP08840
C     ALLOW ONLY STABILITIES 1 TO 6 AND                                 BLP08850
C     RESTRICT STABILITY VARIATION TO 'IDELS' CLASSES/HOUR              BLP08860
C                                                                       BLP08870
      DO 75 I=1,24                                                      BLP08880
      ISTAB=KST(I)                                                      BLP08890
      ISTAB=MIN0(ISTAB,6)                                               BLP08900
      IDSTAB=ISTAB-KSTOLD                                               BLP08910
      IF(IABS(IDSTAB).GT.IDELS)ISTAB=KSTOLD+ISIGN(IDELS,IDSTAB)         BLP08920
      KSTOLD=ISTAB                                                      BLP08930
      KST(I)=ISTAB                                                      BLP08940
C     IF AMBIENT TEMPERATURE IS MISSING, ASSUME T=293.0 DEG. K          BLP08950
      IF(TEMP(I).LE.0.0)TEMP(I)=293.                                    BLP08960
75    CONTINUE                                                          BLP08970
C                                                                       BLP08980
C     IF LMETOT = .TRUE., WRITE HOURLY METEOROLOGY                      BLP08990
C                                                                       BLP09000
      IF(.NOT.LMETOT)RETURN                                             BLP09010
C
CPES  Begin PES Code Changes

      IF(IDAYS(JDAY).NE.1)RETURN
      WRITE(6,12)IYR,IMO,JDAY,(NH,NH=1,24),KST,SPEED,TEMP,RANDWD,
     1 (HLH(1,N),N=1,24),(HLH(2,N2),N2=1,24)                            BLP09040
12    FORMAT('0','IYR = ',I2,3X,'IMO = ',I2,3X,'JDAY = ',I4/
     1 4X,'HR=',3X,I4,23I5/                                             BLP09060
     1 4X,'ISTAB=',I4,23I5/4X,'WS=  ',24F5.1/4X,'TEMP=',24F5.0/         BLP09070
C
C     FORMAT CHANGED FROM 12F TO 24F TO WRITE RURAL AND URBAN HEIGHTS   ACHD9080
C     ON SAME LINE WITH NO CR/LF                                        ACHD9081
     2 4X,'WD-R=',24F5.0/4X,'H-RURAL=',24F6.0/                          ACHD9082
     3 4X,'H-URBAN=',24F6.0//                                           ACHD9083
C     HEADERS ADDED TO ANNOTATE PLUME RISE HEIGHTS AND DISTANCES        ACHD9084
     4 3X,'YR',1X,'JDAY',2X,'HR',5X,'DH1',5X,'DH2',5X,'DH3',5X,'DH4',   ACHD9085
     5 5X,'DH5',5X,'DH6',5X,'DH7',5X,'XF1',5X,'XF2',5X,'XF3',5X,'XF4',  ACHD9086
     6 5X,'XF5',5X,'XF6',5X,'XF7',7X,'XFB',5X,'XFS')                    ACHD9087
C
CPES  End PES Code Changes
      RETURN                                                            BLP09100
185   CONTINUE                                                          BLP09110
C                                                                       BLP09120
C     READ UP TO 24 HOURS OF FORMATTED METEOROLOGICAL DATA              BLP09130
C     FROM UNIT 5                                                       BLP09140
C                                                                       BLP09150
      READ(5,110)IHRMAX                                                 BLP09160
110   FORMAT(I2)                                                        BLP09170
      IF(IHRMAX.LE.24.AND.IHRMAX.GE.1)GO TO 161                         BLP09180
      WRITE(6,159)IHRMAX                                                BLP09190
159   FORMAT(/////10X,'EXECUTION TERMINATING -- IHRMAX MUST ',          BLP09200
     1 'BE SPECIFIED BY THE USER TO BE '/'0',9X,'BETWEEN ',             BLP09210
     2 '1 AND 24 WHEN THE FORMATTED METEOROLOGICAL USER INPUT '/        BLP09220
     3 '0',9X,'OPTION IS REQUESTED  --  (IHRMAX = ',                    BLP09230
     4 I5,')')                                                          BLP09240
C     CALL WAUDIT
      STOP                                                              BLP09250
161   CONTINUE                                                          BLP09260
CPES  Begin PES Code Changes
```

```
C     Set Julian Day = 1 for User Input Formatted Met Data
      JDAY = 1

      WRITE(6,1400) VERSN, RUNDAT, RUNTIM
1400  FORMAT('1',11X,'BLP -- MULTIPLE BUOYANT LINE AND POINT ',
     1'SOURCE DISPERSION MODEL     SCRAM VERSION (DATED ',A5,')',17X,A8,
     2/,123X,A8 / ' ',13('**********'))

CPES  End PES Code Changes
      WRITE(6,171)                                                      BLP09310
171   FORMAT(/'0',20X,'USER INPUT FORMATTED METEOROLOGICAL DATA'//      BLP09320
     1 '0',5X,'HOUR',3X,'STABILITY',3X,'WIND SPEED',3X,'WIND ',         BLP09330
     2 'DIRECTION',3X,'TEMPERATURE',3X,'MIXING HEIGHT'/                 BLP09340
     3 15X,'CLASS',8X,'(M/S)',8X,'(DEGREES)',6X,'(DEG. K)',9X,          BLP09350
     4 '(M)')                                                           BLP09360
      DO 100 I=1,IHRMAX                                                 BLP09370
      READ(5,112)KST(I),SPEED(I),RANDWD(I),TEMP(I),HMIX(I)              BLP09380
112   FORMAT(I1,9X,F10.2,F10.2,F10.2,F10.2)                             BLP09390
      IF(KST(I).GT.6)KST(I)=6                                           BLP09400
      WRITE(6,114)I,KST(I),SPEED(I),RANDWD(I),TEMP(I),HMIX(I)           BLP09410
114   FORMAT('0',6X,I2,8X,I1,9X,F5.2,10X,F5.1,11X,F5.1,9X,F5.0)         BLP09420
100   CONTINUE                                                          BLP09430
      RETURN                                                            BLP09440
      END                                                               BLP09450
CPES  Begin PES Code Changes

      SUBROUTINE JULIAN(INYR,INMN,INDY,JDY)
C***********************************************************************
C        Based on JULIAN Module of ISC3 Short Term Model
C
C        PURPOSE:    CONVERT YR/MN/DY DATE TO JULIAN DAY (1-366),
C                    INCLUDES TEST FOR 100 AND 400 YEAR CORRECTIONS
C
C        PROGRAMMER: Roger Brode
C
C        DATE:       June 24, 1999
C
C        INPUTS:     YEAR,  INYR (4 DIGIT)
C                    MONTH, INMN
C                    DAY,   INDY
C
C        OUTPUT:     JULIAN DAY,  JDY (1-366)
C
C        CALLED FROM:   MET
C
C        ERROR HANDLING:   Checks for Invalid Month or Day
C***********************************************************************

C     Variable Declarations
      IMPLICIT NONE

      SAVE
      INTEGER :: NDAY(12), IDYMAX(12)
      INTEGER :: INYR, INMN, INDY, JDY

C     Variable Initializations
      DATA NDAY/0,31,59,90,120,151,181,212,243,273,304,334/
      DATA IDYMAX/31,29,31,30,31,30,31,31,30,31,30,31/
      JDY = 0

C     Check for Invalid Month or Day
      IF (INMN.LT.1 .OR. INMN.GT.12) THEN
         WRITE(*,*) 'Invalid Month in Met Data File for IMO = ',INMN
         WRITE(6,*) 'Invalid Month in Met Data File for IMO = ',INMN
         STOP
      ELSE IF (INDY .GT. IDYMAX(INMN)) THEN
         WRITE(*,*) 'Invalid Day in Met Data File for IMO = ',INMN,
     &              ' and IDY = ',INDY
         WRITE(6,*) 'Invalid Day in Met Data File for IMO = ',INMN,
     &              ' and IDY = ',INDY
```

```
         STOP
      END IF

C     Determine JULIAN Day Number; For Non-Leap Year First
      IF ((MOD(INYR,4) .NE. 0) .OR.
     &    (MOD(INYR,100) .EQ. 0 .AND. MOD(INYR,400) .NE. 0)) THEN
C        Not a Leap Year
         IF (INMN.NE.2 .OR. (INMN.EQ.2 .AND. INDY.LE.28)) THEN
            JDY = INDY + NDAY(INMN)
         ELSE
            WRITE(*,*) 'Invalid Date; 2/29 in Non-Leap Year for IYR = ',
     &                  INYR
            WRITE(6,*) 'Invalid Date; 2/29 in Non-Leap Year for IYR = ',
     &                  INYR
            STOP
         END IF
      ELSE
C        Leap Year
         JDY = INDY + NDAY(INMN)
         IF (INMN .GT. 2)  JDY = JDY + 1
      END IF

 999  CONTINUE

      RETURN
      END

CPES  End PES Code Changes
C
      SUBROUTINE COORD(THETA)
C
C
      DIMENSION XSCS(10,129)
      REAL LELEV
      REAL TCHK(4)/90.,180.,270.,360./
      INTEGER IL(4)/4*1/,ISEG(4)/1,129,129,1/
      COMMON/SOURCE/NLINES,XLBEG(10),XLEND(10),DEL(10),YSCS(10),QT(10),
     1 HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)
      COMMON/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY,XRSCS(100),
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC
      EQUIVALENCE (XRCS(1,1),XSCS(1,1))
      DATA RAD/57.29578/
      TRAD=THETA/RAD
      COST=COS(TRAD)
      SINT=SIN(TRAD)
      IF(NLINES.LT.1)GO TO 250
C
C     CALCULATE SOURCE COORDINATES FOR EACH SOURCE LINE SEGMENT
C
      DO 25 I=1,NLINES
      DXX=DEL(I)/128.
      XSCS(I,1)=XLBEG(I)
      DO 25 J=2,129
      XSCS(I,J)=XSCS(I,J-1)+DXX
25    CONTINUE
      IL(3)=NLINES
      IL(4)=NLINES
C
C     CALCULATE XN, YN (ORIGINS OF TRANSLATED COORDINATE SYSTEM
C     IN TERMS OF THE SCS COORDINATES
C
      DO 5 I=1,4
      IF(THETA.GE.TCHK(I))GO TO 5
      ISAVE=I
      ILINE=IL(I)
      ISEGN=ISEG(I)
      XN=XSCS(ILINE,ISEGN)
      YN=YSCS(ILINE)
      GO TO 6
```

