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Part II

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40 CFR Part 51

Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (Guideline on Air Quality Models); Proposed Rule

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 51

[AH–FRL–6536–3]

RIN 2060–AF01

Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (Guideline on Air Quality Models)

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: EPA's (*Guideline on Air Quality Models* (*Guideline*) addresses the regulatory application of air quality models for assessing criteria pollutants under the Clean Air Act. In today's action we propose to make several additions and changes to the Guideline. We recommend two new dispersion models, AERMOD and CALPUFF, for adoption in appendix A of the *Guideline.* AERMOD would replace the Industrial Source Complex (ISC3) model in many assessments that now use it; AERMOD also would apply to complex terrain. CALPUFF would become a recommended technique for assessing long-range transport of pollutants and their impacts on Federal Class I areas. We revise two existing models: ISC3, by incorporating a new downwash algorithm (PRIME) and renaming the model ISC–PRIME, and the Emissions Dispersion Modeling System (EDMS), by incorporating improved emissions and dispersion modules. We make various editorial changes to update and reorganize information, and remove obsolete models (CDM, RAM and UAM).

DATES: The period for comment on these proposed changes to the *Guideline* closes on July 20, 2000. We plan to hold a public hearing on the proposed changes in Summer 2000. The specific date and time will be announced in a separate document published in the **Federal Register**.

ADDRESSES: We have established an official record for this rulemaking under docket number A–99–05. You may submit comments pertinent to this proposal to docket no. A–99–05 at the following address: Air Docket (6102), Room M–1500, Waterside Mall, U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, DC. 20460. This docket is available for public inspection and copying between 8 a.m. and 5:30 p.m., Monday through Friday, at the address above. Please furnish duplicate comments to Tom Coulter, Air Quality Modeling Group (MD–14), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. You may send electronic versions of comments pertinent to this proposal to: A–AND–R–DOCKET@epamail.epa.gov. Alternatively, comments are acceptable in WordPerfect 6.1 (or higher), preferably zipped (*e.g.,* PKware) as an attachment to the e-mail message. You must include the docket identification (A–99–05) with all electronic submittals. You may file electronic comments on this proposal online at many Federal Depository Libraries.

The hearing will be the main agenda for the 7th Conference on Air Quality Modeling, and the location will be announced in a separate document published in the **Federal Register**.

FOR FURTHER INFORMATION CONTACT: Joseph A. Tikvart, Leader, Air Quality Modeling Group (MD–14), Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711; telephone (919) 541–5561 or C. Thomas Coulter, telephone (919) 541–0832.

SUPPLEMENTARY INFORMATION:

Background

The *Guideline* is used by EPA, States, and industry to prepare and review new source permits and State Implementation Plan revisions. The *Guideline* is intended to ensure consistent air quality analyses for activities regulated at 40 CFR 51.112, 51.117, 51.150, 51.160, 51.166, and 52.21. We originally published the *Guideline* in April 1978 and it was incorporated by reference in the regulations for the Prevention of Significant Deterioration (PSD) of Air Quality in June 1978. We revised the *Guideline* in 1986, and updated it with supplement A in 1987, supplement B in July 1993, and supplement C in August 1995. We published the *Guideline* as appendix W to 40 CFR part 51 when we issued supplement B. We republished the *Guideline* in August 1996 (61 FR 41838) to adopt the CFR system for labeling paragraphs.

Air Quality Modeling Conference

We held the Sixth Conference on Air Quality Modeling (6th conference) in Washington, DC on August 9–10, 1995. As required by Section 320 of the Clean Air Act, these conferences take place approximately every three years to standardize modeling procedures. The sixth conference featured presentations in several key modeling areas. One presentation, by the Interagency Workgroup on Air Quality Modeling (IWAQM [1]), covered long range transport modeling. Another presentation, by the American Meteorological Society (AMS)/EPA Regulatory Model Improvement Committee (AERMIC), covered developing an enhanced Gaussian dispersion model with boundary layer parameterization: AERMOD [2]. Also at the 6th conference, the Electric Power Research Institute (EPRI) presented recent research efforts to better define and characterize dispersion around buildings (downwash effects). These efforts were part of a program called the Plume RIse Model Enhancements (PRIME), and PRIME is proposed for integration within ISC3 (ISC–PRIME).

The presentations were followed by a critical review/discussion of the CALPUFF and AERMOD modeling systems, facilitated jointly by the Air & Waste Management Association's AB–3 Committee and the American Meteorological Society's Committee of Meteorological Aspects of Air Pollution. For the new and revised models described, we asked the public to address the following questions:

- What is the scientific merit of the models presented?
- What is their accuracy?
- What should be the regulatory use of individual models for specific applications?
- What implementation issues are apparent and what additional guidance is needed?
- What are the resource requirements of modeling systems presented?
- What additional information or analyses are needed?

We placed a transcript of the 6th conference proceedings and a copy of all written comments in Docket AQM–95–01. Answers to the above questions are reflected in the comments, which we reviewed and summarized (II–G–01). To the extent possible, we believe we have addressed the main concerns in the refinements proposed today, which focus on the two new modeling systems, as well as the enhancement of ISC3 with EPRI's PRIME downwash model (ISC–PRIME).

AERMOD

AERMOD is a state-of-the-practice Gaussian plume dispersion model whose formulation is based on planetary boundary layer principles. At the 6th conference, AERMIC members presented interim developmental and

[1] IWAQM was formed in 1991 to provide a focus for development of technically sound air quality models for regulatory assessments of long range transport of pollutant source impacts on federal Class I areas. IWAQM is an interagency collaboration that includes efforts by EPA, U.S. Forest Service, National Park Service, and Fish and Wildlife Service.

[2] AMS/EPA Regulatory MODel

evaluation results of AERMOD. AERMOD provides better characterization of plume dispersion than does the ISC3. Comprehensive comments were submitted on the AERMOD code and formulation document and on the AERMET draft User's Guide (AERMET is the meteorological preprocessor for AERMOD). The comments on the AERMET User's Guide were detailed and generally editorial in nature. Comments on AERMOD identified inconsistencies in the AERMOD code as well as among variables and recommended specific default values.

Commenters expressed concern that data bases historically used by EPA lack the variables required by AERMET and AERMOD. The deficiencies were thought to obstruct or weaken AERMOD's evaluation. We disagree that the data bases used for the AERMOD evaluations (Kincaid, Lovett, Martins Creek, Tracy, etc.) were not of the type used historically by EPA and furthermore believe that they contain the critical variables needed by AERMOD. One comment described a perceived ''persistence of modeling procedures [by EPA] rather than an evolution to other techniques.'' This tendency, the commenter believes, has been influenced by testing candidate techniques with the deficient data bases mentioned earlier. According to the commenter, this leaves the new candidate technique no way to show its possible superiority over existing techniques. The commenter argued for a change in this pattern. We disagree with this criticism in that we believe AERMOD has been adequately tested and represents, through its formulations, a technical advancement over its predecessors.

CALPUFF

CALPUFF is a Lagrangian dispersion model that simulates pollutant releases as a continuous series of *puffs.* IWAQM carefully studied the potential regulatory application of CALPUFF in its Phase 1 report.[3] At the 6th conference, IWAQM recommended that EPA consider CALPUFF as a preferred technique for long-range air pollution transport assessments (for example, for federal Class I areas). In its Phase 2 report,[4] IWAQM has, to the extent possible, attempted to resolve the concern and criticism over applying the CALPUFF modeling system.

On the whole, comments appeared to support IWAQM's efforts to simplify and clarify the modeling methods for addressing long-range transport and dispersion. The comments endorsed IWAQM's recommendation to employ one model for all sources and distances. The comments also endorsed IWAQM's recommendation of an approach whereby a group of stakeholders is established that, through consensus, defines the modeling methods, inventories, data bases, and significance criteria to be applied in assessing impacts for a given Class I area. This activity would precede an actual regulatory assessment.

Comments suggested that the Level 1 screen described in IWAQM's Phase I interim recommendations was not working well and needed improvement. IWAQM has attempted to do this by developing a screening procedure that uses CALPUFF with ISC-type meteorological input data, and has shown the results to be conservative for the case(s) tested (see footnote 4).[5] However, the screening approach may not give conservative concentration estimates in all cases (see below).

Comments suggested that more comparisons with tracer studies were needed for transport distances of 50–200km. IWAQM sponsored four such evaluations.

Commenters also sought clearer guidance on the limits of such modeling assessments, such as cases with intervening terrain between the sources and receptors of interest. IWAQM has attempted to make the modeling community(see footnote 4) aware that conducting a long-range transport assessment requires competent individuals, expert judgement, and strong interaction and coordination with the applicable reviewing authorities.

Comments suggested that comparisons were needed to assess whether CALPUFF can provide results similar to ISC3 and CTDMPLUS for steady-state meteorological conditions. We supported this work and examined CALPUFF for equivalency to ISC3,[6] both in a steady-state mode as well as non-steady-state (that is, when meteorological conditions varied hourly). For steady state conditions, CALPUFF mimicked ISC3 to a substantial degree. In non-steady state conditions, occurrences of calms and recirculations resulted in higher source impacts with CALPUFF than for ISC3 for most comparisons made.

ISC–PRIME

The development of PRIME by EPRI featured four key components: a field effort, laboratory modeling of fluids, developing model codes, and independently evaluating models.[7] The field measurements were made at a combustion turbine site in New Jersey in February and March 1994. Wind tunnel experiments have been done at EPA's Fluid Modeling Facility and at a facility at Monash University in Australia. PRIME is modular, it explicitly takes into account stack location and all three building dimensions, and attempts to model the shape of the ellipsoid cavity and the flow of the streamline descents over the top of the cavity. Plume rise calculations are enhanced to treat plumes that are not neutrally buoyant and have no vertical velocity. Unfortunately, at the time of the 6th modeling conference, evaluation work was incomplete and the PRIME code was unavailable for beta testing.

Comments received at the 6th modeling conference commended EPRI's development of PRIME as ''a significant improvement over the existing ISC algorithm'' and one that could ''provide accurate estimates for idealized building geometries.'' Based on comments, potential problems were anticipated for proper treatment of the myriad combinations of building geometry, wind approach angle, upwind roughnesses, stabilities, etc. Commenters questioned whether all these effects could be parameterized into a robust algorithm to accurately treat downwash at actual sites. Another strong concern was the extent to which the algorithm would work under stable stratification, which is difficult to simulate in a wind tunnel. One commenter even suggested the application of a simpler approach, *i.e.*, the original work by Huber and Snyder who employed a ''building downwash amplification factor'', as careful parameterization of this factor might

[3] Environmental Protection Agency, 1993. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase I report: Interim Recommendation for Modeling Long range Transport and Impacts on Regional Visibility; EPA Publication No. EPA–454/R–93–015.

[4] Environmental Protection Agency, 1998. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport Impacts. EPA Publication No. EPA–454/R–98–019.

[5] Environmental Protection Agency, 1998. Analyses of the CALMET/CALPUFF Modeling System in a Screening Mode. EPA Publication No. EPA–454/R–98–010. Office of Air Quality Planning & Standards, Research Triangle Park, NC.

[6] Environmental Protection Agency, 1998. A Comparison of CALPUFF with ISC3. EPA Publication No. EPA–454/R–98–020. Office of Air Quality Planning & Standards, Reserch Triangle Park, NC.

[7] Schulman, L.L., D.G. Strimaitis, and J.S. Scire, 1999. Development and Evaluation of the PRIME Plume Rise and Building Downwash Model. 34pp. + 10 figures (submitted to Journal of the Air & Waste Management Association) (A–99–05, II–A–13).

lead to acceptable accuracy with other benefits. The commenter also suggested that an integral plume rise model had been shown to yield good agreement with field and wind tunnel observations for treating plume trajectories. In terms of PRIME's evaluation, the commenter suggested using, as a basis for comparison, a version of ISC3 that excluded the Schulman-Scire downwash algorithm.

Since the 6th modeling conference, EPRI released a beta test version of PRIME, which was installed within ISC3 (hence, ISC–PRIME). Beta testing of ISC–PRIME shows significantly improved performance in comparison to ISC3.[8] To the extent possible, EPRI has attempted to address the comments on the PRIME algorithm and its documentation. A consequence analysis for using ISC–PRIME (versus ISC3) has also been prepared.[9]

Proposed Action

AERMOD

We propose revising section 4 of the *Guideline* to replace ISC3 by AERMOD as a state-of-the-practice technique for many air quality impact assessments. Applications for which AERMOD is suited are stated in subsequent sections of the *Guideline* and include assessment of plume impacts from traditional stationary sources in simple, intermediate, and complex terrain. In fact, since differentiation of simple versus complex terrain is unnecessary with AERMOD, we merged pertinent guidance in section 5 (Model Use in Complex Terrain) with that in section 4. You will find developmental, evaluation and peer scientific review references for AERMOD cited as appropriate. A model formulation document,[10] as well as a key evaluation reference for the AERMOD modeling system,[11] have been placed in the docket. We added a summary description of AERMOD to appendix A [12] of the *Guideline*, where you are directed to note additional evaluation references and a series of user's manuals. The essential codes, preprocessors, and test cases have been uploaded to our website (www.epa.gov/scram001; see 7th Conference).

We invite your comment on whether we have reasonably addressed technical concerns and are on sound footing to recommend AERMOD for its intended applications. AERMOD lacks a general (all-terrain) screening tool, so we invite your comment on the practicality of using SCREEN3 as an interim tool for AERMOD and ISC–PRIME screening in simple terrain.

CALPUFF

In its Phase 2 recommendations, IWAQM recommended the CALPUFF modeling system for refined use in modeling long-range transport and dispersion to characterize reasonably attributable impacts from one or a few sources for PSD Class I impacts. We endorse its recommendation and are proposing CALPUFF for addition to appendix A of the *Guideline.* We have imposed conforming revisions to section 6 to recommend CALPUFF for regulatory applications involving long-range transport and have suggested a possible screening approach. We also propose CALPUFF for use for all downwind distances for those applications involving complex wind regimes, with case-by-case justification. Studies that support the above recommendations are summarized in IWAQM's Phase II Report (*op. cit.*).

The essential codes, utilities, preprocessors and test cases have been uploaded to the developers' Internet website (www.src.com/calpuff/calpuff1.htm). The documentation for CALMET and CALPUFF have been properly cited in the *Guideline* and are available from the aforementioned website. A peer review has also been cited and has been placed in the docket.

We solicit your comments on our proposal to recommend CALPUFF for its intended applications.

ISC–PRIME

We have proposed the use of ISC–PRIME [13] in section 4 of the *Guideline,* where we emphasize that if you are interested in treating aerodynamic downwash or dry deposition, ISC–PRIME is the recommended model. We have proposed editorial revisions in sections 5–7 of the *Guideline* to make it clear when use of ISC–PRIME is appropriate instead of AERMOD.

The formulation and evaluation of the PRIME algorithm are described in open literature (*op. cit.*) The essential codes, utilities, and test cases have been uploaded to our website (www.epa.gov/scram001; see 7th Conference). We invite your comment on whether we are on sound footing to recommend use of ISC–PRIME as proposed.

We intend to consider AERMOD, ISC–PRIME, and CALPUFF as our recommended techniques for their intended applications (as specified in the *Guideline*) starting one year after we issue the final rule, and that the models be used in their regulatory default modes. The models *may* be used in the interim (*i.e.*, as soon as we issue the final rule). We invite your comment on the reasonableness of the timing of this implementation schedule.

We are aware that, where downwash is of concern, some potential users of AERMOD and ISC–PRIME might find joint application of the two models burdensome. We invite comment on this matter and seek input on alternative approaches that ensure that the latest science is used (as included in both AERMOD and PRIME) for regulatory modeling applications. One alternative considered by AERMIC is the direct inclusion of the PRIME algorithm in AERMOD. This effort, including testing, performance evaluation for the PRIME data bases, and peer scientific review, could take up to 12 months.

Proposed Editorial Changes

Editorial changes are described by affected sections. For a more detailed showing of before/after effects, you are referred to a redline/strikeout version (WordPerfect format) of appendix W that has been posted on our website (www.epa.gov/scram001; see 7th Conference).

Preface

You will note some minor revisions to reflect current EPA practice.

Section 2

In a streamlining effort, we removed section 2.2 and added a new section 2.3 to address model availability.

Section 3

We revised section 3 to more accurately reflect current EPA practice, *e.g.*, functions of the Model

[8] Paine, R.J. and F. Lew, 1997. Results of the Independent Evaluation of ISCST3 and ISC–PRIME. Prepared for the Electric Power Research Institute, Palo Alto, CA. ENSR Document Number 2460–026–440. (NTIS No. PB 98–156524)

[9] Paine, R.J. and F. Lew, 1997. Consequence Analysis for ISC–PRIME. Prepared for the Electric Power Research Institute, Palo Alto, CA. ENSR Document Number 2460–026–450. (NTIS No. PB 98–156516)

[10] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee and W.D. Peters, 1998. AERMOD: Description of Model Formulation. (12/15/98 Draft Document) Prepared for Environmental Protection Agency, Research Triangle Park, NC. 113pp. (Docket No. A–99–05; II–A–1)

[11] Paine, R.J., R.F. Lee, R.W. Brode, R.B. Wilson, A.J. Cimorelli, S.G., Perry, J.C. Weil, A. Venkatram and W.D. Peters, 1998: Model Evaluation Results for AERMOD (12/17/98 Draft). Prepared for Environmental Protection Agency, Research Triangle Park, NC. (Docket No. A–99–05, II–A–5)

[12] Appendix A of appendix W is a repository for preferred, refined air quality models recommended for regulatory applications.

[13] Schulman, L.L., D.G. Strimaitis, and J.S. Scire, 1997. Addendum to ISC3 User's Guide, *The PRIME Plume Rise and Building Downwash Model.* Prepared for the Electric Power Research Institute, Palo Alto, CA., Earth Tech Document A287. A–99–05, II–A–12)

Clearinghouse and enhanced criteria for the use of alternative models.

Section 4

As mentioned earlier, we revised section 4 to present AERMOD, ISC-PRIME, and CALPUFF as regulatory modeling techniques for particular applications. We revised section 4.2.2 to reflect the widespread use of short-term models for all averaging periods. Hence, we no longer reference long-term models (*e.g.,* ISCLT) in the *Guideline.*[14]

Section 5

As mentioned above, we merged pertinent guidance in section 5 (Modeling in Complex Terrain) with that in section 4. With the anticipated widespread use of AERMOD for all terrain types, there is no longer any utility in the previous differentiation between simple and complex terrain for model selection. To further simplify, the list of acceptable, yet equivalent, screening techniques for complex terrain was removed. CTSCREEN and guidance for its use are retained; CTSCREEN remains acceptable for all terrain above stack top. The screening techniques whose descriptions we removed, *i.e.,* Valley (as implemented in SCREEN3), COMPLEX I (as implemented in ISC3), and RTDM remain available for use in applicable cases where established/accepted procedures are used. Consultation with the appropriate Regional Office is still advised for application of these screening models.

Section 6

We revised section 6 (renumbered to section 5) to reflect the new PM–2.5 and ozone ambient air quality standards that were issued on July 18, 1997 (62 FR 38652 & 62 FR 38856). Footnotes have been inserted to provide caveats pertaining to the recent Court decision to remand or vacate parts of these new standards. You will note that we inserted respective subsections for particulate matter and lead from section 7, so that section 5 now primarily contains modeling guidance for the criteria pollutants regulated in Part 51 (SO_2 analyses are covered in section 4).

• We enhanced the subsection on particulate matter as much as possible to reflect the Agency's current thinking on approaches for fine particulates (PM–2.5). You will note that we removed the references to the Climatological Dispersion Model (CDM 2.0) as well as to RAM from this section, and also deleted CDM and RAM from appendix A (see below).

• We enhanced the subsection on ozone to better reflect modeling approaches we currently envision, and added a reference for current guidance on ozone attainment demonstrations.[15] You will note that we removed the reference to the Urban Airshed Model (UAM–IV) from this section, and deleted UAM from appendix A. UAM–IV is no longer the recommended photochemical model for attainment demonstrations for ozone. We believe that it will frequently be necessary to consider the regional scale for such demonstrations and that, since the last revision to appendix W, newer models have become available. We invite comment on the need to integrate ozone and fine particle impacts (*i.e.,* the ''one atmosphere'' approach). Are modeling tools and air program policies sufficiently developed to provide guidance on an integrated approach at this time? We also invite comments on whether specific validated tools have been sufficiently developed to calculate impacts of individual point sources of ozone and PM–2.5 precursor pollutants. Are there any models that can be recommended for source-specific ozone and PM–2.5 assessments?

• We updated the subsection on carbon monoxide by removing reference to RAM. While UAM–IV is deleted from appendix A, reference to areawide analyses is retained. For refined intersection modeling, CAL3QHCR is specifically mentioned for use on a case-by-case basis.

• In the subsection on NO_2 models, we added a third tier for the screening approach that allows the use of the ozone limiting method on a case-by-case basis. You may recall that this approach was removed with the *Guideline* update promulgated on August 9, 1995 (60 FR 40465).

• In the subsection on lead, we deleted references to 40 CFR 51.83, 51.84, and 51.85, conforming to previous EPA action (51 FR 40661).

Section 7

For regional scale modeling, we removed reference to the Regional Oxidant Model (ROM) and the Regional Acid Deposition Model (RADM) from section 7 because they are outdated and replaced by a reference to Models-3[16] in section 5. We enhanced the subsection on visibility to reflect the provisions of the Clean Air Act, including those for reasonable attribution of visibility impairment and regional haze, as well as the new NAAQS for PM–2.5. For assessment of reasonably attributable haze impairment due to one or a small group of sources, CALPUFF is available for use on a case-by-case basis. We identify REMSAD and new approaches under the Models-3 umbrella for possible use to develop and evaluate national policy and assist State and local control agencies. For long range transport analyses, we present and recommend the CALPUFF modeling system. To facilitate use of a complex air quality and meteorological modeling system like CALPUFF, we stipulate that a written protocol may be considered for developing consensus in the methods and procedures to be followed. Finally, in the subsection on air pathway analyses, we identify the availability of AERMOD and removed specific reference to DEGADIS (other heavy gas models are also available on a case-by-case basis).

Section 8

We revised section 8 (renumbered to section 7) to better reflect our current regulatory practice for the general modeling considerations addressed.

• In subsection 7.2.4, we introduce the atmospheric stability characterization for AERMOD.

