AERMOD IMPLEMENTATION GUIDE

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PREFACE

This document provides information on the recommended use of AERMOD to address specific issues and concerns related to the implementation of AERMOD for regulatory applications. The following recommendations augment the use of experience and judgment in the proper application of dispersion models. Advanced coordination with reviewing authorities, including the development of modeling protocols, is recommended for regulatory applications of AERMOD.

ACKNOWLEDGMENTS

The AERMOD Implementation Guide has been developed through the collaborative efforts of EPA OAQPS, EPA Regional Office, State and local agency dispersion modelers, through the activities of the AERMOD Implementation Workgroup. The efforts of all contributors are gratefully acknowledged.

CONTENTS

1.0 WHAT'S NEW IN THIS DOCUMENT

Revisions dated January 9, 2008:

The following sections have been affected by this revision:

3.1 DETERMINING SURFACE CHARACTERISTICS

This section includes an expanded discussion and updated recommendations regarding the determination of surface characteristics to be used in processing meteorological data for AERMOD. A discussion of the AERSURFACE tool has also been included. The previous Section 3.1.1 has been removed, and recommendations regarding meteorological data selections for urban applications in the previous Sections 3.1.2 to 3.1.4 have been moved to Sections 3.3 and 5.4.

3.3 PROCESSING SITE-SPECIFIC METEOROLOGICAL DATA FOR URBAN APPLICATIONS

This new section contains clarified recommendations regarding processing of site-specific meteorological data for urban applications, formerly contained in Section 3.1.4.

4.1 MODELING SOURCES WITH TERRAIN-FOLLOWING PLUMES IN SLOPING TERRAIN

This section has been revised to address the issue of modeling terrain-following plumes in up- and down-sloping terrain more generically, since the issue is not strictly limited to gently down-sloping terrain.

5.4 METEOROLOGICAL DATA SELECTIONS FOR URBAN APPLICATIONS

This new section contains clarified recommendations regarding meteorological data selections for urban applications, formerly contained in Section 3.1.

2.0 DOCUMENT BACKGROUND AND PURPOSE

2.1 BACKGROUND (10/19/07)

In April 2005, the AERMOD Implementation Workgroup (AIWG) was formed in anticipation of AERMOD's promulgation as a replacement for the Industrial Source Complex (ISCST3) model. AERMOD fully replaced ISCST3 as the regulatory model on December 9, 2006 (EPA, 2005a), after a one-year grandfather period. The primary purpose for forming the AIWG was to develop a comprehensive approach for dealing with implementation issues for which guidance is needed. A result of this initial AIWG was the publication of the first version of the AERMOD Implementation Guide on September 27, 2005.

In 2007, a new AIWG was formed as a standing workgroup to provide support to EPA's Office of Air Quality Planning and Standards (OAQPS). This document represents the combined efforts of AIWG and OAQPS in relation to the implementation of the AERMOD regulatory model.

2.2 PURPOSE (10/19/07)

This document provides information on the recommended use of AERMOD to address a range of issues and types of applications. Topics are organized based on implementation issues, with additional information as appropriate on whether they impact the modules of the AERMOD modeling system (AERMOD, AERMET, and AERMAP) or related programs (AERSURFACE, AERSCREEN, and BPIPPRM). The document contains a section which highlights changes from the previous version. This is located in Section 1 of the document for use as a quick reference. Each section is also identified with the date (mm/dd/yy) that it was added or last updated. Only sections with substantive changes or new recommendations are identified with new revision dates. Revision dates are not updated for sections with only minor edits to clarify the wording or to correct typographical errors.

The recommendations contained within this document represent the current best use practices as determined by EPA, through the implementation of AIWG. The document is not intended as a replacement of, or even a supplement to the *Guideline on Air Quality Models* (EPA, 2005b). Rather, it is designed to provide consistent, technically sound recommendations to address specific issues and concerns relevant to the regulatory application of AERMOD. As always, advance coordination with the reviewing authorities on the application of AERMOD is advisable. Modeling protocols should be developed, and agreed upon by all parties, in advance of any modeling activity.