```
5     CONTINUE                                                       BLP09880
6     CONTINUE                                                       BLP09890
C                                                                    BLP09900
C     TRANSLATE COORDINATES                                          BLP09910
C                                                                    BLP09920
C     TRANSLATE LINE SOURCE SEGMENT COORDINATES                      BLP09930
      DO 10 I=1,NLINES                                               BLP09940
      DO 10 J=1,129                                                  BLP09950
      XRCS(I,J)=XSCS(I,J)-XN                                         BLP09960
      YRCS(I,J)=YSCS(I)-YN                                           BLP09970
10    CONTINUE                                                       BLP09980
C     TRANSLATE POINT SOURCE COORDINATES                             BLP09990
      DO 11 I=1,NPTS                                                 BLP10000
      XPRCS(I)=XPSCS(I)-XN                                           BLP10010
      YPRCS(I)=YPSCS(I)-YN                                           BLP10020
11    CONTINUE                                                       BLP10030
C     TRANSLATE RECEPTOR COORDINATES                                 BLP10040
      DO 12 I=1,NREC                                                 BLP10050
      XRRCS(I)=XRSCS(I)-XN                                           BLP10060
      YRRCS(I)=YRSCS(I)-YN                                           BLP10070
12    CONTINUE                                                       BLP10080
C                                                                    BLP10090
C     ROTATE COORDINATE SYSTEM                                       BLP10100
C                                                                    BLP10110
C     ROTATE LINE SOURCE SEGMENT COORDINATES                         BLP10120
      DO 20 I=1,NLINES                                               BLP10130
      DO 20 J=1,129                                                  BLP10140
      XSAVE=XRCS(I,J)                                                BLP10150
      YSAVE=YRCS(I,J)                                                BLP10160
      XRCS(I,J)=XSAVE*COST+YSAVE*SINT                                BLP10170
      YRCS(I,J)=YSAVE*COST-XSAVE*SINT                                BLP10180
20    CONTINUE                                                       BLP10190
      IF(NPTS.LT.1)GO TO 260                                         BLP10200
C     ROTATE POINT SOURCE COORDINATES                                BLP10210
      DO 21 I=1,NPTS                                                 BLP10220
      XSAVE=XPRCS(I)                                                 BLP10230
      YSAVE=YPRCS(I)                                                 BLP10240
      XPRCS(I)=XSAVE*COST+YSAVE*SINT                                 BLP10250
      YPRCS(I)=YSAVE*COST-XSAVE*SINT                                 BLP10260
21    CONTINUE                                                       BLP10270
260   CONTINUE                                                       BLP10280
C     ROTATE RECEPTOR COORDINATES                                    BLP10290
      DO 22 I=1,NREC                                                 BLP10300
      XSAVE=XRRCS(I)                                                 BLP10310
      YSAVE=YRRCS(I)                                                 BLP10320
      XRRCS(I)=XSAVE*COST+YSAVE*SINT                                 BLP10330
      YRRCS(I)=YSAVE*COST-XSAVE*SINT                                 BLP10340
22    CONTINUE                                                       BLP10350
      RETURN                                                         BLP10360
250   CONTINUE                                                       BLP10370
C                                                                    BLP10380
C     WITH NO LINE SOURCES, JUST ROTATE THE POINT SOURCE AND         BLP10390
C     RECEPTOR COORDINATES                                           BLP10400
C                                                                    BLP10410
      IF(NPTS.LT.1)GO TO 360                                         BLP10420
C     ROTATE POINT SOURCE COORDINATES                                BLP10430
      DO 321 I=1,NPTS                                                BLP10440
      XSAVE=XPSCS(I)                                                 BLP10450
      YSAVE=YPSCS(I)                                                 BLP10460
      XPRCS(I)=XSAVE*COST+YSAVE*SINT                                 BLP10470
      YPRCS(I)=YSAVE*COST-XSAVE*SINT                                 BLP10480
321   CONTINUE                                                       BLP10490
360   CONTINUE                                                       BLP10500
C     ROTATE RECEPTOR COORDINATES                                    BLP10510
      DO 322 I=1,NREC                                                BLP10520
      XSAVE=XRSCS(I)                                                 BLP10530
      YSAVE=YRSCS(I)                                                 BLP10540
      XRRCS(I)=XSAVE*COST+YSAVE*SINT                                 BLP10550
      YRRCS(I)=YSAVE*COST-XSAVE*SINT                                 BLP10560
322   CONTINUE                                                       BLP10570
      RETURN                                                         BLP10580
```

```
      END                                                               BLP10590
C
      SUBROUTINE CONTRB(RCOMPR)                                         BLP10600
C                                                                       BLP10610
C                                                                       BLP10620
      REAL CHI(100),PARTCH(100),CHIL(100),FTSAVE(129)                   BLP10630
      REAL L,LEFF,LD,LELEV                                              BLP10640
      INTEGER NSEGA(7)/3,5,9,17,33,65,129/                              BLP10650
      LOGICAL LSHEAR,LTRANS,RCOMPR                                      BLP10660
      COMMON/PRLS/XFB,LEFF,LD,R0,XFINAL,XFS                             BLP10670
      COMMON/SOURCE/NLINES,XLBEG(10),XLEND(10),DEL(10),YSCS(10),QT(10), BLP10680
     1 HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),                 BLP10690
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),     BLP10700
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)      BLP10710
      COMMON/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY,XRSCS(100),          BLP10720
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC                 BLP10730
      COMMON/RINTP/XDIST(7),DH(7)                                       BLP10740
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR BLP10750
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP10760
     1 LTRANS                                                           BLP10770
      COMMON/PBLDAT/TWOPBL,PBL1P6                                       BLP10780
      COMMON/OUTPT/IPCL(11),IPCP(51)                                    BLP10790
      COMMON/PARM/CRIT,TER1,DECFAC,XBACKG,CONST2,CONST3,MAXIT           BLP10800
      DATA PI/3.1415927/,SRT2DP/0.7978846/,IWPBL/0/,JITCT/0/            BLP10810
      DO 5 I=1,NREC                                                     BLP10820
      CHIL(I)=0.0                                                       BLP10830
5     CHI(I)=0.0                                                        BLP10840
      IF(NLINES.LT.1)GO TO 2000                                         BLP10850
      ITHETA=THETA+0.5                                                  BLP10860
      WSST=WS*(HB/ZMEAS)**P                                             BLP10870
C     SET EFFECTIVE WIND SPEED USED IN PLUME RISE                       BLP10880
C     CALCULATIONS, U, TO STACK HEIGHT WIND SPEED, WSST --              BLP10890
C     IF USING WIND SHEAR OPTION IN PLUME RISE, U WILL BE               BLP10900
C     CALCULATED IN SUBROUTINE WSC                                      BLP10910
      U=WSST                                                            BLP10920
      IF(LSHEAR)CALL WSC(ISTAB,WSST,U,S,P)                              BLP10930
      CALL LENG(THETA,U)                                                BLP10940
C                                                                       BLP10950
C     CALCULATE DISTANCE TO FINAL RISE                                  BLP10960
C                                                                       BLP10970
      IF(ISTAB.LE.4)GO TO 6                                             BLP10980
C     CALCULATE DISTANCE TO FINAL RISE FOR STABLE CONDITIONS            BLP10990
      UNSRT=16.*U*U/S-XFB*XFB/3.                                        BLP11000
      IF(UNSRT.LE.0.0)GO TO 105                                         BLP11010
      XFS=0.5*(XFB+SQRT(UNSRT))                                         BLP11020
      GO TO 106                                                         BLP11030
105   XFS=(12.*XFB*U*U/S)**0.3333333                                    BLP11040
106   CONTINUE                                                          BLP11050
      XFSXX=U*PI/SQRT(S)                                                BLP11060
      XFS=AMIN1(XFS,XFSXX)                                              BLP11070
      IF(XFS.GT.XFB)GO TO 7                                             BLP11080
      DO 18 I=2,7                                                       BLP11090
18    XDIST(I)=XFS                                                      BLP11100
      GO TO 10                                                          BLP11110
6     XFS=XFB+XFINAL                                                    BLP11120
7     CONTINUE                                                          BLP11130
C     FIND 5 INTERMEDIATE DOWNWIND DISTANCES (IN ADDITION TO XFB)       BLP11140
C     AT WHICH PLUME RISE WILL BE CALCULATED                            BLP11150
      DO 9 I=2,7                                                        BLP11160
      RI=FLOAT(I)                                                       BLP11170
      XDIST(I)=XFS-(XFS-XFB)*(7.-RI)/5.                                 BLP11180
9     CONTINUE                                                          BLP11190
10    CONTINUE                                                          BLP11200
      CALL RISE(U,ISTAB,S)                                              BLP11210
C
C     WRITE PLUME RISE HEIGHTS AND DISTANCES OF FULL BUOYANCY (XFB),    ACHD1211
C     FINAL RISE (XFS), AND INTERMEDIATE HEIGHTS & DISTANCES            ACHD1212
      WRITE(6,5555) IYR,JDAY,IHOUR,DH,XDIST,XFB,XFS                     ACHD1213
5555  FORMAT(1X,I4,2X,I3,2X,I2,14(F8.2),2X,2(F8.2))                     ACHD1214
C
C                                                                       BLP11220
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C     CALCULATE PARTIAL CONCENTRATIONS DUE TO THE LINE SOURCES
C
C     LOOP OVER LINES
C
      DO 1000 LNUM=1,NLINES
      DLMIN=DEL(LNUM)/128.
      ZB=LELEV(LNUM)
      ZLINE=HS(LNUM)
      WSST=WS*(ZLINE/ZMEAS)**P
      CUQ=QT(LNUM)/((NSEGA(1)-1)*WSST)
C     SRT2DP = SQRT(2./PI)
      SZ0=R0*SRT2DP
      ZV=1000.*XVZ(SZ0,ISTAB)
      SY0=SZ0/2.
      YV=1000.*XVY(SY0,ISTAB)
      XB=XRCS(LNUM,1)
      YB=YRCS(LNUM,1)
      XE=XRCS(LNUM,129)
      YE=YRCS(LNUM,129)
      XMAXL=AMAX1(XB,XE)
      XMINL=AMIN1(XB,XE)
      YMAXL=AMAX1(YB,YE)
      YMINL=AMIN1(YB,YE)
      DXEL=XE-XB
      DYEL=YE-YB
C
C     LOOP OVER RECEPTORS
C
      DO 500 I=1,NREC
      SUM=0.0
      PARTCH(I)=0.0
      NSEG=0
      NCONTR=0
      XRECEP=XRRCS(I)
      THT=RELEV(I)-ZB
C
C     IF RECEPTOR IS UPWIND OF THE LINE, CHI = 0.0
C
      IF(XRECEP.LE.XMINL)GO TO 500
      YRECEP=YRRCS(I)
C     IWOSIG KEEPS TRACK OF WHETHER ANY LINE SEGMENT IS WITHIN
C     ONE SIGMA Y OF THE CURRENT RECEPTOR (0=NO,1=YES)
      IWOSIG=0
C     DEFINE REGION OF INFLUENCE
C     MAX DISTANCE FROM ANY SOURCE SEGMENT TO CURRENT RECEPTOR
C     IS EQUAL TO (XRECEP-XMINL)
      XRMXKM=(XRECEP-XMINL)/1000.
      CALL SIGMAY(XRMXKM,ISTAB,SYC)
      YLOW=YMINL-4.*SYC
      YHIGH=YMAXL+4.*SYC
      IF(YRECEP.LT.YLOW.OR.YRECEP.GT.YHIGH)GO TO 500
      YLOW=YLOW+DLMIN
      YHIGH=YHIGH-DLMIN
      IF(YRECEP.LT.YLOW.OR.YRECEP.GT.YHIGH)GO TO 500
C     CHECK IF RECEPTOR IS DIRECTLY DOWNWIND OF
C     THE LINE (IDW=0=NO,IDW=1=YES)
      IDW=1
      IF(YRECEP.LT.YMINL.OR.YRECEP.GT.YMAXL)IDW=0
C     CHECK IF RECEPTOR IS ON THE DOWNWIND SIDE OF THE LINE
      IF(XRECEP.GE.XMAXL)GO TO 477
      IF(MOD(ITHETA,90).EQ.0)GO TO 477
      EM=DYEL/DXEL
      B=YE-EM*XE
      IF(XRECEP.LT.(YRECEP-B)/EM)NCONTR=999
477   CONTINUE
      NSEG0=NSEGA(1)
      NNEW=NSEG0
      ITER=0
      INDL=1
      IDELTA=128/(NSEG0-1)
498   CONTINUE
```