• In subsection 7.2.5, we describe the plume rise approaches used by AERMOD and ISC–PRIME.

• We revised subsection 7.2.6 to refer back to subsection 5.2.3 for details on chemical transformation of NO_X.

• We merged subsection 7.2.8 (Urban/Rural Classification) with subsection 7.2.3 (Dispersion Coefficients).

• We merged discussions in subsections 7.2.9 (Fumigation) and 7.2.10 (Stagnation) into one new subsection (Complex Winds), and identify the availability of CALPUFF for certain situations on a case-by-case basis.

• We removed the distinction between short-term and long-term

[14] Note that because Appendix W is designed to guide assessments for criteria pollutants, the proposed discontinuation of ISCLT for purposes herein does not preclude its use for other pollutant assessments, as applicable. For example, the ASPEN model (Assessment System for Population Exposure Nationwide) uses the capabilities of ISCLT to estimate ambient concentrations of toxic pollutants nationwide by census tract. Such applications require the abbreviated computing possible with ISCLT.

[15] Environmental Protection Agency, 1998. Use of Models and Other Analyses in Attainment Demonstrations for the 8-hr Ozone NAAQS (Draft). Office of Air Quality Planning & Standards, Research Triangle Park, NC. (Docket No. A–99–05, II–A–14) (Also available on SCRAM website, www.epa.gov/scram001, as draft8hr.pdf)

[16] Environmental Protection Agency, 1998. EPA Third-Generation Air Quality Modeling System. Models-3, Volume 9b: User Manual. EPA Publication No. EPA–600/R–98/069(b). Office of Research and Development, Washington, D.C.

models because when assessing the impacts from criteria air pollutants, long-term estimates are now practicable using hour-by-hour meteorological data.

Section 9

We renumbered section 9 as section 8 and made the following changes:

• We revised subsection 8.2.3 (recommendations for estimating background concentrations from nearby sources) to reflect a settlement reached on October 16, 1997 in a petition brought by the Utility Air Regulatory Group (UARG). This petition, *Appalachian Power Company et al.* v. *EPA* (D.C. Circuit), No. 93–1631, was filed on November 3, 1993. The plaintiffs challenged the modeling assumptions required for existing point sources and new (or modified) existing point source compliance demonstrations as set forth in tables 9–1 and 9–2 of the *Guideline.* In accordance with the settlement, we are clarifying the definition of ''nearby sources.'' The ''maximum allowable emission limit,'' specified in Tables 8–1 and 8–1 (formerly 9–1 and 9–2), is tied in certain circumstances [17] to the emission rate representative of a nearby source's maximum physical capacity to emit. We are also clarifying that nearby sources should be modeled only when they operate at the same time as the primary source(s) being modeled. Where a nearby source does not, by its nature, operate at the same time as the primary source being modeled, the burden is on the primary source to demonstrate to the satisfaction of the reviewing authority that this is, in fact, the case. We added footnotes to tables 8–1 and 8–2 to refer back to applicable paragraphs of subsection 8.2.3 that provide the necessary clarification.

• We enhanced section 8.3 (Meteorological Input Data) to develop concepts of meteorological data representativeness, minimum meteorological data requirements, and the use of prognostic mesoscale meteorological models in certain situations. These models (*e.g.,* the Penn State/NCAR MM4 [18, 19, 20] or MM5 [21] model) assimilate meteorological data from several surface and upper air stations in or near a domain and generate a 3-dimensional field of wind, temperature and relative humidity profiles. We revised recommendations for length of record for meteorological data (subsection 8.3.1.2) for long-range transport and complex wind situations.

• We revised subsection 8.3.2 (National Weather Service Data) to inform users that National Weather Service (NWS) surface and upper air meteorological data are available on CD–ROM from the National Climatic Data Center. Recent years of such surface data are derived from the NWS's Automated Surface Observing System (ASOS). We invite you to comment on the usefulness of ASOS meteorological data for air quality modeling. More specifically, we invite comment on whether the policy of modeling with the most recent 5 years of NWS meteorological data (section 8.3.1.2) should include ASOS data. We also invite comment on whether the period of record must be the most recent 5 years—regardless of whether it contains ASOS data. Similarly, should the policy to model with the most recent full year of meteorological data (*i.e.,* section 10.2.3.4) include ASOS data?

• We revised subsection 8.3.3.1 to clarify that, while site-specific measurements are frequently made ''on-property '' (*i.e.,* on the source's premises), acquisition of adequately representative site-specific data does not preclude collecting data from a location off property. Conversely, collection of meteorological data on property does not of itself guarantee adequate representativeness. The subsection was also enhanced by improving the discussion of collection of temperature difference measurements; a paragraph was developed that focuses on measurement of aloft winds for simulation of plume rise, dispersion and transport (some details for AERMOD and CTDMPLUS were moved to their respective appendix A descriptions); a paragraph was added to address collection and use of direct turbulence measurements; and the paragraph that discusses meteorological data preprocessor has been enhanced.

• We revised subsection 8.3.3.2 by removing reference to the STAR processing routine because ISCLT and CDM 2.0 (for which STAR formatted data were developed) have been removed.

• We revised subsection 8.3.4 (Treatment of Calms) to increase accuracy and to include information pertaining to AERMOD.

Section 10

We revised section 10 (renumbered section 9) to include AERMOD, ISC–PRIME, and CALPUFF.

Section 11

We propose minor revisions for section 11 (renumbered section 10) to reflect the new ambient air quality standards for fine particles and ozone. Because EPA has retreated from its emissions trading (''bubble'') policy for SO_2, we have deleted subsection 11.2.3.4.

Section 12 & 13

We redesignated section 13 (Bibliography) as section 11 and retained section 12 (References). We revised them by adding some references, deleting obsolete/superseded ones, and resequencing. You will note that peer scientific reviews for AERMOD, CALPUFF and ISC–PRIME have been included.

Section 14

In a streamlining effort, we removed section 14 (Glossary). Given current familiarity with modeling terminology, we no longer consider that maintenance of such a glossary is as necessary as it once may have been. For these and other reasons relating to Office of Federal Register policy (see discussion of appendix B below), we intend to revise the glossary and place it on EPA's Internet SCRAM website.

We invite your comment on any of the changes proposed above (Proposed editorial changes) for appendix W text, including the merging of sections 4 and 5.

Appendix A

We updated the introduction to appendix A (section A.0). As mentioned before, we added AERMOD and CALPUFF to appendix A, and modified the ISC3 description (now, ISC–PRIME) to include the EPRI downwash

[17] See section 8.2.3. of the *Guideline.*

[18] Stauffer, D.R. and Seaman, N.L., 1990. Use of four-dimensional data assimilation in a limited-area mesoscale model. Part I: Experiments with synoptic-scal data. *Monthly Weather Review,* 118:1250–1277.

[19] Stauffer, D.R., Seaman, N.L., and Binkowski, F.S., 1991. Use of four-dimensional data assimilation in a limited-area mesoscale model. Part II: Effect of data assimilation within the planetary boundary layer. *Monthly Weather Review,* 119: 734–754.

[20] Hourly Modeled Sounding Data. MM4—1990 Meteorological Data, 12-volume CD–ROM. Jointly produced by NOAA's National Climatic Data Center and Atmospheric Sciences Modeling Division. August 1995. Can be ordered from NOAA National Data Center's Internet website @ WWW.NNDC.NOAA.GOV/.

[21] www.mmm.ucar.edu/mm5/mm5-home.html

algorithm. We propose removing the Climatological Dispersion Model (CDM 2.0), the Gaussian-Plume Multiple Source Air Quality Algorithm (RAM), and the Urban Airshed Model (UAM) from appendix A. These models have been superseded and are no longer considered preferred techniques.

In the mid-1980s, the Federal Aviation Administration (FAA) developed the Emissions and Dispersion Modeling System (EDMS) to assess the air quality of proposed airport development projects by. In response to the growing needs of the air quality analysis community and changes in regulations (*e.g.,* conformity requirements from the Clean Air Act Amendment of 1990), FAA updated EDMS to version 3.1. Accordingly, we included a revised summary description for EDMS in appendix A. The emissions module of EDMS 3.1 includes input and methodology enhancements. The dispersion module of EDMS 3.1 also has improved and has been refined to incorporate code from two EPA dispersion models: PAL2 and CALINE3. The dispersion module also has been revised to allow the user greater flexibility in specifying inputs such as dispersion settings and coefficients, hourly operational profiles for aircraft queues, and meteorological data. EDMS 3.1 features provide greater resolution in defining emissions and dispersion concentrations, and have the potential to increase or decrease the results, depending on the individual scenario. EDMS has never been subjected to performance evaluation, and no studies of its performance have been cited. We invite comment on whether this compromises its viability as a recommended/preferred model for assessing airport impacts on air quality. We also invite suggestions as to how this deficiency can be addressed.

Appendix B: To Be Moved to Website (www.epa.gov/scram001)

Appendix B of the *Guideline* has been a repository for over 20 alternate models to be used with case-by-case justification. These models have not necessarily been the subject of any performance evaluation, and their inclusion in appendix B does not mean the Agency sanctions their use. They are listed for convenience, and have been used in few regulatory applications. Production and maintenance of the appendix B information currently in CFR text presents a real burden to EPA. Accordingly, we propose to move the appendix B repository of alternate model summary descriptions to our Internet SCRAM website (www.epa.gov/scram001). Placement of this material on the website offers many advantages. In this format, we will be able to maintain the list and model descriptions more easily and inexpensively. We could, for example, routinely make revisions on a nominally annual basis, whereas the current system imposes a nominally 3-year cycle for such revisions. Model developers could list their own website address for users to obtain more information. We invite your comments on the proposed movement of the list of alternative model descriptions to our website.

Several model developers have submitted new dispersion models for inclusion in this website repository of alternate models:

- Second-Order Closure Integrated Puff Model (SCIPUFF);
- Open Burn/Open Detonation Dispersion Model (OBODM);
- Atmospheric Dispersion Modeling System (ADMS); and
- Comprehensive Air Quality Model with extensions (CAMx).

As described below, codes for these models, as well as applicable documentation, have been uploaded to our Internet SCRAM website for your review. We have included summary descriptions in docket no. A–99–05 for your review and comment. Finally, we propose deleting a model currently listed in appendix B, MESOPUFF II, which CALPUFF replaces.

Appendix C

We also propose removing appendix C (Example Air Quality Analysis Checklist) from the CFR. We believe this checklist is outdated, in need of revision, and would be more practical to maintain if posted on EPA's Internet SCRAM website (as is our intention for appendix B).

Availability of Related Information

Our Air Quality Modeling Group maintains an Internet website (Support Center for Regulatory Air Models—SCRAM) at: www.epa.gov/scram001. You may find codes and documentation for models proposed for adoption in today's action on the SCRAM website. In addition, we have uploaded various support documents (*e.g.,* evaluation reports) that are now available for review.

Administrative Requirements

A. Executive Order 12866

Under Executive Order 12866 [58 FR 51735 (October 4, 1993)], the Agency must determine whether the regulatory action is "significant" and therefore subject to review by the Office of Management and Budget (OMB) and the requirements of the Executive Order. The Order defines "significant regulatory action" as one that is likely to result in a rule that may:

(1) Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities;

(2) Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;

(3) Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs of the rights and obligations of recipients thereof; or

(4) Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Order.

This rule is not a "significant regulatory action" under the terms of Executive Order 12866 and is therefore not subject to OMB review.

B. Paperwork Reduction Act

This proposed rule does not contain any information collection requirements subject to review by OMB under the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.*

C. Regulatory Flexibility Act (RFA), as Amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), 5 U.S.C. 601 et seq.

The RFA generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For purposes of assessing the impacts of today's rule on small entities, small entity is defined as: (1) A small business that meets the RFA default definitions for small business (based on Small Business Administration size standards), as described in 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

We do not anticipate that today's proposal will have any impacts on small entities, because existing and new sources of air emissions that model air quality for State Implementation Plans and the prevention of significant deterioration are typically not small entities. The modeling techniques described today are primarily used by state air control agencies and by industry.

To the extent that any small entities would ever have to model air quality using the modeling techniques described in today's proposal, the impacts of using updated modeling techniques would be minimal, if not non-existent. The action proposed today incorporates comments received at the 6th Conference on Air Quality Modeling in August 1995 in Washington, D.C. The proposal features several new modeling systems and serves to increase efficiency and accuracy. These systems employ procedural concepts that are very similar to those currently used, changing only mathematical formulations and specific data elements. Any impact on small entities would mainly be ascribed to the proposed use of AERMOD, which will replace ISC3. Computer run times for AERMOD may be longer than those for ISC3, owing to AERMOD's increased sophistication so that more time may be involved in preparing input data using AERMOD's preprocessors (AERMET and AERMAP) relative to an ISC3 run. However, this is more than compensated by AERMOD's capability to treat simple and complex terrain problems in one model, which actually affords a timesaving advantage. Moreover, we designed AERMOD's output formats to mimic those of ISC3, thus easing interpretation of results. Therefore, we do not believe that AERMOD's use poses a significant or unreasonable burden on any small entities. The proposed action imposes no new regulatory burdens and, as such, there will be no additional impact on small entities regarding reporting, recordkeeping, compliance requirements.

After considering the economic impacts of today's proposed rule on small entities, I certify that this action will not have a significant economic impact on a substantial number of small entities.

D. Executive Order 13132 (Federalism)

Executive Order 13132, entitled ''Federalism '' (64 FR 43255, August 10, 1999), requires EPA to develop an accountable process to ensure ''meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications.'' ''Policies that have federalism implications'' is defined in the Executive Order to include regulations that have ''substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government.''

Under Section 6 of Executive Order 13132, EPA may not issue a regulation that has federalism implications, that imposes substantial direct compliance costs, and that is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by State and local governments, or EPA consults with State and local officials early in the process of developing the proposed regulation. EPA also may not issue a regulation that has federalism implications and that preempts State law, unless the Agency consults with State and local officials early in the process of developing the proposed regulation.

This proposed rule does not have federalism implications. It will not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government, as specified in Executive Order 13132. This rule does not create a mandate on State, local or tribal governments. The rule does not impose any enforceable duties on these entities. The proposal would add better, more accurate techniques for air dispersion modeling analyses and does not impose any additional requirements for any of the affected parties covered under Executive Order 13132. Thus, the requirements of section 6 of the Executive Order do not apply to this rule.

E. Executive Order 13084: Consultation and Coordination With Indian Tribal Governments

Under Executive Order 13084, EPA may not issue a regulation that is not required by statute, that significantly or uniquely affects the communities of Indian tribal governments, and that imposes substantial direct compliance costs on those communities, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by the tribal governments, or EPA consults with those governments. If EPA complies by consulting, Executive Order 13084 requires EPA to provide to the Office of Management and Budget, in a separately identified section of the preamble to the rule, a description of the extent of EPA's prior consultation with representatives of affected tribal governments, a summary of the nature of their concerns, and a statement supporting the need to issue the regulation. In addition, Executive Order 13084 requires EPA to develop an effective process permitting elected officials and other representatives of Indian tribal governments ''to provide meaningful and timely input in the development of regulatory policies on matters that significantly or uniquely affect their communities.''

Today's proposed rule does not significantly or uniquely affect the communities of Indian tribal governments. As stated above with respect to Executive Order 12875, the proposal does not impose any additional requirements for the regulated community, including Indian Tribal Governments. Accordingly, the requirements of section 3(b) of Executive Order 13084 do not apply to this rule.

F. Executive Order 13045: Protection of Children From Environmental Health Risks and Safety Risks

Executive Order 13045 applies to any rule that EPA determines (1) to be ''economically significant '' as defined under Executive Order 12866, and (2) the environmental health or safety risk addressed by the rule has a disproportionate effect on children. If the regulatory action meets both the criteria, the Agency must evaluate the environmental health or safety effects of the planned rule on children; and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the Agency.

This proposed rule is not subject to Executive Order 13045, entitled ''Protection of Children from Environmental Health Risks and Safety Risks '' (62 FR 19885, April 23, 1997) because it does not an economically significant regulatory action as defined by Executive Order 12866 and the action does not involve decisions on environmental health or safety risks that may disproportionately affect children.

G. Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), Public Law 104–4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and tribal governments and the private sector. Under section 202 of the UMRA, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with ''Federal mandates'' that may result in expenditures to State, local, and tribal governments, in the aggregate, or to the private sector, of $100 million or more in any one year. Before promulgating an EPA rule for which a written statement is needed, section 205 of the UMRA generally requires EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows EPA to adopt an alternative other than the least costly, most cost-effective or least burdensome alternative if the Administrator publishes with the final rule an explanation why that alternative was not adopted. Before EPA establishes any regulatory requirements that may significantly or uniquely affect small governments, including tribal governments, it must have developed under section 203 of the UMRA a small government agency plan.

The plan must provide for notifying potentially affected small governments, enabling officials of affected small governments to have meaningful and timely input in the development of EPA regulatory proposals with significant Federal intergovernmental mandates, and informing, educating, and advising small governments on compliance with the regulatory requirements.

Today's rule contains no Federal mandates (under the regulatory provisions of Title II of the UMRA) for State, local, or tribal governments or the private sector.

List of Subjects in 40 CFR Part 51

Environmental protection, Administrative practice and procedure, Air pollution control, Carbon monoxide, Intergovernmental relations, Nitrogen oxides, Ozone, Particulate matter, Reporting and recordkeeping requirements, Sulfur oxides.

Dated: February 8, 2000.

Carol M. Browner,

Administrator.

Part 51, chapter I, title 40 of the Code of Federal Regulations is proposed to be amended as follows:

PART 51—REQUIREMENTS FOR PREPARATION, ADOPTION, AND SUBMITTAL OF IMPLEMENTATION PLANS

1. The authority citation for part 51 continues to read as follows:

Authority: 42 U.S.C. 7410, 7414, 7421, 7470–7479, 7491, 7492, 7601, and 7602.

2. Appendix W to Part 51 is revised to read as follows:

Appendix W to Part 51—Guideline on Air Quality Models

Preface

a. Industry and control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes. In the 1977 Clean Air Act, Congress mandated such consistency and encouraged the standardization of model applications. The Guideline on Air Quality Models (hereafter, Guideline) was first published in April 1978 to satisfy these requirements by specifying models and providing guidance for their use. The Guideline provides a common basis for estimating the air quality concentrations of criteria pollutants used in assessing control strategies and developing emission limits.

b. The continuing development of new air quality models in response to regulatory requirements and the expanded requirements for models to cover even more complex problems have emphasized the need for periodic review and update of guidance on these techniques. Three primary on-going activities provide direct input to revisions of the Guideline. The first is a series of annual EPA workshops conducted for the purpose of ensuring consistency and providing clarification in the application of models. The second activity is the solicitation and review of new models from the technical and user community. In the March 27, 1980 **Federal Register**, a procedure was outlined for the submittal to EPA of privately developed models. After extensive evaluation and scientific review, these models, as well as those made available by EPA, are considered for recognition in the Guideline. The third activity is the extensive on-going research efforts by EPA and others in air quality and meteorological modeling.

c. Based primarily on these three activities, new sections and topics are included as needed. EPA does not make changes to the guidance on a predetermined schedule, but rather on an as needed basis. EPA believes that revisions of the Guideline should be timely and responsive to user needs and should involve public participation to the greatest possible extent. All future changes to the guidance will be proposed and finalized in the **Federal Register**. Information on the current status of modeling guidance can always be obtained from EPA's Regional Offices.

Table of Contents

Appendix A to Appendix W of Part 51—Summaries of Preferred Air Quality Models

List of Tables

Table No. and *Title*

1.0 Introduction

a. The Guideline recommends air quality modeling techniques that should be applied to State Implementation Plan (SIP) revisions for existing sources and to new source reviews, including prevention of significant deterioration (PSD).[1, 2, 3] Applicable only to criteria air pollutants, it is intended for use by EPA Regional Offices in judging the adequacy of modeling analyses performed by EPA, State and local agencies and by industry. The guidance is appropriate for use by other Federal agencies and by State agencies with air quality and land management responsibilities. The Guideline serves to identify, for all interested parties, those techniques and data bases EPA considers acceptable. The Guideline is not intended to be a compendium of modeling techniques. Rather, it should serve as a common measure of acceptable technical analysis when supported by sound scientific judgement.

b. Due to limitations in the spatial and temporal coverage of air quality measurements, monitoring data normally are not sufficient as the sole basis for demonstrating the adequacy of emission limits for existing sources. Also, the impacts of new sources that do not yet exist can only be determined through modeling. Thus, models, while uniquely filling one program need, have become a primary analytical tool in most air quality assessments. Air quality measurements can be used in a complementary manner to dispersion models, with due regard for the strengths and weaknesses of both analysis techniques. Measurements are particularly useful in assessing the accuracy of model estimates. The use of air quality measurements alone however could be preferable, as detailed in a later section of this document, when models are found to be unacceptable and monitoring data with sufficient spatial and temporal coverage are available.

c. It would be advantageous to categorize the various regulatory programs and to apply a designated model to each proposed source needing analysis under a given program. However, the diversity of the nation's topography and climate, and variations in source configurations and operating characteristics dictate against a strict modeling ''cookbook.'' There is no one model capable of properly addressing all conceivable situations even within a broad category such as point sources. Meteorological phenomena associated with threats to air quality standards are rarely amenable to a single mathematical treatment; thus, case-by-case analysis and judgement are frequently required. As modeling efforts become more complex, it is increasingly important that they be directed by highly competent individuals with a broad range of experience and knowledge in air quality meteorology. Further, they should be coordinated closely with specialists in emissions characteristics, air monitoring and data processing. The judgement of experienced meteorologists and analysts is essential.

d. The model that most accurately estimates concentrations in the area of interest is always sought. However, it is clear from the needs expressed by the States and EPA Regional Offices, by many industries and trade associations, and also by the deliberations of Congress, that consistency in the selection and application of models and data bases should also be sought, even in case-by-case analyses. Consistency ensures that air quality control agencies and the general public have a common basis for estimating pollutant concentrations, assessing control strategies and specifying emission limits. Such consistency is not, however, promoted at the expense of model and data base accuracy. The Guideline provides a consistent basis for selection of the most accurate models and data bases for use in air quality assessments.

e. Recommendations are made in the Guideline concerning air quality models, data bases, requirements for concentration estimates, the use of measured data in lieu of model estimates, and model evaluation procedures. Models are identified for some specific applications. The guidance provided here should be followed in air quality analyses relative to State Implementation Plans and in supporting analyses required by EPA, State and local agency air programs. EPA may approve the use of another technique that can be demonstrated to be more appropriate than those recommended in this guide. This is discussed at greater length in Section 3.0. In all cases, the model applied to a given situation should be the one that provides the most accurate representation of atmospheric transport, dispersion, and chemical transformations in the area of interest. However, to ensure consistency, deviations from this guide should be carefully documented and fully supported.

f. From time to time situations arise requiring clarification of the intent of the guidance on a specific topic. Periodic workshops are held with the headquarters, Regional Office, State, and local agency modeling representatives to ensure consistency in modeling guidance and to promote the use of more accurate air quality models and data bases. The workshops serve to provide further explanations of Guideline requirements to the Regional Offices and workshop reports are issued with this clarifying information. In addition, findings from on-going research programs, new model submittals, or results from model evaluations and applications are continuously evaluated. Based on this information changes in the guidance may be indicated.

g. All changes to the Guideline must follow rulemaking requirements since the Guideline is codified in Appendix W of Part 51. EPA will promulgate proposed and final rules in the **Federal Register** to amend this Appendix. Ample opportunity for public comment will be provided for each proposed change and public hearings scheduled if requested.

h. A wide range of topics on modeling and data bases are discussed in the Guideline. Chapter 2 gives an overview of models and their appropriate use. Chapter 3 provides specific guidance on the use of ''preferred'' air quality models and on the selection of alternative techniques. Chapters 4 through 6 provide recommendations on modeling techniques for application to simple-terrain stationary source problems, complex terrain problems, and mobile source problems. Specific modeling requirements for selected regulatory issues are also addressed. Chapter 7 discusses issues common to many modeling analyses, including acceptable model components. Chapter 8 makes recommendations for data inputs to models including source, meteorological and background air quality data. Chapter 9 covers the uncertainty in model estimates and how that information can be useful to the regulatory decision-maker. The last chapter summarizes how estimates and measurements of air quality are used in assessing source impact and in evaluating control strategies.

i. Appendix W to 40 CFR Part 51 itself contains an appendix: Appendix A. Thus, when reference is made to ''Appendix A'' in this document, it refers to Appendix A to Appendix W to 40 CFR Part 51. Appendix A contains summaries of refined air quality models that are ''preferred'' for specific applications; both EPA models and models developed by others are included.

