San Joaquin Valley
Air Pollution Control District

Guidance for Air Dispersion Modeling

September, 2022

TABLE OF CONTENTS

1 INTRODUCTION 1
2 APPLICATION OF MODELS 1
2.1 Modeling Overview 1
2.2 Regulatory Models 2
2.2.1 AERSCREEN Overview 3
2.2.2 AERMOD Overview 3
2.3 Model Validations 4
3 MODEL INPUT DATA 5
3.1 Model Requirements 5
3.1.1 AERSCREEN Air Dispersion Modeling 6
3.1.2 AERMOD Air Dispersion Modeling 6
3.2 Regulatory and Non-Regulatory Option Use 7
3.3 Coordinate System 8
3.4 Averaging Times 8
3.5 Pollutant Specific Options 8
3.5.1 Conversion of NOx to NO_2 8
3.6 Defining Sources 9
3.6.1 Selection, Description and Parameters 9
3.6.2 Source Grouping 19
3.6.3 Special Considerations 19
3.6.4 Variable Emissions 19
3.7 Building Impacts 19
3.7.1 Good Engineering Practice (GEP) Stack Heights and Structure Influence Zones 20
3.7.2 Defining Buildings 23
3.8 Multiple Pollutants 25
3.8.1 Normalized Emission Rate and Summation Concepts 25
4 GEOGRAPHICAL INFORMATION INPUTS 26
4.1 Comparison of Screening and Refined Model Requirements 26
4.2 Coordinate System 27
4.2.1 Local 27
4.2.2 Universal Transverse Mercator 27
4.3 Terrain 28
4.3.1 Terrain Concerns in Short-Range Modeling 28
4.3.2 Flat and Complex Terrain 28

4.3.3 Terrain Data ... 30
4.3.4 Obtaining Terrain Data ... 30
4.3.5 Preparing Terrain Data for Model Use ... 31
4.4 Land Use Characterization ... 31
4.4.1 Wind Direction Dependent Land Use ... 33
4.4.2 Mixed Land Use Types ... 34
4.4.3 Seasonal Land Use Characterization ... 34
4.4.4 Standard and Non-Default Surface Characteristics ... 34
4.4.5 Defining Urban and Rural Conditions ... 34
5 METEOROLOGICAL DATA ... 36
5.1 Comparison of Screening and Refined Model Requirements ... 36
5.2 Preparing Meteorological Data for Refined Modeling ... 36
5.3 Data Assessment: Representativeness ... 37
5.4 User Developed Local Meteorological Data ... 37
6 RECEPTOR LOCATIONS ... 37
6.1 Receptor Types ... 38
6.1.1 Cartesian Receptor Grids ... 38
6.1.2 Polar Receptor Grids ... 38
6.1.3 Multi-Tier Grids ... 39
6.1.4 Fenceline Receptors ... 40
6.1.5 Discrete & Sensitive Receptors ... 40
6.2 Minimum Receptor Requirements for Capturing and Assessing Maxima ... 41
7 OTHER MODELING CONSIDERATIONS ... 44
7.1 Explanation for Alternative Model Use ... 44
7.2 Use of Modeled Results in Combination with Monitoring Data ... 44
8 GLOSSARY OF TERMS ... 45

1 INTRODUCTION

The modeling guidelines contained hereafter are based on a document entitled “Provision of Services to Develop Guidance for Air Dispersion Modeling” developed by Dr. Jesse Thé of Lakes Environmental Software. Contents of this document were modified to conform to the San Joaquin Valley Air Pollution Control District’s (District), requirements.

The Guidance for Air Dispersion Modeling is designed to provide direction on methods for air dispersion modeling in the San Joaquin Valley. The use of air dispersion models, namely the United States Environmental Protection Agency (U.S. EPA) AERSCREEN for screening analyses and the U.S. EPA AERMOD for refined analyses, enable more representative assessments that make use of current science. This document is intended to provide insight into recommended modeling approaches and provide consistency in the modeling methods used.

The Guidance for Air Dispersion Modeling is not designed to provide theoretical background on the models it discusses. Technical documents covering these topics can be easily obtained from several U.S. EPA sources, and are further referenced in this document. This document will provide details on performing a successful modeling study including:

- Model Background and Applicability
- Model Selection and Study Approach
- Model Input Data Requirements
- Geographical Information
- Meteorological Data Requirements and Acquisition
- Information/Parameters for Inclusion in an Assessment

2 APPLICATION OF MODELS

2.1 Modeling Overview

Air quality models use mathematical and numerical/statistical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. Based on inputs of meteorological data and source information like emission rates and stack height, these models are designed to characterize primary pollutants that are emitted directly into the atmosphere and, in some cases, secondary pollutants that are formed as a result of complex chemical reactions within the atmosphere. In general, air quality models may adopt a Lagrangian or Eulerian approach. Lagrangian models simulate dispersion or reactions in parcels of air that move along with the wind trajectory. Eulerian models divide the problem domain into fixed grid cells with various methods then used to solve equations over the full domain. The most commonly used types of air quality models include the following:

- Dispersion Models. Dispersion models are typically Lagrangian models that use mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations. Dispersion models are typically used to determine compliance with National Ambient Air Quality Standards (NAAQS), and other regulatory requirements such as New Source Review (NSR) and Prevention of Significant Deterioration (PSD) regulations. Examples of dispersion models include: AERMOD/AERSCREEN, CALPUFF, and CALINE3.

- Photochemical Models. Photochemical models are typically used for regulatory analysis and attainment demonstrations. Photochemical models tend to be large-scale air quality models that simulate the changes of pollutant concentrations in the atmosphere using a set of mathematical equations characterizing the chemical and physical processes in the atmosphere. These models are applied at multiple spatial scales from local, regional, national, to global. Most photochemical model are Eulerian, because this approach better and more fully characterizes physical processes in the atmosphere and predicts species concentrations throughout a three-dimensional domain. Examples of photochemical models are Community Multi-scale Air Quality (CMAQ), Comprehensive Air quality Model with extensions (CAMx), Regional Modeling System for Aerosols and Deposition (REMSAD), and Urban Airshed Model Variable Grid (UAM-V).

- Receptor Models. Receptor models are mathematical or statistical procedures for identifying and quantifying the sources of air pollutants at a receptor location. Unlike photochemical and dispersion air quality models, receptor models do not use pollutant emissions, meteorological data and chemical transformation mechanisms to estimate the contribution of sources to receptor concentrations. Instead, receptor models use the chemical and physical characteristics of gases and particles measured at the source and receptor to both identify the presence of and to quantify source contributions to receptor concentrations. These models are a natural complement to other air quality models and are used as part of State Implementation Plans (SIPs) for identifying sources contributing to air quality problems. Examples of receptor models are Chemical Mass Balance (CMB), UNMIX, and Positive Matrix Factorization (PMF).

2.2 Regulatory Models

The US EPA identifies preferred air quality models in Appendix A to Appendix W of 40 CFR Part 51. In addition, US EPA lists alternate air quality models and recommended screening models on their Support Center for Regulatory Atmospheric Modeling (SCRAM) website. For regulatory purposes the District’s preferred screening model is AERSCREEN, and the preferred refined model is AERMOD. Alternative models may be used with approval of the reviewing agency.

2.2.1 AERSCREEN Overview

AERSCREEN[1] is the screening version of AERMOD that has replaced SCREEN3. The AERSCREEN model consists of two main components:

- MAKEMET. The MAKEMET program generates a site-specific matrix of meteorological conditions for input to the dispersion model.
- AERSCREEN. The AERSCREEN command-prompt interface program interfaces with MAKEMET for generating the meteorological matrix, but also interfaces with AERMAP and BPIPPRM to automate the processing of terrain and building information respectively, and interfaces with the AERMOD model utilizing the SCREEN option to perform the modeling runs.

AERSCREEN can perform all the single source short-term (1-hr) calculations performed by AERMOD. The program also includes averaging time factors for estimating worst-case 3-hr, 8-hr, 24-hr and annual average concentration. In addition, AERSCREEN is able to predict concentrations due to inversion break-up and shoreline fumigation.

2.2.2 AERMOD Overview

The American Meteorological Society/EPA Regulatory Model Improvement Committee's (AERMIC) Regulatory Model, AERMOD[2,3,4] was specially designed to support the U.S. EPA's regulatory modeling programs. AERMOD is the next-generation air dispersion model that incorporates concepts such as planetary boundary layer theory and advanced methods for handling complex terrain. AERMOD was developed to replace the Industrial Source Complex Model-Short Term (ISCST3) as U.S. EPA's preferred model for most small-scale regulatory applications.[5,6]

The AERMOD atmospheric dispersion modeling system is an integrated system that includes three modules. The first module is AERMET, a meteorological data preprocessor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts. You can find a more detailed explanation of

---

[1] U.S. Environmental Protection Agency, 2015. AERSCREEN User's Guide. July 2015 (EPA-454/B-15-005).
[2] U.S. Environmental Protection Agency, 1998. Revised Draft - User's Guide for the AMS/EPA Regulatory Model – AERMOD. Office of Air Quality Planning and Standards, Research Triangle Park, NC.
[3] Paine, R.J., R.W. Brode, R.B. Wilson, A.J. Cimorelli, S.G. Perry, J.C. Weil, A. Venkatram, W.D. Peters and R.F. Lee, 2003. AERMOD: The Latest Features and Evaluation Results. Paper # 69878 to be presented at the Air and Waste Management Association 96th Annual Conference and Exhibition, June 22-26, 2003. Air and Waste Management Association, Pittsburgh, PA 15222.
[4] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee, W.D. Peters, R.W. Brode, J.O. Paumier, 2002: AERMOD: Description of Model Formulation. U.S. Environmental Protection Agency, EPA-454/R-02-002d (draft dated October 31, 2002). Available from http://www.epa.gov/scram001.
[5] U.S. Environmental Protection Agency, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models (Revised), Volume 1. EPA-454/B-95-003a. Office of Air Quality Planning and Standards, Research Triangle Park, NC.
[6] U.S. Environmental Protection Agency, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume II – Description of Algorithms. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Available from website http://www.epa.gov/scram001 as of January 2003.

the AERMET processor on EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website. The second module is AERMAP, a terrain data preprocessor that incorporates complex terrain using USGS Digital Elevation Data. In addition, AERMOD makes use of the non-regulatory program Building Profile Input Program, Plume Rise Model Enhancements (BPIPRIME), a multi-building dimensions program incorporating the GEP technical procedures for PRIME applications.

AERMOD's Modeling Capabilities (non-exhaustive list):

- The AERMOD model can be used to model primary pollutants.
- The AERMOD model can handle multiple sources, including point, volume, area, line, and open pit source types.
- Source emission rates can be treated as constant or may be varied by month, season, hour-of-day, or other optional periods of variation. These variable emission rate factors may be specified for a single source or for a group of sources.
- The model can account for the effects of aerodynamic downwash due to nearby buildings on point source emissions.
- The model contains algorithms for modeling the effects of settling and removal (through dry deposition) of large particulates and for modeling the effects of precipitation scavenging for gases or particulates.
- Receptor locations can be specified as gridded and/or discrete receptors in a Cartesian or polar coordinate system.
- For applications involving elevated terrain, the user must also input a hill height scale along with the receptor elevation. The U.S. EPA AERMAP terrain-preprocessing program[7] can be used to generate hill height scales as well as terrain elevations for all receptor locations.
- Results can be predicted for concentration, total deposition, dry deposition, and/or wet deposition.

2.3 Model Validations

The U.S. EPA AERMOD model has been extensively studied and validated. Studies have typically demonstrated good correlation with real-world values. AERMOD demonstrates the ability to handle complex terrain very well, closely matching the trends of field observations from validation studies. A summary of the evaluation studies was prepared by Paine, et al[8]. This and more detailed reports can be found at the U.S. EPA SCRAM website.