```
      NSEG=NSEG+NNEW
C
C     LOOP OVER LINE SEGMENTS
C
      DO 499 ISEG=1,NNEW
      FTSAVE(INDL)=0.0
C     IF CURRENT RECEPTOR IS UPWIND OF A SOURCE SEGMENT, THEN
C     THIS SOURCE SEGMENT DOES NOT CONTRIBUTE
      IF(XRCS(LNUM,INDL).GE.XRECEP)GO TO 495
      DOWNX=XRECEP-XRCS(LNUM,INDL)
      CROSSY=YRECEP-YRCS(LNUM,INDL)
      VIRTXZ=DOWNX+ZV
      VIRTXY=DOWNX+YV
      VXYKM=VIRTXY/1000.
      VXZKM=VIRTXZ/1000.
      CALL DBTSIG(VXZKM,VXYKM,ISTAB,SIGY,SIGZ)
C
C     IF CROSSWIND DISTANCE > 4 * SIGY, THEN THIS SOURCE SEGMENT
C     DOES NOT CONTRIBUTE
      IF(4.*SIGY.LT.ABS(CROSSY))GO TO 495
      IF(ABS(CROSSY).LT.SIGY)IWOSIG=1
      CALL ZRISE(LNUM,INDL,I,Z)
C
C     INCLUDE TERRAIN CORRECTION IN DETERMINING THE PLUME HEIGHT
C
      HNT=Z+ZLINE
C     TER1=(1.-TERAN(ISTAB)); THT=RELEV(I)-LELEV(LNUM)
      TERRAN=TER1*AMIN1(HNT,THT)
      H=HNT-TERRAN
      IF(H.GT.DPBL.AND.ISTAB.LE.4)GO TO 495
C
C     SOLVE THE GAUSSIAN POINT SOURCE EQUATION
C
      CALL GAUSS(CROSSY,SIGY,SIGZ,H,FT)
C     INCLUDE DECAY IN DETERMINING CHI
      DELTAT=DOWNX/WSST
      FT=FT*(1.-DELTAT*DECFAC)
      FTSAVE(INDL)=FT
      NCONTR=NCONTR+1
495   INDL=INDL+IDELTA
499   CONTINUE
C
C     FIRST TIME THROUGH LOOP, CALCULATE THE FIRST CHI ESTIMATE
C
      IF(NNEW.NE.NSEG0)GO TO 714
      INDL=1
      NSEGM1=NSEG0-1
      SUM=(FTSAVE(1)+FTSAVE(129))/2.
      DO 712 ISEG2=2,NSEGM1
      INDL=INDL+IDELTA
      SUM=SUM+FTSAVE(INDL)
712   CONTINUE
C     IF RECEPTOR IS WITHIN REGION OF INFLUENCE BUT NOT DIRECTLY
C     DOWNWIND OF ANY PART OF THE LINE, AND SUM=0.0, CHI=0.0
      IF(SUM.LE.0.0.AND.IDW.NE.1)GO TO 500
C
C     CALCULATE THE REFINED CHI ESTIMATE
C
713   CONTINUE
      ITER=ITER+1
      IDIV=MIN0(ITER,2)
      IDELTA=IDELTA/IDIV
      INDL=1+IDELTA/2
C     INDL IS THE SUBCRIPT OF THE FIRST NEW LINE SEGMENT
C     (SAVE AS INDLSV)
      INDLSV=INDL
      NNEW=NSEGM1**ITER+0.1
C     IF MORE THAN 129 LINE SEGMENTS (I.E., 64 NEW SEGMENTS)
C     ARE REQUIRED, CONTINUE TO INCREASE THE NUMBER OF
C     SEGMENTS BUT ONLY OVER THE SECTION OF THE LINE
C     WHICH IS CONTRIBUTING
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      IF(NNEW.GT.64)GO TO 759
      GO TO 498
714   CONTINUE
C     SUBSCRIPT OF THE FIRST NEW LINE SEGMENT IS INDLSV
C     SUBSCRIPT OF THE LAST NEW LINE SEGMENT IS INDLLN
      INDLLN=129-IDELTA/2
C     SUM THE FIRST AND LAST NEW LINE SEGMENTS
      SUM2=FTSAVE(INDLSV)+FTSAVE(INDLLN)
C     IF THERE ARE ONLY 2 NEW LINE SEGMENTS, SKIP THIS LOOP
      IF(NNEW.LE.2)GO TO 717
      INDL=INDLSV
      I2=NNEW-1
C
C     FIND THE SUM OF ALL THE NEW LINE SEGMENTS
C
      DO 715 ISEG3=2,I2
      INDL=INDL+IDELTA
      SUM2=SUM2+FTSAVE(INDL)
715   CONTINUE
717   CONTINUE
C
C     COMPARE THE NEW ESTIMATE WITH THE PREVIOUS ESTIMATE
C
      SUM2=SUM/2.+SUM2/(2.**ITER)
C     AT LEAST ONE LINE SEGMENT MUST BE WITHIN ONE SIGMA Y OF
C     THE LINE (IF THE RECEPTOR IS DIRECTLY DOWNWIND OF ANY PART
C     OF THE LINE)
      IF(IDW.EQ.1.AND.IWOSIG.NE.1)GO TO 758
      DIFF=ABS(SUM2-SUM)
      IF(DIFF*CUQ.LT.0.1)GO TO 720
      CORR=DIFF/SUM2
      IF(CORR.LT.CRIT)GO TO 720
758   CONTINUE
      SUM=SUM2
      GO TO 713
C     IF 129 SOURCE SEGMENTS NOT SUFFICIENT, CONTINUE
C     TO INCREASE NUMBER OF SEGMENTS, BUT ONLY OVER THE
C     SECTION OF LINE WHICH IS CONTRIBUTING
759   CONTINUE
      CALL SORT(FTSAVE,IBMIN,IBMAX,IWPBL)
      IF(IWPBL.NE.999)GO TO 4949
      IWPBL=0
      PARTCH(I)=0.0
      GO TO 500
4949  CONTINUE
      IBMAX1=IBMAX-1
      IH=0
      IGMAX=1
939   CONTINUE
      SUM2=0.0
      XGMAX1=IGMAX+1
      DO 940 IG=IBMIN,IBMAX1
C     XCLN = X COORDINATE (RCS) OF CURRENT (NEWEST) LINE SEGMENT
C     YCLN = Y COORDINATE (RCS) OF CURRENT (NEWEST) LINE SEGMENT
      XSEG1=XRCS(LNUM,IG)
      XDIFF=XRCS(LNUM,IG+1)-XSEG1
      YSEG1=YRCS(LNUM,IG)
      YDIFF=YRCS(LNUM,IG+1)-YSEG1
      DO 940 IGSUB=1,IGMAX
      WEIGHT=FLOAT(IGSUB)/XGMAX1
      XCLN=XSEG1+WEIGHT*XDIFF
      YCLN=YSEG1+WEIGHT*YDIFF
      DOWNX=XRECEP-XCLN
      CROSSY=YRECEP-YCLN
      VIRTXZ=DOWNX+ZV
      VIRTXY=DOWNX+YV
      VXYKM=VIRTXY/1000.
      VXZKM=VIRTXZ/1000.
      CALL DBTSIG(VXZKM,VXYKM,ISTAB,SIGY,SIGZ)
      CALL ZRISE(LNUM,IG,I,Z)
C     INCLUDE TERRAIN CORRECTION IN DETERMINING THE PLUME HEIGHT
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      HNT=Z+ZLINE                                                       BLP13360
C     TER1=(1.-TERAN(ISTAB)); THT=RELEV(I)-LELEV(LNUM)                  BLP13370
      TERRAN=TER1*AMIN1(HNT,THT)                                        BLP13380
      H=HNT-TERRAN                                                      BLP13390
      CALL GAUSS(CROSSY,SIGY,SIGZ,H,FT)                                 BLP13400
C     INCLUDE DECAY IN DETERMINING CHI                                  BLP13410
      DELTAT=DOWNX/WSST                                                 BLP13420
      FT=FT*(1.-DELTAT*DECFAC)                                          BLP13430
      SUM2=SUM2+FT                                                      BLP13440
      NCONTR=NCONTR+1                                                   BLP13450
940   CONTINUE                                                          BLP13460
C     COMPARE THE NEW ESTIMATE WITH THE PREVIOUS ESTIMATE               BLP13470
      SUM2=SUM/2.+SUM2/(2.**ITER)                                       BLP13480
      DIFF=ABS(SUM2-SUM)                                                BLP13490
      IF(DIFF*CUQ.LT.0.1)GO TO 720                                      BLP13500
      CORR=DIFF/SUM2                                                    BLP13510
      IF(CORR.LT.CRIT)GO TO 720                                         BLP13520
      SUM=SUM2                                                          BLP13530
      ITER=ITER+1                                                       BLP13540
      IF(ITER.GE.MAXIT)GO TO 599                                        BLP13550
      IH=IH+1                                                           BLP13560
      IGMAX=2**IH                                                       BLP13570
      GO TO 939                                                         BLP13580
720   CONTINUE                                                          BLP13590
      SUM=SUM2                                                          BLP13600
C     TEST TO MAKE SURE AT LEAST TWO LINE SEGMENTS CONTRIBUTED          BLP13610
C     TO THE CHI ESTIMATE                                               BLP13620
C     (UNLESS RECEPTOR IS ON THE UPWIND SIDE OF THE LINE WITH           BLP13630
C     SOME SOURCE SEGMENTS DOWNWIND AND SOME SOURCE SEGMENTS            BLP13640
C     UPWIND -- IN THAT CASE JUST USE THE TEST FOR CONVERGENCE)         BLP13650
      IF(NCONTR.LT.2)GO TO 713                                          BLP13660
C     CALCULATE CONCENTRATION (IN MICROGRAMS)                           BLP13670
C     USE STACK HEIGHT WIND SPEED FOR DILUTION                          BLP13680
      PARTCH(I)=CUQ*SUM                                                 BLP13690
      CHIL(I)=CHIL(I)+PARTCH(I)                                         BLP13700
      GO TO 500                                                         BLP13710
599   WRITE(6,600)MAXIT,I,LNUM,CORR,CRIT,ITER,IHOUR,JDAY,IYR            BLP13720
600   FORMAT(//'0','TOO MANY ITERATIONS IN LINE SOURCE CALCULATIONS',   BLP13730
     1 ' -- MAXIT = ',I2/1X,'RECEPTOR ',I3,                             BLP13740
     1 ' PROBABLY TOO CLOSE TO LINE ',I2/                               BLP13750
     2 1X,'CORR = ',F6.2/1X,'CRIT = ',F6.2/1X,'ITER = ',I3/             BLP13760
     3 1X,'(IHOUR,JDAY,IYR) = ','(',I2,',',I3,',',I2,')')               BLP13770
      JITCT=JITCT+1                                                     BLP13780
      IF(JITCT.GT.100)GO TO 6491                                        BLP13790
      SUM=SUM2                                                          BLP13800
      PARTCH(I)=CUQ*SUM                                                 BLP13810
      CHIL(I)=CHIL(I)+PARTCH(I)                                         BLP13820
      GO TO 500                                                         BLP13830
6491  WRITE(6,6492)                                                     BLP13840
6492  FORMAT(//'0','TOO MANY EXCEEDENCES OF LINE SOURCE ',              BLP13850
     1 'ITERATION MAXIMUM -- EXECUTION TERMINATING')                    BLP13860
C     CALL WAUDIT
      STOP                                                              BLP13870
500   CONTINUE                                                          BLP13880
      IF(IPCL(LNUM).EQ.1)CALL OUTPUT(LNUM,PARTCH,NREC,RCOMPR)           BLP13890
1000  CONTINUE                                                          BLP13900
      IF(IPCL(11).EQ.1)CALL OUTPUT(11,CHIL,NREC,RCOMPR)                 BLP13910
C                                                                       BLP13920
C     CALCULATE PARTIAL CONCENTRATIONS DUE TO THE POINT SOURCES         BLP13930
C                                                                       BLP13940
C     LOOP OVER POINTS                                                  BLP13950
C                                                                       BLP13960
2000  IF(NPTS.LT.1)GO TO 9999                                           BLP13970
      IF(ISTAB.GT.4)SQRTS=SQRT(S)                                       BLP13980
      DO 2100 NUMPT=1,NPTS                                              BLP13990
      ZB=PELEV(NUMPT)                                                   BLP14000
      XSTACK=XPRCS(NUMPT)                                               BLP14010
      YSTACK=YPRCS(NUMPT)                                               BLP14020
      ZSTACK=PHS(NUMPT)                                                 BLP14030
      WSST=WS*(ZSTACK/ZMEAS)**P                                         BLP14040
      CUQ=PQ(NUMPT)/WSST                                                BLP14050
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      BUOYFX=APTS(NUMPT)*(TSTACK(NUMPT)-TDEGK)                          BLP14060
      IF(ISTAB.GT.4)GO TO 7150                                          BLP14070
C     CALCULATE DISTANCE TO FINAL RISE                                  BLP14080
      IF(BUOYFX.GT.55.)GO TO 7010                                       BLP14090
C     THE CONSTANT 49. = 3.5*14.                                        BLP14100
      XSMT=49.*BUOYFX**0.625                                            BLP14110
      GO TO 7015                                                        BLP14120
7010  XSMT=3.5*CONST3*BUOYFX**0.4                                       BLP14130
      GO TO 7015                                                        BLP14140
7150  XSMT=3.14159*WSST/SQRTS                                           BLP14150
7015  CONTINUE                                                          BLP14160
C                                                                       BLP14170
C     IF THE POINT SOURCE BUILDING DOWNWASH OPTION IS REQUESTED,        BLP14180
C     DETERMINE THE EFFECTS (IF ANY) OF BUILDING DOWNWASH               BLP14190
C                                                                       BLP14200
      ZV=0.0                                                            BLP14210
      YV=0.0                                                            BLP14220
      IF(IDOWNW(NUMPT).NE.1)GO TO 512                                   BLP14230
C     CALCULATE THE MOMENTUM RISE AT A DOWNWIND DISTANCE OF 2.*HB       BLP14240
C     FM3 = 3.*FM (I.E., 3.*VERTICAL MOMENTUM FLUX TERM)                BLP14250
      FM3=BPTS(NUMPT)*TDEGK                                             BLP14260
      BETAM=0.3333333+WSST/VEXIT(NUMPT)                                 BLP14270
      IF(ISTAB.GT.4)GO TO 509                                           BLP14280
      EFFHT=ZSTACK+(FM3*TWOHB/(BETAM*BETAM*WSST*WSST))**0.3333333       BLP14290
      GO TO 511                                                         BLP14300
509   EFFHT=ZSTACK+(FM3*SIN(SQRTS*TWOHB/WSST)/                          BLP14310
     1 (BETAM*BETAM*WSST*SQRTS))**0.3333333                             BLP14320
511   CONTINUE                                                          BLP14330
      RATIO=EFFHT/HB                                                    BLP14340
      RATIO=AMAX1(RATIO,1.0)                                            BLP14350
C     IF RATIO GE 3.0, SIGY AND SIGZ ARE NOT MODIFIED                   BLP14360
C     IF RATIO LT 3.0 AND GT 1.2, ONLY SIGZ IS MODIFIED                 BLP14370
C     IF RATIO LE 1.2, BOTH SIGY AND SIGZ ARE MODIFIED                  BLP14380
      IF(RATIO.GE.3.0)GO TO 512                                         BLP14390
      R0Z=HB*(1.5-RATIO/2.)                                             BLP14400
      SZ0=SRT2DP*R0Z                                                    BLP14410
      ZV=1000.*XVZ(SZ0,ISTAB)                                           BLP14420
      A=5.0*R0Z                                                         BLP14430
      B=8.3333333*R0Z*R0Z                                               BLP14440