2.0 Overview of Model Use

a. Before attempting to implement the guidance contained in this document, the reader should be aware of certain general information concerning air quality models and their use. Such information is provided in this section.

2.1 Suitability of Models

a. The extent to which a specific air quality model is suitable for the evaluation of source impact depends upon several factors. These include: (1) The meteorological and topographic complexities of the area; (2) the level of detail and accuracy needed for the analysis; (3) the technical competence of those undertaking such simulation modeling; (4) the resources available; and (5) the detail and accuracy of the data base, *i.e.*, emissions inventory, meteorological data, and air quality data. Appropriate data should be available before any attempt is made to apply a model. A model that requires detailed, precise, input data should not be used when such data are unavailable. However, assuming the data are adequate, the greater the detail with which a model considers the spatial and temporal variations in emissions and meteorological conditions, the greater the ability to evaluate the source impact and to distinguish the effects of various control strategies.

b. Air quality models have been applied with the most accuracy, or the least degree of uncertainty, to simulations of long term averages in areas with relatively simple topography. Areas subject to major topographic influences experience meteorological complexities that are extremely difficult to simulate. Although models are available for such circumstances, they are frequently site specific and resource intensive. In the absence of a model capable of simulating such complexities, only a preliminary approximation may be feasible until such time as better models and data bases become available.

c. Models are highly specialized tools. Competent and experienced personnel are an essential prerequisite to the successful application of simulation models. The need for specialists is critical when the more sophisticated models are used or the area being investigated has complicated meteorological or topographic features. A model applied improperly, or with inappropriate data, can lead to serious misjudgements regarding the source impact or the effectiveness of a control strategy.

d. The resource demands generated by use of air quality models vary widely depending on the specific application. The resources required depend on the nature of the model and its complexity, the detail of the data base, the difficulty of the application, and the amount and level of expertise required. The costs of manpower and computational facilities may also be important factors in the selection and use of a model for a specific analysis. However, it should be recognized that under some sets of physical circumstances and accuracy requirements, no present model may be appropriate. Thus, consideration of these factors should lead to selection of an appropriate model.

2.2 Levels of Sophistication of Models

a. There are two levels of sophistication of models. The first level consists of relatively simple estimation techniques that generally use preset, worst-case meteorological conditions to provide conservative estimates of the air quality impact of a specific source, or source category. These are called screening techniques or screening models. The purpose of such techniques is to eliminate the need of more detailed modeling for those sources that clearly will not cause or contribute to ambient concentrations in excess of either the National Ambient Air Quality Standards (NAAQS)[4] or the allowable prevention of significant deterioration (PSD) concentration increments.[2 3] If a screening technique indicates that the concentration contributed by the source exceeds the PSD increment or the increment remaining to just meet the NAAQS, then the second level of more sophisticated models should be applied.

b. The second level consists of those analytical techniques that provide more detailed treatment of physical and chemical atmospheric processes, require more detailed and precise input data, and provide more specialized concentration estimates. As a result they provide a more refined and, at least theoretically, a more accurate estimate of source impact and the effectiveness of control strategies. These are referred to as refined models.

c. The use of screening techniques followed, as appropriate, by a more refined analysis is always desirable, however there are situations where the screening techniques are practically and technically the only viable option for estimating source impact. In such cases, an attempt should be made to acquire or improve the necessary data bases and to develop appropriate analytical techniques.

2.3 Availability of Models

a. For most of the screening and refined models discussed in the Guideline, codes, associated documentation and other useful information are available for download from EPA's Support Center for Regulatory Air Modeling (SCRAM) Internet website at *www.epa.gov/scram001.* A list of alternate models that can be used with case-by-case justification (Section 3.2), a glossary of terms, and an example air quality analysis checklist are also posted on this website. This is a site with which modelers should become familiar.

3.0 Recommended Air Quality Models

a. This section recommends refined modeling techniques that are preferred for use in regulatory air quality programs. The status of models developed by EPA, as well as those submitted to EPA for review and possible inclusion in this guidance, is discussed. The section also addresses the selection of models for individual cases and provides recommendations for situations where the preferred models are not applicable. Two additional sources of modeling guidance are the Model Clearinghouse[5] and periodic Regional/State/Local Modelers workshops.

b. In all regulatory analyses, especially if other than preferred models are selected for use, early discussions among Regional Office staff, State and local control agencies, industry representatives, and where appropriate, the Federal Land Manager, are invaluable and are encouraged. Agreement on the data base(s) to be used, modeling techniques to be applied and the overall technical approach, prior to the actual analyses, helps avoid misunderstandings concerning the final results and may reduce the later need for additional analyses. The use of an air quality analysis checklist, such as is posted on EPA's Internet SCRAM website (Section 2.3), and the preparation of a written protocol help to keep misunderstandings at a minimum.

c. It should not be construed that the preferred models identified here are to be permanently used to the exclusion of all others or that they are the only models available for relating emissions to air quality. The model that most accurately estimates concentrations in the area of interest is always sought. However, designation of specific models is needed to promote consistency in model selection and application.

d. The 1980 solicitation of new or different models from the technical community[6] and the program whereby these models were evaluated, established a means by which new models are identified, reviewed and made available in the Guideline. There is a pressing need for the development of models for a wide range of regulatory applications. Refined models that more realistically simulate the physical and chemical process in the atmosphere and that more reliably estimate pollutant concentrations are needed. Thus, the solicitation of models is considered to be continuous.

3.1 Preferred Modeling Techniques

3.1.1 Discussion

a. EPA has developed models suitable for regulatory application. Other models have been submitted by private developers for possible inclusion in the Guideline. These refined models have undergone evaluation exercises[7 8 9 10 11 12 13 14 15 16] that include statistical measures of model performance in comparison with measured air quality data as suggested by the American Meteorological Society[17] and, where possible, peer scientific reviews.[18 19 20 21 22 23 24]

b. When a single model is found to perform better than others, it is recommended for application as a preferred model and listed in Appendix A. If no one model is found to clearly perform better through the evaluation exercise, then the preferred model listed in Appendix A is selected on the basis of other factors such as past use, public familiarity, cost or resource requirements, and availability. No further evaluation of a preferred model is required for a particular application if the EPA recommendations for regulatory use specified for the model in the Guideline are followed. Alternative models to those listed in Appendix A should generally be compared with measured air quality data when they are used for regulatory applications consistent with recommendations in Section 3.2.

c. The solicitation of new refined models which are based on sounder scientific principles and which more reliably estimate pollutant concentrations is considered by EPA to be continuous. Models that are submitted in accordance with the established provisions will be evaluated as submitted. These requirements are:

i. The model must be computerized and functioning in a common computer code suitable for use on a variety of computer systems.

ii. The model must be documented in a user's guide which identifies the mathematics of the model, data requirements and program operating characteristics at a level of detail comparable to that available for currently recommended models.

iii. The model must be accompanied by a complete test data set including input parameters and output results. The test data must be included in the user's guide as well as provided in computer-readable form.

iv. The model must be useful to typical users, e.g., State air pollution control agencies, for specific air quality control problems. Such users should be able to operate the computer program(s) from available documentation.

v. The model documentation must include a comparison with air quality data (and/or tracer measurements) or with other well-established analytical techniques.

vi. The developer must be willing to make the model available to users at reasonable cost or make it available for public access through the Internet or National Technical Information Service: The model cannot be proprietary.

d. The evaluation process will include a determination of technical merit, in accordance with the above six items including the practicality of the model for use in ongoing regulatory programs. Each model will also be subjected to a performance evaluation for an appropriate data base and to a peer scientific review. Models for wide use (not just an isolated case) That are found to perform better will be proposed for inclusion as preferred models in future Guideline revisions.

3.1.2 Recommendations

a. Appendix A identifies refined models that are preferred for use in regulatory applications. If a model is required for a particular application, the user should select a model from that appendix. These models may be used without a formal demonstration of applicability as long as they are used as indicated in each model summary of Appendix A. Further recommendations for the application of these models to specific source problems are found in subsequent sections of the Guideline.

b. If changes are made to a preferred model without affecting the concentration estimates, the preferred status of the model is unchanged. Examples of modifications that do not affect concentrations are those made to enable use of a different computer or those that affect only the format or averaging time of the model results. However, when any changes are made, the Regional Administrator should require a test case example to demonstrate that the concentration estimates are not affected.

c. A preferred model should be operated with the options listed in Appendix A as ''Recommendations for Regulatory Use.'' If other options are exercised, the model is no longer ''preferred.'' Any other modification to a preferred model that would result in a change in the concentration estimates likewise alters its status as a preferred model. Use of the model must then be justified on a case-by-case basis.

3.2 Use of Alternative Models

3.2.1 Discussion

a. Selection of the best techniques for each individual air quality analysis is always encouraged, but the selection should be done in a consistent manner. A simple listing of models in this guide cannot alone achieve that consistency nor can it necessarily provide the best model for all possible situations. EPA reports [25 26] are available to assist in developing a consistent approach when justifying the use of other than the preferred modeling techniques recommended in the Guideline. Reference [27] contains advanced statistical techniques for determining which model performs better than other competing models. In many cases, this protocol should be considered preferentially to the material in Chapter 3 of reference 25. The procedures in these documents provide a general framework for objective decision-making on the acceptability of an alternative model for a given regulatory application. The documents contain procedures for conducting both the technical evaluation of the model and the field test or performance evaluation.

b. This section discusses the use of alternate modeling techniques and defines three situations when alternative models may be used.

3.2.2 Recommendations

a. Determination of acceptability of a model is a Regional Office responsibility. Where the Regional Administrator finds that an alternative model is more appropriate than a preferred model, that model may be used subject to the recommendations below. This finding will normally result from a determination that (1) a preferred air quality model is not appropriate for the particular application; or (2) a more appropriate model or analytical procedure is available and applicable.

b. An alternative model should be evaluated from both a theoretical and a performance perspective before it is selected for use. There are three separate conditions under which such a model may normally be approved for use: (1) if a demonstration can be made that the model produces concentration estimates equivalent to the estimates obtained using a preferred model; (2) if a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model in Appendix A; or (3) if the preferred model is less appropriate for the specific application, or there is no preferred model. Any one of these three separate conditions may make use of an alternative model acceptable. Some known alternative models that are applicable for selected situations are listed on EPA's SCRAM Internet website (Section 2.3). However, inclusion there does not confer any unique status relative to other alternative models that are being or will be developed in the future.

c. Equivalency, condition (1) in paragraph 3.2.2b, is established by demonstrating that the maximum or highest, second highest concentrations are within 2 percent of the estimates obtained from the preferred model. The option to show equivalency is intended as a simple demonstration of acceptability for an alternative model that is so nearly identical (or contains options that can make it identical) to a preferred model that it can be treated for practical purposes as the preferred model. Two percent was selected as the basis for equivalency since it is a rough approximation of the fraction that PSD Class I increments are of the NAAQS for SO_2, *i.e.*, the difference in concentrations that is judged to be significant. However, notwithstanding this demonstration, models that are not equivalent may be used when one of the two other conditions identified below are satisfied.

d. For condition (2) in paragraph 3.2.2 b, the procedures and techniques for determining the acceptability of a model for an individual case based on superior performance are contained in references 25–27 and should be followed, as appropriate. Preparation and implementation of an evaluation protocol which is acceptable to both control agencies and regulated industry is an important element in such an evaluation.

e. Finally, for condition (3) in paragraph 3.2.2b, an alternative refined model may be used provided that:

i. The model has received a scientific peer review;

ii. The model can be demonstrated to be applicable to the problem on a theoretical basis;

iii. The data bases which are necessary to perform the analysis are available and adequate;

iv. Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates; and

v. A protocol on methods and procedures to be followed has been established.

3.3 Availability of Supplementary Modeling Guidance

a. The Regional Administrator has the authority to select models that are appropriate for use in a given situation. However, there is a need for assistance and guidance in the selection process so that fairness and consistency in modeling decisions is fostered among the various Regional Offices and the States. To satisfy that need, EPA established the Model Clearinghouse [5] and also holds periodic workshops with headquarters, Regional Office, State, and local agency modeling representatives.

b. The Regional Office should always be consulted for information and guidance concerning modeling methods and interpretations of modeling guidance, and to ensure that the air quality model user has available the latest most up-to-date policy and procedures. As appropriate, the Regional Office may request assistance from the Model Clearinghouse after an initial evaluation and decision has been reached concerning the application of a model, analytical technique or data base in a particular regulatory action.

4.0 Traditional Stationary Source Models

4.1 Discussion

a. Guidance in this section applies to modeling analyses for which the predominant meteorological conditions that control the design concentration are steady state and for which the transport distances are nominally 50km or less. The models recommended in this section are generally used in the air quality impact analysis of stationary sources for most criteria pollutants. The averaging time of the concentration estimates produced by these models ranges from 1 hour to an annual average.

b. Simple terrain, as used here, is considered to be an area where terrain features are all lower in elevation than the top of the stack of the source(s) in question. Complex terrain is defined as terrain exceeding the height of the stack being modeled.

c. In the early 1980s, model evaluation exercises were conducted to determine the ''best, most appropriate point source model'' for use in simple terrain.[8 18] No one model was found to be clearly superior, and, based on past use, public familiarity, and availability, ISC (predecessor to ISC3 [28]) became the recommended model for a wide range of regulatory applications. Other refined models which also employed the basic Gaussian kernel, i.e., BLP, CALINE3, OCD, and EDMS, were developed for specialized applications (Appendix A).

d. Encouraged by the development of pragmatic methods for better characterization of plume dispersion [29 30 31 32], the AMS/EPA Regulatory Model Improvement Committee (AERMIC) developed AERMOD [33]. AERMOD employs state-of-practice parameterizations for characterizing the meteorological influences and dispersion. The model utilizes a probability density function (pdf) and the superposition of several Gaussian plumes to characterize the distinctly non-Gaussian nature of the vertical pollutant distribution for elevated plumes during convective conditions; otherwise the distribution is Gaussian. Also, nighttime urban boundary layers (and plumes within them) have the turbulence enhanced by AERMOD to simulate the influence of the urban heat island. AERMOD has been evaluated using a variety of data sets and has been found to perform better than ISC3 for many applications, and as well or better than CTDMPLUS for several complex terrain data sets (Section A.1; subsection n). Currently, AERMOD does not contain algorithms for dry deposition.

e. A new building downwash algorithm was developed and tested within the ISC3 construct, ISC–PRIME,[24] which is in Appendix A. ISC–PRIME has been evaluated using a variety of data sets and has been found to perform better than ISC3 (Section A.7; subsection n). ISC–PRIME retains the dry deposition inherent in ISC3.

4.2 Recommendations

4.2.1 Screening Techniques

4.2.1.1 Simple Terrain

a. Where a preliminary or conservative estimate is desired, point source screening techniques are an acceptable approach to air quality analyses. EPA has published guidance for screening procedures,[34] and a computerized version of the recommended screening technique, SCREEN, is available.[35]

b. All screening procedures should be adjusted to the site and problem at hand. Close attention should be paid to whether the area should be classified urban or rural in accordance with Section 7.2.3. The climatology of the area should be studied to help define the worst-case meteorological conditions. Agreement should be reached between the model user and the reviewing authority on the choice of the screening model for each analysis, and on the input data as well as the ultimate use of the results.

4.2.1.2 Complex Terrain

a. CTSCREEN [36] can be used to obtain conservative, yet realistic, worst-case estimates for receptors located on terrain above stack height. CTSCREEN accounts for the three-dimensional nature of plume and terrain interaction and requires detailed terrain data representative of the modeling domain. The model description and user's instructions are contained in the user's guide.[36] The terrain data must be digitized in the same manner as for CTDMPLUS and a terrain processor is available.[37] A discussion of the model's performance characteristics is provided in a technical paper.[38] CTSCREEN is designed to execute a fixed matrix of meteorological values for wind speed (u), standard deviation of horizontal and vertical wind speeds (σ_v, σ_w), vertical potential temperature gradient ($d\theta/dz$), friction velocity (u_*), Monin-Obukhov length (L), mixing height (z_i) as a function of terrain height, and wind directions for both neutral/stable conditions and unstable convective conditions. Table 4–1 contains the matrix of meteorological variables that is used for each CTSCREEN analysis. There are 96 combinations, including exceptions, for each wind direction for the neutral/stable case, and 108 combinations for the unstable case. The specification of wind direction, however, is handled internally, based on the source and terrain geometry. Although CTSCREEN is designed to address a single source scenario, there are a number of options that can be selected on a case-by-case basis to address multi-source situations. However, the Regional Office should be consulted, and concurrence obtained, on the protocol for modeling multiple sources with CTSCREEN to ensure that the worst case is identified and assessed. The maximum concentration output from CTSCREEN represents a worst-case 1-hour concentration. Time-scaling factors of 0.7 for 3-hour, 0.15 for 24-hour and 0.03 for annual concentration averages are applied internally by CTSCREEN to the highest 1-hour concentration calculated by the model.

b. Placement of receptors requires very careful attention when modeling in complex terrain. Often the highest concentrations are predicted to occur under very stable conditions, when the plume is near, or impinges on, the terrain. The plume under such conditions may be quite narrow in the vertical, so that even relatively small changes in a receptor's location may substantially affect the predicted concentration. Receptors within about a kilometer of the source may be even more sensitive to location. Thus, a dense array of receptors may be required in some cases. In order to avoid excessively large computer runs due to such a large array of receptors, it is often desirable to model the area twice. The first model run would use a moderate number of receptors carefully located over the area of interest. The second model run would use a more dense array of receptors in areas showing potential for high concentrations, as indicated by the results of the first model run.

c. As mentioned above, digitized contour data must be preprocessed [37] to provide hill shape parameters in suitable input format. The user then supplies receptors either through an interactive program that is part of the model or directly, by using a text editor; using both methods to select receptors will generally be necessary to assure that the maximum concentrations are estimated by either model. In cases where a terrain feature may ''appear to the plume'' as smaller, multiple hills, it may be necessary to model the terrain both as a single feature and as multiple hills to determine design concentrations.

d. Other screening techniques [28 35 39] may be acceptable for complex terrain cases where established procedures are used. The user is encouraged to confer with the Regional Office if any unresolvable problems are encountered, *e.g.,* applicability, meteorological data, receptor siting, or terrain contour processing issues.

4.2.2 Refined Analytical Techniques

a. A brief description of each preferred model for refined applications is found in Appendix A. Also listed in that appendix are availability, the model input requirements, the standard options that should be selected when running the program, and output options.

b. For a wide range of regulatory applications in all types of terrain, the recommended model is AERMOD. This recommendation is based on extensive developmental and performance evaluation (Section A.1; subsection n). Differentiation of simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the well-known dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions.

c. If dry deposition or aerodynamic building downwash is important for the modeling analysis, *e.g.,* paragraphs 5.2.2.2(e), 5.2.5(b), 6.2.2(b), and 7.2.7(b), the recommended model is ISC–PRIME. Line sources can be simulated with ISC–PRIME if point or volume sources are appropriately combined. If buoyant plume rise from line sources is important for the modeling analysis, the recommended model is BLP. For other special modeling applications, CALINE3 (or CAL3QHCR on a case-by-case basis), OCD, and EDMS are recommended as described in Sections 5 and 6.

d. If the modeling application involves a well defined hill or ridge and a detailed dispersion analysis of the spatial pattern of plume impacts is of interest, CTDMPLUS, listed in Appendix A, is available. CDTMPLUS provides greater resolution of concentrations about the contour of the hill feature than does AERMOD through a different plume-terrain interaction algorithm.

TABLE 4–1A.—NEUTRAL/STABLE METEOROLOGICAL MATRIX FOR CTSCREEN

Variable:	Specific values				
$U_\wedge$(m/s)	1.0	2.0	3.0	4.0	5.0
σ_v(m/s)	0.3	0.75	....	....	....
σ_w(m/s)	0.08	0.15	0.30	0.75	....
$\Delta\theta/\Delta z$ (K/m)	0.01	0.02	0.035	....	....
WD	(Wind direction is optimized internally for each meteorological combination.)				