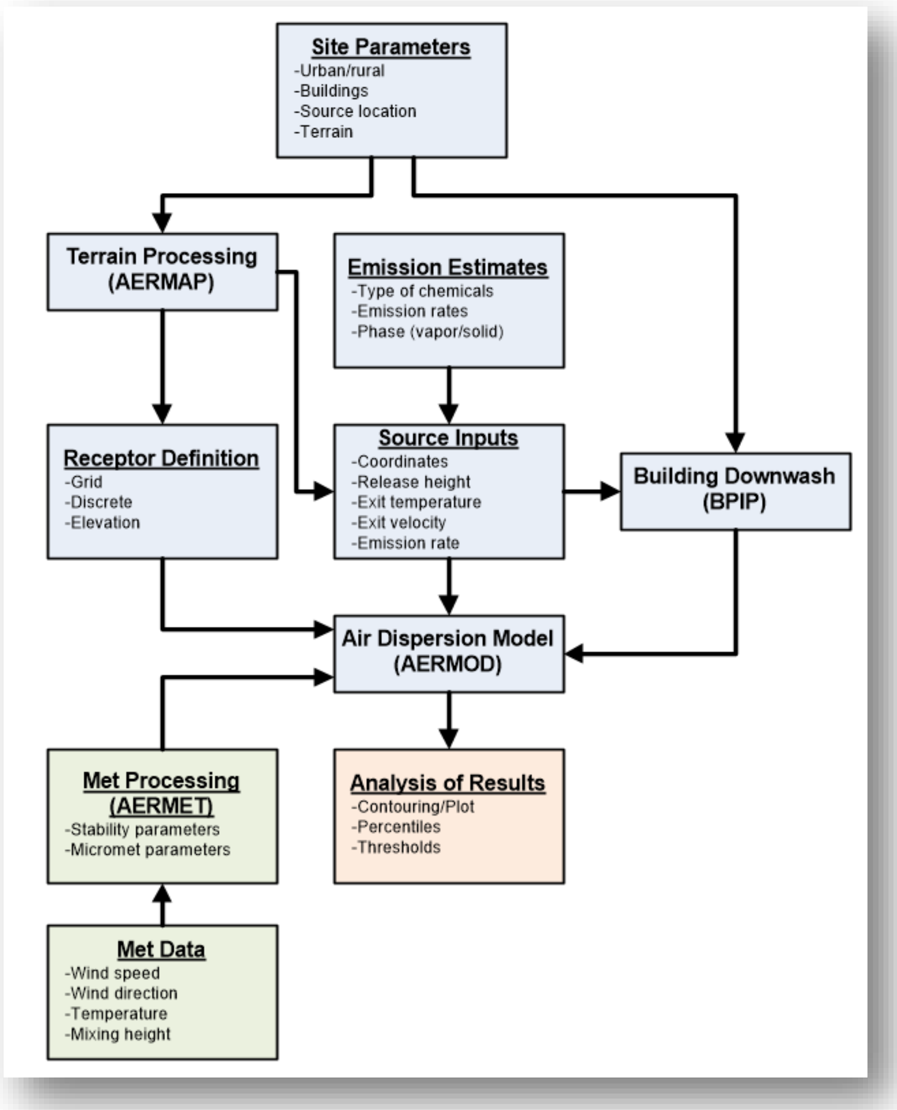
[7] U.S. Environmental Protection Agency, 1998. Revised Draft - User's Guide for the AERMOD Terrain Preprocessor (AERMAP). Office of Air Quality Planning and Standards, Research Triangle Park, NC.
[8] Paine, R.J., R.W. Brode, R.B. Wilson, A.J. Cimorelli, S.G. Perry, J.C. Weil, A. Venkatram, W.D. Peters and R.F. Lee, 2003. AERMOD: The Latest Features and Evaluation Results. Paper # 69878 presented at the Air and Waste Management Association 96th Annual Conference and Exhibition, June 22-26, 2003. Air and Waste Management Association, Pittsburgh, PA 15222.

3 MODEL INPUT DATA

3.1 Model Requirements

Refined air dispersion modeling using the U.S. EPA AERMOD model can be broken down into a series of steps, which is outlined in Section 3.1.2 of this guidance document. A general overview of the process typically followed for performing an air dispersion modeling assessment is presented in Figure 3-1 below. The figure is not meant to be exhaustive in all data elements, but rather provides a picture of the major steps involved in an assessment.

Figure 3-1. Generalized Process for Performing a Refined Air Dispersion Modeling Assessment



3.1.1 AERSCREEN Air Dispersion Modeling

The AERSCREEN model[9] was developed to provide an easy-to-use method of obtaining pollutant concentration estimates. To perform a modeling study using AERSCREEN, data for the following input requirements must be supplied:

- Source type (point, volume, area, circular area, flare, capped point source, or horizontal point source)
- Physical source and emissions characteristics. For example, a point source requires:
    - Emission rate (lb/hr or g/s)
    - Stack height (feet or meters)
    - Stack inside diameter (inches or meters)
    - Stack gas exit velocity (ft/s or m/s) or flow rate (ACFM)
    - Stack gas exit temperature (degrees Fahrenheit or Kelvin)
- Ambient air temperature (MAKEMET)
- Receptor height above ground
- Meteorology: AERSCREEN can consider all conditions, or a specific stability class and wind speed can be provided
- Building Downwash: If this option is used then building dimensions (height, length and width) must be specified
- Terrain: AERSCREEN supports flat, elevated, and complex terrain. If elevated or complex terrain is used, distance and terrain heights must be provided
- Inversion break-up and shoreline fumigation: AERSCREEN supports shoreline fumigation. If used, distance to shoreline must be provided

As can be seen above, the input requirements are minimal to perform a screening analysis using AERSCREEN. This model is normally used as an initial screening tool to assess single sources of emissions. AERMOD is discussed in the following sections, and has many more detailed options allowing for better source characterization.

3.1.2 AERMOD Air Dispersion Modeling

AERMOD has many input options that are displayed throughout this document as well as in its technical document[10]. An overview of the modeling approach and general steps for using AERMOD are provided below. The general process for performing an air dispersion assessment using AERMOD includes:

- Meteorological data processing – AERMET
- Digital terrain elevation data processing, if terrain is being considered – AERMAP
- Building downwash analysis, if required, using source and building information - BPIP-PRIME
- Final site characterization – complete source and receptor information

---

[9] U.S. Environmental Protection Agency, 2015. AERSCREEN User's Guide. EPA-454/B-15-005. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

[10] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee, W.D. Peters, R.W. Brode, J.O. Paumier, and L Thurman, 2017: AERMOD Model Formulation and Evaluation. U.S. Environmental Protection Agency, EPA-454/R-17-001 draft dated May 17, 2017. Available from http://www.epa.gov/scram.

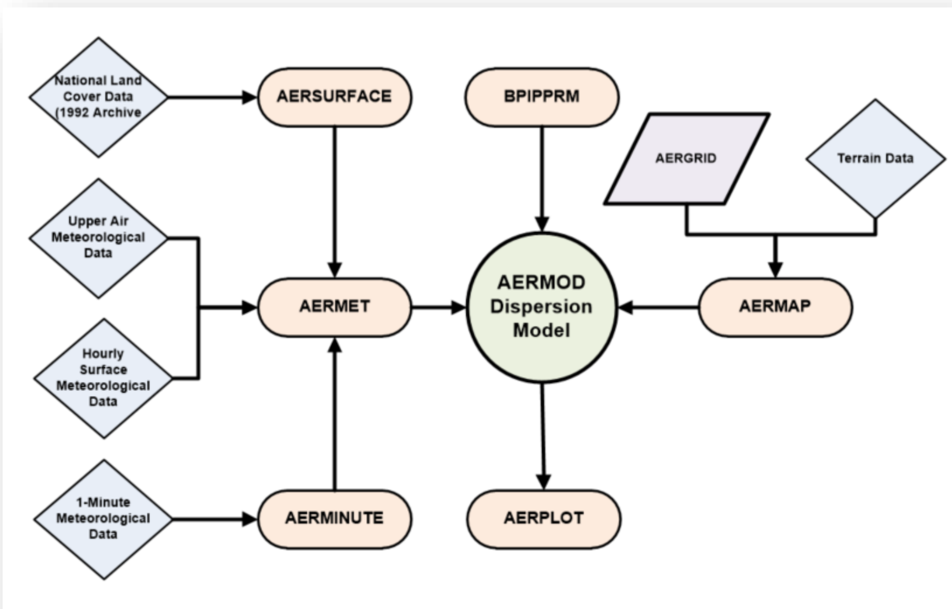
- Running the model - AERMOD
- Visualizing and analyzing results

As can be seen below, the AERMOD modeling system is comprised of three primary components as presented below in Figure 3-2:

1. AERMET – Meteorological Data Preprocessor
2. AERMAP – Digital Terrain Preprocessor
3. AERMOD – Air Dispersion Model

To successfully perform a complex terrain air dispersion modeling analysis using AERMOD, you must first complete the processing steps required by AERMET and AERMAP. See Section 5 of this guidance document for more information on meteorological data.

Figure 3-2. The AERMOD Air Dispersion Modeling System



3.2 Regulatory and Non-Regulatory Option Use

The AERMOD model contains several regulatory options, which are set by default, as well as non-regulatory options and Alpha and Beta options. Alpha options are scientific/formulation updates that are considered to be in the research phase and have not been fully evaluated and peer reviewed by the scientific community; and non-scientific model options in development that still need rigorous testing and for which EPA is seeking feedback from the user community. Beta options are scientific updates to the formulation of AERMOD that have been fully vetted through the scientific community with appropriate evaluation and peer review. Beta options are planned for future promulgation as regulatory options. AERMOD's regulatory options can be used without justification. Non-regulatory, Alpha or Beta options may not be used without prior approval from the reviewing agency.

3.3 Coordinate System

A coordinate system is required for all modeling assessments. The system should include sources, receptors and, where necessary, other geographical features. Employing a standard coordinate system for all projects increases the efficiency of the review process while providing real-world information of the site. The AERMOD model's terrain pre-processor, AERMAP, requires digital terrain in Universal Transverse Mercator (UTM) coordinates. The UTM system uses meters as its basic unit of measurement and allows for more precise definition of locations than latitude/longitude.

For more information on coordinate systems and geographical information inputs, see Section 4 of this guidance document.

3.4 Averaging Times

A key advantage to the more refined air dispersion models is the ability to compare effects-based standards with appropriate averaging times. Effects-based averaging times means that a contaminant could be assessed using modeled exposure concentrations over the most appropriate averaging period for that contaminant. The ability to assess local air quality using a more appropriate effects-based averaging time means the refined air dispersion models provide a more representative assessment of health and environmental impacts of air emissions from a facility. Please refer to the District Policy APR-1925 (*Policy for District Rule 2201 Ambient Air Quality Analysis Modeling)* for additional information and requirements for modeling pollutants having state or federal ambient air quality standards.

3.5 Pollutant Specific Options

3.5.1 Conversion of NOx to NO_2

U.S. EPA's Appendix W of 40 CFR Part 51, Section 4.2.3.4 provides a tiered approach for modeling the conversion of NOx to NO_2 as follows:

- Tier 1: Assumes full conversion of NOx to NO_2, with no additional steps or data needed. This is the most conservative approach
- Tier 2: Assumes an ambient equilibrium between NO and NO_2. This is implemented by multiplying TIER 1 results by the Ambient Ratio Method 2 (ARM2). The minimum and maximum NO_2/NOx ratios should use U.S. EPA default values (0.5 and 0.9, respectively)
- Tier 3: Includes other more advanced screening techniques such as the Ozone Limiting Method (OLM) and Plume Volume Molar Ratio Method (PVMRM). As discussed in U.S. EPA's Appendix W, PVMRM is most appropriate for analyses with relatively isolated and elevated sources. OLM is more appropriate for analyses with area sources, near-surface releases, or where plume overlap from

multiple sources will occur. When using OLM, use the option OLMGROUP ALL in AERMOD. Use of any other alternative methods such as paired sums analysis require District approval. Tier 3 NO_2 modeling resources are available on the District's website at https://www.valleyair.org/busind/pto/Tox_Resources/AirQualityMonitoring.htm

3.6 Defining Sources

3.6.1 Selection, Description and Parameters

The U.S. EPA AERSCREEN and AERMOD models support a variety of source types that can be used to characterize most emissions within a study area. The following sections outline the primary source types and their input requirements. Since AERSCREEN is the screening version of AERMOD, many of the inputs are the same. However, differences between the two models will be noted in the sections that follow. Detailed descriptions on the input fields for these models can be found in the *AERSCREEN User's Guide*[11] and the *AERMOD: Description of Model Formulation*[12].

3.6.1.1 Point Sources

Point sources are typically used when modeling releases from stacks and isolated vents. Point sources are assumed to have a vertical release that is unobstructed by a fixed cap (flappers are okay). AERMOD also includes options to model capped stack and horizontal stack releases. Some important issues to consider when using point sources are:

- To model a plume that is released at ambient temperature, the user can enter the stack exit temperature as "0.0" degrees K. This will prompt AERMOD to adjust the exit temperature for each hour to match the ambient temperature
- To model a plume that is released at a fixed temperature above the ambient temperature, the user can enter the stack exit temperature as a negative value equal in magnitude to the degree K temperature difference
- AERMOD does not include algorithms to model plumes that are released at temperatures below ambient temperature. Consultation with the reviewing agency is recommended before conducting this type of modeling

Input requirements for point sources are presented in Table 3-1.

[11] U.S. Environmental Protection Agency. 2015. AERSCREEN User's Guide. EPA-454/B-15-005. Office of Air Quality Planning and Standards, Research Triangle Park, NC.
[12] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee, W.D. Peters, R.W. Brode, J.O. Paumier. 2002. AERMOD: Description of Model Formulation. U.S. Environmental Protection Agency, EPA-454/R-02-002d (draft dated October 31, 2002). Available from http://www.epa.gov/scram001.

Table 3-1. Summary of AERSCREEN and AERMOD Point Source Inputs.