      IF(RATIO.GT.1.2)GO TO 512                                         BLP14450
      R0Y=HB*(6.-5.*RATIO)/2.                                           BLP14460
      SY0=SRT2DP*R0Y                                                    BLP14470
      YV=1000.*XVY(SY0,ISTAB)                                           BLP14480
512   CONTINUE                                                          BLP14490
C                                                                       BLP14500
C     LOOP OVER RECEPTORS                                               BLP14510
C                                                                       BLP14520
      DO 2050 I=1,NREC                                                  BLP14530
      PARTCH(I)=0.0                                                     BLP14540
      DOWNX=XRRCS(I)-XSTACK                                             BLP14550
      IF(DOWNX.LE.0.0)GO TO 2050                                        BLP14560
      CROSSY=YRRCS(I)-YSTACK                                            BLP14570
      VIRTXZ=DOWNX+ZV                                                   BLP14580
      VIRTXY=DOWNX+YV                                                   BLP14590
      VXZKM=VIRTXZ/1000.                                                BLP14600
      VXYKM=VIRTXY/1000.                                                BLP14610
      CALL DBTSIG(VXZKM,VXYKM,ISTAB,SIGY,SIGZ)                          BLP14620
      IF(4.*SIGY.LT.ABS(CROSSY))GO TO 2050                              BLP14630
      IF(IDOWNW(NUMPT).NE.1)GO TO 1517                                  BLP14640
      ZSAVE=9999.                                                       BLP14650
C                                                                       BLP14660
C     IF THE SHEAR AND DOWNWASH OPTIONS ARE BOTH REQUESTED,             BLP14670
C     USE THE MINIMUM OF Z(SHEAR) AND Z(DOWNWASH)                       BLP14680
C                                                                       BLP14690
      IF(LSHEAR)CALL PTRISE(BUOYFX,ZSTACK,XSMT,DOWNX,WSST,ZSAVE,LSHEAR, BLP14700
     1 LTRANS)                                                          BLP14710
      IF(ISTAB.GT.4)GO TO 1515                                          BLP14720
1514  CONTINUE                                                          BLP14730
      EXR=AMIN1(DOWNX,XSMT)                                             BLP14740
      IF(.NOT.LTRANS)EXR=XSMT                                           BLP14750
      IF(.NOT.LTRANS.AND.ISTAB.GE.5)EXR=2.*WSST/SQRT(S)                 BLP14760
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      C=-4.16666667*BUOYFX*EXR*EXR/WSST**3
      GO TO 1516
1515  IF(DOWNX.LT.2.*WSST/SQRT(S))GO TO 1514
      C=-16.666667*BUOYFX/(WSST*S)
1516  CONTINUE
      CALL CUBIC(A,B,C,Z)
      Z=AMIN1(Z,ZSAVE)
      GO TO 1518
1517  CONTINUE
      CALL PTRISE(BUOYFX,ZSTACK,XSMT,DOWNX,WSST,Z,LSHEAR,LTRANS)
1518  CONTINUE
      HNT=Z+ZSTACK
      THT=RELEV(I)-ZB
C     TER1=(1.-TERAN(ISTAB))
      TERRAN=TER1*AMIN1(HNT,THT)
      H=HNT-TERRAN
      IF(H.GT.DPBL.AND.ISTAB.LE.4)GO TO 2050
      CALL GAUSS(CROSSY,SIGY,SIGZ,H,FT)
C     INCLUDE DECAY IN DETERMINING CHI
      DELTAT=DOWNX/WSST
      FT=FT*(1.-DELTAT*DECFAC)
      PARTCH(I)=CUQ*FT
      CHI(I)=CHI(I)+PARTCH(I)
2050  CONTINUE
      ICODE=100+NUMPT
      IF(IPCP(NUMPT).EQ.1)CALL OUTPUT(ICODE,PARTCH,NREC,RCOMPR)
2100  CONTINUE
      IF(IPCP(51).EQ.1)CALL OUTPUT(151,CHI,NREC,RCOMPR)
9999  CONTINUE
      DO 9050 I=1,NREC
      CHI(I)=CHI(I)+CHIL(I)+XBACKG
9050  CONTINUE
      CALL OUTPUT(999,CHI,NREC,RCOMPR)
      RETURN
      END
C
      SUBROUTINE GAUSS(CROSSY,SIGY,SIGZ,H,FT)
C
C
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR
      COMMON/PBLDAT/TWOPBL,PBL1P6
      DATA TMIN/0.0512/,TMAX/9.21/
      TD1=3.1415927*SIGY*SIGZ
      YPSIG=CROSSY/SIGY
      EXPYP=0.5*YPSIG*YPSIG
C     PREVENT UNDERFLOWS
      IF(EXPYP.GT.50.)GO TO 495
      F=EXP(-EXPYP)
      GO TO 496
495   F=0.0
      GO TO 443
496   CONTINUE
C     IF MIXING HEIGHT (DPBL) GE 5000 M OR FOR STABLE CONDITIONS,
C     NEGLECT THE REFLECTION TERMS
      IF(ISTAB.GE.5.OR.DPBL.GT.5000.)GO TO 451
C     IF SIGZ GT 1.6*DPBL, ASSUME A UNIFORM VERTICAL DISTRIBUTION
      IF(SIGZ.GT.PBL1P6)GO TO 460
C     CALCULATE MULTIPLE EDDY REFLECTIONS TERMS
C     USING A FOURIER SERIES METHOD -- SEE ERT MEMO CS 093
      F1=1
      T=(SIGZ/DPBL)**2
      H2=H/DPBL
      IF(T.GE.0.6)GO TO 500
      ARG=2.*(1.-H2)/T
      IF(ARG.GE.TMAX)GO TO 400
      IF(ARG.LT.TMIN)F1=F1+1.-ARG
      IF(ARG.GE.TMIN)F1=F1+EXP(-ARG)
      ARG=2.*(1.+H2)/T
      IF(ARG.GE.TMAX)GO TO 400
      F1=F1+EXP(-ARG)
      ARG=4.*(2.-H2)/T
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      IF(ARG.GE.TMAX)GO TO 400                                          BLP15470
      F1=F1+EXP(-ARG)                                                   BLP15480
      ARG=4.*(2.+H2)/T                                                  BLP15490
      IF(ARG.LT.TMAX)F1=F1+EXP(-ARG)                                    BLP15500
400   ARG=-0.5*H2*H2/T                                                  BLP15510
      IF(ARG.LT.-90.)F1=0.0                                             BLP15520
C     CONSTANT 0.797885 = SQRT(2./PI)                                   BLP15530
      IF(ARG.GE.-90.)F1=0.797885*F1*EXP(ARG)/SIGZ                       BLP15540
      IF(F1.LT.1.E-30)F1=0.0                                            BLP15550
      GO TO 1500                                                        BLP15560
C     CONSTANT 4.934802 = PI*PI/2.                                      BLP15570
500   ARG=4.934802*T                                                    BLP15580
      IF(ARG.GE.TMAX)GO TO 900                                          BLP15590
      F1=F1+2.*EXP(-ARG)*COS(3.141593*H2)                               BLP15600
C     CONSTANT 19.739209 = 2.*PI*PI                                     BLP15610
      ARG=19.739209*T                                                   BLP15620
      IF(ARG.LT.TMAX)F1=F1+2.*EXP(-ARG)*COS(6.283185*H2)                BLP15630
900   F1=F1/DPBL                                                        BLP15640
      IF(F1.LT.1.E-30)F1=0.0                                            BLP15650
1500  CONTINUE                                                          BLP15660
C     THE CONSTANT 1.25331414 = SQRT(PI/2.)                             BLP15670
      F1=1.25331414*SIGZ*F1                                             BLP15680
      GO TO 445                                                         BLP15690
451   CONTINUE                                                          BLP15700
      HPSIG=H/SIGZ                                                      BLP15710
      EXPHP=0.5*HPSIG*HPSIG                                             BLP15720
      IF(EXPHP.GT.50)GO TO 443                                          BLP15730
      F1=EXP(-EXPHP)                                                    BLP15740
      GO TO 445                                                         BLP15750
443   F1=0.0                                                            BLP15760
445   CONTINUE                                                          BLP15770
C     FIND PRODUCT OF EXPONENTIAL TERMS DIVIDED BY (PI*SIGY*SIGZ)       BLP15780
      FT=F*F1/TD1                                                       BLP15790
      GO TO 470                                                         BLP15800
460   CONTINUE                                                          BLP15810
C     VERTICAL DISTRIBUTION ASSUMED UNIFORM                             BLP15820
C     THE CONSTANT 2.5066283 = SQRT(2.*PI)                              BLP15830
      FT=F/(2.5066283*SIGY*DPBL)                                        BLP15840
470   RETURN                                                            BLP15850
      END                                                               BLP15860
C
      SUBROUTINE SORT(FTSAVE,IBMIN,IBMAX,IWPBL)                         BLP15870
C                                                                       BLP15880
C                                                                       BLP15890
      REAL FTSAVE(129)                                                  BLP15900
      ISAFE=0                                                           BLP15910
      IB=0                                                              BLP15920
      IF(FTSAVE(129).NE.0.0)IB=129                                      BLP15930
      IF(FTSAVE(1).NE.0.0)IB=1                                          BLP15940
      IF(IB.NE.0)GO TO 970                                              BLP15950
      DO 950 ILEVEL=1,7                                                 BLP15960
      NEACHL=2**(ILEVEL-1)                                              BLP15970
      INCR=2**(8-ILEVEL)                                                BLP15980
      INDEX=1+INCR/2                                                    BLP15990
      DO 945 NC=1,NEACHL                                                BLP16000
      IF(FTSAVE(INDEX).EQ.0.0)GO TO 944                                 BLP16010
      IB=INDEX                                                          BLP16020
      GO TO 970                                                         BLP16030
944   INDEX=INDEX+INCR                                                  BLP16040
945   CONTINUE                                                          BLP16050
950   CONTINUE                                                          BLP16060
      IF(IB.NE.0)GO TO 970                                              BLP16070
      IWPBL=999                                                         BLP16080
      RETURN                                                            BLP16090
970   IBMIN=IB-1                                                        BLP16100
      IBMAX=IB+1                                                        BLP16110
      IBMIN=AMAX0(IBMIN,1)                                              BLP16120
      IBMAX=AMIN0(IBMAX,129)                                            BLP16130
975   CONTINUE                                                          BLP16140
      INCRM=0                                                           BLP16150
      INCRP=0                                                           BLP16160
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      IF(FTSAVE(IBMIN).NE.0.0)INCRM=1
      IF(IBMIN.EQ.1)INCRM=0
      IF(FTSAVE(IBMAX).NE.0.0)INCRP=1
      IF(IBMAX.EQ.129)INCRP=0
      IBMIN=IBMIN-INCRM
      IBMAX=IBMAX+INCRP
      IF(INCRM.EQ.0.AND.INCRP.EQ.0)GO TO 980
      ISAFE=ISAFE+1
      IF(ISAFE.GT.129)GO TO 980
      GO TO 975
980   CONTINUE
      RETURN
      END
C
      SUBROUTINE OUTPUT(ICODE,CHIS,NREC,RCOMPR)
C
C
      REAL CHIS(NREC)
      LOGICAL RCOMPR
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR
C
C     THIS SUBROUTINE OUTPUTS ALL CHI ARRAYS TO TAPE (OR DISK)
C
C     ICODE IDENTIFIES THE CHI ARRAY TO FOLLOW:
C
C     ICODE = 1 TO 10 IMPLIES THE CHI ARRAY IS THE PARTIAL
C     CONTRIBUTION OF LINE NUMBER "ICODE" AT EACH RECEPTOR
C
C     ICODE = 11 IMPLIES THE CHI ARRAY IS THE PARTIAL
C     CONTRIBUTION OF ALL THE LINES AT EACH RECEPTOR
C
C     ICODE = 101 TO 150 IMPLIES THE CHI ARRAY IS THE PARTIAL
C     CONTRIBUTION OF POINT SOURCE NUMBER "ICODE - 100" AT
C     EACH RECEPTOR
C
C     ICODE = 151 IMPLIES THE CHI ARRAY IS THE PARTIAL
C     CONTRIBUTION OF ALL THE POINT SOURCES AT EACH RECEPTOR
C
C     ICODE = 999 IMPLIES THE CHI ARRAY IS THE TOTAL
C     CONCENTRATION SUMMED OVER ALL THE POINT AND LINE SOURCES AT
C     EACH RECEPTOR
      IDAYHR=JDAY*100+IHOUR
C     ROUND THE WS (NEAREST TENTHS OF M/S) AND
C     THE DPBL (NEAREST METER)
      IWS=(WS+0.05)*10
      IDPBL=DPBL+0.5
      IWD=WD
      ICD=IWS*10000+ISTAB*1000+ICODE
      IMET2=IWD*10000+IDPBL
      IF(RCOMPR)GO TO 10
      WRITE(20)IDAYHR,ICD,IMET2,CHIS
      RETURN
10    CONTINUE
      CALL COMPRS(IDAYHR,ICD,IMET2,NREC,CHIS)
      RETURN
      END
C
      SUBROUTINE PTRISE(BUOYFX,ZSTACK,XSMT,DOWNX,WSST,Z,LSHEAR,LTRANS)
C
C
      LOGICAL LSHEAR,LTRANS
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR
      COMMON/PARM/CRIT,TER1,DECFAC,XBACKG,CONST2,CONST3,MAXIT
C
C     THIS SUBROUTINE CALCULATES POINT SOURCE PLUME RISE
C     WITH AN OPTIONAL VERTICAL WIND SPEED SHEAR CORRECTION FOR
C     BOTH NEUTRAL AND STABLE PLUME RISE
C
C     A VALUE OF 0.6 IS ASSUMED FOR THE ENTRAINMENT
C     PARAMETER (BETA)
C
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      X=DOWNX                                                           BLP16860
      IF(.NOT.LSHEAR)GO TO 145                                          BLP16870
C     CONSTANT 2.777778 = 1./(BETA*BETA) WITH BETA=0.6                  BLP16880
      CS=2.777778*BUOYFX                                                BLP16890
      CS2=ZSTACK**P                                                     BLP16900
      EP=3.*(1.+P)                                                      BLP16910