Exceptions:
(1) If $U \leq 2$ m/s and $\sigma_v \leq 0.3$ m/s, then include $\sigma_w = 0.04$ m/s.
(2) If $\sigma_w = 0.75$ m/s and $U \geq 3.0$ m/s, then $\Delta\theta/\Delta z$ is limited to ≤ 0.01 K/m.
(3) If $U \geq 4$ m/s, then $\sigma_w \geq 0.15$ m/s.
(4) $\sigma_w \leq \sigma_V$

TABLE 4–1B.—UNSTABLE/CONVECTIVE METEOROLOGICAL MATRIX FOR CTSCREEN

Variable:	Specific values				
U (m/s)	1.0	2.0	3.0	4.0	5.0
U_* (m/s)	0.1	0.3	0.5	....	....
L (m)	−10	−50	−90	....	....
$\Delta\theta/\Delta z$ (K/m)	0.030	(potential temperature gradient above Z_i)			
Z_i (m)	0.5h	1.0h	1.5h	h= terrain height)	

5.0 Models for Ozone, Particulate Matter, Carbon Monoxide, Nitrogen Dioxide, and Lead

5.1 Discussion

a. This section identifies modeling approaches or models appropriate for addressing ozone (O_3),[a] carbon monoxide (CO), nitrogen dioxide (NO_2), particulates (PM–2.5 and PM–10),[b, c] and lead. These pollutants are often associated with emissions from numerous sources. Generally, mobile sources contribute significantly to emissions of these pollutants or their precursors. For cases where it is of interest to estimate concentrations of CO or NO_2 near a single or small group of stationary sources, refer to Section 4. (Modeling approaches for SO_2 are discussed in Section 4.)

b. Several of the pollutants mentioned in the preceding paragraph are closely related to each other in that they share common sources of emissions and/or are subject to chemical transformations of similar precursors.[40 41] For example, strategies designed to reduce ozone could have an effect on the secondary component of PM–2.5 and vice versa. Thus, it makes sense to use models which take into account the chemical coupling between O_3 and PM–2.5, when feasible. This should promote consistency among methods used to evaluate strategies for reducing different pollutants as well as consistency among the strategies themselves. Regulatory requirements for the different pollutants are likely to be due at different times. Thus, the following paragraphs identify appropriate modeling approaches for pollutants individually.

c. The NAAQS for ozone was revised on July 18, 1997 and is now based on an 8-hour averaging period (62 FR 38856). Models for ozone are needed primarily to guide choice of strategies to correct an observed ozone problem in an area not attaining the NAAQS for ozone. Use of photochemical grid models is the recommended means for identifying strategies needed to correct high ozone concentrations in such areas. Such models need to consider emissions of volatile organic compounds (VOC), nitrogen oxides (NO_X) and carbon monoxide (CO), as well as means for generating meteorological data governing transport and dispersion of ozone and its precursors. Other approaches, such as Lagrangian or observational models may be used to guide choice of appropriate strategies to consider with a photochemical grid model. These other approaches may be sufficient to address ozone in an area where observed concentrations are near the NAAQS or only slightly above it. Such a decision needs to be made on a case-by-case basis in concert with the appropriate Regional Office.

d. A control agency with jurisdiction over one or more areas with significant ozone problems should review available ambient air quality data to assess whether the problem is likely to be significantly impacted by regional transport.[42] Choice of a modeling approach depends on the outcome of this review. In cases where transport is considered significant, use of a nested regional model may be the preferred approach. If the observed problem is believed to be primarily of local origin, use of a model, with a single horizontal grid resolution and geographical coverage that is less than that of a regional model, may suffice.

e. The fine particulate matter NAAQS, promulgated on July 18, 1997 (62 FR 38652), includes particles with an aerodynamic diameter nominally less than or equal to 2.5 micrometers (PM–2.5). Models for PM–2.5 are needed to assess adequacy of a proposed strategy for meeting annual and/or 24-hour NAAQS for PM–2.5. PM–2.5 is a mixture consisting of several diverse components. Because chemical/physical properties and origins of each component differ, it may be appropriate to use either a single model capable of addressing several of the important components or to model primary and secondary components using different models. Effects of a control strategy on PM–2.5 is estimated from the sum of the effects on the components composing PM–2.5. Model users may refer to guidance [43] for further details concerning appropriate modeling approaches.

f. A control agency with jurisdiction over one or more areas with PM–2.5 problems should review available ambient air quality data to assess which components of PM–2.5 are likely to be major contributors to the problem. If it is determined that regional transport of secondary particulates, such as sulfates or nitrates, is likely to contribute significantly to the problem, use of a regional model may be the preferred approach. Otherwise, coverage may be limited to a domain that is urban scale or less. Special care should be taken to select appropriate geographical coverage for a modeling application.[43]

g. The NAAQS for PM–10 was promulgated in July 1987 (40 CFR 50.6). A SIP development guide [44] is available to assist in PM–10 analyses and control strategy development. EPA promulgated regulations for PSD increments measured as PM–10 in a document published on June 3, 1993 (§ 51.166(c)). As an aid to assessing the impact on ambient air quality of particulate matter generated from prescribed burning activities, a reference [45] is available.

h. Models for assessing the impact of CO emissions are needed for a number of different purposes. Examples include evaluating effects of point sources, congested intersections and highways, as well as the cumulative effect of numerous sources of CO in an urban area.

i. Models for assessing the impact of sources on ambient NO_2 concentrations are primarily needed to meet new source review requirements, such as addressing the effect of a proposed source on PSD increments for annual concentrations of NO_2. Impact of an individual source on ambient NO_2 depends, in part, on the chemical environment into which the source's plume is to be emitted. There are several approaches for estimating effects of an individual source on ambient NO_2. One approach is through use of a plume-in-grid algorithm imbedded within a photochemical grid model. However, because of the rigor and complexity involved, and because this approach may not be capable of defining sub-grid concentration gradients, the plume-in-grid approach may be impractical for estimating effects on an annual PSD increment. A second approach is to develop site-specific conversion factors based on measurements. If it is not possible to develop site-specific conversion factors and use of the plume-in-grid algorithm is also not feasible, other screening procedures may be considered.

j. In January 1999 (40 CFR Part 58, Appendix D), EPA gave notice that concern about ambient lead impacts was being shifted away from roadways and toward a focus on stationary point sources. EPA has also issued guidance on siting ambient monitors in the vicinity of such sources. [46] For lead, the SIP should contain an air quality analysis to determine the maximum quarterly lead concentration resulting from major lead point sources, such as smelters, gasoline additive plants, etc. General guidance for lead SIP development is also available.[47]

5.2 Recommendations

5.2.1 Models for Ozone

a. *Choice of Models for Multi-source Applications.* Simulation of ozone formation and transport is a highly complex and resource intensive exercise. Control agencies with jurisdiction over areas with ozone problems are encouraged to use photochemical grid models, such as the Models-3/Community Multi-scale Air Quality (CMAQ) modeling system,[48] to evaluate the relationship between precursor species and ozone. Judgement on the suitability of a model for a given application should consider factors that include use of the model in an attainment test, development of emissions and meteorological inputs to the model and choice of episodes to model.[42] Similar models for the 8-hour NAAQS and for the 1-hour NAAQS are appropriate.

b. *Choice of Models to Complement Photochemical Grid Models.* As previously noted, observational models, Lagrangian models, or the Empirical Kinetics Modeling Approach (EKMA) [49, 50] may be used to help guide choice of strategies to simulate with a photochemical grid model and to corroborate results obtained with a grid model. EPA has issued guidance [42] in selecting appropriate techniques.

c. *Estimating the Impact of Individual Sources.* Choice of methods used to assess the impact of an individual source depends on the nature of the source and its emissions. Thus, model users should consult with the appropriate Regional Office to determine the most suitable approach on a case-by-case basis (Section 3.2.2).

5.2.2 Models for Particulate Matter

5.2.2.1 PM–2.5

a. *Choice of Models for Multi-source Applications.* Simulation of phenomena resulting in high ambient PM–2.5 can be a multi-faceted and complex problem resulting from PM–2.5's existence as an aerosol mixture. Treating secondary components of PM–2.5, such as sulfates and nitrates, can be a highly complex and resource-intensive exercise. Control agencies with jurisdiction over areas with secondary PM–2.5 problems are encouraged to use models which integrate chemical and physical processes important in the formation, decay and transport of these species (*e.g.*, Models-3/CMAQ [48] or REMSAD [51]). Primary components can be simulated using less resource-intensive techniques. Suitability of a modeling approach or mix of modeling approaches for a given application requires technical judgement [43], as well as professional experience in choice of models, use of the model(s) in an attainment test, development of emissions and meteorological inputs to the model and selection of days to model.

b. *Choice of Analysis Techniques to Complement Air Quality Simulation Models.* Observational models may be used to corroborate predictions obtained with one or more air quality simulation models. They may also be potentially useful in helping to define specific source categories contributing to major components of PM–2.5.[43]

c. *Estimating the Impact of Individual Sources.* Choice of methods used to assess the impact of an individual source depends on the nature of the source and its emissions. Thus, model users should consult with the appropriate Regional Office to determine the most suitable approach on a case-by-case basis (Section 3.2.2).

5.2.2.2 PM–10

a. Screening techniques like those identified in Section 4 are applicable to PM–10. Conservative assumptions which do not allow removal or transformation are suggested for screening. Thus, it is recommended that subjectively determined values for ''half-life'' or pollutant decay not be used as a surrogate for particle removal. Proportional models (rollback/forward) may not be applied for screening analysis, unless such techniques are used in conjunction with receptor modeling.[44]

b. Refined models such as those discussed in Section 4 are recommended for PM–10. However, where possible, particle size, gas-to-particle formation, and their effect on ambient concentrations may be considered. For point sources of small particles and for source-specific analyses of complicated sources, use the appropriate recommended steady-state plume dispersion model (Section 4.2.2). For guidance on determination of design concentrations, see paragraph 7.2.1.1(e).

c. Receptor models [52 53 54] have proven useful for helping validate emission inventories and for corroborating source-specific impacts estimated by dispersion models. In regulatory applications, dispersion models have been used in conjunction with receptor models to attribute source (or source category) contributions. Guidance is available for PM–10 sampling and analysis applicable to receptor modeling.[55]

d. Under certain conditions, recommended dispersion models may not be reliable. In such circumstances, the modeling approach should be approved by the appropriate Regional Office on a case-by-case basis. Analyses involving model calculations for stagnation conditions should also be justified on a case-by-case basis (Section 7.2.8).

e. Fugitive dust usually refers to dust put into the atmosphere by the wind blowing over plowed fields, dirt roads or desert or sandy areas with little or no vegetation. Reentrained dust is that which is put into the air by reason of vehicles driving over dirt roads (or dirty roads) and dusty areas. Such sources can be characterized as line, area or volume sources. Emission rates may be based on site-specific data or values from the general literature. Fugitive emissions include the emissions resulting from the industrial process that are not captured and vented through a stack but may be released from various locations within the complex. Where such fugitive emissions can be properly specified, use the recommended steady-state dispersion model (Section 4.2.2) that handles gravitational settling and dry deposition. In some unique cases a model developed specifically for the situation may be needed. Due to the difficult nature of characterizing and modeling fugitive dust and fugitive emissions, it is recommended that the proposed procedure be cleared by the appropriate Regional Office for each specific situation before the modeling exercise is begun.

5.2.3 Models for Carbon Monoxide

a. Guidance is available for analyzing CO impacts at roadway intersections.[56] The recommended screening model for such analyses is CAL3QHC.[57 58] This model combines CALINE3 (listed in Appendix A) with a traffic model to calculate delays and queues that occur at signalized intersections. The screening approach is described in reference 56; a refined approach may be considered on a case-by-case basis with CAL3QHCR.[59] The latest version of the MOBILE (mobile source emission factor) model should be used for emissions input to intersection models.

b. For analyses of highways characterized by uninterrupted traffic flows, CALINE3 is recommended, with emissions input from the latest version of the MOBILE model.

c. For urban area wide analyses of CO, an Eulerian grid model should be used. Information on SIP development and requirements for using such models can be found in several references.[56 60 61 62]

d. Where point sources of CO are of concern, they should be treated using the screening and refined techniques described in Section 4 of the Guideline.

5.2.4 Models for Nitrogen Dioxide (Annual Average)

a. A tiered screening approach is recommended to obtain annual average estimates of NO_2 from point sources for New Source Review analysis, including PSD, and for SIP planning purposes. This multi-tiered approach is conceptually shown in Figure 5–1 and described in paragraphs 5.2.4 b through d:

b. For Tier 1 (the initial screen), use an appropriate model from Appendix A to estimate the maximum annual average concentration and assume a total conversion of NO to NO_2. If the concentration exceeds the NAAQS and/or PSD increments for NO_2, proceed to the 2nd level screen.

c. For Tier 2 (2nd level) screening analysis, multiply the Tier 1 estimate(s) by an empirically derived NO_2 / NO_x value of 0.75 (annual national default).[63] The reviewing agency may establish an alternative default NO_2 / NO_x ratio based on ambient annual average NO_2 and annual average NO_x data representative of area wide quasi-equilibrium conditions Alternative default NO_2/NO_x ratios should be based on data satisfying quality assurance procedures that ensure data accuracy for both NO_2 and NO_x within the typical range of measured values. In areas with relatively low NO_x concentrations, the quality assurance procedures used to determine compliance with the NO_2 national ambient air quality standard may not be adequate. In addition, default NO_2/NO_x ratios, including the 0.75 national default value, can underestimate long range NO2 impacts and should be used with caution in long range transport scenarios.

d. For Tier 3 (3rd level) analysis, a detailed screening method may be selected on a case-by-case basis. For point source modeling, other refined screening methods, such as the ozone limiting method [64], may also be considered. Also, a site-specific NO_2/NO_x ratio may be used as a detailed screening method if it meets the same restrictions as described for alternative default NO_2/NO_x ratios. Ambient NO_{2x} monitors used to develop a site-specific ratio should be sited to obtain the NO_2 and NO_x concentrations under quasi-equilibrium conditions. Data obtained from monitors sited at the maximum NO_x impact site, as may be required in a PSD pre-construction monitoring program, likely reflect transitional NO_x conditions. Therefore, NO_x data from maximum impact sites may not be suitable for determining a site-specific NO_2/NO_x ratio that is applicable for the entire modeling analysis. A site-specific ratio derived from maximum impact data can only be used to estimate NO_2 impacts at receptors located within the same distance of the source as the source-to-monitor distance.

e. In urban areas (Section 7.2.3), a proportional model may be used as a preliminary assessment to evaluate control strategies to meet the NAAQS for multiple minor sources, i.e., minor point, area and mobile sources of NO_x; concentrations resulting from major point sources should be estimated separately as discussed above, then added to the impact of the minor sources. An acceptable screening technique for urban complexes is to assume that all NO_x is emitted in the form of NO_2 and to use a model from Appendix A for nonreactive pollutants to estimate NO_2 concentrations. A more accurate estimate can be obtained by: (1) calculating the annual average concentrations of NO_x with an urban model, and (2) converting these estimates to NO_2 concentrations using an empirically derived annual NO_2 / NO_x ratio. A value of 0.75 is recommended for this ratio. However, a spatially averaged alternative default annual NO_2 / NO_x ratio may be determined from an existing air quality monitoring network and used in lieu of the 0.75 value if it is determined to be representative of prevailing ratios in the urban area by the reviewing agency. To ensure use of appropriate locally derived annual average NO_2 / NO_x ratios, monitoring data under consideration should be limited to those collected at monitors meeting siting criteria defined in 40 CFR Part 58, Appendix D as representative of ''neighborhood'', ''urban'', or ''regional'' scales. Furthermore, the highest annual spatially averaged NO_2 / NO_x ratio from the most recent 3 years of complete data should be used to foster conservatism in estimated impacts.

f. To demonstrate compliance with NO_2 PSD increments in urban areas, emissions from major and minor sources should be included in the modeling analysis. Point and area source emissions should be modeled as discussed above. If mobile source emissions do not contribute to localized areas of high ambient NO_2 concentrations, they should be modeled as area sources. When modeled as area sources, mobile source emissions should be assumed uniform over the entire highway link and allocated to each area source grid square based on the portion of highway link within each grid square. If localized areas of high concentrations are likely, then mobile sources should be modeled as line sources using an appropriate steady-state plume dispersion model (e.g., CAL3QHCR; Section 5.2.3).

g. More refined techniques to handle special circumstances may be considered on a case-by-case basis and agreement with the reviewing authority should be obtained. Such techniques should consider individual quantities of NO and NO_2 emissions, atmospheric transport and dispersion, and atmospheric transformation of NO to NO_2. Where they are available, site-specific data on the conversion of NO to NO_2 may be used. Photochemical dispersion models, if used for other pollutants in the area, may also be applied to the NO_x problem.

5.2.5 Models for Lead

a. For major lead point sources, such as smelters, which contribute fugitive emissions and for which deposition is important, use the appropriate recommended steady-state plume dispersion model (Section 4.2.2). To model an entire major urban area or to model areas without significant sources of lead emissions, as a minimum a proportional (rollback) model may be used for air quality analysis. The rollback philosophy assumes that measured pollutant concentrations are proportional to emissions. However, urban or other dispersion models are encouraged in these circumstances where the use of such models is feasible.

b. In modeling the effect of traditional line sources (such as a specific roadway or highway) on lead air quality, dispersion models applied for other pollutants can be used. Dispersion models such as CALINE3 and CAL3QHCR have been used for modeling carbon monoxide emissions from highways and intersections (Section 5.2.3). However, where deposition is of concern, ISC-PRIME may be used. Also, where there is a point source in the middle of a substantial road network, the lead concentrations that result from the road network should be treated as background (Section 8.2); the point source and any nearby major roadways should be modeled separately using the appropriate recommended steady-state plume dispersion model (Section 4.2.2).

6.0 Other Model Requirements

6.1 Discussion

a. This section covers those cases where specific techniques have been developed for special regulatory programs. Most of the programs have, or will have when fully developed, separate guidance documents that cover the program and a discussion of the tools that are needed. The following paragraphs reference those guidance documents, when they are available. No attempt has been made to provide a comprehensive discussion of each topic since the reference documents were designed to do that. This section will undergo periodic revision as new programs are added and new techniques are developed.

b. Other Federal agencies have also developed specific modeling approaches for their own regulatory or other requirements.[65] Although such regulatory requirements and manuals may have come about because of EPA rules or standards, the implementation of such regulations and the use of the modeling techniques is under the jurisdiction of the agency issuing the manual or directive.

c. The need to estimate impacts at distances greater than 50km (the nominal distance to which EPA considers most steady-state Gaussian plume models are applicable) is an important one especially when considering the effects from secondary pollutants. Unfortunately, models originally available to EPA had not undergone sufficient field evaluation to be recommended for general use. Data bases from field studies at mesoscale and long range transport distances were limited in detail. This limitation was a result of the expense to perform the field studies required to verify and improve mesoscale and long range transport models. Meteorological data adequate for generating three-dimensional wind fields were particularly sparse. Application of models to complicated terrain compounds the difficulty of making good assessments of long range transport impacts. EPA completed limited evaluation of several long range transport (LRT) models against two sets of field data and evaluated results.[13] Based on the results, EPA concluded that long range and mesoscale transport models were limited for regulatory use to a case-by-case basis. However a more recent series of comparisons has been completed for a new model, CALPUFF (Section A.4). Several of these field studies involved three-to-four hour releases of tracer gas sampled along arcs of receptors at distances greater than 50km downwind. In some cases, short-term concentration sampling was available, such that the transport of the tracer puff as it passed the arc could be monitored. Differences on the order of 10 to 20 degrees were found between the location of the simulated and observed center of mass of the tracer puff. Most of the simulated centerline concentration maxima along each arc were within a factor of two of those observed. It was concluded from these case studies that the CALPUFF dispersion model had performed in a reasonable manner, and had no apparent bias toward over or under prediction, so long as the transport distance was limited to less than 300km.[66]

6.2 Recommendations

6.2.1 Visibility

a. Visibility in important natural areas (*e.g.*, Federal Class I areas) is protected under a number of provisions of the Clean Air Act, including Sections 169A and 169B (addressing impacts primarily from existing sources) and Section 165 (new source review). Visibility impairment is caused by light scattering and light absorption associated with particles and gases in the atmosphere. In most areas of the country, light scattering by PM–2.5 is the most significant component of visibility impairment. The key components of PM–2.5 contributing to visibility impairment include sulfates, nitrates, organic carbon, elemental carbon, and crustal material.

b. The visibility regulations as promulgated in December 1980 (40 CFR 51.300—51.307) require States to mitigate visibility impairment, in any of the 156 mandatory Federal Class I areas, that is found to be ''reasonably attributable'' to a single source or a small group of sources. In 1985, EPA promulgated Federal Implementation Plans (FIPs) for several States without approved visibility provisions in their SIPs. The IMPROVE (Interagency Monitoring for Protected Visual Environments) monitoring network, a cooperative effort between EPA, the States, and Federal land management agencies, was established to implement the monitoring requirements in these FIPs. Data has been collected by the IMPROVE network since 1988.

c. In 1999, EPA issued revisions to the 1980 regulations to address visibility impairment in the form of regional haze, which is caused by numerous, diverse sources (*e.g.*, stationary, mobile, and area sources) located across a broad region (40 CFR 51.308—51.309). The state of relevant scientific knowledge has expanded significantly since the Clean Air Act Amendments of 1977. A number of studies and reports[67 68] have concluded that long range transport (*e.g.*, up to hundreds of kilometers) of fine particulate matter plays a significant role in visibility impairment across the country. Section 169A of the Act requires states to develop SIPs containing long-term strategies for remedying existing and preventing future visibility impairment in 156 mandatory Class I federal areas. In order to develop long-term strategies to address regional haze, many States will need to conduct regional-scale modeling of fine particulate concentrations and associated visibility impairment (*e.g.*, light extinction and deciview metrics).

d. Guidance and a screening model, VISCREEN, are available.[69] VISCREEN can be used to calculate the potential impact of a plume of specified emissions for specific transport and dispersion conditions. If a more comprehensive analysis is required, any refined model should be selected in consultation with the EPA Regional Office and the appropriate Federal Land Manager who is responsible for determining whether there is an adverse effect by a plume on a Class I area. PLUVUE II, an alternative model listed on EPA's Internet SCRAM website (Section 2.3), may be applied on a case-by-case basis when refined plume visibility evaluations are needed.

e. CALPUFF (Section A.4) may be applied on a case-by-case basis when assessment is needed of reasonably attributable haze impairment due to one or a small group of sources. The procedures and analyses should be determined in consultation with the appropriate Regional Office, the appropriate regulatory permitting authority, and the appropriate Federal Land Manager (FLM).

f. Regional scale models are used by EPA to develop and evaluate national policy and assist State and local control agencies. Two such models which can be used to assess visibility impacts from source emissions are Models-3[48] and REMSAD[51]. Model users should consult with the appropriate Regional Office to determine the most suitable approach on a case-by-case basis (Section 3.2.2).