3.0 METEOROLOGICAL DATA AND PROCESSING

3.1 DETERMINING SURFACE CHARACTERISTICS (01/09/08)

When applying the AERMET meteorological processor (EPA, 2004a) to prepare the meteorological data for the AERMOD model (EPA, 2004b), the user must determine appropriate values for three surface characteristics: surface roughness length $\{z_o\}$, albedo $\{r\}$, and Bowen ratio $\{B_o\}$. 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. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux. This section provides recommendations regarding several issues associated with determining appropriate surface characteristics for AERMOD modeling applications.

3.1.1 Meteorological data representativeness considerations (01/09/08)

When using National Weather Service (NWS) data for AERMOD, data representativeness can be thought of in terms of constructing realistic planetary boundary layer (PBL) similarity profiles and adequately characterizing the dispersive capacity of the atmosphere. As such, the determination of representativeness should include a comparison of the surface characteristics (i.e., z_o, B_o and r) between the NWS measurement site and the source location, coupled with a determination of the importance of those differences relative to predicted concentrations. Site-specific meteorological data are assumed by definition to be representative of the application site; however, the determination of representativeness of site-specific data for AERMOD applications should also include an assessment of surface characteristics of the measurement and source locations and cannot be based solely on proximity. The recommendations presented in this section for determining surface characteristics for AERMET apply to both site-specific and non-site-specific (e.g. NWS) meteorological data.

The degree to which predicted pollutant concentrations are influenced by surface parameter differences between the application site and the meteorological measurement site depends on the nature of the application (i.e., release height, plume buoyancy, terrain influences, downwash considerations, design metric, etc.). For example, a difference in z_o for one application may translate into an unacceptable difference in the design concentration, while for another application the same difference in z_o may lead to an insignificant difference in design concentration. If the reviewing agency is uncertain as to the representativeness of a meteorological measurement site, a site-specific sensitivity analysis may be needed in order to quantify, in terms of expected changes in the design concentration, the significance of the differences in each of the surface characteristics.

If the proposed meteorological measurement site's surface characteristics are determined to NOT be representative of the application site, it may be possible that another nearby meteorological measurement site may be representative of both meteorological parameters and surface characteristics. Failing that, it is likely that site-specific meteorological data will be required.

3.1.2 Methods for determining surface characteristics (01/09/08)

Several sources of data may be utilized in determining appropriate surface characteristics for use in processing meteorological data for AERMOD. This may include printed topographic and land use, land cover (LULC) maps available from the U. S. Geological Survey (USGS), aerial photos from web-based services, site visits and/or site photographs, and digitized databases of land use and land cover data available from USGS. A sound understanding of the important physical processes represented in the AERMOD model algorithms and the sensitivity of those algorithms to surface characteristics is needed in order to properly interpret the available data and make an appropriate determination. The temporal representativeness of the source(s) of land cover data used relative to the meteorological data period to be processed should be considered as part of this assessment.

The availability of high resolution digitized land cover databases provides an opportunity to apply systematic procedures to determine surface characteristics based on an objective analysis of the gridded land cover data across a domain. A proper analysis of such data must take into consideration the relationship between surface characteristics and the meteorological measurements on which the surface characteristics will be applied. While the following discussion offers specific recommendations regarding the methods for determining surface characteristics from digitized land cover data, the general principles on which these recommendations are based are also applicable to determining surface characteristics from other sources of non-digitized land use and land cover data.