      P3=3.+P                                                           BLP16920
      TP3=2.*P3                                                         BLP16930
145   CONTINUE                                                          BLP16940
      X=AMIN1(X,XSMT)                                                   BLP16950
      IF(.NOT.LTRANS)X=XSMT                                             BLP16960
      IF(ISTAB.GT.4)GO TO 150                                           BLP16970
      IF(.NOT.LSHEAR)GO TO 170                                          BLP16980
C                                                                       BLP16990
C     NEUTRAL-UNSTABLE PLUME RISE WITH SHEAR                            BLP17000
C                                                                       BLP17010
16    CONTINUE                                                          BLP17020
C     BETA (ENTRAINMENT PARAMETER) IS ASSUMED TO BE 0.6                 BLP17030
      A1=CS*X*X/WSST**3                                                 BLP17040
C     CONSTANT 0.8735805 = (2./3.)**(1./3.)                             BLP17050
      RMULT=0.8735805*(EP*EP*CS2**3/(TP3*A1**P))**(1./EP)               BLP17060
      RMULT=AMIN1(RMULT,1.0)                                            BLP17070
      Z=RMULT*(1.5*A1)**0.333333                                        BLP17080
      IF(ISTAB.LE.4)GO TO 39                                            BLP17090
      Z=AMIN1(Z,(6./CSV1)**0.333333)                                    BLP17100
      Z=AMIN1(Z,5.0*BUOYFX**0.25/S**0.375)                              BLP17110
39    CONTINUE                                                          BLP17120
      RETURN                                                            BLP17130
C                                                                       BLP17140
C     NEUTRAL-UNSTABLE PLUME RISE -- NO SHEAR                           BLP17150
C                                                                       BLP17160
170   CONTINUE                                                          BLP17170
      Z=1.6*(BUOYFX*X*X)**0.333333/WSST                                 BLP17180
      IF(ISTAB.GT.4)Z=AMIN1(Z,ZB)                                       BLP17190
      RETURN                                                            BLP17200
C                                                                       BLP17210
C     STABLE PLUME RISE -- NO SHEAR                                     BLP17220
C                                                                       BLP17230
175   CONTINUE                                                          BLP17240
      ZMTT=5.0*BUOYFX**0.25/S**0.375                                    BLP17250
C     CONST2 HAS A DEFAULT VALUE OF 2.6 (BRIGGS, 1975)                  BLP17260
      ZB=CONST2*(BUOYFX/(WSST*S))**0.333333                             BLP17270
      ZB=AMIN1(ZB,ZMTT)                                                 BLP17280
      IF(X.LT.XSMT)GO TO 170                                            BLP17290
      Z=ZB                                                              BLP17300
      RETURN                                                            BLP17310
C                                                                       BLP17320
C     STABLE PLUME RISE WITH SHEAR                                      BLP17330
C                                                                       BLP17340
150   CONTINUE                                                          BLP17350
      IF(.NOT.LSHEAR)GO TO 175                                          BLP17360
      XPFS=SQRT((TP3*CS2*CS/(WSST*S))**(EP/P3)*TP3*WSST**3/(EP*EP*CS2**3BLP17370
     1 *CS))                                                            BLP17380
      CSV1=WSST*S/CS                                                    BLP17390
      IF(X.LT.XPFS)GO TO 16                                             BLP17400
C     CONSTANT 0.5503212 = (1./6.)**(1./3.)                             BLP17410
      RMULT=0.5503212*CSV1**(P/(3.*P3))*(TP3*CS2)**(1./P3)              BLP17420
      RMULT=AMIN1(RMULT,1.0)                                            BLP17430
      Z=RMULT*(6./CSV1)**0.333333                                       BLP17440
      Z=AMIN1(Z,5.0*BUOYFX**0.25/S**0.375)                              BLP17450
      RETURN                                                            BLP17460
      END                                                               BLP17470
C
      SUBROUTINE CUBIC(A,B,C,Z)                                         BLP17480
C                                                                       BLP17490
C                                                                       BLP17500
C                                                                       BLP17510
C     SOLVES FOR ONE ROOT OF THE CUBIC EQUATION:                        BLP17520
C     Z**3 + A*Z**2 + B*Z + C = 0                                       BLP17530
C                                                                       BLP17540
      IMPLICIT  DOUBLE PRECISION (A-H,O-Z)                              XXX17545
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      REAL A,B,C,Z                                                      XXX17547
      DATA ONE/1.0/                                                     BLP17550
      A3=A/3.                                                           BLP17560
      AP=B-A*A3                                                         BLP17570
      BP=2.*A3**3-A3*B+C                                                BLP17580
      AP3=AP/3.                                                         BLP17590
      BP2=BP/2.                                                         BLP17600
      TROOT=BP2*BP2+AP3*AP3*AP3                                         BLP17610
      IF(TROOT.LE.0.0)GO TO 50                                          BLP17620
      TR=SQRT(TROOT)                                                    BLP17630
      APP=(-BP2+TR)**0.333333                                           BLP17640
      BSV=-BP2-TR                                                       BLP17650
      IF(BSV .EQ. 0) GO TO 45                                           XXX17655
      SGN=SIGN(ONE,BSV)                                                 BLP17660
      BPP=SGN*(ABS(BSV))**0.333333                                      BLP17670
      Z=APP+BPP-A3                                                      BLP17680
      RETURN                                                            BLP17690
   45 CONTINUE                                                          XXX17691
C     BSV (& BPP) = 0.0                                                 XXX17692
      Z=APP-A3                                                          XXX17693
      RETURN                                                            XXX17694
50    CM=2.*SQRT(-AP3)                                                  BLP17700
      ALPHA=ACOS(BP/(AP3*CM))/3.                                        BLP17710
      Z=CM*COS(ALPHA)-A3                                                BLP17720
      RETURN                                                            BLP17730
      END                                                               BLP17740
C
      SUBROUTINE WSC(ISTAB,UM,U,S,P)                                    BLP17750
C                                                                       BLP17760
C                                                                       BLP17770
      REAL L                                                            BLP17780
      LOGICAL LSHEAR,LTRANS                                             BLP17790
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP17800
     1 LTRANS                                                           BLP17810
C     CALCULATES AN EFFECTIVE U USING THE LINE SOURCE PLUME             BLP17820
C     RISE EQUATION (LINE SOURCE TERM ONLY)                             BLP17830
C     MATCHED AT X = XF (FINAL RISE)                                    BLP17840
      IF(ISTAB.GT.4)GO TO 50                                            BLP17850
C                                                                       BLP17860
C     NEUTRAL (OR UNSTABLE) CONDITIONS                                  BLP17870
C                                                                       BLP17880
      P3=3.*P                                                           BLP17890
      EP=2.+P3                                                          BLP17900
      EPI=1./EP                                                         BLP17910
C     CONSTANT 2.4=4.*BETA WITH BETA=0.6                                BLP17920
      T1=(EP*EP*N*FPRIME*HB**P3/(2.4*(2.+P)*L*UM**3))**EPI              BLP17930
      Z=T1*XMATCH**(2.*EPI)                                             BLP17940
C     CONSTANT 1.2 = 2.*BETA WITH BETA=0.6                              BLP17950
      U=(N*FPRIME/(1.2*L)*(XMATCH/Z)**2)**0.333333                      BLP17960
      U=AMAX1(U,UM)                                                     BLP17970
      RETURN                                                            BLP17980
50    CONTINUE                                                          BLP17990
C                                                                       BLP18000
C     STABLE CONDITIONS                                                 BLP18010
C                                                                       BLP18020
      P2=2.+P                                                           BLP18030
C     CONSTANT 0.6 = BETA                                               BLP18040
      Z=(P2*HB**P*N*FPRIME/(0.6*L*UM*S))**(1./P2)                       BLP18050
C     CONSTANT 3.3333333 = 2./BETA WITH BETA=0.6                        BLP18060
      U=3.3333333*N*FPRIME/(L*S*Z*Z)                                    BLP18070
      U=AMAX1(U,UM)                                                     BLP18080
      RETURN                                                            BLP18090
      END                                                               BLP18100
C
      SUBROUTINE LENG(THETA,U)                                          BLP18110
C                                                                       BLP18120
C                                                                       BLP18130
      REAL L,LEFF,LD,LEFF1,LEFFV                                        BLP18140
      LOGICAL LSHEAR,LTRANS                                             BLP18150
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP18160
     1 LTRANS                                                           BLP18170
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      COMMON/PRLS/XFB,LEFF,LD,R0,XFINAL,XFS                             BLP18180
      DATA RAD/0.0174533/                                               BLP18190
C                                                                       BLP18200
C     THIS SUBROUTINE CALCULATES XFB,LEFF,LD,R0                         BLP18210
C                                                                       BLP18220
C     FPRIME IS THE BUOYANCY FLUX OF ONE LINE; FP IS THE EFFECTIVE      BLP18230
C     BUOYANCY FLUX OF N LINES                                          BLP18240
      FP=N*FPRIME                                                       BLP18250
      TRAD=THETA*RAD                                                    BLP18260
      SINT=ABS(SIN(TRAD))                                               BLP18270
      COST=ABS(COS(TRAD))                                               BLP18280
C     CALCULATE DISTANCE OF FULL BUOYANCY (XFB)                         BLP18290
      DXM=DX+WB                                                         BLP18300
      XFB=L*COST+(N-1)*DXM*SINT                                         BLP18310
C     CALCULATE EFFECTIVE LINE SOURCE LENGTH (LEFF) AND                 BLP18320
C     EFFECTIVE DOWNWASH LINE LENGTH (LD)                               BLP18330
      LEFF1=L*SINT                                                      BLP18340
      IF(N.EQ.1)GO TO 112                                               BLP18350
C     CONSTANT 0.8333333 = 1./(2.*BETA) WITH BETA=0.6                   BLP18360
      ZI=0.8333333*DXM                                                  BLP18370
C     CONSTANT 2.2619467 = 2.*PI*BETA*BETA WITH BETA=0.6                BLP18380
C     CONSTANT 1.5915494 = 3./(PI*BETA) WITH BETA=0.6                   BLP18390
      T1=(2.2619467*U**3/FPRIME)*ZI*ZI*(ZI+1.5915494*WM)                BLP18400
      XI=(T1*L)**0.333333                                               BLP18410
      IF(XI.LE.L)GO TO 55                                               BLP18420
      XI=L/2.+SQRT(12.*T1-3.*L*L)/6.                                    BLP18430
C     CONSTANT 1.2 = 2.*BETA WITH BETA=0.6                              BLP18440
C     CONSTANT 0.6283185 = PI*BETA/3. WITH BETA=0.6                     BLP18450
      LEFFV=FP*(L*L/3.+XI*(XI-L))/(1.2*U**3*ZI*ZI)-0.6283185*ZI         BLP18460