6.2.2 Good Engineering Practice Stack Height

a. The use of stack height credit in excess of Good Engineering Practice (GEP) stack height or credit resulting from any other dispersion technique is prohibited in the development of emission limitations by 40 CFR 51.118 and 40 CFR 51.164. The definitions of GEP stack height and dispersion technique are contained in 40 CFR 51.100. Methods and procedures for making the appropriate stack height calculations, determining stack height credits and an example of applying those techniques are found in several references[70, 71 72 73] which provide a great deal of additional information for evaluating and describing building cavity and wake effects.

b. If stacks for new or existing major sources are found to be less than the height defined by 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. The EPA refined formula height is defined as H + 1.5L (see reference 72). Detailed downwash screening procedures[34] for both the cavity and wake regions should be followed. If more refined concentration estimates are required, the recommended steady-state plume dispersion model in Section 4.2.2 contains algorithms for building wake calculations and should be used.

6.2.3 Long Range Transport (LRT) (*i.e.*, beyond 50km)

a. Section 165(e) of the Clean Air Act requires that suspected adverse impacts on PSD Class I areas be determined. However, 50km is the useful distance to which most steady-state Gaussian plume models are considered accurate for setting emission limits. Since in many cases PSD analyses show that Class I areas may be threatened at distances greater than 50km from new sources, some procedure is needed to (1) determine if an adverse impact will occur, and (2) identify the model to be used in setting an emission limit if the Class I increments are threatened. In addition to the situations just described, there are certain applications containing a mixture of both long range and short range source-receptor relationships in a large modeled domain (*e.g.*, several industrialized areas located along a river or valley). Historically, these applications have presented considerable difficulty to an analyst if impacts from sources having transport distances greater than 50km significantly contributed to the design concentrations. To properly analyze applications of this type, a modeling approach is needed which has the capability of combining, in a consistent manner, impacts involving both short and long range transport. The CALPUFF modeling system, listed in Appendix A, has been designed to accommodate both the Class I area LRT situation and the large modeling domain situation. Given the judgement and refinement involved, conducting a LRT modeling assessment will require significant consultation with the EPA Regional Office, the appropriate regulatory permitting authority and, for Class I area analyses, the appropriate Federal Land Manager (FLM). While the ultimate decision on whether a Class I area is adversely affected is the responsibility of the permitting authority, the FLM has an affirmative responsibility to protect air quality related values that may be affected, and to provide the appropriate procedures and analysis techniques.

b. If LRT is determined to be important, then refined estimates utilizing the CALPUFF modeling system should be obtained. A screening approach[66] is also available for use on a case-by-case basis that generally provides concentrations that are higher than those obtained using refined characterizations of the meteorological conditions. The meteorological input data requirements for developing the time and space varying three-dimensional winds and dispersion meteorology for refined analyses are discussed in paragraph 8.3.1.2(d). Additional information on applying this model is contained in Appendix A. To facilitate use of complex air quality and meteorological modeling systems, a written protocol may be considered for developing consensus in the methods and procedures to be followed.

6.2.4 Modeling Guidance for Other Governmental Programs

a. When using the models recommended or discussed in the Guideline in support of programmatic requirements not specifically covered by EPA regulations, the model user should consult the appropriate Federal or State agency to ensure the proper application and use of the models. For modeling associated with PSD permit applications that involve a Class I area, the appropriate Federal Land Manager should be consulted on all modeling questions.

b. The Offshore and Coastal Dispersion (OCD) model, described in Appendix A, was developed by the Minerals Management Service and is recommended for estimating air quality impact from offshore sources on onshore, flat terrain areas. The OCD model is not recommended for use in air quality impact assessments for onshore sources. Sources located on or just inland of a shoreline where fumigation is expected should be treated in accordance with Section 7.2.8.

c. The Emissions and Dispersion Modeling System (EDMS), described in Appendix A, was developed by the Federal Aviation Administration and the United States Air Force and is recommended for air quality assessment of primary pollutant impacts at airports or air bases. Regulatory application of EDMS is intended for estimating the cumulative effect of changes in aircraft operations, point source, and mobile source emissions on pollutant concentrations. It is not intended for PSD, SIP, or other regulatory air quality analyses of point or mobile sources at or peripheral to airport property that are independent of changes in aircraft operations. If changes in other than aircraft operations are associated with analyses, a model recommended in Chapter 4 or 5 should be used.

7.0 General Modeling Considerations

7.1 Discussion

a. This section contains recommendations concerning a number of different issues not explicitly covered in other sections of this guide. The topics covered here are not specific to any one program or modeling area but are common to nearly all modeling analyses for criteria pollutants.

7.2 Recommendations

7.2.1 Design Concentrations (see also Section 10.2.3.1)

7.2.1.1 Design Concentrations for SO_2, PM–10, CO, Pb, and NO_2

a. An air quality analysis for SO_2, PM–10, CO, Pb, and NO_2 is required to determine if the source will (1) cause a violation of the NAAQS, or (2) cause or contribute to air quality deterioration greater than the specified allowable PSD increment. For the former, background concentration (Section 8.2) should be added to the estimated impact of the source to determine the design concentration. For the latter, the design concentration includes impact from all increment consuming sources.

b. If the air quality analyses are conducted using the period of meteorological input data recommended in Section 8.3.1.2 (*e.g.*, 5 years of National Weather Service (NWS) data or 1 year of site-specific data; Section 8.3.3), then the design concentration based on the highest, second-highest short term concentration or long term average, whichever is controlling, should be used to determine emission limitations to assess compliance with the NAAQS and PSD increments.

c. When sufficient and representative data exist for less than a 5-year period from a nearby NWS site, or when site-specific data have been collected for less than a full continuous year, or when it has been determined that the site-specific data may not be temporally representative (Section 8.3.3), then the highest concentration estimate should be considered the design value. This is because the length of the data record may be too short to assure that the conditions producing worst-case estimates have been adequately sampled. The highest value is then a surrogate for the concentration that is not to be exceeded more than once per year (the wording of the deterministic standards). Also, the highest concentration should be used whenever selected worst-case conditions are input to a screening technique, as described in EPA guidance.

d. If the controlling concentration is an annual average value and multiple years of data (site-specific or NWS) are used, then the design value is the highest of the annual averages calculated for the individual years. If the controlling concentration is a quarterly average and multiple years are used, then the highest individual quarterly average should be considered the design value.

e. As long a period of record as possible should be used in making estimates to determine design values and PSD increments. If more than 1 year of site-specific data is available, it should be used.

7.2.1.2 Design Concentrations for O_3 and PM–2.5

a. Guidance and specific instructions for the determination of the 1-hr and 8-hr design concentrations for ozone are provided in Appendix H and I (respectively) of reference 4. No definitive guidance for determining design concentrations for PM–2.5 has been issued. For all SIP revisions the user should check with the Regional Office to obtain the most recent guidance documents and policy memoranda concerning the pollutant in question. There are currently no PSD increments for O_3 and PM–2.5.

7.2.2 Critical Receptor Sites

a. Receptor sites for refined modeling should be utilized in sufficient detail to estimate the highest concentrations and possible violations of a NAAQS or a PSD increment. In designing a receptor network, the emphasis should be placed on receptor resolution and location, not total number of receptors. The selection of receptor sites should be a case-by-case determination taking into consideration the topography, the climatology, monitor sites, and the results of the initial screening procedure. For large sources (those equivalent to a 500MW power plant) and where violations of the NAAQS or PSD increment are likely, 360 receptors for a polar coordinate grid system and 400 receptors for a rectangular grid system, where the distance from the source to the farthest receptor is 10km, are usually adequate to identify areas of high concentration. Additional receptors may be needed in the high concentration location if greater resolution is indicated by terrain or source factors.

7.2.3 Dispersion Coefficients

a. Steady-state Gaussian plume models used in most applications should employ dispersion coefficients consistent with those contained in the preferred models in Appendix A. Factors such as averaging time, urban/rural surroundings (see paragraphs 7.2.3 b through f), and type of source (point vs. line) may dictate the selection of specific coefficients. Coefficients used in some Appendix A models are identical to, or at least based on, Pasquill-Gifford coefficients [74] in rural areas and McElroy-Pooler [75] coefficients in urban areas. A key feature of AERMOD's formulation is the use of directly observed variables of the boundary layer to parameterize dispersion.[33] Research is continuing toward the development of methods to determine dispersion coefficients directly from measured or observed variables.[76 77]

b. The selection of either rural or urban dispersion coefficients in a specific application should follow one of the procedures suggested by Irwin [78] and briefly described below. These include a land use classification procedure or a population based procedure to determine whether the character of an area is primarily urban or rural.

c. Land Use Procedure: (1) Classify the land use within the total area, A_o, circumscribed by a 3km radius circle about the source using the meteorological land use typing scheme proposed by Auer [79]; (2) if land use types I1, I2, C1, R2, and R3 account for 50 percent or more of A_o, use urban dispersion coefficients; otherwise, use appropriate rural dispersion coefficients.

d. Population Density Procedure: (1) Compute the average population density, $\bar{p}$ per square kilometer with A_o as defined above; (2) If $\bar{p}$ is greater than 750 people/km^2, use urban dispersion coefficients; otherwise use appropriate rural dispersion coefficients.

e. Of the two methods, the land use procedure is considered more definitive. Population density 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.

f. Sources located in an area defined as urban should be modeled using urban dispersion parameters. Sources located in areas defined as rural should be modeled using the rural dispersion parameters. For analyses of whole urban complexes, the entire area should be modeled as an urban region if most of the sources are located in areas classified as urban.

g. Buoyancy-induced dispersion (BID), as identified by Pasquill, [80] is included in the preferred models and should be used where buoyant sources, *e.g.*, those involving fuel combustion, are involved.

7.2.4 Stability Categories

a. The Pasquill approach to classifying stability is commonly used in preferred models (Appendix A). The Pasquill method, as modified by Turner,[81] was developed for use with commonly observed meteorological data from the National Weather Service and is based on cloud cover, insolation and wind speed.

b. Procedures to determine Pasquill stability categories from other than NWS data are found in Section 8.3. Any other method to determine Pasquill stability categories must be justified on a case-by-case basis.

c. For a given model application where stability categories are the basis for selecting dispersion coefficients, both σ_y and σ_z should be determined from the same stability category. ''Split sigmas'' in that instance are not recommended. Sector averaging, which eliminates the σ_y term, is commonly acceptable in complex terrain screening methods.

d. AERMOD, also a preferred model in Appendix A, uses a planetary boundary layer scaling parameter to characterize stability.[33] This approach represents a departure from the discrete, hourly stability categories estimated under the Pasquill-Gifford-Turner scheme.

7.2.5 Plume Rise

a. The plume rise methods of Briggs [82, 83] are incorporated in many of the preferred models and are recommended for use in many modeling applications. In AERMOD,[33] for the stable boundary layer, plume rise is estimated using an iterative approach, similar to that in the CTDMPLUS model. In the convective boundary layer, plume rise is superposed on the displacements by random convective velocities. [84] In ISC-PRIME, plume rise is computed using the methods of Briggs excepting cases involving building downwash, in which a numerical solution of the mass, energy, and momentum conservation laws is performed.[24] No explicit provisions in these models are made for multistack plume rise enhancement or the handling of such special plumes as flares; these problems should be considered on a case-by-case basis.

b. Since there is insufficient information to identify and quantify dispersion during the transitional plume rise period, gradual plume rise is not generally recommended for use. There are two exceptions where the use of gradual plume rise is appropriate: (1) In complex terrain screening procedures to determine close-in impacts; (2) when calculating the effects of building wakes. The building wake algorithm in ISC–PRIME incorporates and automatically (*i.e.,* internally) exercises the thermodynamically based gradual plume rise calculations as described in paragraph 7.2.5 a . If the building wake is calculated to affect the plume for any hour, gradual plume rise is also used in downwind dispersion calculations to the distance of final plume rise, after which final plume rise is used. Plumes captured by the near wake are re-emitted to the far wake as a ground-level volume source.

c. Stack tip downwash generally occurs with poorly constructed stacks and when the ratio of the stack exit velocity to wind speed is small. An algorithm developed by Briggs [83] is the recommended technique for this situation and is found in the point source preferred models.

7.2.6 Chemical Transformation

a. The chemical transformation of SO_2 emitted from point sources or single industrial plants in rural areas is generally assumed to be relatively unimportant to the estimation of maximum concentrations when travel time is limited to a few hours. However, in urban areas, where synergistic effects among pollutants are of considerable consequence, chemical transformation rates may be of concern. In urban area applications, a half-life of 4 hours [81] may be applied to the analysis of SO_2 emissions. Calculations of transformation coefficients from site-specific studies can be used to define a ''half-life'' to be used in a steady-state Gaussian plume model with any travel time, or in any application, if appropriate documentation is provided. Such conversion factors for pollutant half-life should not be used with screening analyses.

b. Use of models incorporating complex chemical mechanisms should be considered only on a case-by-case basis with proper demonstration of applicability. These are generally regional models not designed for the evaluation of individual sources but used primarily for region-wide evaluations. Visibility models also incorporate chemical transformation mechanisms which are an integral part of the visibility model itself and should be used in visibility assessments.

7.2.7 Gravitational Settling and Deposition

a. An ''infinite half-life'' should be used for estimates of particle concentrations when steady-state Gaussian plume models containing only exponential decay terms for treating settling and deposition are used.

b. Gravitational settling and deposition may be directly included in a model if either is a significant factor. When particulate matter sources can be quantified and settling and dry deposition are problems, use the recommended steady-state plume dispersion model (Section 4.2.2).

7.2.8 Complex Winds

a. *Inhomogeneous Local Winds.* In many parts of the United States, the ground is neither flat nor is the ground cover (or land use) uniform. These geographical variations can generate local winds and circulations, and modify the prevailing ambient winds and circulations. Geographic effects are most apparent when the ambient winds are light or calm.[85] In general these geographically induced wind circulation effects are named after the source location of the winds, *e.g.*, lake and sea breezes, and mountain and valley winds. In very rugged hilly or mountainous terrain, along coastlines, or near large land use variations, the characterization of the winds is a balance of various forces, such that the assumptions of steady-state straight-line transport both in time and space are inappropriate. In the special cases described, the CALPUFF modeling system (described in Appendix A) may be applied on a case-by-case basis for air quality estimates in such complex non-steady-state meteorological conditions. The purpose of choosing a modeling system like CALPUFF is to fully treat the time and space variations of meteorology effects on transport and dispersion. The setup and application of the model should be determined in consultation with the Regional Office and the appropriate regulatory permitting authority consistent with limitations of paragraph 3.2.2(e). The meteorological input data requirements for developing the time and space varying three-dimensional winds and dispersion meteorology for these situations are discussed in paragraph 8.3.1.2(e).

b. *Inversion Breakup Fumigation.* Inversion breakup fumigation occurs when a plume (or multiple plumes) is emitted into a stable layer of air and that layer is subsequently mixed to the ground through convective transfer of heat from the surface or because of advection to less stable surroundings. Fumigation may cause excessively high concentrations but is usually rather short-lived at a given receptor. There are no recommended refined techniques to model this phenomenon. There are, however, screening procedures [34] that may be used to approximate the concentrations. Considerable care should be exercised in using the results obtained from the screening techniques.

c. *Shoreline Fumigation.* Fumigation can be an important phenomenon on and near the shoreline of bodies of water. This can affect both individual plumes and area-wide emissions. When fumigation conditions are expected to occur from a source or sources with tall stacks located on or just inland of a shoreline, this should be addressed in the air quality modeling analysis. The Shoreline Dispersion Model (SDM) listed on EPA's Internet SCRAM website (Section 2.3) may be applied on a case-by-case basis when air quality estimates under shoreline fumigation conditions are needed.[86] Information on the results of EPA's evaluation of this model together with other coastal fumigation models is available.[87] Selection of the appropriate model for applications where shoreline fumigation is of concern should be determined in consultation with the Regional Office.

d. *Stagnation.* Stagnation conditions are characterized by calm or very low wind speeds, and variable wind directions. These stagnant meteorological conditions may persist for several hours to several days. During stagnation conditions, the dispersion of air pollutants, especially those from low-level emissions sources, tends to be minimized, potentially leading to relatively high ground-level concentrations. When stagnation periods such as these are found to occur, they should be addressed in the air quality modeling analysis. WYNDvalley, listed on EPA's Internet SCRAM website (Section 2.3), may be applied on a case-by-case basis for stagnation periods of 24 hours or longer in valley-type situations. Caution should be exercised when applying WYNDvalley to elevated point sources. If point sources are of interest, users should note the guidance provided for CALPUFF in paragraph 7.2.8 a. Users should consult with the appropriate Regional Office prior to regulatory application of WYNDvalley.

7.2.9 Calibration of Models

a. Calibration of models is not common practice and is subject to much error and misunderstanding. There have been attempts by some to compare model estimates and measurements on an event-by-event basis and then to calibrate a model with results of that comparison. This approach is severely limited by uncertainties in both source and meteorological data and therefore it is difficult to precisely estimate the concentration at an exact location for a specific increment of time. Such uncertainties make calibration of models of questionable benefit. Therefore, model calibration is unacceptable.

8.0 Model Input Data

a. Data bases and related procedures for estimating input parameters are an integral part of the modeling procedure. The most appropriate data available should always be selected for use in modeling analyses. Concentrations can vary widely depending on the source data or meteorological data used. Input data are a major source of uncertainties in any modeling analysis. This section attempts to minimize the uncertainty associated with data base selection and use by identifying requirements for data used in modeling. A checklist of input data requirements for modeling analyses is posted on EPA's Internet SCRAM website (Section 2.3). More specific data requirements and the format required for the individual models are described in detail in the users' guide for each model.

8.1 Source Data

8.1.1 Discussion

a. Sources of pollutants can be classified as point, line and area/volume sources. Point sources are defined in terms of size and may vary between regulatory programs. The line sources most frequently considered are roadways and streets along which there are well-defined movements of motor vehicles, but they may be lines of roof vents or stacks such as in aluminum refineries. Area and volume sources are often collections of a multitude of minor sources with individually small emissions that are impractical to consider as separate point or line sources. Large area sources are typically treated as a grid network of square areas, with pollutant emissions distributed uniformly within each grid square.

b. Emission factors are compiled in an EPA publication commonly known as AP–42 [88]; an indication of the quality and amount of data on which many of the factors are based is also provided. Other information concerning emissions is available in EPA publications relating to specific source categories. The Regional Office should be consulted to determine appropriate source definitions and for guidance concerning the determination of emissions from and techniques for modeling the various source types.

8.1.2 Recommendations

a. For point source applications the load or operating condition that causes maximum ground-level concentrations should be established. As a minimum, the source should be modeled using the design capacity (100 percent load). If a source operates at greater than design capacity for periods that could result in violations of the standards or PSD increments, this load [d] should be modeled. Where the source operates at substantially less than design capacity, and the changes in the stack parameters associated with the operating conditions could lead to higher ground level concentrations, loads such as 50 percent and 75 percent of capacity should also be modeled. A range of operating conditions should be considered in screening analyses; the load causing the highest concentration, in addition to the design load, should be included in refined modeling. For a power plant, the following (b–h) is typical of the kind of data on source characteristics and operating conditions that may be needed. Generally, input data requirements for air quality models necessitate the use of metric units; where English units are common for engineering usage, a conversion to metric is required.

b. *Plant layout.* The connection scheme between boilers and stacks, and the distance and direction between stacks, building parameters (length, width, height, location and orientation relative to stacks) for plant structures which house boilers, control equipment, and surrounding buildings within a distance of approximately five stack heights.

c. *Stack parameters.* For all stacks, the stack height and inside diameter (meters), and the temperature (K) and volume flow rate (actual cubic meters per second) or exit gas velocity (meters per second) for operation at 100 percent, 75 percent and 50 percent load.

d. *Boiler size.* For all boilers, the associated megawatts, 10^6 BTU/hr, and pounds of steam per hour, and the design and/or actual fuel consumption rate for 100 percent load for coal (tons/hour), oil (barrels/hour), and natural gas (thousand cubic feet/hour).

e. *Boiler parameters.* For all boilers, the percent excess air used, the boiler type (*e.g.*, wet bottom, cyclone, etc.), and the type of firing (*e.g.*, pulverized coal, front firing, etc.).

f. *Operating conditions.* For all boilers, the type, amount and pollutant contents of fuel, the total hours of boiler operation and the boiler capacity factor during the year, and the percent load for peak conditions.

g. *Pollution control equipment parameters.* For each boiler served and each pollutant affected, the type of emission control equipment, the year of its installation, its design efficiency and mass emission rate, the date of the last test and the tested efficiency, the number of hours of operation during the latest year, and the best engineering estimate of its projected efficiency if used in conjunction with coal combustion; data for any anticipated modifications or additions.

h. *Data for new boilers or stacks.* For all new boilers and stacks under construction and for all planned modifications to existing boilers or stacks, the scheduled date of completion, and the data or best estimates

[d] Malfunctions which may result in excess emissions are not considered to be a normal operating condition. They generally should not be considered in determining allowable emissions. However, if the excess emissions are the result of poor maintenance, careless operation, or other preventable conditions, it may be necessary to consider them in determining source impact.

available for paragraphs 8.1.2b through g following completion of construction or modification.

i. In stationary point source applications for compliance with short term ambient standards, SIP control strategies should be tested using the emission input shown on Table 8–1. When using a refined model, sources should be modeled sequentially with these loads for every hour of the year. To evaluate SIPs for compliance with quarterly and annual standards, emission input data shown in Table 8–1 should again be used. Emissions from area sources should generally be based on annual average conditions. The source input information in each model user's guide should be carefully consulted and the checklist (paragraph 8.0(a)) should also be consulted for other possible emission data that could be helpful. PSD and NAAQS compliance demonstrations should follow the emission input data shown in Table 8–2. For purposes of emissions trading, new source review and demonstrations, refer to current EPA policy and guidance to establish input data.

j. Line source modeling of streets and highways requires data on the width of the roadway and the median strip, the types and amounts of pollutant emissions, the number of lanes, the emissions from each lane and the height of emissions. The location of the ends of the straight roadway segments should be specified by appropriate grid coordinates. Detailed information and data requirements for modeling mobile sources of pollution are provided in the user's manuals for each of the models applicable to mobile sources.

k. The impact of growth on emissions should be considered in all modeling analyses covering existing sources. Increases in emissions due to planned expansion or planned fuel switches should be identified. Increases in emissions at individual sources that may be associated with a general industrial/commercial/residential expansion in multi-source urban areas should also be treated. For new sources the impact of growth on emissions should generally be considered for the period prior to the start-up date for the source. Such changes in emissions should treat increased area source emissions, changes in existing point source emissions which were not subject to preconstruction review, and emissions due to sources with permits to construct that have not yet started operation.