Based on model formulations and model sensitivities, the relationship between the surface roughness upwind of the measurement site and the measured wind speeds is generally the most important consideration. The effective surface roughness length should be based on an upwind distance that captures the net influence of surface roughness elements on the measured wind speeds needed to properly characterize the magnitude of mechanical turbulence in the approach flow. A number of studies have examined the response of the atmosphere to abrupt changes in the surface roughness, and provide some insight into the relationship between measured winds and surface roughness [e.g., Blom and Warenta (1969), Businger (1986), Högström and Högström (1978), Horst and Weil (1994), Irwin (1978), Rao, et al. (1974), and Taylor (1969)]. Such changes in surface roughness result in the development of an internal boundary layer (IBL) which grows with distance downwind of the roughness change, and defines the layer influenced by the transition in surface roughness. The size and structure of the IBL is very complex, even for idealized cases of uniform roughness upwind and downwind of the transition. The IBL is also affected by the magnitude and direction of the roughness change and the stability of the upstream flow. The IBL generally grows more slowly for stable conditions than for neutral or unstable approach flow, and will also tend to grow more slowly for rough-to-smooth transitions than for smooth-to-rough transitions. The relationship between surface roughness and measured wind speeds is even more complex in real world applications given the typically patchy nature of the heterogeneity of surface roughness elements.

The recommended upwind distance for surface roughness should take into account the fact that surface roughness effects in AERMOD are more important for stable atmospheric conditions than for neutral/unstable conditions, and that meteorological monitoring sites are typically characterized by open (low roughness) exposures in order to accommodate recommended siting criteria (EPA, 2000). For typical measurement programs, including NWS stations, the reference wind measurements will be taken for an anemometer height of approximately 10 meters above ground. An upwind distance based on the recommended siting criterion of at least 10 times the height of nearby obstacles (EPA, 2000), which would correspond to a distance of about 100m for typical obstacles such as trees and 2-3 story buildings, is considered inadequate for this purpose. However, the previous recommendation to use an upwind distance of 3 kilometers for surface roughness is considered too large because the boundary layer up to typical measurement heights of 10m will generally respond to changes in roughness length over much shorter distances. Including land cover information across an upwind distance that is too large could misrepresent the amount of mechanical turbulence present in the approach flow and bias model results, especially for low-level releases.

The recommended upwind distance for processing land cover data to determine the effective surface roughness for input to AERMET is 1 kilometer relative to the meteorological tower location. This recommended distance is considered a reasonable balance of the complex factors cited in the discussion above. If land cover varies significantly by direction, then surface roughness should be determined based on sector. However, the width of the sectors should be no smaller than a 30-degree arc. Further information on the definition of sectors for surface roughness is provided in the AERMET user's guide (EPA, 2004a). Exceptions to the recommended default distance of 1 kilometer for surface roughness may be considered on a case-by-case basis for applications involving site-specific wind speed measurements taken at heights well above 10m, in situations with significant discontinuities in land cover just beyond the recommended 1 kilometer upwind distance, or for sites with significant terrain discontinuities (e.g., the top of a mesa or a narrow, steep valley). Another factor that may need to be considered in some cases for determining an effective surface roughness length is the potential contribution of nearby terrain or other significant surface expression, not reflected in the land cover data, to the generation of mechanical turbulence. Use of a non-default distance for surface roughness estimation, or modification of surface roughness estimates to account for terrain/surface-expression effects, should be documented and justified in a modeling protocol submitted to the appropriate reviewing authority prior to conducting the modeling analysis.

The dependence of meteorological measurements and plume dispersion on Bowen ratio and albedo is very different than the dependence on surface roughness. Effective values for Bowen ratio and albedo are used to estimate the strength of convective turbulence during unstable conditions by determining how much of the incoming radiation is converted to sensible heat flux. These estimates of convective turbulence are not linked as directly with tower measurements as the linkage between the measured wind speed and the estimation of mechanical turbulence intensities driven by surface roughness elements. While local surface characteristics immediately upwind of the measurement site are very important for surface roughness, effective values of Bowen ratio and albedo determined over a larger domain are more appropriate.

The recommended approach for processing digitized land cover data to determine the effective Bowen ratio and albedo for input to AERMET is to average the surface characteristics across a representative domain without any direction or distance dependency. The recommended default domain is a 10km by 10km region centered on the measurement site. Use of the measurement location to define the domain is likely to be adequate for most applications. However, a domain representative of the application site may be more appropriate for some applications, particularly if the majority of sources are elevated releases. The use of an alternative domain for Bowen ratio and albedo should be documented and justified in a modeling protocol submitted to the appropriate reviewing authority prior to conducting the modeling analysis.