      GO TO 110                                                         BLP18470
55    CONTINUE                                                          BLP18480
C     CONSTANT 3.6 = 6.*BETA WITH BETA=0.6                              BLP18490
C     CONSTANT 0.6283185 = PI*BETA/3. WITH BETA=0.6                     BLP18500
      LEFFV=FP/(3.6*L*ZI*ZI)*(XI/U)**3-0.6283185*ZI                     BLP18510
110   LEFF=LEFF1+LEFFV*COST                                             BLP18520
      LD=LEFF*SINT                                                      BLP18530
C     CALCULATE DOWNWASHED EDGE RADIUS                                  BLP18540
      R0=AMIN1(HB,LD)/AVFACT                                            BLP18550
      RETURN                                                            BLP18560
C     IF N = 1, NO INTERACTION AT ANY X, I.E.,                          BLP18570
C     LEFFV = WM; FP = FPRIME; XFB = L * COST + WM * SINT               BLP18580
112   LEFFV=WM                                                          BLP18590
      FP=FPRIME                                                         BLP18600
      XFB=XFB+WM*SINT                                                   BLP18610
      GO TO 110                                                         BLP18620
      END                                                               BLP18630
C
      SUBROUTINE RISE(U,ISTAB,S)                                        BLP18640
C                                                                       BLP18650
C                                                                       BLP18660
      REAL L,LEFF,LD                                                    BLP18670
      LOGICAL LSHEAR,LTRANS                                             BLP18680
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP18690
     1 LTRANS                                                           BLP18700
      COMMON/PRLS/XFB,LEFF,LD,R0,XFINAL,XFS                             BLP18710
      COMMON/RINTP/XDIST(7),DH(7)                                       BLP18720
C                                                                       BLP18730
C     THIS SUBROUTINE CALCULATES LINE SOURCE PLUME RISE                 BLP18740
C     USING AN OPTIONAL VERTICAL WIND SHEAR CORRECTED 'EFFECTIVE' WIND  BLP18750
C     SPEED FOR BOTH NEUTRAL AND STABLE CONDITIONS                      BLP18760
C                                                                       BLP18770
C     CONSTANT 1.5915494 = 3./(PI*BETA) WITH BETA=0.6                   BLP18780
C     CONSTANT 5.0 = 3./BETA WITH BETA=0.6                              BLP18790
      A=1.5915494*LEFF+5.*R0                                            BLP18800
C     CONSTANT 5.3051648 = 6./(PI*BETA*BETA) WITH BETA=0.6              BLP18810
C     CONSTANT 8.3333333 = 3./(BETA*BETA) WITH BETA=0.6                 BLP18820
      B=R0*(5.3051648*LD+8.333333*R0)                                   BLP18830
      DO 1000 I=2,7                                                     BLP18840
      X=XDIST(I)                                                        BLP18850
      IF(ISTAB.LE.4)GO TO 90                                            BLP18860
C     WITH STABLE CONDITIONS, USE NEUTRAL RISE EQUATION                 BLP18870
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C     FOR TRANSITIONAL RISE CALCULATIONS, BUT CALCULATE                BLP18880
C     FINAL RISE BASED ON THE FINAL STABLE RISE EQUATION               BLP18890
      IF(X.LT.XFS)GO TO 90                                             BLP18900
C     CALCULATE FINAL (STABLE) PLUME RISE                              BLP18910
C     CONSTANT 5.3051648 = 6./(PI*BETA*BETA) WITH BETA=0.6             BLP18920
92    C=-5.3051648*FP/(U*S)                                            BLP18930
      GO TO 8                                                          BLP18940
90    CONTINUE                                                         BLP18950
      IF(X.LE.XFB)GO TO 80                                             BLP18960
7     CONTINUE                                                         BLP18970
C     CONSTANT 1.3262912 = 3./(2.*PI*BETA*BETA) WITH BETA=0.6          BLP18980
      C=-1.3262912*FP*(XFB*XFB/3.+X*X-XFB*X)/U**3                      BLP18990
8     CONTINUE                                                         BLP19000
      CALL CUBIC(A,B,C,Z)                                              BLP19010
12    CONTINUE                                                         BLP19020
      DH(I)=Z                                                          BLP19030
      GO TO 1000                                                       BLP19040
C     CONSTANT 0.4420971 = 1./(2.*PI*BETA*BETA) WITH BETA=0.6          BLP19050
80    C=-0.4420971*(FP/XFB)*(X/U)**3                                   BLP19060
      GO TO 8                                                          BLP19070
1000  CONTINUE                                                         BLP19080
      RETURN                                                           BLP19090
      END                                                              BLP19100
C
      SUBROUTINE ZRISE(IL,IS,IR,Z)                                     BLP19110
C                                                                      BLP19120
C                                                                      BLP19130
      REAL LEFF,LD,LELEV                                               BLP19140
      COMMON/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY,XRSCS(100),         BLP19150
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC                BLP19160
      COMMON/SOURCE/NLINES,XLBEG(10),XLEND(10),DEL(10),YSCS(10),QT(10), BLP19170
     1 HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),                BLP19180
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),    BLP19190
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)     BLP19200
      COMMON/PRLS/XFB,LEFF,LD,R0,XFINAL,XFS                            BLP19210
      COMMON/RINTP/XDIST(7),DH(7)                                      BLP19220
C                                                                      BLP19230
C     Z1 IS THE PLUME HEIGHT OF THE HIGHEST PLUME SEGMENT AT X = XFB   BLP19240
C     (EXCEPT IN THE SPECIAL CASE OF STABLE CONDITIONS WITH            BLP19250
C     THE DISTANCE TO FINAL RISE (XFS) LESS THAN XFB -- IN             BLP19260
C     THAT CASE, Z1 IS THE HEIGHT OF THE HIGHEST PLUME ELEMENT         BLP19270
C     AT X=XFS)                                                        BLP19280
C     XI IS THE DISTANCE OF THE CURRENT LINE SEGMENT TO XFB            BLP19290
C                                                                      BLP19300
      Z1=DH(2)                                                         BLP19310
      XI=XFB-XRCS(IL,IS)                                               BLP19320
      XI=AMAX1(XI,0.0)                                                 BLP19330
      XI=AMIN1(XI,XFB)                                                 BLP19340
      ZXFB=Z1*(1.-(XFB-XI)/XFB)                                        BLP19350
C     Z2 IS THE PLUME HEIGHT OF THE HIGHEST SEGMENT AT X               BLP19360
      CALL INTRSE(XRRCS(IR),Z2)                                        BLP19370
      DELTAZ=Z2-Z1                                                     BLP19380
      Z=ZXFB+DELTAZ                                                    BLP19390
      RETURN                                                           BLP19400
      END                                                              BLP19410
C
      SUBROUTINE INTRSE(X,Z)                                           BLP19420
C                                                                      BLP19430
C                                                                      BLP19440
      REAL LEFF,LD                                                     BLP19450
      COMMON/PRLS/XFB,LEFF,LD,R0,XFINAL,XFS                            BLP19460
      COMMON/RINTP/XDIST(7),DH(7)                                      BLP19470
C                                                                      BLP19480
C     THIS SUBROUTINE INTERPOLATES THE PLUME RISE OF THE TOP (HIGHEST) BLP19490
C     PLUME ELEMENT AT ANY DISTANCE X USING THE CALCULATED             BLP19500
C     PLUME RISE AT SEVEN POINTS (XDIST(1-7))                          BLP19510
C                                                                      BLP19520
      IF (X.GT.XDIST(7))GO TO 55                                       BLP19530
      DO 10 I=2,6                                                      BLP19540
      IF(X.GT.XDIST(I))GO TO 10                                        BLP19550
      INDEX=I                                                          BLP19560
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      GO TO 11                                                          BLP19570
10    CONTINUE                                                          BLP19580
      INDEX=5                                                           BLP19590
11    CONTINUE                                                          BLP19600
      INDEX1=INDEX-1                                                    BLP19610
      Z=DH(INDEX)-(DH(INDEX)-DH(INDEX1))*(XDIST(INDEX)-X)/              BLP19620
     1 (XDIST(INDEX)-XDIST(INDEX1))                                     BLP19630
      RETURN                                                            BLP19640
55    CONTINUE                                                          BLP19650
C     PLUME REACHES FINAL RISE                                          BLP19660
      Z=DH(7)                                                           BLP19670
      RETURN                                                            BLP19680
      END                                                               BLP19690
C
      SUBROUTINE DBTSIG (X,XY,KST,SY,SZ)                                BLP19700
C                                                                       BLP19710
C                                                                       BLP19720
      DIMENSION XA(7),XB(2),XD(5),XE(8),XF(9),AA(8),BA(8),AB(3),BB(3),  BLP19730
     1 AD(6),BD(6),AE(9),BE(9),AF(10),BF(10)                            BLP19740
      DATA XA/.5,.4,.3,.25,.2,.15,.1/                                   BLP19750
      DATA XB/.4,.2/                                                    BLP19760
      DATA XD /30.,10.,3.,1.,.3/                                        BLP19770
      DATA XE /40.,20.,10.,4.,2.,1.,.3,.1/                              BLP19780
      DATA XF /60.,30.,15.,7.,3.,2.,1.,.7,.2/                           BLP19790
      DATA AA /453.85,346.75,258.89,217.41,179.52,170.22,158.08,122.8/  BLP19800
      DATA BA /2.1166,1.7283,1.4094,1.2644,1.1262,1.0932,1.0542,.9447/  BLP19810
      DATA AB /109.30,98.483,90.673/                                    BLP19820
      DATA BB /1.0971,0.98332,0.93198/                                  BLP19830
      DATA AD /44.053,36.650,33.504,32.093,32.093,34.459/               BLP19840
      DATA BD /0.51179,0.56589,0.60486,0.64403,0.81066,0.86974/         BLP19850
      DATA AE /47.618,35.420,26.970,24.703,22.534,21.628,21.628,23.331, BLP19860
     1 24.26/                                                           BLP19870
      DATA BE /0.29592,0.37615,0.46713,0.50527,0.57154,0.63077,0.75660, BLP19880
     1 0.81956,0.8366/                                                  BLP19890
      DATA AF /34.219,27.074,22.651,17.836,16.187,14.823,13.953,13.953, BLP19900
     1 14.457,15.209/                                                   BLP19910
      DATA BF /0.21716,0.27436,0.32681,0.41507,0.46490,0.54503,0.63227, BLP19920
     1 0.68465,0.78407,0.81558/                                         BLP19930
      GO TO (10,20,30,40,50,60),KST                                     BLP19940
C         STABILITY A (10)                                              BLP19950
   10 TH = (24.167 - 2.5334*ALOG(XY))/57.2958                           BLP19960
      IF (X.GT.3.11) GO TO 69                                           BLP19970
      DO 11 ID = 1,7                                                    BLP19980
      IF(X.GE.XA(ID)) GO TO 12                                          BLP19990
   11 CONTINUE                                                          BLP20000
      ID = 8                                                            BLP20010
   12 SZ = AA(ID) * X ** BA(ID)                                         BLP20020
      GO TO 71                                                          BLP20030
C         STABILITY B (20)                                              BLP20040
   20 TH = (18.333 - 1.8096*ALOG(XY))/57.2958                           BLP20050
      IF(X.GT.35.) GO TO 69                                             BLP20060
      DO 21 ID = 1,2                                                    BLP20070
      IF (X.GE.XB(ID)) GO TO 22                                         BLP20080