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters	--	R
Release type	Vertical, horizontal or capped stack release options	--	R	R
X Coordinate	The x (east-west) coordinate at the center of the point source	m	--	R
Y Coordinate	The y (north-south) coordinate at the center of the point source	m	--	R
Base Elevation	The source base elevation (only used if for elevated terrain)	m	O	O
Emission rate	Mass of emissions per unit time	g/s or lb/hr	R	R
Stack height	Release height above ground	m or ft	R	R
Stack Gas Exit Temperature	The temperature of the released gas	K or F	R	R
Stack Gas Exit Velocity or Flow Rate	If the exit velocity is not known, the model can calculate it from the stack volumetric flow rate (ACFM) using the following formula: $V_s = 4*V/(\pi*(d_s^2))$ Where, V_s = Exit Velocity V = Volumetric Flow Rate d_s = Stack Inside Diameter	m/s or ft/s or ACFM	R	R
Stack Diameter	Stack inside diameter	m or in	R	R

R = required input; O = optional input; -- = input not available

3.6.1.2 Area Sources

Area sources are used to model low-level or ground-level releases with no plume rise (e.g., landfills, storage piles, slag dumps, and lagoons). Both AERSCREEN and AERMOD allow input of rectangular and circular area sources. In addition, AERMOD has available a polygon area source type (see U.S. EPA[13] for details). Some important issues to consider when using area sources are:

- The maximum length/width aspect ratio for area sources is 10 to 1. If this is exceeded, then the area should be divided to achieve a 10 to 1 aspect ratio (or less) for all sub-areas.
- AERMOD may not properly estimate concentrations (and/or deposition) for receptors located within the dimensions of an area source.

Input requirements for rectangular area sources are presented in Table 3-2.

[13] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee, W.D. Peters, R.W. Brode, J.O. Paumier, 2002: AERMOD: Description of Model Formulation. U.S. Environmental Protection Agency, EPA-454/R-02-002d (draft dated October 31, 2002). Available from http://www.epa.gov/scram001.

Table 3-2. Summary of AERSCREEN and AERMOD Rectangular Area Source Inputs.

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters	--	R
X Coordinate	The x (east-west) coordinate at the south-west corner of the area source	m	--	R
Y Coordinate	The y (north-south) coordinate at the south-west corner of the area source	m	--	R
Base Elevation	The source base elevation (only used if for elevated terrain)	m	O	O
Emission Rate	Mass of emissions per unit time for AERSCREEN, or mass of emissions per unit time and area for AERMOD	g/s or lb/hr or g/(s-m^2)	R	R
Release Height	Release height above ground	m or ft	R	R
Length of Long Side or Length of Side X	Length of the long side in AERSCREEN or the east-west side in AERMOD	m or ft	R	R
Length of Short Side or Length of Side Y	Length of the short side in AERSCREEN or the north-south side in AERMOD	m or ft	R	R
Angle	Orientation angle for the rectangular area in degrees from North, measured positive in the clockwise direction	Degrees	--	O
Initial Vertical Dimension of Plume	Parameter used when modeling mechanically-generated emission sources, such as mobile sources, where the emissions may be turbulently mixed by the process that is generating the emissions, and therefore occupy some initial depth	m or ft	O	O

R = required input; O = optional input; -- = input not available

3.6.1.3 Volume Sources

Volume sources are used to model releases from a variety of industrial sources, such as building roof monitors, fugitive leaks from an industrial facility, multiple vents, and conveyor belts. Input requirements for volume sources are presented in Table 3-3.

Table 3-3. Summary of AERSCREEN and AERMOD Volume Source Inputs

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters	--	R
X Coordinate	The x (east-west) coordinate at the center of the volume source	m	--	R
Y Coordinate	The y (north-south) coordinate at the center of the volume source	m	--	R
Base Elevation	The source base elevation (only used if for elevated terrain)	m	O	O
Emission Rate	Mass of emissions per unit time	g/s or lb/hr	R	R
Release Height (Center of Volume Height)	Release height above ground	m or ft	R	R
Length of Side	Length of the side of the volume source	m	--	R
Initial Lateral Dimension of the Volume	See Table 3-4 below for guidance on determining initial dimensions	m or ft	R	R
Initial Vertical Dimension of the Volume	See Table 3-4 below for guidance on determining initial dimensions	m or ft	R	R

R = required input; O = optional input; -- = input not available

Initial lateral and vertical dimensions of volume sources can be estimated using the procedures described by EPA[14]. A summary of these suggested procedures are presented in Table 3-4.

[14]U.S. Environmental Protection Agency, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models - Volume I – User Instructions and Volume II – Description of Model Algorithms. EPA-454/B-95-003a. U.S. Environmental Protection Agency. Research Triangle Park, NC 27711.

Table 3-4. Summary of Suggested Procedures for Estimating Initial Lateral Dimension ($_{yo}$) and Initial Vertical Dimension ($_{zo}$) for Volume and Line Sources.

Type of Source	Procedure for Obtaining Initial Dimension
Initial Lateral Dimension (S_{yo})	
Single Volume Source	S_{yo} = (side length)/4.3
Line Source Represented by Adjacent Volume Sources	S_{yo} = (side length)/2.15
Line Source Represented by Separated Volume Sources	S_{yo} = (center to center distance)/2.15
Initial Vertical Dimension (S_{zo})	
Surface-Based Source (h_e ~ 0)	S_{zo} = (vertical dimension of source)/2.15
Elevated Source (h_e > 0) on or Adjacent to a Building	S_{zo} = (building height)/2.15
Elevated Source (h_e > 0) not on or Adjacent to a Building	S_{zo} = (vertical dimension of source)/4.3

3.6.1.4 Open Pit Sources

The open pit source type is not available in AERSCREEN. Open pit sources are used to simulate fugitive emissions from below-grade open pits, such as surface coal mines and stone quarries. The open pit algorithm uses an effective area for modeling pit emissions, based on meteorological conditions, and then utilizes the numerical integration area source algorithm to model the impact of emissions from the effective area sources. The models accept rectangular pits with an optional rotation angle specified relative to a north-south orientation. Some important issues to consider when using the open pit source are:

- Open pit sources cannot be subdivided. Single, irregularly shaped open pits should be modeled as single rectangular pits of equal area, rather than separate adjacent pits.
- The length to width aspect ratio of the open pits should be less than 10 to 1, or the model will generate a warning message.
- The release height of emissions within the pit cannot exceed the depth of the pit.
- Receptors should not be located within the boundaries of the pit as the model will set their concentration and/or deposition values to zero.

Input requirements for open pit sources are presented in Table 3-5.

Table 3-5. Summary of AERSCREEN and AERMOD Open Pit Source Inputs

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters		R
X Coordinate	The X coordinate for the vertex of the open pit source that occurs in the southwest quadrant of the source	m		R
Y Coordinate	The Y coordinate for the vertex of the open pit source that occurs in the southwest quadrant of the source	m		R
Base Elevation	The source base elevation (only used if for elevated terrain)	m		O
Emission Rate	Mass of emissions per unit time per area	g/(s-m^2)		R
Release Height (from bottom of the pit)	Average release height above the base of the pit	m		R
Length of Side X	Length of the east-west side in AERMOD	m		R
Length of Side Y	Length of the north-south side in AERMOD	m		R
Volume of Open Pit	Volume of the pit	m^3		R
Orientation Angle from North	Orientation angle for the rectangular area in degrees from North, measured positive in the clockwise direction	m		O

R = required input; O = optional input; -- = input not available

3.6.1.5 Line Sources

The line source type is not available in AERSCREEN. Introduced with US EPA AERMOD version 15181, AERMOD line sources are very similar to area sources, which are used to model low-level or ground-level releases with no plume rise such as storage piles, slag dumps, and lagoons. Some important issues to consider when using the line source are:

- The line source type can only be used with AERMOD model version 15181 or higher.
- The line source type utilizes the same routines as the area source type, and will give identical results for equivalent source inputs.
- As with the area source type, the line source type may not properly estimate concentrations (and/or deposition) at receptors located within the dimensions of the source.

Input requirements for line sources are presented in Table 3-6.

Table 3-6. Summary of AERSCREEN and AERMOD Line Source Inputs.

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters		R
X1 Coordinate	The X coordinate for the midpoint of the beginning of the line source	m		R
Y1 Coordinate	The Y coordinate for the midpoint of the beginning of the line source	m		R
X2 Coordinate	The X coordinate of the midpoint of the end of the line source	m		R
Y2 Coordinate	The Y coordinate of the midpoint of the end of the line source	m		R
Width	Width of the line source (must be a minimum of 1 m)	m		R
Base Elevation	The source base elevation (only used if for elevated terrain)	m		O
Emission Rate	Mass of emissions per unit time per area	$g/(s\text{-}m^2)$		R
Release Height	Release height above ground	m or ft		R

R = required input; O = optional input; -- = input not available

Buoyant Line Sources

The buoyant line source type is not available in AERSCREEN. The buoyant line algorithms in the Buoyant Line and Point source (BLP) [15] dispersion model were first incorporated into AERMOD version 14134. Buoyant line source is designed to treat plume rise and dispersion for sources on buildings such as roof top vents of a smelting facility. Some important issues to consider when using the buoyant line source are:

- The buoyant line source type can only be used with AERMOD model version 14134 or higher.
- For multiple line sources of comparable buoyancy flux, the buoyancy parameter is calculated for each line source and then averaged.

Input requirements for buoyant line sources are presented in Table 3-7.

[15] Schulman, L.L., and J.S. Scire, 1980: *Modelling Plume Rise from Low-level Buoyant Line and Point Sources*. Proceedings, Second Joint Conference on Applications of Air Pollution Meteorology, 24-28 March, New Orleans, LA. pp. 133-139.

Table 3-7. Summary of AERSCREEN and AERMOD Buoyant Line Source Inputs.

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters		R
X1 Coordinate	The X coordinate for the start point of the line source	m		R
Y1 Coordinate	The Y coordinate for the start point of the line source	m		R
X2 Coordinate	The X coordinate of the end point of the line source	m		R
Y2 Coordinate	The Y coordinate of the end point of the line source	m		R
Base Elevation	The source base elevation (only used if for elevated terrain)	m or ft		O
Emission Rate	Mass of emissions per unit time per area	$g/(s\text{-}m^2)$		R
Release Height	Release height above ground	m or ft		R
Building Length	Average building length	m		R
Building Height	Average building height	m		R
Building Width	Average building width	m		R
Line Source Width	Line source width	m		R
Separation Between Buildings	Average separation between buildings	m		R
Average Buoyancy Parameter	Average buoyancy parameter used in the plume rise calculations. This is calculated as: F' = [g L Wm w (Ts - Ta)]/Ts where, F' = avg line source buoyancy parameter. g = acceleration of gravity (9.81 m/s**2) L = average line source length (m) Wm = average line source width (m) w = exit velocity (m/s) Ts = exit temperature (K) Ta = ambient air temperature (K)	m^4/s^3		R

R = required input; O = optional input; -- = input not available

3.6.1.6 Flare Sources

Flares are used as control devices for a variety of sources. A flare source type is not available in AERMOD, however AERSCREEN does provide a flare source input screen. This screen converts values provided for flare specific parameters into point source parameters. Some important issues to consider when using the AERSCREEN flare source input screen are:

- AERSCREEN calculates plume rise for flares based on an effective buoyancy flux parameter. An ambient temperature of 293K is assumed in this calculation and therefore no ambient temperature is input by the user.
- It is assumed that 55% of the total heat is lost due to radiation.
- Plume rise is calculated from the top of the flame, assuming that the flame is turned 45 degrees from the vertical.
- For flares, AERSCREEN assumes a stack gas exit velocity (V_s) of 20 m/s, an effective stack gas exit temperature (T_s) of 1,273K, and calculates an effective stack diameter based on the heat release rate.

Input requirements for flares are presented in Table 3-8.

Table 3-8. Summary of AERSCREEN and AERMOD Flare Source Inputs.

Inputs	Description	Units	AERSCREEN	AERMOD
Source ID	An identification name for the source being defined	Up to 8 characters	--	
X Coordinate	The x (east-west) coordinate for the source location	m	--	
Y Coordinate	The y (north-south) coordinate for the source location	m	--	
Base Elevation	The source base elevation (only used if for elevated terrain)	m	O	
Effective Release Height	The effective release height should be given as the stack height plus the flare height.	m or ft	R	
Emission rate	Mass of emissions per unit time	g/s or lb/hr	R	
Stack Gas Exit Temperature	The temperature of the released gas	K or F	R	
Stack Inside Diameter	Stack inside diameter	m or ft	R	
Stack Gas Exit Velocity or Flow Rate	If the exit velocity is not known, the model can calculate it from the stack volumetric flow rate (ACFM) using the following formula: $V_s = 4*V/(\pi*(d_s^2))$ Where, V_s = Exit Velocity V = Volumetric Flow Rate d_s = Stack Inside Diameter	Gas Exit Velocity (m/s or ft/s), Gas Flow Rate (ACFM)	R	

R = required input; O = optional input; -- = input not available

3.6.2 Source Grouping

Source groups enable modeling results for specific groups of one or more sources. Analysis of individual groups of sources can be performed by using the SRCGROUP option. The default in AERMOD is the creation of a source group "ALL" that combines all the source contributions in space and time into a single value for each receptor and time period. Source groups can be used to analyze group contributions from particular sources together with sources able to exist in more than one group at a time.