Beyond defining the appropriate domains to use for processing digitized land cover data, additional considerations are needed regarding the computational methods for processing of the data. Due to the fact that the width of a sector increases with distance from the measurement site, the land cover further from the site would receive a higher effective weight than land cover closest to the site if a direct area-weighted averaging approach were used to calculate an effective surface roughness. An inverse-distance weighting is recommended for determining surface roughness from digitized land cover data in order to adjust for this factor, since the length of an arc (across a sector) is proportional to the distance from the center. In addition, a geometric mean is recommended for calculating the effective surface roughness due to the fact that the AERMOD formulations are dependent on the $ln(z_o)$. Note that the arithmetic average of the $ln(z_o)$ is mathematically equivalent to the geometric mean of z_o. Since the Bowen ratio represents the ratio between sensible heat flux and latent heat flux, the use of a geometric mean is also recommended for calculating effective values of Bowen ratio. Geometric means are more appropriate for calculating "average" values of ratios; for example, the "average" for Bowen ratios of 0.5 and 2.0 should be 1.0, which is accomplished with the use of a geometric mean. A simple arithmetic average is recommended for calculating effective values of albedo.

These recommendations for determining surface characteristics supersede previous recommendations and should be followed unless case-by-case justification can be provided for an alternative method. The recommendations described above are briefly summarized below:

1. The determination of the **surface roughness length** should be based on an inverse-distance weighted geometric mean for a default upwind distance of 1 kilometer relative to the measurement site. Surface roughness length may be varied by sector to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.
2. The determination of the **Bowen ratio** should be based on a simple unweighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 10km by 10km region centered on the measurement site.
3. 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 10km by 10km region centered on the measurement site.

An important aspect of determining surface characteristics from digitized land cover data is the assignment of surface characteristic values for each of the parameters (surface roughness, Bowen ratio and albedo) to the land cover categories contained in the dataset. Several references are available to guide those assignments, including Sections 4.7.7 and 5.4 of the AERMET user's guide (EPA, 2004a), Garrett (1992), Gifford (1968), Oke (1978), Randerson (1984), and Stull (1988). Due to the somewhat subjective nature of this process, and the fact that specific land cover categories may include a wide range of values for some surface characteristics, the methods and assumptions used to assign surface characteristics based on land cover categories should be thoroughly documented and justified.

3.1.3 Use of AERSURFACE for determining surface characteristics (01/09/08)

EPA has developed a tool called AERSURFACE (EPA, 2008) that can be used as an aid in determining realistic and reproducible surface characteristic values, including albedo, Bowen ratio, and surface roughness length, for input to AERMET, the meteorological processor for AERMOD. The current version of AERSURFACE supports the use of land cover data from the USGS National Land Cover Data 1992 archives (NLCD92). The NLCD92 archive provides land cover data at a spatial resolution of 30 meters based on a 21-category classification scheme applied consistently over the continental U.S. AERSURFACE incorporates look-up tables of representative surface characteristic values by land cover category and seasonal category. Further details regarding application of the AERSURFACE tool are provided in the AERSURFACE User's Guide (EPA, 2008).

The AERSURFACE tool incorporates the recommended methods for determining surface characteristics from digitized land cover data described in Section 3.1.2. While the AERSURFACE tool is <u>not</u> currently considered to be part of the AERMOD regulatory modeling system, i.e. the use of AERSURFACE is not required for regulatory applications of AERMOD, the recommended methodology described in Section 3.1.2 should be followed unless case-by-case justification can be provided for an alternative method.

3.2 SELECTING UPPER AIR SOUNDING LEVELS (10/19/07)

The AERMET meteorological processor requires full upper air soundings (radiosonde data) representing the vertical potential temperature profile near sunrise in order to calculate convective mixing heights. For AERMOD applications within the U.S., the early morning sounding, nominally collected at 12Z (or UTC/GMT), is typically used for this purpose. Upper air soundings can be obtained from the Radiosonde Data of North America CDs for the period 1946 through 1997, which are available for purchase from the National Climatic Data Center (NCDC). Upper air soundings for the period 1994 to the present are also available for free download from the Radiosonde Database Access website (http://raob.fsl.noaa.gov/).