TABLE 8–1.—MODEL EMISSION INPUT DATA FOR POINT SOURCES [1]

Averaging time	Emission limit (#/MMBtu) [2]	×	Operating level (MMBtu/hr) [2]	×	Operating factor (*e.g.*, hr/yr,hr/day)
Stationary Point Source(s) Subject to SIP Emission Limit(s) Evaluation for Compliance with Ambient Standards (Including Areawide Demonstrations)					
Annual & quarterly	Maximum allowable emission limit or federally enforceable permit limit.		Actual or design capacity (whichever is greater), or federally enforceable permit condition.		Actual operating factor averaged over most recent 2 years.[3]
Short term	Maximum allowable emission limit or federally enforceable permit limit.		Actual or design capacity (whichever is greater), or federally enforceable permit condition [4].		Continuous operation, *i.e.*, all hours of each time period under consideration (for all hours of the meteorological data base).[5]
Nearby Source(s) [6, 7]—Same input requirements as for stationary point source(s) above					
Other Source(s) [7]—If modeled (Section 8.2.3), input data requirements are defined below					
Annual & quarterly	Maximum allowable emission limit or federally enforceable permit limit [6].		Annual level when actually operating, averaged over the most recent 2 years [3].		Actual operating factor averaged over the most recent 2 years.[3]
Short term	Maximum allowable emission limit or federally enforceable permit limit [6].		Annual level when actually operating, averaged over the most recent 2 years [3].		Continuous operation, *i.e.*, all hours of each time period under consideration (for all hours of the meteorological data base).[5]

[1] The model input data requirements shown on this table apply to stationary source control strategies for STATE IMPLEMENTATION PLANS. For purposes of emissions trading, new source review, or prevention of significant deterioration, other model input criteria may apply. Refer to the policy and guidance for these programs to establish the input data.

[2] Terminology applicable to fuel burning sources; analogous terminology (*e.g., #*/throughput) may be used for other types of sources.

[3] Unless it is determined that this period is not representative.

[4] Operating levels such as 50 percent and 75 percent of capacity should also be modeled to determine the load causing the highest concentration.

[5] If operation does not occur for all hours of the time period of consideration (*e.g.*, 3 or 24 hours) and the source operation is constrained by a federally enforceable permit condition, an appropriate adjustment to the modeled emission rate may be made (*e.g.*, if operation is only 8 a.m. to 4 p.m. each day, only these hours will be modeled with emissions from the source. Modeled emissions should not be averaged across non-operating time periods.)

[6] See paragraph 8.2.3(c).

[7] See paragraph 8.2.3(d).

TABLE 8–2.—POINT SOURCE MODEL INPUT DATA (EMISSIONS) FOR PSD NAAQS COMPLIANCE DEMONSTRATIONS

Averaging time	Emission limit (#/MMBtu) [1]	×	Operating level (MMBtu/hr) [1]	×	Operating factor (e.g., hr/yr,hr/day)
Proposed Major New or Modified Source					
Annual & quarterly	Maximum allowable emission limit or federally enforceable permit limit.		Design capacity or federally enforceable permit condition.		Continuous operation (i.e., 8760 hours).[2]

TABLE 8–2.—POINT SOURCE MODEL INPUT DATA (EMISSIONS) FOR PSD NAAQS COMPLIANCE DEMONSTRATIONS—Continued

Averaging time	Emission limit (#/MMBtu)[1]	×	Operating level (MMBtu/hr)[1]	×	Operating factor (e.g., hr/yr,hr/day)
Short term: (≤24 hours)	Maximum allowable emis sion limit or federally enforceable permit limit.		Design capacity or federally enforceable permit condition[3].		Continuous operation (i.e., all hours of each time period un der consideration) (for all hours of the meteorological data base).[2]
			Nearby Source(s)[4,6]		
Annual & quarterly	Maximum allowable emission limit or federally enforceable permit limit[5].		Actual or design capacity (whichever is greater), or federally enforceable permit condition.		Actual operating factor averaged over the most recent 2 years.[7,8]
Short term: (≤24 hours)	Maximum allowable emission limit or federally enforceable permit limit[5].		Actual or design capacity (whichever is greater), or federally enforceable permit condition[3].		Continuous operation (i.e., all hours of each time period un der consideration) (for all hours of the meteorological data base).[2]
			Other Source(s)[6,9]		
Annual & quarterly	Maximum allowable emission limit or federally enforceable permit limit[5].		Annual level when actually operating, averaged over the most recent 2 years[7].		Actual operating factor averaged over the most recent 2 years.[7,8]
Short term (≤24 hours)	Maximum allowable emission limit or federally enforceable permit limit[5].		Annual level when actually operating, averaged over the most recent 2 years[7].		Continuous operation (*i.e.*, all hours of each time period under consideration) (for all hours of the meteorological data base).[2]

[1] Terminology applicable to fuel burning sources; analogous terminology (*e.g., #*/throughput) may be used for other types of sources.
[2] If operation does not occur for all hours of the time period of consideration (e.g., 3 or 24 hours) and the source operation is constrained by a federally enforceable permit condition, an appropriate adjustment to the modeled emission rate may be made (e.g., if operation is only 8:00 a.m. to 4:00 p.m. each day, only these hours will be modeled with emissions from the source. Modeled emissions should not be averaged across non-operating time periods.
[3] Operating levels such as 50 percent and 75 percent of capacity should also be modeled to determine the load causing the highest concentration.
[4] Includes existing facility to which modification is proposed if the emissions from the existing facility will not be affected by the modification. Otherwise use the same parameters as for major modification.
[5] See paragraph 8.2.3(c).
[6] See paragraph 8.2.3(d).
[7] Unless it is determined that this period is not representative.
[8] For those permitted sources not in operation or that have not established an appropriate factor, continuous operation (i.e., 8760) should be used.
[9] Generally, the ambient inpacts from non-nearby (background) sources can be represented by air quality data unless adequate data do not exist.

8.2 Background Concentrations

8.2.1 Discussion

a. Background concentrations are an essential part of the total air quality concentration to be considered in determining source impacts. Background air quality includes pollutant concentrations due to: (1) natural sources; (2) nearby sources other than the one(s) currently under consideration; and (3) unidentified sources.

b. Typically, air quality data should be used to establish background concentrations in the vicinity of the source(s) under consideration. The monitoring network used for background determinations should conform to the same quality assurance and other requirements as those networks established for PSD purposes.[89] An appropriate data validation procedure should be applied to the data prior to use.

c. If the source is not isolated, it may be necessary to use a multi-source model to establish the impact of nearby sources. Since sources don't typically operate at their maximum allowable capacity (which may include the use of ''dirtier'' fuels), modeling is necessary to express the potential contribution of background sources, and this impact would not be captured via monitoring. Background concentrations should be determined for each critical (concentration) averaging time.

8.2.2 Recommendations (Isolated Single Source)

a. Two options (paragraph 8.2.2b or c) are available to determine the background concentration near isolated sources.

b. Use air quality data collected in the vicinity of the source to determine the background concentration for the averaging times of concern. Determine the mean background concentration at each monitor by excluding values when the source in question is impacting the monitor. The mean annual background is the average of the annual concentrations so determined at each monitor. For shorter averaging periods, the meteorological conditions accompanying the concentrations of concern should be identified. Concentrations for meteorological conditions of concern, at monitors not impacted by the source in question, should be averaged for each separate averaging time to determine the average background value. Monitoring sites inside a 90° sector downwind of the source may be used to determine the area of impact. One hour concentrations may be added and averaged to determine longer averaging periods.

c. If there are no monitors located in the vicinity of the source, a ''regional site'' may be used to determine background. A ''regional site'' is one that is located away from the area of interest but is impacted by similar natural and distant man-made sources.

8.2.3 Recommendations (Multi-Source Areas)

a. In multi-source areas, two components of background should be determined: contributions from nearby sources and contributions from other sources.

b. *Nearby Sources:* All sources expected to cause a significant concentration gradient in the vicinity of the source or sources under consideration for emission limit(s) should be explicitly modeled. The number of such sources is expected to be small except in unusual situations. Owing to both the uniqueness of each modeling situation and the large number of variables involved in identifying nearby sources, no attempt is made here to comprehensively define this term. Rather, identification of nearby sources calls for the exercise of professional judgement by the reviewing authority. This guidance is not intended to alter the exercise of that judgement or to comprehensively define which sources are nearby sources.

c. For compliance with the short-term and annual ambient standards, the nearby sources as well as the primary source(s) should be evaluated using an appropriate Appendix A model with the emission input data shown in Table 8–1 or 8–2. When modeling a nearby source that does not have a permit and the emission limit contained in the SIP for a particular source category is greater than the emissions possible given the source's maximum physical capacity to emit, the ''maximum allowable emission limit'' for such a nearby source may be calculated as the emission rate representative of the nearby source's maximum physical capacity to emit, considering its design specifications and allowable fuels and process materials. However, the burden is on the permit applicant to sufficiently document what the maximum physical capacity to emit is for such a nearby source.

d. It is appropriate to model nearby sources only during those times when they, by their nature, operate at the same time as the primary source(s) being modeled. Where a primary source believes that a nearby source does not, by its nature, operate at the same time as the primary source being modeled, the burden is on the primary source to demonstrate to the satisfaction of the reviewing authority that this is, in fact, the case. Whether or not the primary source has adequately demonstrated that fact is a matter of professional judgement left to the discretion of the reviewing authority. The following examples illustrate two cases in which a nearby source may be shown not to operate at the same time as the primary source(s) being modeled. Some sources are only used during certain seasons of the year. Those sources would not be modeled as nearby sources during times in which they do not operate. Similarly, emergency backup generators that never operate simultaneously with the sources that they back up would not be modeled as nearby sources. To reiterate, in these examples and other appropriate cases, the burden is on the primary source being modeled to make the appropriate demonstration to the satisfaction of the reviewing authority.

e. The impact of the nearby sources should be examined at locations where interactions between the plume of the point source under consideration and those of nearby sources (plus natural background) can occur. Significant locations include: (1) The area of maximum impact of the point source; (2) the area of maximum impact of nearby sources; and (3) the area where all sources combine to cause maximum impact. These locations may be identified through trial and error analyses.

f. *Other Sources:* That portion of the background attributable to all other sources (*e.g.,* natural sources, minor sources and distant major sources) should be determined by the procedures found in Section 8.2.2 or by application of a model using Table 8–1 or 8–2.

8.3 Meteorological Input Data

a. The meteorological data used as input to a dispersion model should be selected on the basis of spatial and climatological (temporal) representativeness as well as the ability of the individual parameters selected to characterize the transport and dispersion conditions in the area of concern. The representativeness of the data is dependent on: (1) The proximity of the meteorological monitoring site to the area under consideration; (2) the complexity of the terrain; (3) the exposure of the meteorological monitoring site; and (4) the period of time during which data are collected. The spatial representativeness of the data can be adversely affected by large distances between the source and receptors of interest and the complex topographic characteristics of the area. Temporal representativeness is a function of the year-to-year variations in weather conditions. Where appropriate, data representativeness should be viewed in terms of the appropriateness of the data for constructing realistic boundary layer profiles and three dimensional meteorological fields, as described in paragraphs 8.3c and d.

b. Model input data are normally obtained either from the National Weather Service or as part of an site-specific measurement program. Local universities, Federal Aviation Administration (FAA), military stations, industry and pollution control agencies may also be sources of such data. Some recommendations for the use of each type of data are included in this subsection.

c. Regulatory application of AERMOD requires careful consideration of minimum data for input to AERMET. Data representativeness, in the case of AERMOD, means utilizing data of an appropriate type for constructing realistic boundary layer profiles. Of paramount importance is the requirement that all meteorological data used as input to AERMOD must be both laterally and vertically representative of the transport and dispersion within the analysis domain. The representativeness of data that were collected off-site should be judged, in part, by comparing the surface characteristics in the vicinity of the meteorological monitoring site with the surface characteristics that generally describe the analysis domain. Furthermore, since the spatial scope of each variable could be different, representativeness should be judged for each variable separately. For example, for a variable such as wind direction, the data may need to be collected very near plume height to be adequately representative, whereas, for a variable such as temperature, data from a station several kilometers away from the source may in some cases be considered to be adequately representative.

d. For long range transport modeling assessments (as discussed in Section 6.2.3) or in assessments where the transport winds are complex and the application involves a non-steady-state dispersion model (as discussed in Section 7.2.8), use of output from prognostic mesoscale meteorological models is encouraged.[90 91 92] Some diagnostic meteorological processors are designed to appropriately blend available NWS comparable meteorological observations, local site-specific meteorological observations, and prognostic mesoscale meteorological data, using empirical relationships, to diagnostically adjust the wind field for mesoscale and local-scale effects. These diagnostic adjustments can sometimes be improved through the use of strategically placed site-specific meteorological observations. The placement of these special meteorological observations (often more than one location is needed) involves expert judgement, and is specific to the terrain and land use of the modeling domain.

8.3.1 Length of Record of Meteorological Data

8.3.1.1 Discussion

a. The model user should acquire enough meteorological data to ensure that worst-case meteorological conditions are adequately represented in the model results. The trend toward statistically based standards suggests a need for all meteorological conditions to be adequately represented in the data set selected for model input. The number of years of record needed to obtain a stable distribution of conditions depends on the variable being measured and has been estimated by Landsberg and Jacobs[93] for various parameters. Although that study indicates in excess of 10 years may be required to achieve stability in the frequency distributions of some meteorological variables, such long periods are not reasonable for model input data. This is due in part to the fact that hourly data in model input format are frequently not available for such periods and that hourly calculations of concentration for long periods may be prohibitively expensive. Another study[94] compared various periods from a 17-year data set to determine the minimum number of years of data needed to approximate the concentrations modeled with a 17-year period of meteorological data from one station. This study indicated that the variability of model estimates due to the meteorological data input was adequately reduced if a 5-year period of record of meteorological input was used.

8.3.1.2 Recommendations

a. Five years of representative meteorological data should be used when estimating concentrations with an air quality model. Consecutive years from the most recent, readily available 5-year period are preferred. The meteorological data should be adequately representative, and may be site specific or from a nearby NWS station.

b. The use of 5 years of NWS meteorological data or at least 1 year of site-specific data is required. If one year or more (including partial years), up to five years, of site-specific data is available, these data are preferred for use in air quality analyses. Such data should have been subjected to quality assurance procedures as described in Section 8.3.3.2.

c. For permitted sources whose emission limitations are based on a specific year of meteorological data, that year should be added to any longer period being used (*e.g.,* 5 years of NWS data) when modeling the facility at a later time.

d. For LRT situations (as discussed in Section 6.2.3) and for complex wind situations (as discussed in paragraph 7.2.8(a)), if only NWS or comparable standard meteorological observations are employed, five years of meteorological data (within and near the modeling domain) should be used. Consecutive years from the most recent, readily available 5-year period are preferred. Less than five years of meteorological data may be used if mesoscale meteorological fields are available, as discussed in paragraph 8.3(d). These mesoscale meteorological fields should be used in conjunction with available standard NWS or comparable meteorological observations within and near the modeling domain. If site-specific meteorological data are available, these data may be especially helpful for local-scale complex wind situations, when appropriately blended together with standard NWS or comparable observations and mesoscale meteorological fields.

8.3.2 National Weather Service Data

8.3.2.1 Discussion

a. The NWS meteorological data are routinely available and familiar to most model users. Although the NWS does not provide direct measurements of all the needed dispersion model input variables, methods have been developed and successfully used to translate the basic NWS data to the needed model input. Direct measurements of model input parameters have been made for limited model studies and those methods and techniques are becoming more widely applied; however, many model applications still rely heavily on the NWS data.

b. Many models use the standard hourly weather observations available from the National Climatic Data Center (NCDC). These observations are then ''preprocessed'' before they can be used in the models.

8.3.2.2 Recommendations

a. The preferred models listed in Appendix A all accept as input the NWS meteorological data preprocessed into model compatible form. If NWS sata are judged to be adequately representative for a particular modeling application, they may be used. NCDC makes available surface [95 96] and upper air [97] meteorological data in CD–ROM format.

b. Although most NWS measurements are made at a standard height of 10 meters, the actual anemometer height should be used as input to the preferred model. Note that AERMOD at a minimum requires wind observations at a height above ground between seven times the local surface roughness height and 100 meters.

c. Wind directions observed by the National Weather Service are reported to the nearest 10 degrees. A specific set of randomly generated numbers has been developed for use with the preferred EPA models and should be used to ensure a lack of bias in wind direction assignments within the models.

d. Data from universities, FAA, military stations, industry and pollution control agencies may be used if such data are equivalent in accuracy and detail to the NWS data, and they are judged to be adequately representative for the particular application.

8.3.3 Site-Specific Data

8.3.3.1 Discussion

a. Spatial or geographical representativeness is best achieved by collection of all of the needed model input data in close proximity to the actual site of the source(s). Site-specific measured data are therefore preferred as model input, provided that appropriate instrumentation and quality assurance procedures are followed and that the data collected are adequately representative (free from undue local or ''micro'' influences) and compatible with the input requirements of the model to be used. It should be noted that, while site-specific measurements are frequently made ''on-property'' (*i.e.,* on the source's premises), acquisition of adequately representative site-specific data does not preclude collection of data from a location off property. Conversely, collection of meteorological data on property does not of itself guarantee adequate representativeness. For help in determining representativeness of site-specific measurements, technical guidance [98] is available. Site-specific data should always be reviewed for consistency by a qualified meteorologist.

8.3.3.2 Recommendations

a. EPA guidance [98] provides recommendations on the collection and use of site-specific meteorological data. Recommendations on characteristics, siting, and exposure of meteorological instruments and on data recording, processing, completeness requirements, reporting, and archiving are also included. This publication should be used as a supplement to other limited guidance on these subjects.[89] Detailed information on quality assurance is also available.[99] As a minimum, site-specific measurements of ambient air temperature, transport wind speed and direction, and the variables necessary to estimate atmospheric dispersion should be available in meteorological data sets to be used in modeling. Care should be taken to ensure that meteorological instruments are located to provide representative characterization of pollutant transport between sources and receptors of interest. The Regional Office will determine the appropriateness of the measurement locations.

b. All site-specific data should be reduced to hourly averages. Table 8–3 lists the wind related parameters and the averaging time requirements.

c. *Missing Data Substitution.* After valid data retrieval requirements have been met, hours in the record having missing data should be treated according to an established data substitution protocol provided that data from an adequately representative alternative site are available. Such protocols are usually part of the approved monitoring program plan. Data substitution guidance is provided in Section 5.3 of reference 98. If no representative alternative data are available for substitution, the absent data should be coded as missing using missing data codes appropriate to the applicable meteorological pre-processor. Appropriate model options for treating missing data, if available in the model, should be employed.

d. *Solar Radiation Measurements.* Total solar radiation or net radiation should be measured with a reliable pyranometer or net radiometer, sited and operated in accordance with established site-specific meteorological guidance.[98 99]

e. *Temperature Measurements.* Temperature measurements should be made at standard shelter height (2m) in accordance with established site-specific meteorological guidance.[98]

f. *Temperature Difference Measurements.* Temperature difference (ΔT) measurements should be obtained using matched thermometers or a reliable thermocouple system to achieve adequate accuracy. Siting, probe placement, and operation of ΔT systems should be based on guidance found in Chapter 3 of reference 98, and such guidance should be followed when obtaining vertical temperature gradient data for use in plume rise estimates or in determining the critical dividing streamline height.

g. *Winds Aloft.* For simulation of plume rise and dispersion of a plume emitted from a stack, characterization of the wind profile up through the layer in which the plume disperses is required. This is especially important in complex terrain and/or complex wind situations. For tall stacks when site specific data are needed, these winds have been obtained traditionally using meteorological sensors mounted on tall towers. A feasible alternative to tall towers is the use of meteorological remote sensing instruments (*e.g.,* acoustic sounders or radar wind profilers) to provide winds aloft, coupled with 10-meter towers to provide the near-surface winds. (For specific requirements for AERMOD and CTDMPLUS, see Appendix A.) Specifications for wind measuring instruments and systems are contained in reference 98.

h. *Turbulence.* There are several dispersion models that are capable of using direct measurements of turbulence (wind fluctuation) in the characterization of the vertical and lateral dispersion (*e.g.,* CTDMPLUS, AERMOD, CALPUFF). For specific requirements for CTDMPLUS, AERMOD and CALPUFF, see Appendix A. For technical guidance on measurement and processing of turbulence parameters, see reference 98. When turbulence data are used in this manner to directly characterize the vertical and lateral dispersion, the averaging time for the turbulence measurements should be one hour (Table 8–3). There are other dispersion models (*e.g.,* ISC-PRIME, BLP, and CALINE3) that employ P–G stability categories for the characterization of the vertical and lateral dispersion. Methods for using site-specific turbulence data for the characterization of P–G stability categories are discussed in reference 98. When turbulence data are used in this manner to determine the P–G stability category, the averaging time for the turbulence measurements should be 15-minutes.

i. *Stability Categories.* For dispersion models that employ P–G stability categories for the characterization of the vertical and lateral dispersion (*e.g.,* ISC-PRIME), the P–G stability categories, as originally defined, couple near-surface measurements of wind speed with subjectively determined insolation assessments based on hourly cloud cover and ceiling height observations. The wind speed measurements are made at or near 10m. The insolation rate is typically assessed using observations of cloud cover and ceiling height based on criteria outlined by Turner.[74] It is recommended that the P–G stability category be estimated using the Turner method with site-specific wind speed measured at or near 10m and representative cloud cover and ceiling height. Implementation of the Turner method, as well as considerations in determining representativeness of cloud cover and ceiling height in cases for which site-specific cloud observations are unavailable, may be found in Section 6 of reference 98. In the absence of requisite data to implement the Turner method, the SRDT method or wind fluctuation statistics (*i.e.,* the σ_E and σ_A methods) may be used.

j. The SRDT method, described in Section 6.4.4.2 of reference 98, is modified slightly from that published from earlier work [100] and has been evaluated with three site-specific data bases.[101] The two methods of stability classification which use wind fluctuation statistics, the σ_E and σ_A methods, are also described in detail in Section 6.4.4 of reference 106 (note applicable tables in Section 6). For additional information on the wind fluctuation methods, several references are available.[102 103 104 105]

k. *Meteorological Data Preprocessors.* The following meteorological preprocessors are recommended by EPA: AERMET,[106] PCRAMMET,[107] MPRM,[108] METPRO,[109] and CALMET. [110] AERMET, which is patterned after MPRM, should be used to preprocess all data for use with AERMOD. Except for applications that employ AERMOD, PCRAMMET is the recommended meteorological preprocessor for use in applications employing hourly NWS data. MPRM is a general purpose meteorological data preprocessor which supports regulatory models requiring PCRAMMET formatted (NWS) data. MPRM is available for use in applications employing site-specific meteorological data. The latest version (MPRM 1.3) has been configured to implement the SRDT method for estimating P–G stability categories. METPRO is the required meteorological data preprocessor for use with CTDMPLUS. CALMET is available for use with applications of CALPUFF. All of the above mentioned data preprocessors are available for downloading from EPA's Internet SCRAM website (Section 2.3).