   21 CONTINUE                                                          BLP20090
      ID = 3                                                            BLP20100
   22 SZ = AB(ID) * X ** BB(ID)                                         BLP20110
      GO TO 70                                                          BLP20120
C         STABILITY C (30)                                              BLP20130
   30 TH = (12.5 - 1.0857*ALOG(XY))/57.2958                             BLP20140
      SZ = 61.141 *X ** 0.91465                                         BLP20150
      GO TO 70                                                          BLP20160
C         STABILITY D (40)                                              BLP20170
   40 TH = (8.3333-0.72382*ALOG(XY))/57.2958                            BLP20180
      DO 41 ID = 1,5                                                    BLP20190
      IF (X.GE.XD(ID)) GO TO 42                                         BLP20200
   41 CONTINUE                                                          BLP20210
      ID = 6                                                            BLP20220
   42 SZ = AD(ID) * X ** BD(ID)                                         BLP20230
      GO TO 70                                                          BLP20240
C         STABILITY E (50)                                              BLP20250
   50 TH = (6.25 - 0.54287*ALOG(XY))/57.2958                            BLP20260
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      DO 51 ID = 1,8                                                    BLP20270
      IF (X.GE.XE(ID)) GO TO 52                                         BLP20280
   51 CONTINUE                                                          BLP20290
      ID = 9                                                            BLP20300
   52 SZ = AE(ID) * X ** BE(ID)                                         BLP20310
      GO TO 70                                                          BLP20320
C        STABILITY F (60)                                               BLP20330
   60 TH = (4.1667 - 0.36191*ALOG(XY))/57.2958                          BLP20340
      DO 61 ID = 1,9                                                    BLP20350
      IF (X.GE.XF(ID)) GO TO 62                                         BLP20360
   61 CONTINUE                                                          BLP20370
      ID = 10                                                           BLP20380
   62 SZ = AF(ID) * X ** BF(ID)                                         BLP20390
      GO TO 70                                                          BLP20400
   69 SZ = 5000.                                                        BLP20410
      GO TO 71                                                          BLP20420
   70 IF (SZ.GT.5000.) SZ = 5000.                                       BLP20430
   71 SY = 1000. * XY * SIN(TH)/(2.15 * COS(TH))                        BLP20440
      RETURN                                                            BLP20450
      END                                                               BLP20460
C
      SUBROUTINE SIGMAY(XKM,KST,SY)                                     BLP20470
C                                                                       BLP20480
C                                                                       BLP20490
C                                                                       BLP20500
C     THIS SUBROUTINE CALCULATES SIGMA Y                                BLP20510
C                                                                       BLP20520
      GO TO (10,20,30,40,50,60),KST                                     BLP20530
10    TH=(24.167-2.5334*ALOG(XKM))/57.2958                              BLP20540
      GO TO 70                                                          BLP20550
20    TH=(18.333-1.8096*ALOG(XKM))/57.2958                              BLP20560
      GO TO 70                                                          BLP20570
30    TH=(12.5-1.0857*ALOG(XKM))/57.2958                                BLP20580
      GO TO 70                                                          BLP20590
40    TH=(8.3333-0.72385*ALOG(XKM))/57.2958                             BLP20600
      GO TO 70                                                          BLP20610
50    TH=(6.25-0.54287*ALOG(XKM))/57.2958                               BLP20620
      GO TO 70                                                          BLP20630
60    TH=(4.1667-0.36191*ALOG(XKM))/57.2958                             BLP20640
70    SY=1000.*XKM*SIN(TH)/(2.15*COS(TH))                               BLP20650
      RETURN                                                            BLP20660
      END                                                               BLP20670
C
      FUNCTION XVZ (SZO,KST)                                            BLP20680
C                                                                       BLP20690
C                                                                       BLP20700
      DIMENSION SA(7),SB(2),SD(5),SE(8),SF(9),AA(8),AB(3),AD(6),AE(9),  BLP20710
     * AF(10),CA(8),CB(3),CD(6),CE(9),CF(10)                            BLP20720
      DATA SA /13.95,21.40,29.3,37.67,47.44,71.16,104.65/               BLP20730
      DATA SB /20.23,40./                                               BLP20740
      DATA SD /12.09,32.09,65.12,134.9,251.2/                           BLP20750
      DATA SE /3.534,8.698,21.628,33.489,49.767,79.07,109.3,141.86/     BLP20760
      DATA SF /4.093,10.93,13.953,21.627,26.976,40.,54.89,68.84,83.25/  BLP20770
      DATA AA /122.8,158.08,170.22,179.52,217.41,258.89,346.75,453.85/  BLP20780
      DATA AB /90.673,98.483,109.3/                                     BLP20790
      DATA AD /34.459,32.093,32.093,33.504,36.650,44.053/               BLP20800
      DATA AE /24.26,23.331,21.628,21.628,22.534,24.703,26.97,35.42,    BLP20810
     * 47.618/                                                          BLP20820
      DATA AF /15.209,14.457,13.953,13.953,14.823,16.187,17.836,22.651, BLP20830
     * 27.074,34.219/                                                   BLP20840
      DATA CA /1.0585,.9486,.9147,.8879,.7909,.7095,.5786,.4725/        BLP20850
      DATA CB /1.073,1.017,.9115/                                       BLP20860
      DATA CD /1.1498,1.2336,1.5527,1.6533,1.7671,1.9539/               BLP20870
      DATA CE /1.1953,1.2202,1.3217,1.5854,1.7497,1.9791,2.1407,2.6585, BLP20880
     * 3.3793/                                                          BLP20890
      DATA CF /1.2261,1.2754,1.4606,1.5816,1.8348,2.151,2.4092,3.0599,  BLP20900
     * 3.6448,4.6049/                                                   BLP20910
      GO TO (10,20,30,40,50,60),KST                                     BLP20920
C        STABILITY A(10)                                                BLP20930
10    DO 11 ID = 1,7                                                    BLP20940
      IF(SZO.LE.SA(ID)) GO TO 12                                        BLP20950
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11    CONTINUE                                                          BLP20960
      ID = 8                                                            BLP20970
12    XVZ =(SZO/AA(ID))**CA(ID)                                         BLP20980
      RETURN                                                            BLP20990
C        STABILITY B (20)                                               BLP21000
20    DO 21 ID = 1,2                                                    BLP21010
      IF (SZO.LE.SB(ID)) GO TO 22                                       BLP21020
21    CONTINUE                                                          BLP21030
      ID = 3                                                            BLP21040
22    XVZ = (SZO/AB(ID))**CB(ID)                                        BLP21050
      RETURN                                                            BLP21060
C        STABILITY C (30)                                               BLP21070
30    XVZ = (SZO/61.141)**1.0933                                        BLP21080
      RETURN                                                            BLP21090
C        STABILITY D (40)                                               BLP21100
40    DO 41 ID = 1,5                                                    BLP21110
      IF(SZO.LE.SD(ID)) GO TO 42                                        BLP21120
41    CONTINUE                                                          BLP21130
      ID = 6                                                            BLP21140
42    XVZ = (SZO/AD(ID))**CD(ID)                                        BLP21150
      RETURN                                                            BLP21160
C        STABILITY E (50)                                               BLP21170
50    DO 51 ID = 1,8                                                    BLP21180
      IF (SZO.LE.SE(ID)) GO TO 52                                       BLP21190
51    CONTINUE                                                          BLP21200
      ID = 9                                                            BLP21210
52    XVZ = (SZO/AE(ID))**CE(ID)                                        BLP21220
      RETURN                                                            BLP21230
C        STABILITY F(60)                                                BLP21240
60    DO 61 ID = 1,9                                                    BLP21250
      IF(SZO.LE.SF(ID)) GO TO 62                                        BLP21260
61    CONTINUE                                                          BLP21270
      ID = 10                                                           BLP21280
62    XVZ = (SZO/AF(ID))**CF(ID)                                        BLP21290
      RETURN                                                            BLP21300
      END                                                               BLP21310
C
      FUNCTION XVY (SYO,KST)                                            BLP21320
C                                                                       BLP21330
C                                                                       BLP21340
      GO TO (1,2,3,4,5,6),KST                                           BLP21350
1     XVY = (SYO/213.)**1.1148                                          BLP21360
      RETURN                                                            BLP21370
2     XVY = (SYO/155.)**1.097                                           BLP21380
      RETURN                                                            BLP21390
3     XVY = (SYO/103.)**1.092                                           BLP21400
      RETURN                                                            BLP21410
4     XVY = (SYO/68.)**1.076                                            BLP21420
      RETURN                                                            BLP21430
5     XVY = (SYO/50.)**1.086                                            BLP21440
      RETURN                                                            BLP21450
6     XVY = (SYO/33.5)**1.083                                           BLP21460
      RETURN                                                            BLP21470
      END                                                               BLP21480
C
      BLOCK DATA                                                        BLP21490
C                                                                       BLP21500
C                                                                       BLP21510
      REAL L,LELEV                                                      BLP21520
      LOGICAL LSHEAR,LMETIN,LMETOT,LTRANS                               BLP21530
      COMMON/PR/L,HB,WB,WM,FPRIME,FP,XMATCH,DX,AVFACT,TWOHB,N,LSHEAR,   BLP21540
     1 LTRANS                                                           BLP21550
      COMMON/METD/ZMEAS,WS,WD,ISTAB,TDEGK,DPBL,THETA,S,P,IYR,JDAY,IHOUR BLP21560
      COMMON/SOURCE/NLINES,XLBEG(10),XLEND(10),DEL(10),YSCS(10),QT(10), BLP21570
     1 HS(10),XRCS(10,129),YRCS(10,129),TCOR,LELEV(10),                 BLP21580
     2 NPTS,XPSCS(50),YPSCS(50),PQ(50),PHS(50),XPRCS(50),YPRCS(50),     BLP21590
     3 TSTACK(50),APTS(50),BPTS(50),VEXIT(50),PELEV(50),IDOWNW(50)      BLP21600
      COMMON/RCEPT/RXBEG,RYBEG,RXEND,RYEND,RDX,RDY,XRSCS(100),          BLP21610
     1 YRSCS(100),XRRCS(100),YRRCS(100),RELEV(100),NREC                 BLP21620
      COMMON/RINTP/XDIST(7),DH(7)                                       BLP21630
      COMMON/OUTPT/IPCL(11),IPCP(51)                                    BLP21640
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      COMMON/PARM/CRIT,TER1,DECFAC,XBACKG,CONST2,CONST3,MAXIT           BLP21650
      COMMON/METD24/KST(24),SPEED(24),RANDWD(24),HMIX(24),TEMP(24),     BLP21660
     1 DTHTA(2),PEXP(6),IDELS,IDSURF,IYSURF,IDUPER,IYUPER,TERAN(6),     BLP21670
     2 IRU,IHRMAX,LMETIN,LMETOT,IDAYS(366)                              BLP21680
CPES  Begin PES Code Changes