Both of these sources of upper air data offer the following three options for specifying which levels of upper air data to extract:

1) all levels,
2) mandatory and significant levels, or
3) mandatory levels only.

Options 1 and 2 are both acceptable and should provide equivalent results when processed through AERMET. The use of mandatory levels only, Option 3, will not provide an adequate characterization of the potential temperature profile, and is not acceptable for AERMOD modeling applications.

3.3 PROCESSING SITE-SPECIFIC METEOROLOGICAL DATA FOR URBAN APPLICATIONS (01/09/08)

The use of site-specific meteorological data obtained from an urban setting may require some special processing if the measurement site is located within the influence of the urban heat island and site-specific turbulence measurements are available (e.g., σ_θ and/or σ_w). As discussed in Section 5.4, the urban algorithms in AERMOD are designed to enhance the turbulence levels relative to the nearby rural setting during nighttime stable conditions to account for the urban heat island effect. Since the site-specific turbulence measurements will reflect the enhanced turbulence associated with the heat island, site-specific turbulence measurements should not be used when applying AERMOD's urban option, in order to avoid double counting the effects of enhanced turbulence due to the urban heat island.

As also discussed in Section 5.4, the AERMOD urban option (URBANOPT) should be selected for urban applications, regardless of whether the meteorological measurement site is located in an urban setting. This is due to the fact that the limited surface meteorological measurements available from the meteorological measurement program (even with measured turbulence) will not adequately account for the meteorological characteristics of the urban boundary layer included in the AERMOD urban algorithms.

4.0 TERRAIN DATA AND PROCESSING

4.1 MODELING SOURCES WITH TERRAIN-FOLLOWING PLUMES IN SLOPING TERRAIN (01/09/08)

Under the regulatory default mode (DFAULT option on the MODELOPT keyword), for all situations in which there is a difference in elevation between the source and receptor, AERMOD simulates the total concentration as the weighted sum of 2 plume states (Cimorelli, *et al.*, 2004): 1) a horizontal plume state (where the plume's elevation is assumed to be determined by release height and plume rise effects only, and thereby allowing for impingement if terrain rises to the elevation of the plume); and, 2) a terrain-responding plume state (where the plume is assumed to be entirely terrain following).

For cases in which receptor elevations are lower than the base elevation of the source (i.e., receptors that are down-slope of the source), AERMOD will predict concentrations that are less than what would be estimated from an otherwise identical flat terrain situation. While this is appropriate and realistic in most cases, for cases of down-sloping terrain where expert judgment suggests that the plume is terrain-following (e.g., down-slope gravity/drainage flow), AERMOD will tend to underestimate concentrations when terrain effects are taken into account. AERMOD may also tend to underestimate concentrations relative to flat terrain results for cases involving low-level, non-buoyant sources with up-sloping terrain since the horizontal plume component will pass below the receptor elevation. Sears (2003) has examined these situations for low-level area sources, and has shown that as terrain slope increases the ratio of estimated concentrations from AERMOD to ISC (which assumes flat terrain for area sources) decreases substantially.

To avoid underestimating concentrations in such situations, it may be reasonable in cases of terrain-following plumes in sloping terrain to apply the non-DFAULT option to assume flat, level terrain. This determination should be made on a case-by-case basis, relying on the modeler's experience and knowledge of the surrounding terrain and other factors that affect the air flow in the study area, characteristics of the plume (release height and buoyancy), and other factors that may contribute to a terrain-following plume, especially under worst-case meteorological conditions associated with the source. The decision to use the non-DFAULT option for flat terrain, and details regarding how it will be applied within the overall modeling analysis, should be documented and justified in a modeling protocol submitted to the appropriate reviewing authority prior to conducting the analysis.