TABLE 8–3.—AVERAGING TIMES FOR SITE-SPECIFIC WIND AND TURBULENCE MEASUREMENTS

Parameter	Averaging time (hours)
Surface wind speed (for use in stability determinations)	1
Transport direction	1
Dilution wind speed	1
Turbulence measurements (σ_E and σ_A) for use in stability determinations	([1])
Turbulence Measurements for direct input to dispersion models	1

[1] To minimize meander effects in σ_A when wind conditions are light and/or variable, determine the hourly average σ value from four sequential 15-minute σ's according to the following formula:

$$\sigma_{1\text{-hr}} = \sqrt{\frac{\sigma_{15}^2 + \sigma_{15}^2 + \sigma_{15}^2 + \sigma_{15}^2}{4}}$$

8.3.4 Treatment of Calms

8.3.4.1 Discussion

a. Treatment of calm or light and variable wind poses a special problem in model applications since steady-state Gaussian plume models assume that concentration is inversely proportional to wind speed. Furthermore, concentrations may become unrealistically large when wind speeds less than l m/s are input to the model. Procedures have been developed to prevent the occurrence of overly conservative concentration estimates during periods of calms. These procedures acknowledge that a steady-state Gaussian plume model does not apply during calm conditions, and that our knowledge of wind patterns and plume behavior during these conditions does not, at present, permit the development of a better technique. Therefore, the procedures disregard hours which are identified as calm. The hour is treated as missing and a convention for handling missing hours is recommended.

b. NWS meteorological data preprocessed by PCRAMMET for input to ISC–PRIME may take one of two formats: ASCII or binary (unformatted). If the format is ASCII, PCRAMMET does not modify wind speeds having a value of zero. If the format is binary and PCRAMMET detects the occurrence of a calm, it sets the wind speed value of zero to 1.00 m/s and repeats the wind direction from the previous non-calm hour. Models such as ISC–PRIME identify the original calm cases by checking for the occurrence of a 1.00 m/s wind speed coincident with a wind direction equal to that for the previous hour. ISC–PRIME then treats these calm hours as missing, and no concentration is calculated.

c. AERMOD, while fundamentally a steady-state Gaussian plume model, contains improved algorithms for dealing with low wind speed (near calm) conditions. As a result, AERMOD can produce model estimates for conditions when the wind speed may be less than 1 m/s, but still greater than the instrument threshold. Required input to AERMET, the meteorological processor for AERMOD, includes a threshold wind speed and a reference wind speed. The threshold wind speed is typically the threshold of the instrument used to collect the wind speed data. The reference wind speed is selected by the model as the lowest level of non-missing wind speed and direction data where the speed is greater than the wind speed threshold, and the height of the measurement is between seven times the local surface roughness and 100 meters. If the only valid observation of the reference wind speed between these heights is less than the threshold, the hour is considered calm, and no concentration is calculated. None of the observed wind speeds in a measured wind profile that are less than the threshold speed are used in construction of the modeled wind speed profile in AERMOD.

8.3.4.2 Recommendations

a. Hourly concentrations calculated with steady-state Gaussian plume models using calms should not be considered valid; the wind and concentration estimates for these hours should be disregarded and considered to be missing. Critical concentrations for 3-, 8-, and 24-hour averages should be calculated by dividing the sum of the hourly concentrations for the period by the number of valid or non-missing hours. If the total number of valid hours is less than 18 for 24-hour averages, less than 6 for 8-hour averages or less than 3 for 3-hour averages, the total concentration should be divided by 18 for the 24-hour average, 6 for the 8-hour average and 3 for the 3-hour average. For annual averages, the sum of all valid hourly concentrations is divided by the number of non-calm hours during the year. ISC–PRIME and AERMOD have been coded to implement these instructions. For other models listed in Appendix A, a post-processor computer program, CALMPRO [111] has been prepared, is available on the SCRAM Internet website (Section 2.3), and should be used.

b. Stagnant conditions that include extended periods of calms often produce high concentrations over wide areas for relatively long averaging periods. The standard steady-state Gaussian plume models are often not applicable to such situations. When stagnation conditions are of concern, other modeling techniques should be considered on a case-by-case basis (see also Section 7.2.8).

c. When used in steady-state Gaussian plume models except AERMOD, measured site-specific wind speeds of less than l m/s but higher than the response threshold of the instrument should be input as l m/s; the corresponding wind direction should also be input. Wind observations below the response threshold of the instrument should be set to zero, with the input file in ASCII format. For input to AERMOD, no adjustment should be made to the site-specific wind data. In all cases involving steady-state Gaussian plume models, calm hours should be treated as missing, and concentrations should be calculated as in paragraph 8.3.4.2a.

9.0 Accuracy and Uncertainty of Models

9.1 Discussion

a. Increasing reliance has been placed on concentration estimates from models as the primary basis for regulatory decisions concerning source permits and emission control requirements. In many situations, such as review of a proposed source, no practical alternative exists. Therefore, there is an obvious need to know how accurate models really are and how any uncertainty in the estimates affects regulatory decisions. EPA recognizes the need for incorporating such information and has sponsored workshops [112] on model accuracy, the possible ways to quantify accuracy, and on considerations in the incorporation of model accuracy and uncertainty in the regulatory process. The Second (EPA) Conference on Air Quality Modeling, August 1982,[113] was devoted to that subject.

9.1.1 Overview of Model Uncertainty

a. Dispersion models generally attempt to estimate concentrations at specific sites that really represent an ensemble average of numerous repetitions of the same event. The event is characterized by measured or ‘‘known’’ conditions that are input to the models, *e.g.,* wind speed, mixed layer height, surface heat flux, emission characteristics, etc. However, in addition to the known conditions, there are unmeasured or unknown variations in the conditions of this event, *e.g.,* unresolved details of the atmospheric flow such as the turbulent velocity field. These unknown conditions, may vary among repetitions of the event. As a result, deviations in observed concentrations from their ensemble average, and from the concentrations estimated by the model, are likely to occur even though the known conditions are fixed. Even with a perfect model that predicts the correct ensemble average, there are likely to be deviations from the observed concentrations in individual repetitions of the event, due to variations in the unknown conditions. The statistics of these concentration residuals are termed ‘‘inherent’’ uncertainty. Available evidence suggests that this source of uncertainty alone may be responsible for a typical range of variation in concentrations of as much as ±50 percent.[114]

b. Moreover, there is ‘‘reducible’’ uncertainty [115] associated with the model and its input conditions; neither models nor data bases are perfect. Reducible uncertainties are caused by: (1) Uncertainties in the input values of the known conditions (*i.e.,* emission characteristics and meteorological data); (2) errors in the measured concentrations which are used to compute the concentration residuals; and (3) inadequate model physics and formulation. The ‘‘reducible’’ uncertainties can be minimized through better (more accurate and more representative) measurements and better model physics.

c. To use the terminology correctly, reference to model accuracy should be limited to that portion of reducible uncertainty which deals with the physics and the formulation of the model. The accuracy of the model is normally determined by an evaluation procedure which involves the comparison of model concentration estimates with measured air quality data.[116] The statement of accuracy is based on statistical tests or performance measures such as bias, noise, correlation, *etc.*[17] However, information that allows a distinction between contributions of the various elements of inherent and reducible uncertainty is only now beginning to emerge. As a result most discussions of the accuracy of models make no quantitative distinction between (1) limitations of the model versus (2) limitations of the data base and of knowledge concerning atmospheric variability. The reader should be aware that statements on model accuracy and uncertainty may imply the need for improvements in model performance that even the ‘‘perfect’’ model could not satisfy.

9.1.2 Studies of Model Accuracy

a. A number of studies [117] [118] have been conducted to examine model accuracy, particularly with respect to the reliability of short-term concentrations required for ambient standard and increment evaluations. The results of these studies are not surprising. Basically, they confirm what leading atmospheric scientists have said for some time: (1) models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and (2) the models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ±10 to 40 percent are found to be typical,[119] *i.e.,* certainly well within the often quoted factor-of-two accuracy that has long been recognized for these models. However, estimates of concentrations that occur at a specific time and site, are poorly correlated with actually observed concentrations and are much less reliable.

b. As noted in paragraph 9.1.2 a, poor correlations between paired concentrations at fixed stations may be due to ‘‘reducible’’ uncertainties in knowledge of the precise plume location and to unquantified inherent uncertainties. For example, Pasquill [120] estimates that, apart from data input errors, maximum ground-level concentrations at a given hour for a point source in flat terrain could be in error by 50 percent due to these uncertainties. Uncertainty of five to 10 degrees in the measured wind direction, which transports the plume, can result in concentration errors of 20 to 70 percent for a particular time and location, depending on stability and station location. Such uncertainties do not indicate that an estimated concentration does not occur, only that the precise time and locations are in doubt.

9.1.3 Use of Uncertainty in Decision-Making

a. The accuracy of model estimates varies with the model used, the type of application, and site-specific characteristics. Thus, it is desirable to quantify the accuracy or uncertainty associated with concentration estimates used in decision-making. Communications between modelers and decision-makers must be fostered and further developed. Communications concerning concentration estimates currently exist in most cases, but the communications dealing with the accuracy of models and its meaning to the decision-maker are limited by the lack of a technical basis for quantifying and directly including uncertainty in decisions. Procedures for quantifying and interpreting uncertainty in the practical application of such concepts are only beginning to evolve; much study is still required.[112] [113] [115]

b. In all applications of models an effort is encouraged to identify the reliability of the model estimates for that particular area and to determine the magnitude and sources of error associated with the use of the model. The analyst is responsible for recognizing and quantifying limitations in the accuracy, precision and sensitivity of the procedure. Information that might be useful to the decision-maker in recognizing the seriousness of potential air quality violations includes such model accuracy estimates as accuracy of peak predictions, bias, noise, correlation, frequency distribution, spatial extent of high concentration, *etc.* Both space/time pairing of estimates and measurements and unpaired comparisons are recommended. Emphasis should be on the highest concentrations and the averaging times of the standards or increments of concern. Where possible, confidence intervals about the statistical values should be provided. However, while such information can be provided by the modeler to the decision-maker, it is unclear how this information should be used to make an air pollution control decision. Given a range of possible outcomes, it is easiest and tends to ensure consistency if the decision-maker confines his judgement to use of the ‘‘best estimate’’ provided by the modeler (*i.e.,* the design concentration estimated by a model recommended in the Guideline or an alternate model of known accuracy). This is an indication of the practical limitations imposed by current abilities of the technical community.

c. To improve the basis for decision-making, EPA has developed and is continuing to study procedures for determining the accuracy of models, quantifying the uncertainty, and expressing confidence levels in decisions that are made concerning emissions controls.[121 122] However, work in this area involves ''breaking new ground'' with slow and sporadic progress likely. As a result, it may be necessary to continue using the ''best estimate'' until sufficient technical progress has been made to meaningfully implement such concepts dealing with uncertainty.

9.1.4 Evaluation of Models

a. A number of actions have been taken to ensure that the best model is used correctly for each regulatory application and that a model is not arbitrarily imposed. First, the Guideline clearly recommends the most appropriate model be used in each case. Preferred models, based on a number of factors, are identified for many uses. General guidance on using alternatives to the preferred models is also provided. Second, the models have been subjected to a systematic performance evaluation and a peer scientific review. Statistical performance measures, including measures of difference (or residuals) such as bias, variance of difference and gross variability of the difference, and measures of correlation such as time, space, and time and space combined as recommended by the AMS Woods Hole Workshop, [17] were generally followed. Third, more specific information has been provided for justifying the site specific use of alternative models in previously cited EPA guidance.[25 27] Together these documents provide methods that allow a judgement to be made as to what models are most appropriate for a specific application. For the present, performance and the theoretical evaluation of models are being used as an indirect means to quantify one element of uncertainty in air pollution regulatory decisions.

b. In addition to performance evaluation of models, sensitivity analyses are encouraged since they can provide additional information on the effect of inaccuracies in the data bases and on the uncertainty in model estimates. Sensitivity analyses can aid in determining the effect of inaccuracies of variations or uncertainties in the data bases on the range of likely concentrations. Such information may be used to determine source impact and to evaluate control strategies. Where possible, information from such sensitivity analyses should be made available to the decision-maker with an appropriate interpretation of the effect on the critical concentrations.

9.2 Recommendations

a. No specific guidance on the quantification of model uncertainty for use in decision-making is being given at this time. As procedures for considering uncertainty develop and become implementable, this guidance will be changed and expanded. For the present, continued use of the ''best estimate'' is acceptable; however, in specific circumstances for O_3, PM–2.5 and regional haze, additional information and/or procedures may be appropriate.[42 43]

10.0 Regulatory Application of Models

10.1 Discussion

a. Procedures with respect to the review and analysis of air quality modeling and data analyses in support of SIP revisions, PSD permitting or other regulatory requirements need a certain amount of standardization to ensure consistency in the depth and comprehensiveness of both the review and the analysis itself. This section recommends procedures that permit some degree of standardization while at the same time allowing the flexibility needed to assure the technically best analysis for each regulatory application.

b. Dispersion model estimates, especially with the support of measured air quality data, are the preferred basis for air quality demonstrations. Nevertheless, there are instances where the performance of recommended dispersion modeling techniques, by comparison with observed air quality data, may be shown to be less than acceptable. Also, there may be no recommended modeling procedure suitable for the situation. In these instances, emission limitations may be established solely on the basis of observed air quality data as would be applied to a modeling analysis. The same care should be given to the analyses of the air quality data as would be applied to a modeling analysis.

c. The current NAAQS for SO_2 and CO are both stated in terms of a concentration not to be exceeded more than once a year. There is only an annual standard for NO_2 and a quarterly standard for Pb. Standards for fine particulate matter (PM–2.5) are expressed in terms of both long-term (annual) and short-term (daily) averages. The long-term standard is calculated using the three year average of the annual averages while the short-term standard is calculated using the three year average of the 98th percentile of the daily average concentration. For PM–10, the convention is to compare the arithmetic mean, averaged over 3 consecutive years, with the concentration specified in the NAAQS (50 $\mu g/m^3$). The 24-hour NAAQS (150 $\mu g/m^3$) is met if, over a 3-year period, there is (on average) no more than one exceedance per year. For ozone the short term 1-hour standard is expressed in terms of an expected exceedance limit while the short term 8-hour standard is expressed in terms of a three year average of the annual fourth highest daily maximum 8-hour value. The NAAQS are subjected to extensive review and possible revision every 5 years.

d. This section discusses general requirements for concentration estimates and identifies the relationship to emission limits. The following recommendations apply to: (1) Revisions of State Implementation Plans and (2) the review of new sources and the prevention of significant deterioration (PSD).

10.2 Recommendations

10.2.1 Analysis Requirements

a. Every effort should be made by the Regional Office to meet with all parties involved in either a SIP revision or a PSD permit application prior to the start of any work on such a project. During this meeting, a protocol should be established between the preparing and reviewing parties to define the procedures to be followed, the data to be collected, the model to be used, and the analysis of the source and concentration data. An example of requirements for such an effort is contained in the Air Quality Analysis Checklist posted on EPA's Internet SCRAM website (Section 2.3). This checklist suggests the level of detail required to assess the air quality resulting from the proposed action. Special cases may require additional data collection or analysis and this should be determined and agreed upon at this preapplication meeting. The protocol should be written and agreed upon by the parties concerned, although a formal legal document is not intended. Changes in such a protocol are often required as the data collection and analysis progresses. However, the protocol establishes a common understanding of the requirements.

b. An air quality analysis should begin with a screening model to determine the potential of the proposed source or control strategy to violate the PSD increment or NAAQS. For traditional stationary sources, EPA guidance should be followed.[34] Guidance is also available for mobile sources.[56]

c. If the concentration estimates from screening techniques indicate that the PSD increment or NAAQS may be approached or exceeded, then a more refined modeling analysis is appropriate and the model user should select a model according to recommendations in Sections 4–7. In some instances, no refined technique may be specified in this guide for the situation. The model user is then encouraged to submit a model developed specifically for the case at hand. If that is not possible, a screening technique may supply the needed results.

d. Regional Offices should require permit applicants to incorporate the pollutant contributions of all sources into their analysis. Where necessary this may include emissions associated with growth in the area of impact of the new or modified source. PSD air quality assessments should consider the amount of the allowable air quality increment that has already been granted to any other sources. Therefore, the most recent source applicant should model the existing or permitted sources in addition to the one currently under consideration. This would permit the use of newly acquired data or improved modeling techniques if such have become available since the last source was permitted. When remodeling, the worst case used in the previous modeling analysis should be one set of conditions modeled in the new analysis. All sources should be modeled for each set of meteorological conditions selected and for all receptor sites used in the previous applications as well as new sites specific to the new source.

10.2.2 Use of Measured Data in Lieu of Model Estimates

a. Modeling is the preferred method for determining emission limitations for both new and existing sources. When a preferred model is available, model results alone (including background) are sufficient. Monitoring will normally not be accepted as the sole basis for emission limitation. In some instances when the modeling technique available is only a screening technique, the addition of air quality data to the analysis may lend credence to model results.

b. There are circumstances where there is no applicable model, and measured data may need to be used. However, only in the case of an existing source should monitoring data alone be a basis for emission limits. In addition, the following in paragraphs 10.2.2 b.i through iv should be considered prior to the acceptance of the measured data:

i. Does a monitoring network exist for the pollutants and averaging times of concern?

ii. Has the monitoring network been designed to locate points of maximum concentration?

iii. Do the monitoring network and the data reduction and storage procedures meet EPA monitoring and quality assurance requirements?

iv. Do the data set and the analysis allow impact of the most important individual sources to be identified if more than one source or emission point is involved?

v. Is at least one full year of valid ambient data available?

vi. Can it be demonstrated through the comparison of monitored data with model results that available models are not applicable?

c. The number of monitors required is a function of the problem being considered. The source configuration, terrain configuration, and meteorological variations all have an impact on number and placement of monitors. Decisions can only be made on a case-by-case basis. Guidance is available for establishing criteria for demonstrating that a model is not applicable.[25]

d. Sources should obtain approval from the Regional Office or reviewing authority for the monitoring network prior to the start of monitoring. A monitoring protocol agreed to by all concerned parties is highly desirable. The design of the network, the number, type and location of the monitors, the sampling period, averaging time as well as the need for meteorological monitoring or the use of mobile sampling or plume tracking techniques, should all be specified in the protocol and agreed upon prior to start-up of the network.

10.2.3 Emission Limits

10.2.3.1 Design Concentrations

a. Emission limits should be based on concentration estimates for the averaging time that results in the most stringent control requirements. The concentration used in specifying emission limits is called the design value or design concentration and is a sum of the concentration contributed by the source and the background concentration.

b. To determine the averaging time for the design value, the most restrictive NAAQS should be identified by calculating, for each averaging time, the ratio of the difference between the applicable NAAQS (S) and the background concentration (B) to the (model) predicted concentration (P) (*i.e.,* $(S-B)/P$). The averaging time with the lowest ratio identifies the most restrictive standard. If the annual average is the most restrictive, the highest estimated annual average concentration from one or a number of years of data is the design value. When short term standards are most restrictive, it may be necessary to consider a broader range of concentrations than the highest value. For example, for pollutants such as SO_2, the highest, second-highest concentration is the design value. For pollutants with statistically based NAAQS, the design value is found by determining the more restrictive of: (1) The short-term concentration over the period specified in the standard, or (2) the long-term concentration that is not expected to exceed the long-term NAAQS. Determination of design values for PM–10 is presented in more detail in EPA guidance.[44]

10.2.3.2 NAAQS Analyses for New or Modified Sources

a. For new or modified sources predicted to have a significant ambient impact[89] and to be located in areas designated attainment or unclassifiable for the SO_2, Pb, NO_2, or CO NAAQS, the demonstration as to whether the source will cause or contribute to an air quality violation should be based on: (1) The highest estimated annual average concentration determined from annual averages of individual years; or (2) the highest, second-highest estimated concentration for averaging times of 24-hours or less; and (3) the significance of the spatial and temporal contribution to any modeled violation. For Pb, the highest estimated concentration based on an individual calendar quarter averaging period should be used. Background concentrations should be added to the estimated impact of the source. The most restrictive standard should be used in all cases to assess the threat of an air quality violation. For new or modified sources predicted to have a significant ambient impact[89] in areas designated attainment or unclassifiable for the PM–10 NAAQS, the demonstration of whether or not the source will cause or contribute to an air quality violation should be based on sufficient data to show whether: (1) The projected 24-hour average concentrations will exceed the 24-hour NAAQS more than 1 percent of the time, on average ; (2) the expected (*i.e.,* average) annual mean concentration will exceed the annual NAAQS; and (3) the source contributes significantly, in a temporal and spatial sense, to any modeled violation.