      CHARACTER RUNDAT*8, RUNTIM*8, VERSN*5
      COMMON/DATETIME/ RUNDAT, RUNTIM, VERSN
      DATA RUNDAT/' '/, RUNTIM/' '/, VERSN/'99176'/

CPES  End PES Code Changes
      DATA AVFACT/1.0/                                                  BLP21690
      DATA NLINES/0/,NPTS/0/,NREC/0/,TCOR/90.0/                         BLP21700
      DATA ZMEAS/7.0/,DTHTA/0.02,0.035/,IDELS/5/,IDAYS/366*0/           BLP21710
      DATA IRU/1/,IHRMAX/24/                                            BLP21720
      DATA LSHEAR/.TRUE./,LMETIN/.FALSE./,LMETOT/.FALSE./,LTRANS/.TRUE./BLP21730
      DATA PEXP/0.10,0.15,0.20,0.25,0.30,0.30/                          BLP21740
      DATA IYSURF/0/,IYUPER/0/                                          BLP21750
      DATA CRIT/0.02/,DECFAC/0.0/,XBACKG/0.0/,CONST2/2.6/,CONST3/34.49/,BLP21760
     1 TERAN/0.5,0.5,0.5,0.5,0.30,0.30/,MAXIT/14/                       BLP21770
      DATA IPCL/11*0/,IPCP/51*0/                                        BLP21780
      DATA RXBEG/0.0/,RYBEG/0.0/,RXEND/0.0/,RYEND/0.0/,RDX/0.0/,RDY/0.0/BLP21790
      DATA XRSCS/100*0.0/,YRSCS/100*0.0/,RELEV/100*0.0/                 BLP21800
      DATA XLBEG/10*0.0/,XLEND/10*0.0/,YSCS/10*0.0/,                    BLP21810
     1 HS/10*0.0/,QT/10*0.0/,LELEV/10*0.0/                              BLP21820
      DATA XPSCS/50*0.0/,YPSCS/50*0.0/,PHS/50*0.0/,PQ/50*0.0/,          BLP21830
     1 APTS/50*0.0/,TSTACK/50*0.0/,PELEV/50*0.0/,IDOWNW/50*0/           BLP21840
      END                                                               BLP21850
C
      SUBROUTINE COMPRS(IDAYHR,ICD,IMET2,NREC,CHIS)                     BLP21860
C                                                                       BLP21870
C                                                                       BLP21880
      REAL CHIS(NREC),CHIOUT(100)                                       BLP21890
C                                                                       BLP21900
C     ARRAY COMPRESSION TECHNIQUE USES NEGATIVE NUMBERS TO FLAG ZEROES  BLP21910
C     FOR EXAMPLE, CHIS=12.5, 12.2, 0.0, 0.0, 0.0, 10.1, 0.0, 15.1,     BLP21920
C     16.7, 0.0, 0.0, 0.0, 0.0, 0.0 IS STORED AS:                       BLP21930
C     CHIOUT=12.5, 12.2, -3., 10.1, -1., 15.1, 16.7, -5.                BLP21940
C     WHERE -3 REPLACES THREE ZEROES, -1 REPLACES ONE ZERO, ETC.        BLP21950
C                                                                       BLP21960
      NZERO=0                                                           BLP21970
      II=0                                                              BLP21980
      DO 100 I=1,NREC                                                   BLP21990
      IF(CHIS(I).NE.0.0)GO TO 50                                        BLP22000
      NZERO=NZERO+1                                                     BLP22010
      GO TO 100                                                         BLP22020
50    CONTINUE                                                          BLP22030
      IF(NZERO.EQ.0)GO TO 70                                            BLP22040
      II=II+1                                                           BLP22050
      CHIOUT(II)=-NZERO                                                 BLP22060
      NZERO=0                                                           BLP22070
70    CONTINUE                                                          BLP22080
      II=II+1                                                           BLP22090
      CHIOUT(II)=CHIS(I)                                                BLP22100
100   CONTINUE                                                          BLP22110
      IF(NZERO.EQ.0)GO TO 105                                           BLP22120
      II=II+1                                                           BLP22130
      CHIOUT(II)=-NZERO                                                 BLP22140
105   CONTINUE                                                          BLP22150
      WRITE(20)II                                                       BLP22160
      CALL OUT(IDAYHR,ICD,IMET2,II,CHIOUT)                              BLP22170
      RETURN                                                            BLP22180
      END                                                               BLP22190
C
      SUBROUTINE OUT(IDAYHR,ICD,IMET2,II,CHIOUT)                        BLP22200
C                                                                       BLP22210
C                                                                       BLP22220
      REAL CHIOUT(II)                                                   BLP22230
      WRITE(20)IDAYHR,ICD,IMET2,CHIOUT                                  BLP22240
      RETURN                                                            BLP22250
      END                                                               BLP22260
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