3.6.3 Special Considerations

During some air quality studies, modelers may encounter certain source configurations that require special attention. Some examples include emissions from multiple closely spaced stacks, non-standard stacks, roof vents, building openings, storage piles, and storage tanks. Modeling techniques on how to account for the special characteristics of scenarios such as these are available on the District's website.

3.6.4 Variable Emissions

AERMOD contains support for variable emission rates. This allows for modeling of source emissions that may fluctuate over time. Model inputs for variable emissions rates can include the following:

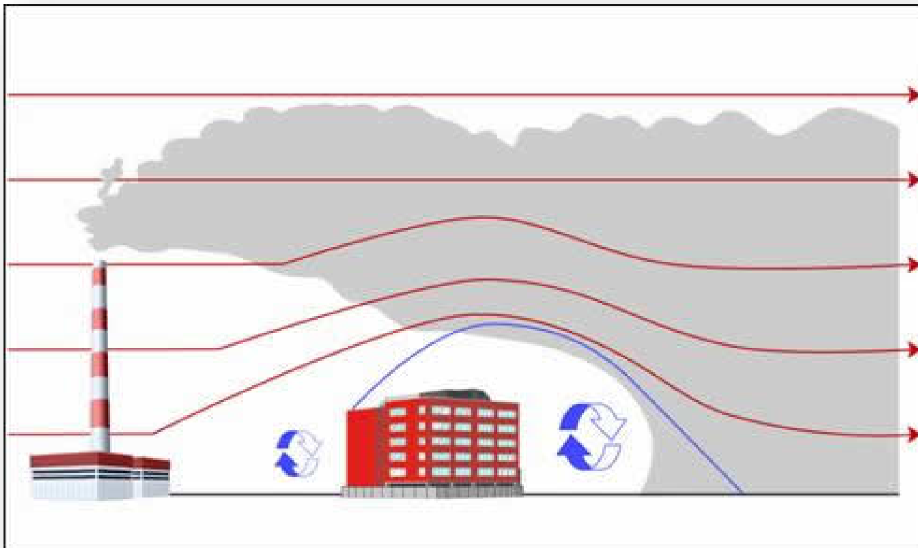
- Season (n=4)
- Month (n=12)
- Hour or day (n=24)
- Season and hour-of-day (n=96)
- Season, hour-of-day, and 3 category day of week (M-F, Sat, Sun; n=288)
- Season, hour-of-day, and 7 days of week (n=672)
- Month, hour-of-day, and 3 category day of week (M-F, Sat, Sun; n=864)
- Month, hour-of-day, and 7 days of week (n=2,016)
- Hour of year as an external file (n=number of hours in the meteorological data set)
- Wind speed (n=6)

3.7 Building Impacts

Buildings and other structures near a relatively short stack can have a substantial effect on plume transport and dispersion, and on the resulting ground-level concentrations that are observed. There has long been a general principle that a stack should be at least 2.5 times the height of adjacent buildings. Beyond that, much of what is known of the effects of buildings on plume transport and diffusion has been obtained from wind tunnel studies and field studies.

When the airflow meets a building (or other obstruction), it is forced up and over the building. On the lee side of the building, the flow separates, leaving a closed circulation containing lower wind speeds. Farther downwind, the air flows downward again. In addition, there is more shear and, as a result, more turbulence. This is the turbulent wake zone (see Figure 3-3).

Figure 3-3. The Building Downwash Concept



If a plume gets caught in the cavity, very high concentrations can result. If the plume escapes the cavity, but remains in the turbulent wake, it may be carried downward and dispersed more rapidly by the turbulence. This can result in either higher or lower concentrations than would occur without the building, depending on whether the reduced height or increased turbulent diffusion has the greater effect.

The height to which the turbulent wake has a significant effect on the plume is generally considered to be about the building height plus 1.5 times the lesser of the building height or width. This results in a height of 2.5 building heights for cubic or squat buildings, and less for tall, slender buildings. Since it is considered good engineering practice to build stacks taller than adjacent buildings by this amount, this height came to be called a “good engineering practice” (GEP) stack height.

3.7.1 Good Engineering Practice (GEP) Stack Heights and Structure Influence Zones

The U.S. EPA[16] states that “If stacks for new or existing major sources are found to be less than the height defined by the EPA’s refined formula for determining GEP height, then air quality impacts associated with cavity or wake effects due to the nearby building structures should be determined.”

[16] U.S. Environmental Protection Agency, 1990. Stack Heights, Section 123, Clean Air Act, 40 CFR Part 51. U. S. Environmental Protection Agency, Research Triangle Park, NC.

The U.S. EPA’s refined formula for determining GEP stack height is:

GEP Stack Height = H + 1.5L

where,

GEP = Good Engineering Practice
H = Building/tier height measured from ground to the highest point
L = Lesser of the building height (PB) or projected building width (PBW)

Building downwash for point sources that are within the Area of Influence of a building should be considered. For U.S. EPA regulatory applications, a building is considered sufficiently close to a stack to cause wake effects when the distance between the stack and the nearest part of the building is less than or equal to five (5) times the lesser of the building height or the projected width of the building.

$Distance_{stack\text{-}bldg} \leq 5L$

For point sources within the Area of Influence, building downwash information (direction-specific building heights and widths) should be included in the modeling project. Using BPIP-PRIME, these direction-specific building heights and widths can be computed.

For downwash analyses with direction-specific building dimensions, wake effects are assumed to occur if the stack is within a rectangle composed of two lines perpendicular to the wind direction, one at 5L downwind of the building and the other at 2L upwind of the building, and by two lines parallel to the wind direction, each at 0.5L away from each side of the building. L is the lesser of the height or projected width. This rectangular area has been termed a Structure Influence Zone (SIZ). Any stack within the SIZ for any wind direction is potentially affected by GEP wake effects for some wind direction or range of wind directions. See Figure 3-4 and Figure 3-5.

Figure 3-4. GEP 5L and Structure Influence Zone (SIZ) Areas of Influence

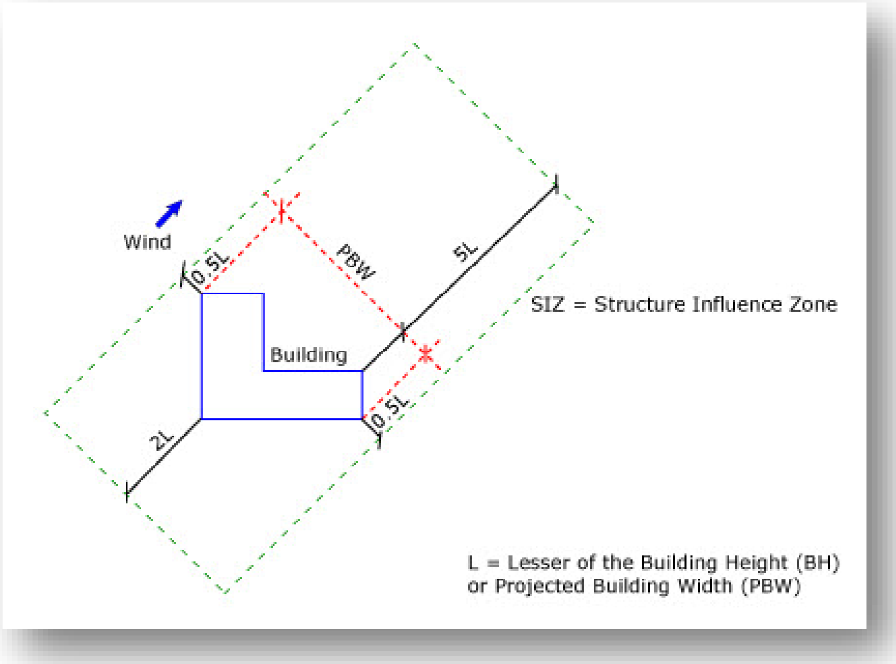
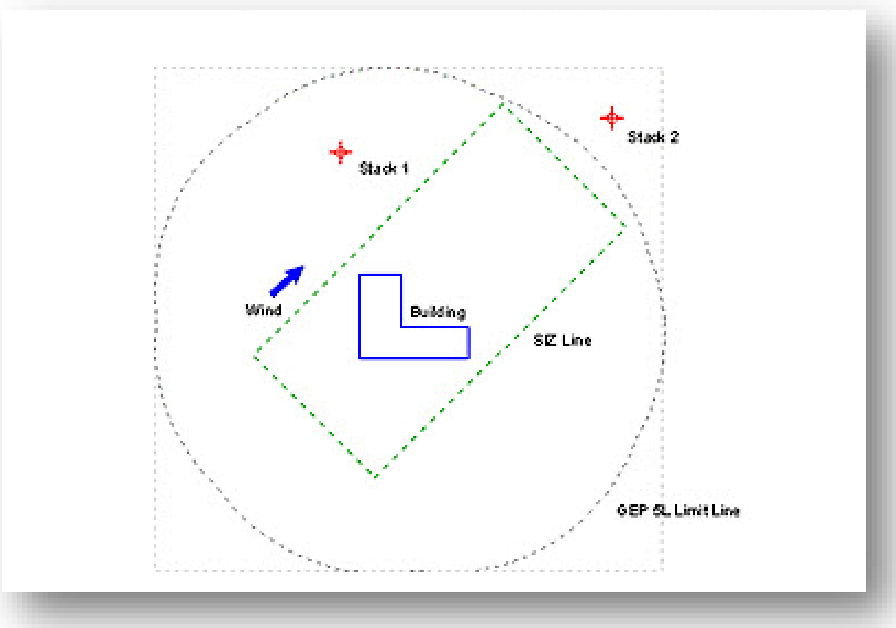


Figure 3-5. GEP 360° 5L and Structure Influence Zone (SIZ) Areas of Influence



3.7.2 Defining Buildings

Both AERSCREEN and AERMOD allow for the consideration of building downwash. The AERSCREEN interface prompts only allow input of parameters for a single tier rectangular or square shaped building. If downwash for multiple buildings, tiers, or more complicated geometries is required, a BPIP-PRM input filename can be specified. AERMOD can consider the effects of complicated sites consisting of up to hundreds of buildings. This results in different approaches to defining buildings as outlined below.

3.7.2.1 AERSCREEN Building Definition

For multiple buildings, tiers, or more complicated geometries, a BPIP-PRM input filename can be specified. Defining a simple, single building in AERSCREEN is straightforward requiring only the following input data:

- Building height (feet or meters)
- Minimum building horizontal dimension (feet or meters)
- Maximum building horizontal dimension (feet or meters)
- Degrees from North of maximum building horizontal dimension (0-179 degrees)
- Degrees from North of stack location relative to building center (0-360 degrees)
- Distance between stack and building center (feet or meters)

Since building downwash estimates depend on transitional momentum plume rise and transitional buoyant plume rise calculations, the selection of effective stack parameters to account for capped stacks, horizontal stacks and flares could influence the estimates. Therefore, building downwash estimates for these sources should be used with extra caution.

3.7.2.2 AERMOD Building Definition

The inclusion of the PRIME (Plume Rise Model Enhancements) algorithm[17] to compute building downwash has produced more accurate results in air dispersion models. Unlike the earlier algorithms used in ISC3, the PRIME algorithm:

1. Accounts for the location of the stack relative to the building
2. Accounts for the deflection of streamlines up over the building and down the other side
3. Accounts for the effects of the wind profile at the plume location for calculating plume rise
4. Accounts for pollutants captured in the recirculation cavity to be transported to the far wake downwind (this is ignored in the earlier algorithms)
5. Avoids discontinuities in the treatment of different stack heights, which were a problem in the earlier algorithms

[17] Schulman, L.L., D.G. Strimaitis and J.S. Scire, 2000: Development and evaluation of the PRIME plume rise and building downwash model. Journal of the Air & Waste Management Association, 50:378-390.

Refined models allow for the capability to consider downwash effects from multiple buildings. AERMOD requires building downwash analysis to first be performed using BPIP-PRIME[17]. The results from BPIP-PRIME can then be incorporated into the modeling studies for consideration of downwash effects.

The U.S. EPA Building Profile Input Program – Plume Rise Model Enhancements (BPIP-PRIME) was designed to incorporate enhanced downwash analysis data for use with the U.S. EPA ISC-PRIME and current AERMOD models. Similar in operation to the U.S. EPA BPIP model, BPIP-PRIME uses the same input data requiring no modifications of existing BPIP projects. The following information is required to perform building downwash analysis within BPIP:

- X and Y location for all stacks and building corners
- Height for all stacks and buildings (meters). For building with more than one height or roofline, identify each height (tier)
- Base elevations for all stacks and buildings

The BPIP User's Guide[18] provides details on how to input building and stack data to the program.