4.2 AERMAP DEM ARRAY AND DOMAIN BOUNDARY (09/27/05)

Section 2.1.2 of the AERMAP User's Guide (EPA, 2004c) states that the DEM array and domain boundary must include all terrain features that exceed a 10% elevation slope from any given receptor. The 10% slope rule may lead to excessively large domains in areas with considerable terrain features (e.g., fjords, successive mountain ranges, etc). In these situations, the reviewing authority may make a case-by-case determination regarding the domain size needed for AERMAP to determine the critical dividing streamline height for each receptor.

4.3 MANUALLY ENTERING TERRAIN ELEVATIONS IN AERMAP (09/27/05)

AERMAP currently does not have the capability of accepting hand-entered terrain data (xyz data). AERMAP can accept terrain data from DEM files only. Therefore, if DEM data is not available, for a particular application, terrain elevations will need to be entered manually in a form that mimics the DEM data format. Instructions for how to accomplish this can be found on the SCRAM web site http://www.epa.gov/scram001/ in a document titled "On inputting XYZ data into AERMAP."

5.0 URBAN APPLICATIONS

5.1 URBAN/RURAL DETERMINATION (10/19/07)

The URBANOPT keyword on the CO pathway in AERMOD, coupled with the URBANSRC keyword on the SO pathway, should be used to identify sources to be modeled using the urban algorithms in AERMOD (EPA, 2004b). To account for the dispersive nature of the "convective-like" boundary layer that forms during nighttime conditions due to the urban heat island effect, AERMOD enhances the turbulence for urban nighttime conditions over that which is expected in the adjacent rural, stable boundary layer, and also defines an urban boundary layer height to account for limited mixing that may occur under these conditions. The magnitude of the urban heat island effect is driven by the urban-rural temperature difference that develops at night. AERMOD currently uses the population input on the URBANOPT keyword as a surrogate to define the magnitude of this differential heating effect. Details regarding the adjustments in AERMOD for the urban boundary layer are provided in Section 5. 8 of the AERMOD model formulation document (Cimorelli, *et al.*, 2004).

Section 7.2.3 of the *Guideline on Air Quality Models* (EPA, 2005b) provides the basis for determining the urban/rural status of a source. For most applications the Land Use Procedure described in Section 7.2.3(c) is sufficient for determining the urban/rural status. However, there may be sources located within an urban area, but located close enough to a body of water or to other non-urban land use categories to result in a predominately rural land use classification within 3 kilometers of the source following that procedure. Users are therefore cautioned against applying the Land Use Procedure on a source-by-source basis, but should also consider the potential for urban heat island influences across the full modeling domain. Furthermore, Section 7.2.3(f) of Appendix W recommends modeling <u>all</u> sources within an ***urban complex*** using the urban option even if some sources may be defined as rural based on the procedures outlined in Section 7.2.3. Such an approach is consistent with the fact that the urban heat island is not a localized effect, but is more regional in character.

Another aspect of the urban/rural determination that may require special consideration on a case-by-case basis relates to tall stacks located within or adjacent to small to moderate size urban areas. In such cases, the stack height, or effective plume height for very buoyant plumes, may extend above the urban boundary layer height. Application of the urban option in AERMOD for these types of sources may artificially limit the plume height. Therefore, use of the urban option may not be appropriate for these sources, since the actual plume is likely to be transported over the urban boundary layer. A proper determination of whether these sources should be modeled separately without the urban option will depend on a comparison of the stack height or effective plume height with the urban boundary layer height. The urban boundary layer height, z_{iuc}, can be calculated from the population input on the URBANOPT keyword, P, based on Equation 104 of the AERMOD formulation document (Cimorelli, *et al.*, 2004):

$$z_{iuc} = z_{iuo} \left(P/P_0\right)^{1/4} \qquad (1)$$

where z_{iu0} is the reference height of 400 meters corresponding to the reference population, P_0, of 2,000,000. Exclusion of these elevated sources from application of the urban option must be justified on a case-by-case basis in consultation with the appropriate reviewing authority.