The BPIP model is divided into two parts. Part one is based on the GEP technical support document[19], this part is designed to determine whether or not a stack is subject to wake effects from a structure or structures. Values are calculated for GEP stack height and GEP related building heights (BH) and projected building widths (PBW). Indication is given to which stacks are being affected by which structure wake effects. Additionally, part two, calculates building downwash BH and PBW values based on references by Tikvart[20,21] and Lee[22]. These can be different from those calculated in Part One. The calculations are performed only if a stack is being influenced by structure wake effects
In addition to the standard variables reported in the output of BPIP, BPIP-PRIME adds the following:

- BUILDLEN: Projected length of the building along the flow
- XBADJ: Along-flow distance from the stack to the center of the upwind face of the projected building

[18] U.S. Environmental Protection Agency, 1995. User's Guide to the Building Profile Input Program, EPA-454/R-93-038, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.
[19] U.S. Environmental Protection Agency, 1985. Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations) – Revised EPA-450/4-80-023R, U.S. Environmental Protection Agency, Research Triangle Park, NC.
[20] Tickvart, J. A., May 11, 1988. Stack-Structure Relationships, Memorandum to Richard L. Daye, U.S. EPA.
[21] Tickvart, J. A., June 28, 1989. Clarification of Stack-Structure Relationships, Memorandum to Regional Modeling Contacts, Regions I-X, U.S. EPA.
[22] Lee, R. F., July 1, 1993. Stack-Structure Relationships – Further clarification of our memoranda dated May 11, 1988 and June 28, 1989, Memorandum to Richard L. Daye, U.S. EPA.

- YBADJ: Across-flow distance from the stack to the center of the upwind face of the projected building

For a more detailed technical description of the EPA BPIP-PRIME model and how it relates to the EPA ISC-PRIME model see the Addendum to ISC3 User's Guide[23].

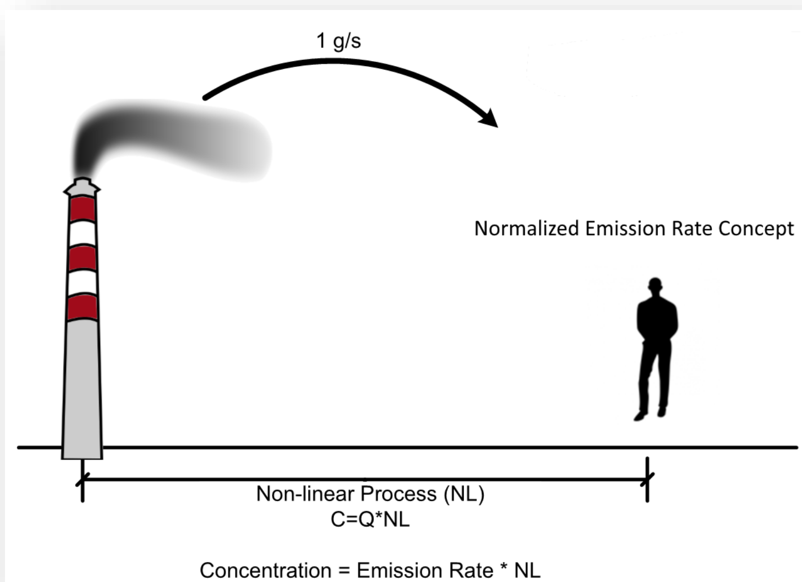
3.8 Multiple Pollutants

Industrial processes often emit multiple pollutants through one or several emission sources. The U.S. EPA models are not equipped to automatically perform modeling of different pollutants that may share the same emission source but have unique emission rates.

3.8.1 Normalized Emission Rate and Summation Concepts

The most common approach to modeling multiple pollutants from multiple sources individually is applying normalized emission rate and summation concepts. Air dispersion modeling is a non-linear process. Modeled concentrations depend on the site's meteorology and variations in terrain. However, once the calculations for a receptor in space are complete, all chemical concentration levels are proportional to their source release rate. Figure 3-6 below will assist in visualizing this concept, by describing an emission rate of 1 g/s.

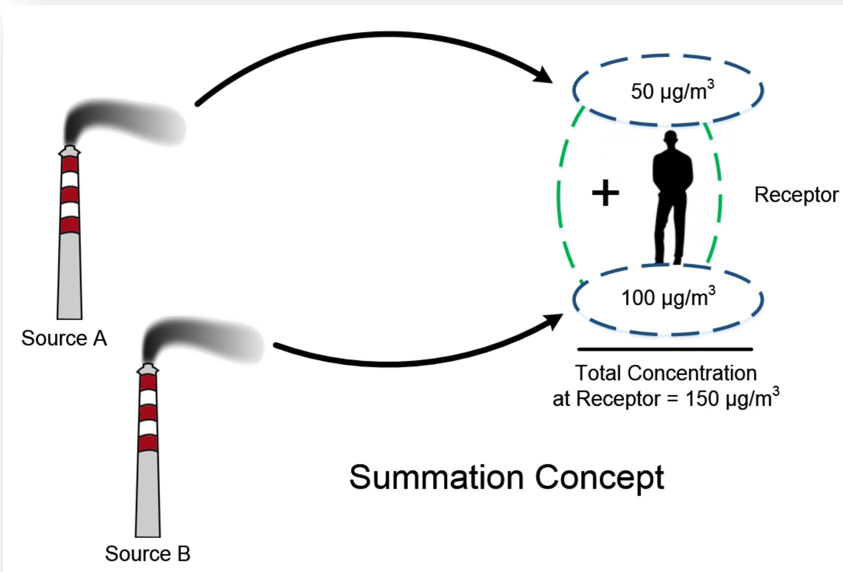
Figure 3-6. Normalized Emission Rate Concept (1 g/s)



[23] Schulman, et al., 1997. Addendum - User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume 1. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

The normalized emission rate concept must be applied source by source, with each source modeled individually using an emission rate of 1 g/s. The concentration at the receptor can then be multiplied by the actual chemical emission rate, and the final result from all the sources will be superimposed. This is called the summation concept (worst-case modeled result), where the concentration and deposition fluxes at a receptor are the linear addition of the resulting values from each source. Figure 3-7 below presents the summation concept.

Figure 3-7. The Summation Concept for Two Sources



A post-processor is needed to effectively process model results that have been performed using normalized emission rate and summation concepts. Final output will provide results for pollutant specific scenarios from multiple sources.

4 GEOGRAPHICAL INFORMATION INPUTS

4.1 Comparison of Screening and Refined Model Requirements

Geographical information requirements range from basic for screening analyses, to advanced for refined modeling. AERSCREEN makes use of geographical information only for terrain data for complex or elevated terrain where it requires simply distance from source and height in a straight-line. The AERMOD model makes use of complete three-dimensional geographic data with support for digital elevation model files and real-world spatial characterization of all model objects.

4.2 Coordinate System

4.2.1 Local

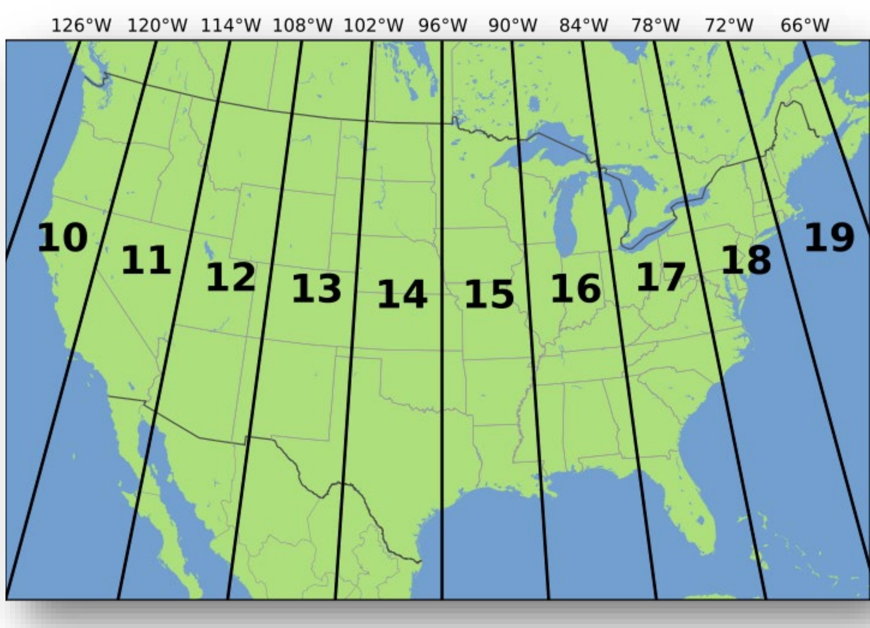
Local coordinates encompass systems that are not based on a geographic standard. For example, a facility may reference its coordinates to a local datum, such as a predefined benchmark. All site measurements then relate to this benchmark which can be defined as the origin of the local coordinate system with coordinates of 0,0 m. All facility buildings and sources could then be related spatially to this origin.

However, local coordinates do not indicate actual geographic position, which would be required to incorporate supplemental data (such as terrain). For this reason, it is advantageous to consider a geographic coordinate system that can specify the location of any object anywhere in the world with precision. The coordinate system most commonly used for air dispersion modeling is the Universal Transverse Mercator (UTM) system.

4.2.2 Universal Transverse Mercator

As described earlier, the UTM coordinate system uses meters as its basic unit of measurement and allows for more precise definition of specific locations than latitude/longitude. The UTM system is not really universal, but it does cover most of the Earth's surface. Only polar areas with latitudes higher than 84° North and 80° South are excluded. The UTM system divides the remainder of the Earth's surface into 60 zones, each spanning 6° of longitude. Each zone has its own origin (0,0), making it necessary to correctly report the zone with the coordinates.

Figure 4-1. UTM Zones in the United States



To keep from using negative numbers in UTMs, the east-west origin is placed 500,000 meters west of the central axis of the zone. This is referred to as the zone's 'false origin'. The zone doesn't extend all the way to the false origin. The origin for north-south values depends on whether you are in the northern or southern hemisphere. In the northern hemisphere, the origin is the equator and all distances north (or 'northings') are measured from the equator. In the southern hemisphere the origin is the South Pole and all northings are measured from there. Once again, having separate origins for the northern and southern hemispheres eliminates the need for any negative values. The average circumference of the earth is 40,030,173 meters, meaning that there are 10,007,543 meters of northing in each hemisphere.

Note: Ensure all model objects (sources, buildings, receptors) are defined in the same horizontal datum. Defining some objects based on a NAD27 (North American datum of 1927) while defining others within a NAD83 (North American datum of 1983) can lead to significant errors in relative locations. The District recommends the use of NAD83 or WGS84 (World Geodetic System 1984).

4.3 Terrain

4.3.1 Terrain Concerns in Short-Range Modeling

Terrain elevations can have a large impact on the air dispersion and deposition modeling results, and therefore on the estimates of potential risk to human health and the environment. Terrain elevation is the elevation relative to the facility base elevation.

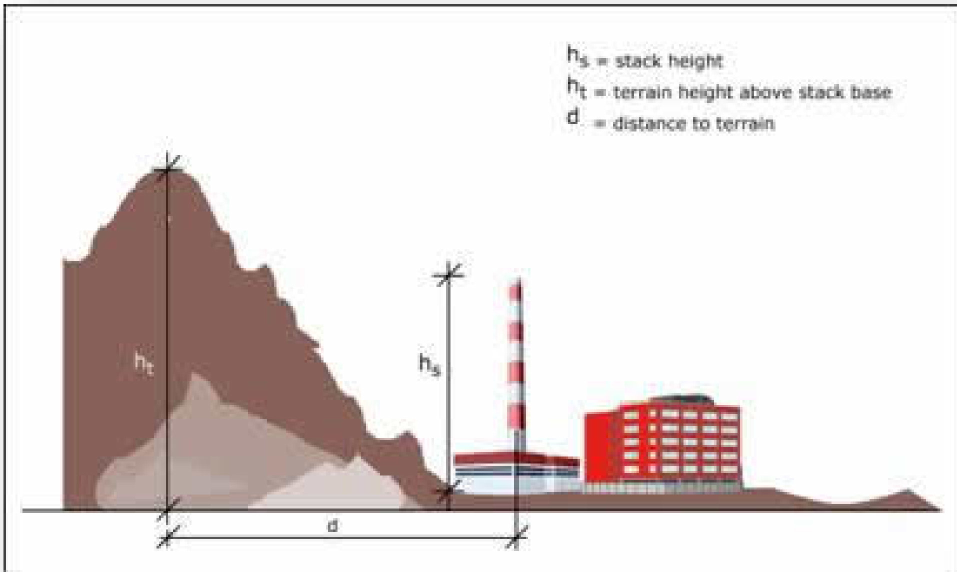
The following section describes the primary types of terrain. The consideration of a terrain type is dependent on the study area, and the definitions below should be considered when determining the characteristics of the terrain for the modeling analysis.

4.3.2 Flat and Complex Terrain

AERMOD considers three different categories of terrain as follows:

Complex Terrain: this is where terrain elevations for the surrounding area, defined as anywhere within 50 km from the stack, are above the top of the stack being evaluated in the air modeling analysis.

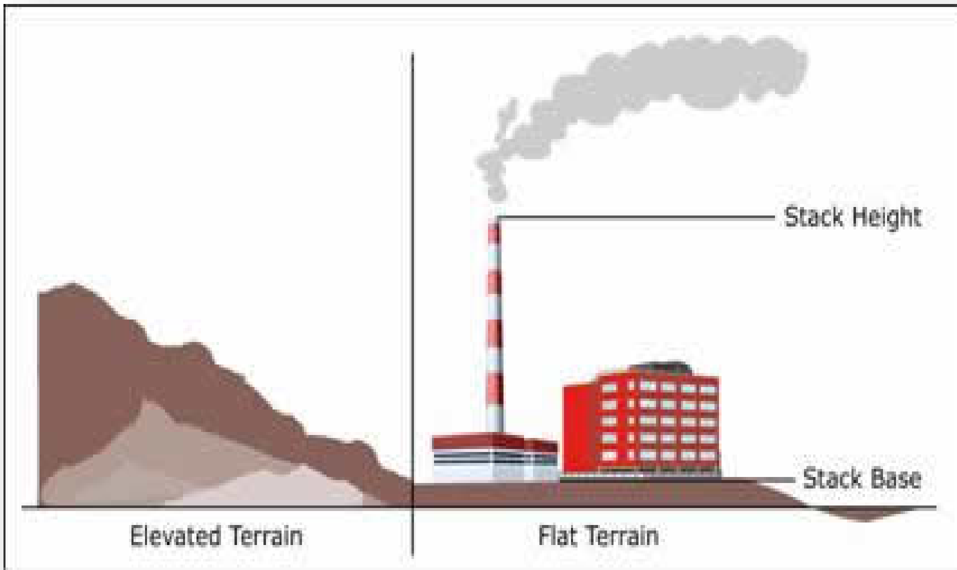
Figure 4-2. Sample Complex Terrain Conditions



<u>Simple Terrain</u>: this is where terrain elevations for the surrounding area are not above the top of the stack being evaluated in the air modeling analysis. The "Simple" terrain can be divided into two categories:

- <u>Simple Flat Terrain</u> is used where terrain elevations are assumed not to exceed stack base elevation. If this option is used, then terrain height is considered to be 0.0 m.
- <u>Simple Elevated Terrain</u>, as illustrated in is used where terrain elevations exceed stack base but are below stack height.

Figure 4-3. Sample Elevated and Flat Terrain Conditions



4.3.3 Terrain Data

Evaluation of the terrain within a given study area is the responsibility of the modeler. At first glance it may be inferred that much of San Joaquin Valley is flat, but it should be remembered that complex terrain is any terrain within the study area that is above the source release height.

The appropriate terrain environment can be determined through the use of digital elevation data or other geographic data sources. Note, the choice of whether or not to use terrain does not affect AERMOD modeling run times. However AERMAP, the terrain pre-processor for AERMOD, does require additional time. If analysis of the terrain environment is performed using digital terrain data, minimal resources are required to execute a model run using that digital terrain dataset.

4.3.4 Obtaining Terrain Data

AERMAP needs standardized computer files of terrain data. The data is available in three distinct formats:

- Digital Elevation Model (DEM) format which follows the old USGS “Blue Book” standard.
- Spatial Data Transfer Standard (SDTS) which formats the DEM and other associated data in metadata form.
- National Elevation Dataset (NED) data which is constantly updated and is available in several formats.

Traditionally, terrain elevation data from the U.S. Geological Survey (USGS) 7.5-Minute Digital Elevation Model (DEM), or equivalent (approx. 30-meter resolution), (processed through AERMAP) has been considered a default for use in AERMOD. Starting in 2011, data from the National Elevation Dataset (NED, https://nationalmap.gov/elevation.html) was also accepted for use in AERMOD. The NED data includes a range of resolutions, from 1-m to 2 arc seconds. When modeling in or near complex terrain, higher resolutions are preferred. In some cases, exceptions from the terrain data requirement may be made in consultation with the appropriate reviewing authority. Digital elevation model (DEM) data covering San Joaquin Valley is available for free from Lakes Environmental's Web GIS.

4.3.5 Preparing Terrain Data for Model Use

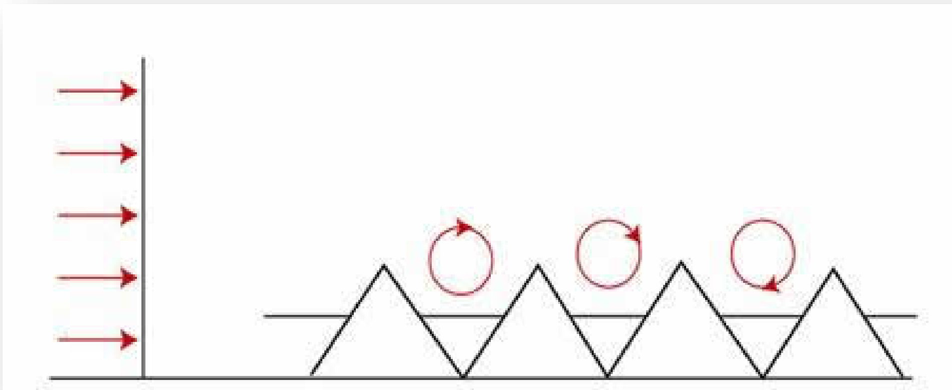
AERMAP is the digital terrain pre-processor for the AERMOD model. It analyzes and prepares digital terrain data for use within an air dispersion modeling project. AERMAP requires that the digital terrain data files be in native (non SDTS) USGS 1-degree or 7.5-minute DEM format. A SDTS and a XYZ conversion program is provided with AERMAP, and many software packages will make these conversions transparently.

4.4 Land Use Characterization

Land use plays an important role in air dispersion modeling from meteorological data processing to defining modeling characteristics such as urban or rural conditions. Land use data can be obtained from digital and paper land-use maps.

These maps provide an indication of the dominant land use types within an area of study, such as industrial, agricultural, forested and others. This information can then be used to determine dominant dispersion conditions and estimate values for parameters such as surface roughness, albedo, and Bowen ratio. The AERSURFACE Utility provides these parameters by using national land cover datasets and look-up tables of surface characteristics that vary by land cover type and season to obtain realistic and reproducible surface characteristic values for use in AERMET.
Surface Roughness Length (m): The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer. This height is not equal to the physical dimensions of the obstacles, but is generally proportional to them (Figure 4-4). For many modeling applications, surface roughness can be considered to be on the order of one tenth of the height of the roughness elements.

Figure 4-4. Surface Roughness Creating Turbulence

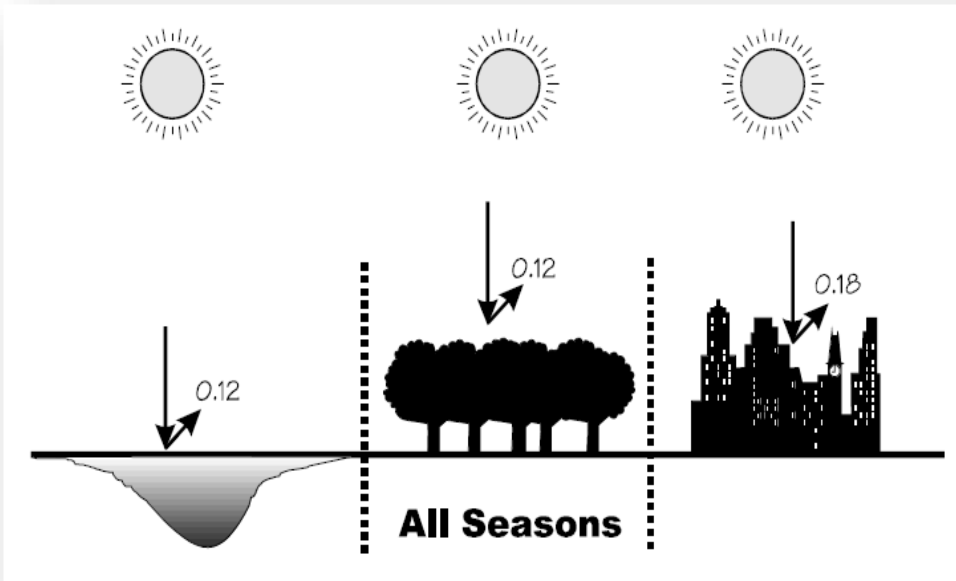


According to the AERMOD Implementation Guide[24], the determination of the surface roughness length should be based on an inverse distance weighted geometric mean for a default upwind distance of 1 kilometer relative to the measurement site. Surface roughness length may be varied by sector to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.

- Albedo: Noon-time albedo is the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. For practical purposes, the selection of a single value for albedo to process a complete year of meteorological data is desirable. If other conditions are used, the District should review the proposed noon-time albedo values used to pre-process the meteorological data.

[24] U.S. EPA. 2015. AERMOD Implementation Guide, Revised 8/3/2015. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Figure 4-5. Typical Albedo Values as a Function of Several Land Use Types and Season



According to the AERMOD Implementation Guide, the determination of the albedo should be based on a simple unweighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for Bowen ratio, with a default domain defined by a 10 km by 10 km region centered on the measurement site.

- Bowen Ratio: The Bowen ratio is a measure of the amount of moisture at the surface. The presence of moisture at the earth's surface alters the energy balance, which in turn alters the sensible heat flux and Monin-Obukhov length. Bowen ratio values vary depending on the surface wetness. Average moisture conditions would be the usual choice for selecting the Bowen ratio. If other conditions are used the District should review the proposed Bowen ratio values used to pre-process the meteorological data. The determination of the Bowen ratio should be based on a simple unweighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 10 km by 10 km region centered on the measurement site.

4.4.1 Wind Direction Dependent Land Use

AERMET also provides the ability to specify land characteristics for up to 12 different contiguous, non-overlapping wind direction sectors that define unique upwind surface characteristics. The following properties of wind sectors must be true:

- The sectors are defined clockwise as the direction from which the wind is blowing, with north at 360°.

- The sectors must cover the full circle so that the end value of one sector matches the beginning of the next sector.
- The beginning direction is considered part of the sector, while the ending direction is not.

Each wind sector can have a unique albedo, Bowen ratio, and surface roughness. Furthermore, these surface characteristics can be specified annually, seasonally, or monthly to better reflect site conditions.

4.4.2 Mixed Land Use Types

Study areas may contain several different regions with varying land use. This can be handled by AERMET through the use of wind sector specific characterization, as described in the previous section.

4.4.3 Seasonal Land Use Characterization

Land use characteristics can be susceptible to seasonal variation. For example, winter conditions can bring increased albedo values due to snow accumulation. AERMET allows for season-specific values for surface roughness, albedo, and Bowen ratio to be defined.

4.4.4 Standard and Non-Default Surface Characteristics

The generation of local meteorological data files can incorporate site-specific surface characteristics. It should be noted that any local meteorological files generated for air dispersion modeling should provide a clear reasoning for the values used to describe surface characteristics. The District must review any proposed surface characteristics prior to use in any modeling being performed.

4.4.5 Defining Urban and Rural Conditions

The classification of a site as urban or rural can be based on the Auer method specified in the EPA document *Guideline on Air Quality Models (40 CFR Part 51, Appendix W)*[25]. From the Auer's method, areas typically defined as Rural include:

- Residences with grass lawns and trees
- Large estates
- Metropolitan parks and golf courses
- Agricultural areas
- Undeveloped land
- Water surfaces

[25] U.S. Environmental Protection Agency, 2001. Appendix W to Part 51 Guideline on Air Quality Models, 40 CFR Part 51. U. S. Environmental Protection Agency, Research Triangle Park, NC.

Auer defines an area as Urban if it has less than 35% vegetation coverage or the area falls into one of the following use types:

Table 4-1. Urban Land Use

Type	Use and Structures	Vegetation
I1	Heavy industrial	Less than 5%
I2	Light/moderate industrial	Less than 5%
C1	Commercial	Less than 15%
R2	Dense single / multi-family	Less than 30%
R3	Multi-family, two-story	Less than 35%

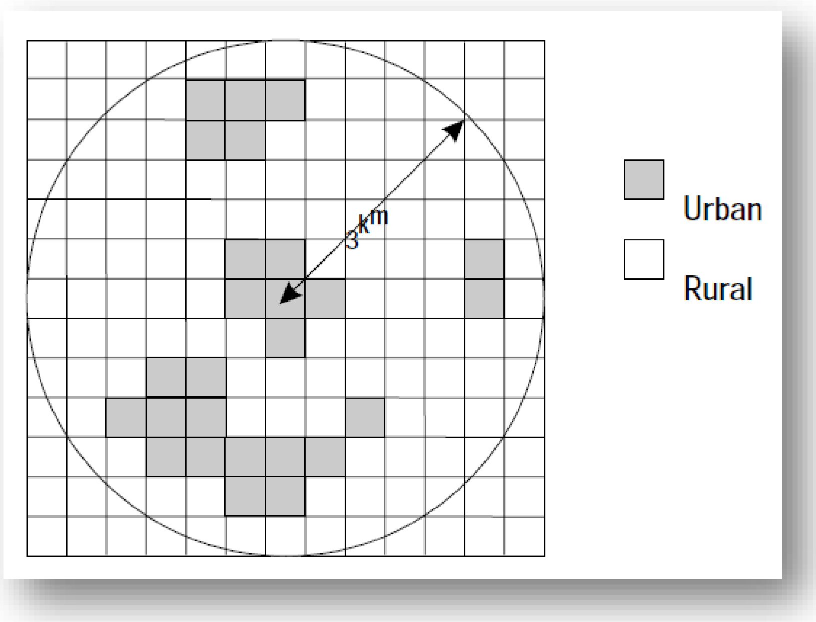
Follow the Auer's method, explained below, for the selection of either urban or rural dispersion coefficients:

Step 1: Draw a circle with a radius of 3 km from the center of the stack or centroid of the polygon formed by the facility stacks.