5.2 SELECTING POPULATION DATA FOR AERMOD'S URBAN MODE (10/19/07)

For relatively isolated urban areas, the user may use published census data corresponding to the Metropolitan Statistical Area (MSA) for that location. For urban areas adjacent to or near other urban areas, or part of urban corridors, the user should attempt to identify that part of the urban area that will contribute to the urban heat island plume affecting the source(s). If this approach results in the identification of clearly defined MSAs, then census data may be used as above to determine the appropriate population for input to AERMOD. Use of population based on the Consolidated MSA (CMSA) for applications within urban corridors is not recommended, since this may tend to overstate the urban heat island effect.

For situations where MSAs cannot be clearly identified, the user may determine the extent of the area, including the source(s) of interest, where the population density exceeds 750 people per square kilometer. The combined population within this identified area may then be used for input to the AERMOD model. Users should avoid using a very fine spatial resolution of population density for this purpose as this could result in significant gaps within the urban area due to parks and other unpopulated areas, making it more difficult to define the extent of the urban area. Population densities by census tract should provide adequate resolution in most cases, and may still be finer resolution than desired in some cases. Since census tracts vary in size and shape, another acceptable approach would be to develop gridded estimates of population data based on census block or block group data. In such cases, a grid resolution on the order of 6 kilometers is suggested. Plotting population density with multiple "contour" levels, such as 0-500, 500-750, 750-1000, 1000-1500, etc., may also be beneficial in identifying which areas near the edge of the urban complex to include even though the population density may fall below the 750 threshold. The user should also bear in mind that the urban algorithms in AERMOD are dependent on population to the one-fourth power, and are therefore not highly sensitive to variations in population. Population estimates to two significant figures should be sufficiently accurate for application of AERMOD.

5.3 OPTIONAL URBAN ROUGHNESS LENGTH – URBANOPT KEYWORD (10/19/07)

The URBANOPT keyword on the CO pathway in AERMOD (EPA, 2004b) includes an optional parameter to specify the urban surface roughness length. The urban surface roughness parameter is used to define a reference height for purposes of adjusting dispersion for surface and low-level releases to account for the enhanced turbulence associated with the nighttime urban heat island. This optional urban roughness length is <u>not</u> used to adjust for differences in roughness length between the meteorological measurement site, used in processing the meteorological data, and the urban application site. Details regarding the adjustments in AERMOD for the urban boundary layer, including the use of the urban roughness length parameter, are provided in Section 5. 8 of the AERMOD model formulation document (Cimorelli, *et al.*, 2004).

The default value of 1 meter for urban surface roughness length, assumed if the parameter is omitted, is considered appropriate for most applications. Any application of AERMOD that utilizes a value other than 1 meter for the urban roughness length should be considered as a non-regulatory application, and would require appropriate documentation and justification as an alternative model, subject to Section 3.2 of the *Guideline on Air Quality Models* (EPA, 2005b). The use of a value other than 1 meter for the urban surface roughness length will be explicitly treated as a non-DFAULT option in the next update to the AERMOD model.

5.4 METEOROLOGICAL DATA SELECTIONS FOR URBAN APPLICATIONS (01/09/08)

5.4.1 Urban applications using NWS meteorological data (01/09/08)

When modeling urban sources, the urban algorithms in AERMOD are designed to enhance the turbulence levels relative to the nearby rural setting during nighttime stable conditions to account for the urban heat island effect (Cimorelli, *et al.*, 2004). For urban applications using representative NWS meteorological data the AERMOD urban option (URBANOPT) should be selected (EPA, 2004b), regardless of whether the NWS site is located in a nearby rural or an urban setting. This is due to the fact that the limited surface meteorological measurements available from NWS stations will not account for the enhanced turbulence or other meteorological characteristics of the urban boundary layer included in the AERMOD urban algorithms. The determination of surface characteristics for processing NWS meteorological data for urban applications should conform to the recommendations presented in Section 3.1.