Step 2: If land use types I1, I2, C1, R2, and R3 account for 50% or more of the area within the circle, then the area is classified as **urban**, otherwise the area is classified as **rural**.

To verify if the area within the 3 km radius is predominantly rural or urban, overlay a grid on top of the circle and identify each square as primarily urban or rural. If more than 50% of the total number of squares is urban than the area is classified as **urban**; otherwise the area is **rural**.

Figure 4-6. Use of a Grid to Determine Urban/ Rural Land Use Classification



An alternative approach to urban/rural classification is the Population Density Procedure:

Compute the average population density per square kilometer within the 3 km radius as defined above,

- If population density > 750 people/km^2, select the **urban** option,
- If population density <= 750 people/km^2, select the **rural** option.

Of the two methods above, the land use procedure is considered a more definitive criterion. The population density procedure should be used with caution and should not be applied to highly industrialized areas where the population density may be low and thus a rural classification would be indicated, but the area is sufficiently built-up so that the urban land use criteria would be satisfied. In this case, the classification should already be Urban and urban dispersion parameters should be used.

5 METEOROLOGICAL DATA

5.1 Comparison of Screening and Refined Model Requirements

Meteorological data is essential for air dispersion modeling as it describes the primary environment through which the pollutants being studied migrate. Similar to other data requirements, screening model requirements are less demanding than refined models.

AERSCREEN uses meteorological data created through the use of the MAKEMET program. MAKEMET requires the following inputs in order to generate meteorological data:

- Minimum wind speed (m/s)
- Anemometer height (m)
- Option to adjust U* (Y/N)
- Number of wind directions
- Wind direction (only if one wind direction was entered for number of wind directions)
- Starting wind direction
- Clockwise wind direction increment
- Min and Max ambient temperatures (K)
- Albedo
- Bowen ration
- Surface roughness (m)

5.2 Preparing Meteorological Data for Refined Modeling

AERMOD models require actual hourly meteorological conditions as inputs. The refined models require pre-processed meteorological data that contains information on surface characteristics and upper air definition. This data is typically provided in a raw or partially processed format that requires processing through a meteorological pre-processor. AERMOD uses a pre-processor known as AERMET, which is described further in the following sections. The following is a brief overview of the process for preparing meteorological data for use with AERMOD. Please contact the District for a more detailed explanation of the process used to prepare meteorological data.

5.3 Data Assessment: Representativeness

Meteorological data quality is of critical importance, particularly for reliable air dispersion modeling using refined models such as AERMOD. Meteorological data should be collected, processed and analyzed throughout the entire creation phase for completeness and quality control.

There are four factors that affect the representativeness of the meteorological data. These are: 1) the proximity of the meteorological site to the area being modeled, 2) the complexity of the terrain, 3) the exposure of the meteorological measurement site, and 4) the time period of the data collection. It should be emphasized that representativeness (both spatial and temporal) of the data is the key requirement. One factor alone should not be the basis for deciding on the representativeness of the data.

The meteorological data that is input to a model should be selected based on its appropriateness for the modeling project. More specifically, the meteorological data should be representative of the wind flow in the area being modeled, so that it can properly represent the transport and diffusion of the pollutants being modeled.

5.4 User Developed Local Meteorological Data

Local meteorological data must be reviewed, and the origin of the data and any formatting applied to the raw data must be outlined. The regulatory agency should review plans to use local meteorological data prior to submission of a modeling report.

The sources of all of the data used, including cloud cover data and upper air data, must be documented. The proponent also needs to justify that the site selected is representative for the modeling application. This would include a description of any topographic impacts or impacts from obstructions (trees, buildings etc.) on the wind monitor. Information on the heights that the wind is measured is also required. The time period of the measurements along with the data completeness and the percentage of calm winds should be reported.

Wind roses showing the wind speed and directions should be provided with the modeling assessment. If wind direction dependent land use was used in deriving the final meteorological file, the selection of the land use should be described.

6 RECEPTOR LOCATIONS

The AERMOD air dispersion model computes the concentration of substances at user-specified spatial points. Modelers commonly refer to these points as receptors. Receptor selection is critical to capturing the maximum point of impact, and proper placement of receptors can be achieved through several approaches. The types of receptors and receptor grids are described below followed by a discussion on the grid extents and receptor densities required to capture maximum concentrations.

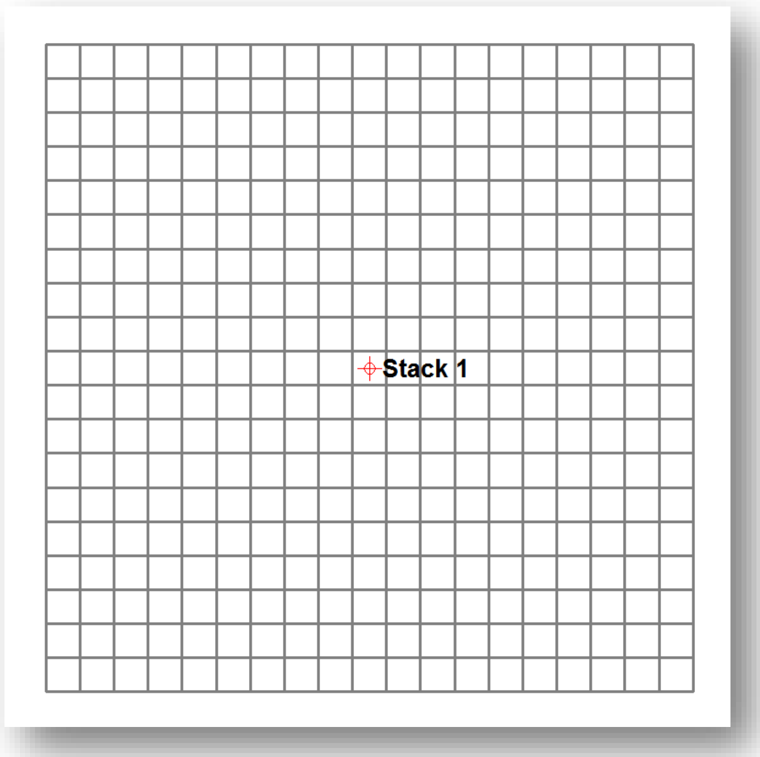
6.1 Receptor Types

AERMOD supports a variety of receptor types that allow for considerable user control over calculating pollutant concentrations. The major receptor types and grid systems are described in the following sub-sections. Further details on additional receptor types can be found in the appropriate documentation for each model.

6.1.1 Cartesian Receptor Grids

Cartesian receptor grids are receptor networks that are defined by an origin with receptor points evenly (uniform) or unevenly (non-uniform) spaced receptor in x and y directions. Figure 6-1 presents a sample uniform Cartesian receptor grid.

Figure 6-1. Example Cartesian Grid

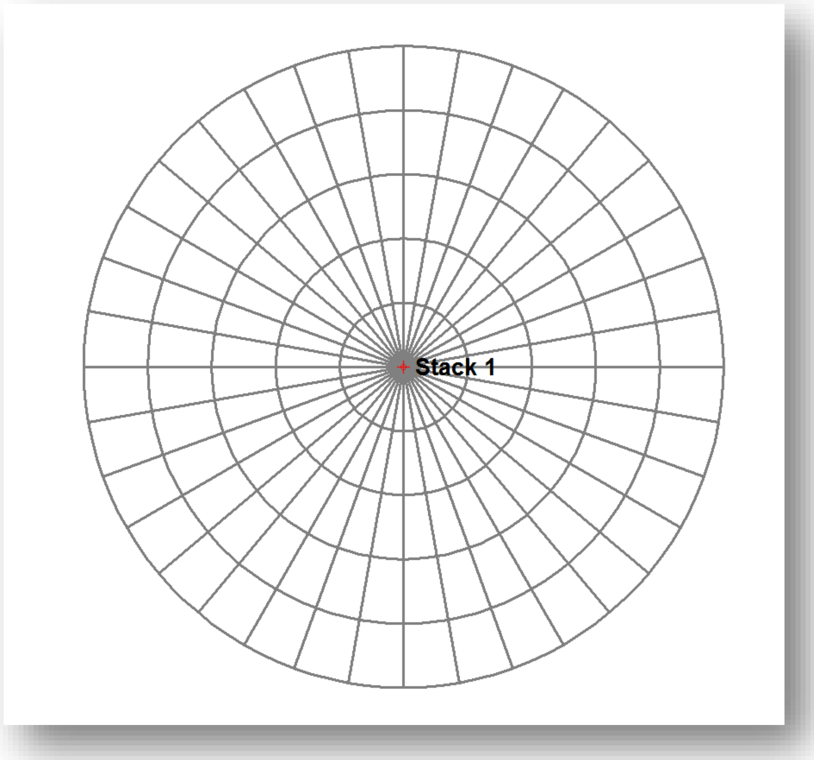


6.1.2 Polar Receptor Grids

Polar receptor grids are receptor networks that are characterized by an origin with receptor points defined by the intersection of concentric rings, which have defined distances in meters from the origin, with direction radials that are separated by specified degree spacing. Figure 6-2 below presents a sample uniform polar receptor grid.

Polar grids are a reasonable choice for facilities with only one source or one dominant source. However, for facilities with a number of significant emissions sources, receptor spacing can become too coarse when using polar grids. As a result, polar grids should generally be used in conjunction with another receptor grid, such as a multi-tier grid, to ensure adequate spacing.

Figure 6-2. Example Polar Grid



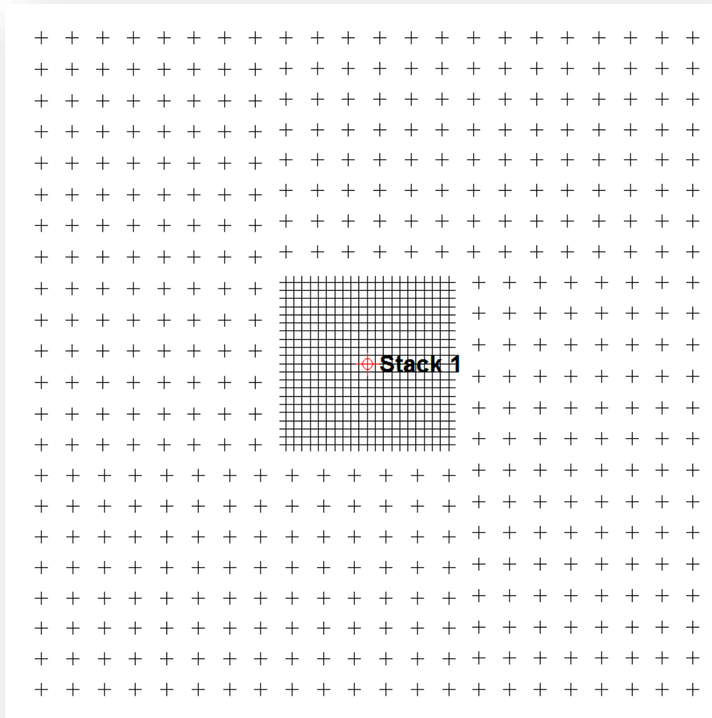
6.1.3 Multi-Tier Grids

Each receptor point requires computational time. Consequently, it is not optimal to specify a dense network of receptors over a large modeling area; the computational time would negatively impact productivity and available time for proper analysis of results. An approach that combines aspects of coarse grids and refined grids in one modeling run is the multi-tier grid.

The multi-tier grid approach strives to achieve proper definition of points of maximum impact while maintaining reasonable computation times without sacrificing sufficient resolution.

Figure 6-3 presents an example of a multi-tier grid.

Figure 6-3. Example Multi-Tier Grid



6.1.4 Fenceline Receptors

With the exception of self-contamination scenarios, dispersion modeling for on-site receptors (within the property boundary) is not necessary. As a result, property boundaries are typically delineated in projects and model results are not required for those areas. However, receptors must be placed along the plant boundary to demonstrate compliance at the nearest reportable geographical locations to the sources.

A receptor network based on the shape of the property boundary that has receptors parallel to the boundaries is often a good choice for receptor geometry. The receptor spacing can then progress from fine to coarse as distance increases from the facility, similar to the multi-tier grid.

6.1.5 Discrete & Sensitive Receptors

Receptor grids do not always cover precise locations that may be of interest in modeling projects. Specific locations of concern can be modeled by placing single receptors, or additional refined receptor grids, at desired locations. This enables the modeler to generate data at specific points for which accurate data is especially critical. In particular, for elevated receptors the maximum concentrations can be larger than found at ground level.

Common locations of sensitive receptors can include, among others, the following:

- Apartments
- Residential zones
- Schools
- Day care centers
- Air intakes on nearby buildings
- Hospitals
- Park
- Care facilities

Depending on the project resolution and location type, these can be characterized by discrete receptors, a series of discrete receptors, or an additional receptor grid.

6.2 Minimum Receptor Requirements for Capturing and Assessing Maxima

Receptor coverage must ensure that the maximum pollutant concentration is captured. For facilities with more than one emission source, the receptor network should include Cartesian or multi-tier grids to ensure that maximum concentrations are obtained. Tall stacks could require grids extending 1 to 15 km, while ground level maxima for emissions from shorter stacks (10 - 20 m height) might be obtained using grids extending a kilometer or less from the property line.

The model could be first run with a coarse receptor grid, and then re-run with finer grids in the areas showing the highest impacts. If this method were used, finer grids should be used for all areas with high concentrations, not just the single highest area.

Figure 6-4 and Figure 6-5 present the application of the District's recommended receptor densities to a sample site.

Figure 6-4. Example Polar Grid Layout

<u>Polar Grid Requirements</u>

- 36 directional radials
- 10 degree directional increments
- Ring distances from origin:
    - 25m
    - 50m
    - 100m
    - 250m
    - 500m
    - 1000m

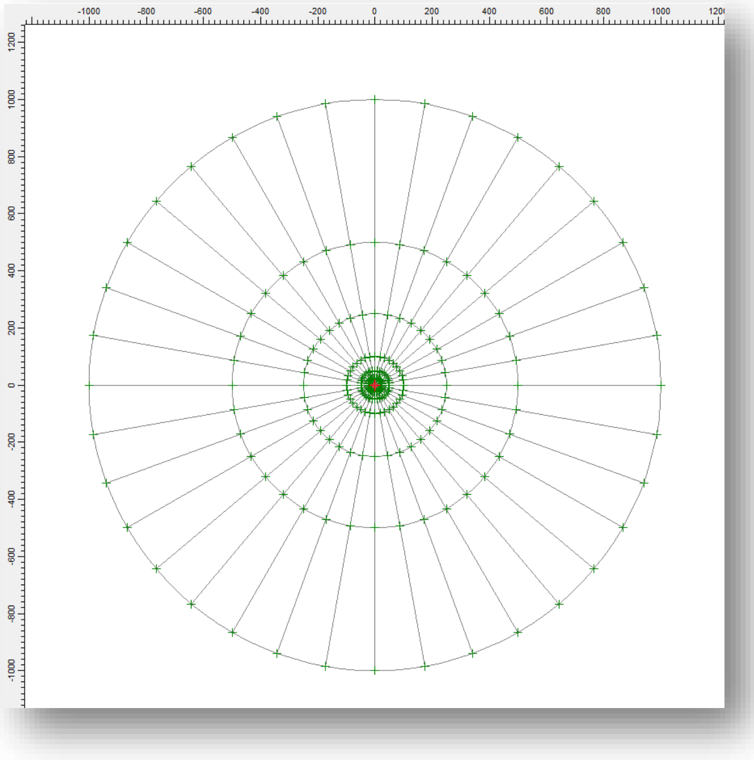
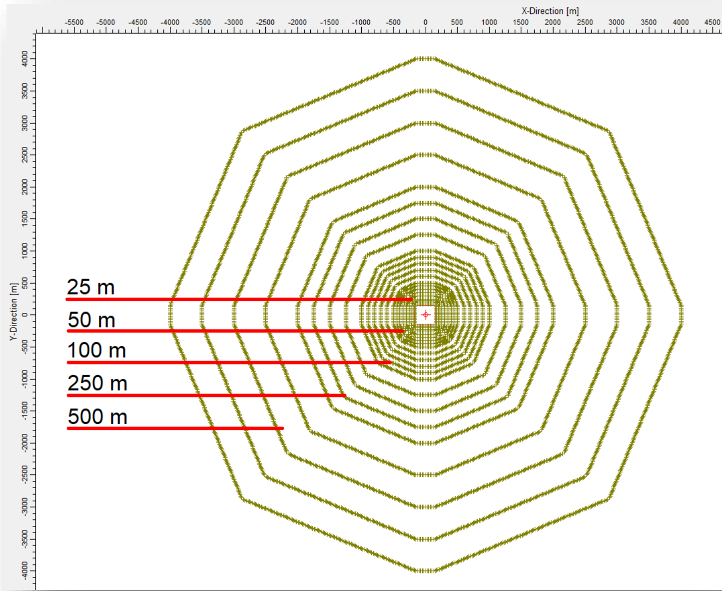


Figure 6-5. Example Telescoping Fenceline Grid Layout

<u>Fenceline Grid Requirements</u>

- 25 m spacing from the fenceline out to 100 m
- 50 m spacing from 100 to 250 m
- 100 m spacing from 250 to 500 m
- 250 m spacing from 500 to 1000 m
- 500 m spacing from 1000 to 2000 m



The densities of the receptors can progress from fine resolution near the source, centroid of the sources, or most significant source (not from the property line for polar grid) to coarser resolution farther away. Model runs with the telescoping receptor grids would ensure that maximum ground level off property concentrations are captured.

Discrete receptors are required at locations where there are elevated points of impact such as apartment buildings and air intakes on nearby buildings. These are needed to ensure that maximum impacts are obtained. Other discrete receptors are required for sensitive receptors such as schools and hospitals.

The final extent and details of the receptors used are the responsibility of the modeler who must demonstrate that the maximum impact has been captured and ensure the levels have dropped well below the standard and/or the guideline of the contaminant being studied. Certain stack characteristics, such as tall stacks, may inherently require more receptor coverage.

7 OTHER MODELING CONSIDERATIONS

7.1 Explanation for Alternative Model Use

Due to some limitations inherent in AERMOD (and most other plume models), there are some situations where the use of an alternative model may be appropriate. Acceptable alternative models and their use are further described in the Guideline on Air Quality Models ("Appendix W" to 40 CFR Part 51) and approved by the reviewing agency.

The use of any alternative model should first be reviewed by the District for suitability to the study application. If an alternative model is used, justification for its use over a preferred model must be discussed. An understanding of the alternative model, its data requirements, and the quality of data applied with the model must be demonstrated.

7.2 Use of Modeled Results in Combination with Monitoring Data

Monitoring and modeling should be considered complementary assessment tools to evaluate potential impacts on the local community. For cases where reliable information is available on the emission rates and source characteristics for a facility, modeled results can identify maximum impact areas and concentration patterns that could assist in locating monitoring sites. Model runs using a number of years of meteorological data would show the variations in the locations and the magnitude of maximum concentrations and can also provide information on the frequency of high concentrations.

The U.S. EPA Guideline on Air Quality Models states that modeling is the preferred method for determining concentrations and that monitoring alone would normally not be accepted for determining emission limitations.

8 GLOSSARY OF TERMS

AERMAP: The terrain preprocessor for AERMOD. AERMAP allows the use of digital terrain data in AERMOD.

AERMET: The meteorological preprocessor for AERMOD.

AERMIC: American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee.

AERMINUTE: A meteorological data preprocessor for AERMOD that processes 1-minute ASOS wind data to generate hourly average winds for input to AERMET.

AERMOD: An air dispersion model developed by AERMIC that has replaced the ISCST model.

AERSCREEN: The EPA recommended screening model based on AERMOD.

AERSURFACE: A tool that processes land cover data to determine the surface characteristics for use in AERMET.

Air Emissions: Release of pollutants into the air from a source.

Albedo: Portion of the incoming solar radiation reflected and scatter back to space.

Ambient Air: Air that is accessible to the public.

AMS: American Meteorological Society.

AP-42: EPA Document Number AP-42, Compilation of Air Pollutant Emission Factors, Environmental protection Agency, Research Triangle Park, North Carolina. Supplements are published regularly. This document includes process description and emission factors for a broad range of criteria pollutant emission sources.

ASOS: The Automated Surface Observing Systems (ASOS) program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). The ASOS system serves as the nation's primary surface weather observing network.

Background Concentration: Concentration already present and due to natural or human caused sources.

Calm: Cessation of horizontal wind.

Complex Terrain: Terrain exceeding the height of the stack being modeled.

Dalton's Law of Particles Pressures: Each gas in a gaseous mixture exerts pressure independently of the others. The partial pressure of each gas is proportional to its volume fraction in the mixture.

DEM: Digital Elevation Model. Digital files that contain terrain elevations typically at a consistent interval across a standard region of the Earth's surface.

Dispersion Model: A group of related mathematical algorithms used to estimate (model) the dispersion of pollutants in the atmosphere due to transport by the mean (average) wind and small-scale turbulence.

Diurnal: Daytime period.

Emission Factor: An estimate of the rate at which a pollutant is released to the atmosphere.

Episode: High increase in pollution levels caused by stagnation.

Flagpole Receptor: Any receptor located above ground level.

Fugitive Dust: Dust discharged to the atmosphere in a stream such as that from unpaved roads, storage piles and heavy construction operations.

GMT: Greenwich Mean Time, the time at the 0 ° meridian.

Graham's Law: The diffusion rate of the gas on another is inversely proportional to the square root of their densities.

$$\frac{Dg_1}{\sqrt{\rho g_2}} = \frac{Dg_2}{\sqrt{\rho g_1}}$$

Henry's Law: The weight of a gas dissolved in a liquid is proportional to the pressure that it exerts above the liquid.

$C_g = k_H * P_g$

Where,

C_g = Concentration of gas in liquid
k_H = Henry's Constant
P_g = Gas Pressure above the liquid

Henry's Constant: Constant that correlates the Pressure of gas, above the liquid, and its concentration on the liquid.

Inventory: A compilation of source, control device, emissions and other information relating to sources of a pollutant or group of pollutants.

Inversion: An increase in ambient air temperature with height. This is the opposite of the usual case.

IRIS: Integrated Risk Information System Database.

ISCST: Industrial Source Complex – Short Term Dispersion Model.

Lee side: The lee side of a building is the side that is sheltered from the wind.

Mixing Height: Top of the neutral or unstable layer and also the depth through which atmospheric pollutants are typically mixed by dispersive processes.

Monin-Obukhov Length: A constant, characteristic length scale for any particular example of flaw. It is negative in unstable conditions (upward heat flux), positive for stable conditions, and approach infinity as the actual lapse rate for ambient air reaches the dry adiabatic lapse rate.

NWS: National Weather Service. A U.S. government organization associated with the National Oceanic and Atmosphere Administration.

Pasquill Stability Categories: A classification of the dispersive capacity of the atmosphere, originally defined using surface wind speed, solar insolation (daytime) and cloudness (night time). They have since been reinterpreted using various other meteorological variables.

PCRAMMET: Meteorological program used for regulatory applications capable of processing twice-daily mixing heights (TD-9689 FORMAT) and hourly surface weather observations (CD-144 format) for use in dispersion models such as ISCST, CRSTER, MPTER and RAM.

Potential Temperature: Useful concept in determining stability in the atmosphere. It identifies the dry adiabatic to which a temperature and pressure is related.

If θ increases with height→stable→atmosphere
If θ decreases with height→unstable→atmosphere

$$\theta = T * (P/P_o)^{0.286}$$

Where

θ = The temperature a gas would have if it were compressed, or expanded, adiabatically from a given state (P,T) to a pressure of 1000mb.
T = temperature [degrees kelvin]
P_o = reference pressure = 1000 milli-bar
P = point pressure [milli-bar]

Preferred Model: A refined model that is recommended for a specific type of regulatory application.

Primary Pollutant: Substance emitted from the source.

Regulatory Model: A dispersion model that has been approved for use by the regulatory offices of the U.S. EPA, specifically one that included in Appendix A of the Guideline on Air Quality Models (Revised), such as the ISC model.

Screening Technique: A relatively simple analysis technique to determine if a given source is likely to pose a threat to air quality. Concentration estimates from screening techniques are conservative.

Simple Terrain: An area where terrain features are all lower in elevation than the top of the stack of the source.

Stagnation: A calm lasting more than 36 hours.

Upper Air Data (or soundings): Meteorological data obtained from balloon-borne instrumentation that provides information on pressure, temperature, humidity and wind away from the surface of the earth.

U.S. EPA: United States Environmental Protection Agency.

Vertical Potential Temperature Gradient: The change of potential temperature with height, used in modeling the plume rise through a stable layer, and indicates the strength of the stable temperature inversion. A positive value means that potential temperature increases with height above ground and indicates a stable atmosphere.

Wind Profile Component: The value of the exponent used to specify the profile of wind speed with height according to the power law.

Worst Case: The maximum exposure, dose, or risk that can conceivably happen to specific receptors.