5.4.2 Urban applications using site-specific meteorological data (01/09/08)

In most cases, site-specific meteorological data used for urban applications should be treated in a manner similar to NWS data described in Section 5.4.1, regardless of whether the measurement site is located in a nearby rural or an urban setting. That is, the AERMOD urban option should be selected and the surface characteristics should be determined based on the recommendations in Section 3.1. This is due to the fact that the limited surface meteorological measurements available from the meteorological measurement program will not adequately account for the meteorological characteristics of the urban boundary layer included in the AERMOD urban algorithms. However, if the measurement site is located in an urban setting and site-specific turbulence measurements are available (e.g., σ_θ or σ_w), some adjustments to the meteorological data input to AERMOD may be necessary, as discussed in Section 3.3.

6.0 SOURCE CHARACTERIZATION

6.1 CAPPED AND HORIZONTAL STACKS (09/27/05)

For capped and horizontal stacks that are NOT subject to building downwash influences a simple screening approach (Model Clearinghouse procedure for ISC) can be applied. This approach uses an effective stack diameter to maintain the flow rate, and hence the buoyancy, of the plume, while suppressing plume momentum by setting the exit velocity to 0.001 m/s. To appropriately account for stack-tip downwash, the user should first apply the non-default option of no stack-tip downwash (i.e., NOSTD keyword). Then, for capped stacks, the stack release height should be reduced by three actual stack diameters to account for the maximum stack-tip downwash adjustment while no adjustment to release height should be made for horizontal releases.

Capped and horizontal stacks that are subject to building downwash should not be modeled using an effective stack diameter to simulate the restriction to vertical flow since the PRIME algorithms use the stack diameter to define the initial plume radius which, in turn, is used to solve conservation laws. The user should input the actual stack diameter and exit temperature but set the exit velocity to a nominally low value, such as 0.001 m/s. This approach will have the desired effect of restricting the vertical flow while avoiding the mass conservation problem inherent with effective diameter approach. The approach suggested here is expected to provide a conservative estimate of impacts. Also, since PRIME does not explicitly consider stack-tip downwash, no adjustments to stack height should be made.

6.2 USE OF AREA SOURCE ALGORITHM IN AERMOD (09/27/05)

Because of issues related to excessive run times and technical issues with model formulation, the approach that AERMOD uses to address plume meander has not been implemented for area sources. As a result, concentration predictions for area sources may be overestimated under very light wind conditions (i.e., $u \ll 1.0$ m/s). In general, this is not expected to be a problem for meteorological data collected using standard wind instruments since instrument thresholds are generally too high. However, the problem could arise with meteorological data derived from very low threshold instruments, such as sonic anemometers. While not currently accepted for regulatory applications of AERMOD, this problem has also arisen when data from a gridded meteorological model was used to drive AERMOD. Meteorological grid models can at times produce extremely light winds. During such conditions time-averaged plumes tend to spread primarily as a result of low frequency eddy translation rather than eddy diffusion. AERMOD treats this meander effect by estimating the concentration from two limiting states: 1) a coherent plume state that considers lateral diffusive turbulence only (the mean wind direction is well defined) and 2) a random plume state (mean wind direction is poorly defined) that allows the plume to spread uniformly, about the source, in the x-y plane. The final concentration predicted by AERMOD is a weighted sum of these two bounding concentrations. Interpolation between the coherent and random plume concentrations is accomplished by assuming that the total horizontal "energy" is distributed between the wind's mean and turbulent components.

In order to avoid overestimates for area sources during light wind conditions, it is recommended that, where possible, a volume source approximation be used to model area sources. This approach can be applied with confidence for situations in which the receptors are displaced from the source. However, for applications where receptors are located either directly adjacent to, or inside the area source, AERMOD's area source algorithm will need to be used. For these circumstances, caution should be exercised if excessive concentrations are predicted during extremely light wind conditions. On a case-by-case basis, the reviewing authority should decide whether such predictions are unrealistic. One possible remedy would be to treat such hourly predictions as missing data.

It is EPA's intention to correct this problem. A version of AERMOD that includes meander for area sources will be developed as soon as practicable.

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