10.2.3.3 PSD Air Quality Increments and Impacts

a. The allowable PSD increments for criteria pollutants are established by regulation and cited in 40 CFR 51.166. These maximum allowable increases in pollutant concentrations may be exceeded once per year at each site, except for the annual increment that may not be exceeded. The highest, second-highest increase in estimated concentrations for the short term averages as determined by a model should be less than or equal to the permitted increment. The modeled annual averages should not exceed the increment.

b. Screening techniques defined in Section 4 can sometimes be used to estimate short term incremental concentrations for the first new source that triggers the baseline in a given area. However, when multiple increment-consuming sources are involved in the calculation, the use of a refined model with at least 1 year of on-site or 5 years of off-site NWS data is normally required. In such cases, sequential modeling must demonstrate that the allowable increments are not exceeded temporally and spatially, *i.e.,* for all receptors for each time period throughout the year(s) (time period means the appropriate PSD averaging time, *e.g.,* 3-hour, 24-hour, etc.).

c. The PSD regulations require an estimation of the SO_2, particulate matter (PM–10), and NO_2 impact on any Class I area. Normally, steady-state Gaussian plume models should not be applied at distances greater than can be accommodated by the steady state assumptions inherent in such models. The maximum distance for refined steady-state Gaussian plume model application for regulatory purposes is generally considered to be 50km. Beyond the 50km range, screening techniques may be used to determine if more refined modeling is needed. If refined models are needed, long range transport models should be considered in accordance with Section 6.2.4. As previously noted in Sections 3 and 6, the need to involve the Federal Land Manager in decisions on potential air quality impacts, particularly in relation to PSD Class I areas, cannot be overemphasized.

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Appendix A to Appendix W of Part 51—Summaries of Preferred Air Quality Models

Table of Contents

A.0 Introduction and Availability

(1) This appendix summarizes key features of refined air quality models preferred for specific regulatory applications. For each model, information is provided on availability, approximate cost (where applicable), regulatory use, data input, output format and options, simulation of atmospheric physics, and accuracy. These models may be used without a formal demonstration of applicability provided they satisfy the recommendations for regulatory use; not all options in the models are necessarily recommended for regulatory use.

(2) Many of these models have been subjected to a performance evaluation using comparisons with observed air quality data. Where possible, several of the models contained herein have been subjected to evaluation exercises, including (1) statistical performance tests recommended by the American Meteorological Society and (2) peer scientific reviews. The models in this appendix have been selected on the basis of the results of the model evaluations, experience with previous use, familiarity of the model to various air quality programs, and the costs and resource requirements for use.

(3) With the exception of EDMS, codes and documentation for all models listed in this appendix are available from EPA's Support Center for Regulatory Air Models (SCRAM) website at *www.epa.gov/scram001.* Documentation is also available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161; phone: (800) 553–6847. Where possible, accession numbers are provided.

A.1 AMS/EPA Regulatory Model—AERMOD

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Availability

The model codes and associated documentation are available on EPA's Internet SCRAM website (Section A.0).

Abstract

AERMOD is a steady-state plume dispersion model for assessment of pollutant concentrations from a variety of sources. AERMOD simulates transport and dispersion from multiple point, area, or volume sources based on an up-to-date characterization of the atmospheric boundary layer. Sources may be located in rural or urban areas, and receptors may be located in simple or complex terrain. AERMOD accounts for building wake effects (*i.e.,* plume downwash). The model employs hourly sequential preprocessed meteorological data to estimate concentrations for averaging times from one hour to one year. AERMOD is designed to operate in concert with two pre-processor codes: AERMET processes meteorological data for input to AERMOD, and AERMAP processes terrain elevation data and generates receptor information for input to AERMOD.

a. Recommendations for Regulatory Use

(1) AERMOD is appropriate for the following applications:

- Point, volume, and area sources;
- Surface, near-surface, and elevated releases;
- Rural or urban areas;
- Simple and complex terrain;
- Transport distances over which steady-state assumptions are appropriate, up to 50 km;
- 1-hour to annual averaging times; and
- Continuous toxic air emissions.

(2) For regulatory applications of AERMOD, the regulatory default option should be set, *i.e.,* the parameter DFAULT should be employed in the MODELOPT record in the COntrol Pathway. The DFAULT option requires the use of terrain elevation data, stack-tip downwash, sequential date checking, and does not permit the use of the model in the SCREEN mode. In the regulatory default mode, pollutant half life or decay options are not employed, except in the case of an urban source of sulfur dioxide where a four-hour half life is applied. Terrain elevation data from the U.S. Geological Survey 7.5-Minute Digital Elevation Model (edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html) or equivalent (approx. 30-meter resolution) should be used in all applications. In some cases, exceptions of the terrain data requirement may be made in consultation with the permit/SIP reviewing authority.

b. Input Requirements

(1) Source data: Required input includes source type, location, emission rate, stack height, stack inside diameter, stack gas exit velocity, stack gas temperature, area and volume source dimensions, and source elevation. Building dimensions and variable emission rates are optional.

(2) Meteorological data: The AERMET meteorological preprocessor requires input of surface characteristics, including surface roughness (z_o), Bowen ratio, and albedo by sector and season or month, as well as, hourly observations of wind speed between $7z_o$ and 100m (reference wind speed measurement from which a vertical profile can be developed), wind direction, cloud cover, and temperature between z_o and 100m (reference temperature measurement from which a vertical profile can be developed). A morning sounding (in National Weather Service format) from a representative upper air station, latitude, longitude, time zone, and wind speed threshold are also required in AERMET. Additionally, measured profiles of wind, temperature, vertical and lateral turbulence may be required in certain applications (*e.g.,* in complex terrain) to adequately represent the meteorology affecting plume transport and dispersion. Optionally, measurements of solar, or net radiation may be input to AERMET. Two files are produced by the AERMET meteorological preprocessor for input to the AERMOD dispersion model. The surface file contains observed and calculated surface variables, one record per hour. The profile file contains the observations made at each level of a meteorological tower (or remote sensor), or the one-level observations taken from other representative data (*e.g.,* National Weather Service surface observations), one record per level per hour.

(i) Data used as input to AERMET should possess an adequate degree of representativeness to insure that the wind, temperature and turbulence profiles derived by AERMOD are both laterally and vertically representative of the source area. The adequacy of input data should be judged independently for each variable. The values for surface roughness, Bowen ratio, and albedo should reflect the surface characteristics in the vicinity of the meteorological tower, and should be adequately representative of the modeling domain. Finally, the primary atmospheric input variables including wind speed and direction, ambient temperature, cloud cover, and a morning upper air sounding should also be adequately representative of the source area.

(ii) For recommendations regarding the length of meteorological record needed to perform a regulatory analysis with AERMOD, see Section 8.3.1.

(3) Receptor data: Receptor coordinates, elevations, height above ground, and height scales are produced by the AERMAP terrain preprocessor for input to AERMOD. Discrete receptors and/or multiple receptor grids, Cartesian and/or polar, may be employed in AERMOD. AERMAP requires input of Digital Elevation Model (DEM) terrain data produced by the U.S. Geological Survey (USGS), or other equivalent data. AERMAP can be used optionally to estimate source elevations.

c. Output

Printed output options include input information, high concentration summary tables by receptor for user-specified averaging periods, maximum concentration summary tables, and concurrent values summarized by receptor for each day processed. Optional output files can be generated for: A listing of occurrences of exceedances of user-specified threshold value; a listing of concurrent (raw) results at each receptor for each hour modeled, suitable for post-processing; a listing of design values that can be imported into graphics software for plotting contours; an unformatted listing of raw results above a threshold value with a special structure for use with the TOXX model component of TOXST; a listing of concentrations by rank (*e.g.,* for use in quantile-quantile plots); and, a listing of concentrations, including arc-maximum normalized concentrations, suitable for model evaluation studies.

d. Type of Model

AERMOD is a steady-state plume model, using Gaussian distributions in the vertical and horizontal for stable conditions, and in the horizontal for convective conditions. The vertical concentration distribution for convective conditions results from an assumed bi-Gaussian probability density function of the vertical velocity.

e. Pollutant Types

AERMOD is applicable to primary pollutants and continuous releases of toxic and hazardous waste pollutants. Chemical transformation is treated by simple exponential decay. Settling and deposition are not yet simulated by AERMOD.

f. Source-Receptor Relationships

AERMOD applies user-specified locations for sources and receptors. Actual separation between each source-receptor pair is used. Source and receptor elevations are user input or are determined by AERMAP using USGS DEM terrain data. Receptors may be located at user-specified heights above ground level.

g. Plume Behavior

(1) In the convective boundary layer (CBL), the transport and dispersion of a plume is characterized as the superposition of three modeled plumes: The direct plume (from the stack), the indirect plume, and the penetrated plume, where the indirect plume accounts for the lofting of a buoyant plume near the top of the boundary layer, and the penetrated plume accounts for the portion of a plume that, due to its buoyancy, penetrates above the mixed layer, but can disperse downward and re-enter the mixed layer. In the CBL, plume rise is superposed on the displacements by random convective velocities (Weil *et al.,* 1997).

(2) In the stable boundary layer, plume rise is estimated using an iterative approach, similar to that in the CTDMPLUS model (Perry, 1992; Section 11.0, ref. 33).

(3) Stack-tip downwash and buoyancy induced dispersion effects are modeled. Building wake effects are simulated for stacks less than good engineering practice height using the methods contained in ISCST (Section 11.0, ref. 60). For stacks higher than building height plus one-half the lesser of the building height or building width, the building wake algorithm of Huber and Snyder (1976) is used. For lower stacks, the building wake algorithm of Schulman and Scire (Schulman and Hanna, 1986) is used, but stack-tip downwash and buoyancy-induced dispersion are not used.

(4) For elevated terrain, AERMOD incorporates the concept of the critical dividing streamline height, in which flow below this height remains horizontal, and flow above this height tends to rise up and over terrain (Snyder *et al.,* 1985). Plume

concentration estimates are the weighted sum of these two limiting plume states. However, consistent with the steady-state assumption of uniform horizontal wind direction over the modeling domain, straight-line plume trajectories are assumed, with adjustment in the plume/receptor geometry used to account for the terrain effects.

h. Horizontal Winds

Vertical profiles of wind are calculated for each hour based on measurements and surface-layer similarity (scaling) relationships. At a given height above ground, for a given hour, winds are assumed constant over the modeling domain. The effect of the vertical variation in horizontal wind speed on dispersion is accounted for through simple averaging over the plume depth.

i. Vertical Wind Speed

In convective conditions, the effects of random vertical updraft and downdraft velocities are simulated with a bi-Gaussian probability density function. In both convective and stable conditions, the mean vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Gaussian horizontal dispersion coefficients are estimated as continuous functions of the parameterized (or measured) ambient lateral turbulence and also account for buoyancy-induced and building wake-induced turbulence. Vertical profiles of lateral turbulence are developed from measurements and similarity (scaling) relationships. Effective turbulence values are determined from the portion of the vertical profile of lateral turbulence between the plume height and the receptor height. The effective lateral turbulence is then used to estimate horizontal dispersion.

k. Vertical Dispersion

In the stable boundary layer, Gaussian vertical dispersion coefficients are estimated as continuous functions of parameterized vertical turbulence. In the convective boundary layer, vertical dispersion is characterized by a bi-Gaussian probability density function, and is also estimated as a continuous function of parameterized vertical turbulence. Vertical turbulence profiles are developed from measurements and similarity (scaling) relationships. These turbulence profiles account for both convective and mechanical turbulence. Effective turbulence values are determined from the portion of the vertical profile of vertical turbulence between the plume height and the receptor height. The effective vertical turbulence is then used to estimate vertical dispersion.

l. Chemical Transformation

Chemical transformations are generally not treated by AERMOD. However, AERMOD does contain an option to treat chemical transformation using simple exponential decay, although this option is typically not used in regulatory applications, except for sources of sulfur dioxide in urban areas. Either a decay coefficient or a half life is input by the user.

m. Physical Removal

Neither wet or dry deposition of particulate or gaseous pollutants is currently simulated by AERMOD.

n. Evaluation Studies

API, 1998: Evaluation of State of the Science of Air Quality Dispersion Model, Scientific Evaluation, prepared by Woodward-Clyde Consultants, Lexington, Massachusetts, for American Petroleum Institute, Washington, D.C., 20005–4070.

Paine, R.J., R.F. Lee, R.W. Brode, R.B. Wilson, A.J Cimorelli, S.G. Perry, J.C. Weil, A. Venkatram and W.D. Peters, 1998: Model Evaluation Results for AERMOD (12/17/98 Draft). Prepared for Environmental Protection Agency, Research Triangle Park, NC. (Docket No. A–99–05, II–A–5)

A.2 Buoyant Line and Point Source Dispersion Model (BLP)

Reference

Schulman, Lloyd L. and Joseph S. Scire, 1980. Buoyant Line and Point Source (BLP) Dispersion Model User's Guide. Document P–7304B. Environmental Research and Technology, Inc., Concord, MA. (NTIS No. PB 81–164642)

Availability

The computer code is available on EPA's Internet SCRAM website and also on diskette (as PB 90–500281) from the National Technical Information Service (see Section A.0).

Abstract

BLP is a Gaussian plume dispersion model designed to handle unique modeling problems associated with aluminum reduction plants, and other industrial sources where plume rise and downwash effects from stationary line sources are important.

a. Recommendations for Regulatory Use

(1) The BLP model is appropriate for the following applications:

- Aluminum reduction plants which contain buoyant, elevated line sources;
- Rural areas;
- Transport distances less than 50 kilometers;
- Simple terrain; and
- One hour to one year averaging times.

(2) The following options should be selected for regulatory applications:

(i) Rural (IRU=1) mixing height option;

(ii) Default (no selection) for plume rise wind shear (LSHEAR), transitional point source plume rise (LTRANS), vertical potential temperature gradient (DTHTA), vertical wind speed power law profile exponents (PEXP), maximum variation in number of stability classes per hour (IDELS), pollutant decay (DECFAC), the constant in Briggs' stable plume rise equation (CONST2), constant in Briggs' neutral plume rise equation (CONST3), convergence criterion for the line source calculations (CRIT), and maximum iterations allowed for line source calculations (MAXIT); and

(iii) Terrain option (TERAN) set equal to 0.0, 0.0, 0.0, 0.0, 0.0, 0.0

(3) For other applications, BLP can be used if it can be demonstrated to give the same estimates as a recommended model for the same application, and will subsequently be executed in that mode.

(4) BLP can be used on a case-by-case basis with specific options not available in a recommended model if it can be demonstrated, using the criteria in Section 3.2, that the model is more appropriate for a specific application.

b. Input Requirements

(1) Source data: Point sources require stack location, elevation of stack base, physical stack height, stack inside diameter, stack gas exit velocity, stack gas exit temperature, and pollutant emission rate. Line sources require coordinates of the end points of the line, release height, emission rate, average line source width, average building width, average spacing between buildings, and average line source buoyancy parameter.

(2) Meteorological data: Hourly surface weather data from punched cards or from the preprocessor program PCRAMMET which provides hourly stability class, wind direction, wind speed, temperature, and mixing height.

(3) Receptor data: locations and elevations of receptors, or location and size of receptor grid or request automatically generated receptor grid.

c. Output

(1) Printed output (from a separate post-processor program) includes:

(2) Total concentration or, optionally, source contribution analysis; monthly and annual frequency distributions for 1-, 3-, and 24-hour average concentrations; tables of 1-, 3-, and 24-hour average concentrations at each receptor; table of the annual (or length of run) average concentrations at each receptor;

(3) Five highest 1-, 3-, and 24-hour average concentrations at each receptor; and

(4) Fifty highest 1-, 3-, and 24-hour concentrations over the receptor field.

d. Type of Model

BLP is a gaussian plume model.

e. Pollutant Types

BLP may be used to model primary pollutants. This model does not treat settling and deposition.

f. Source-Receptor Relationship

(1) BLP treats up to 50 point sources, 10 parallel line sources, and 100 receptors arbitrarily located.

(2) User-input topographic elevation is applied for each stack and each receptor.

g. Plume Behavior

(1) BLP uses plume rise formulas of Schulman and Scire (1980).

(2) Vertical potential temperature gradients of 0.02 Kelvin per meter for E stability and 0.035 Kelvin per meter are used for stable plume rise calculations. An option for user input values is included.

(3) Transitional rise is used for line sources.

(4) Option to suppress the use of transitional plume rise for point sources is included.

(5) The building downwash algorithm of Schulman and Scire (1980) is used.

h. Horizontal Winds

(1) Constant, uniform (steady-state) wind is assumed for an hour.

(2) Straight line plume transport is assumed to all downwind distances.

(3) Wind speeds profile exponents of 0.10, 0.15, 0.20, 0.25, 0.30, and 0.30 are used for stability classes A through F, respectively. An option for user-defined values and an option to suppress the use of the wind speed profile feature are included.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

(1) Rural dispersion coefficients are from Turner (1969), with no adjustment made for variations in surface roughness or averaging time.

(2) Six stability classes are used.

k. Vertical Dispersion

(1) Rural dispersion coefficients are from Turner (1969), with no adjustment made for variations in surface roughness.

(2) Six stability classes are used.

(3) Mixing height is accounted for with multiple reflections until the vertical plume standard deviation equals 1.6 times the mixing height; uniform mixing is assumed beyond that point.

(4) Perfect reflection at the ground is assumed.

l. Chemical Transformation

Chemical transformations are treated using linear decay. Decay rate is input by the user.

m. Physical Removal

Physical removal is not explicitly treated.

n. Evaluation Studies

Schulman, L.L. and J.S. Scire, 1980. Buoyant Line and Point Source (BLP) Dispersion Model User's Guide, P–7304B. Environmental Research and Technology, Inc., Concord, MA.

Scire, J.S. and L.L. Schulman, 1981. Evaluation of the BLP and ISC Models with SF_6 Tracer Data and SO_2 Measurements at Aluminum Reduction Plants. APCA Specialty Conference on Dispersion Modeling for Complex Sources, St. Louis, MO.

A.3 CALINE3

Reference

Benson, Paul E, 1979. CALINE3—A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets. Interim Report, Report Number FHWA/CA/TL–79/23. Federal Highway Administration, Washington, D.C. (NTIS No. PB 80–220841)

Availability

The CALINE3 model is available on diskette (as PB 95–502712) from NTIS. The source code and user's guide are also available on EPA's Internet SCRAM website (Section A.0).

Abstract

CALINE3 can be used to estimate the concentrations of nonreactive pollutants from highway traffic. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of ''at-grade,'' ''fill,'' ''bridge,'' and ''cut section'' highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation, and receptor location. The model has adjustments for averaging time and surface roughness, and can handle up to 20 links and 20 receptors. It also contains an algorithm for deposition and settling velocity so that particulate concentrations can be predicted.

a. Recommendations for Regulatory Use

CALINE–3 is appropriate for the following applications:

- Highway (line) sources;
- Urban or rural areas;
- Simple terrain;
- Transport distances less than 50 kilometers; and
- One-hour to 24-hour averaging times.

b. Input Requirements

(1) Source data: up to 20 highway links classed as ''at-grade,'' ''fill'' ''bridge,'' or ''depressed''; coordinates of link end points; traffic volume; emission factor; source height; and mixing zone width.

(2) Meteorological data: wind speed, wind angle (measured in degrees clockwise from the Y axis), stability class, mixing height, ambient (background to the highway) concentration of pollutant.

(3) Receptor data: coordinates and height above ground for each receptor.

c. Output

Printed output includes concentration at each receptor for the specified meteorological condition.

d. Type of Model

CALINE–3 is a Gaussian plume model.

e. Pollutant Types

CALINE–3 may be used to model primary pollutants.

f. Source-Receptor Relationship

(1) Up to 20 highway links are treated.

(2) CALINE–3 applies user input location and emission rate for each link. User-input receptor locations are applied.

g. Plume Behavior

Plume rise is not treated.

h. Horizontal Winds

(1) User-input hourly wind speed and direction are applied.

(2) Constant, uniform (steady-state) wind is assumed for an hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

(1) Six stability classes are used.

(2) Rural dispersion coefficients from Turner (1969) are used, with adjustment for roughness length and averaging time.

(3) Initial traffic-induced dispersion is handled implicitly by plume size parameters.

k. Vertical Dispersion

(1) Six stability classes are used.

(2) Empirical dispersion coefficients from Benson (1979) are used including an adjustment for roughness length.

(3) Initial traffic-induced dispersion is handled implicitly by plume size parameters.

(4) Adjustment for averaging time is included.

l. Chemical Transformation

Not treated.

m. Physical Removal

Optional deposition calculations are included.

n. Evaluation Studies

Bemis, G.R. *et al.,* 1977. Air Pollution and Roadway Location, Design, and Operation—Project Overview. FHWA–CA–TL–7080–77–25, Federal Highway Administration, Washington, D.C.

Cadle, S.H. *et al.,* 1976. Results of the General Motors Sulfate Dispersion Experiment, GMR–2107. General Motors Research Laboratories, Warren, MI.

Dabberdt, W.F., 1975. Studies of Air Quality on and Near Highways, Project 2761. Stanford Research Institute, Menlo Park, CA.

A.4 CALPUFF

References

Scire, J.S., D.G. Strimaitis, and R.J. Yamartino, 1998. A User's Guide for the CALPUFF Dispersion Model (Version 5.0). Earth Tech, Inc., Concord, MA.

Scire J.S., F. R. Robe, M.E. Fernau, and R.J. Yamartino, 1998. A User's Guide for the CALMET Meteorological Model (Version 5.0). Earth Tech, Inc., Concord, MA.

Availability

The model code and its documentation are available for download from the model developers' Internet website: www.src.com/calpuff/calpuff1.htm. You may also contact Joseph Scire, Earth Tech, Inc., 196 Baker Avenue, Concord, MA 01742; Telephone: (978) 371–4200, Fax: (978) 371–2468, e-mail: jss@src.com.

Abstract

CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion modeling that simulates the effects of time-and space-varying meteorological conditions on pollutant transport, transformation, and removal. CALPUFF is intended for use on scales from tens of meters from a source to hundreds of kilometers. It includes algorithms for near-field effects such as building downwash, transitional buoyant and momentum plume rise, partial plume penetration, subgrid scale terrain and coastal interactions effects, and terrain impingement as well as longer range effects such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, vertical wind shear, overwater transport, plume fumigation, and visibility effects of particulate matter concentrations.

a. Recommendations for Regulatory Use

(1) CALPUFF is appropriate for long range transport (source-receptor distances of 50km to 200km) of emissions from point, volume, area, and line sources. The meteorological input data should be fully characterized with

time-and-space-varying three dimensional wind and meteorological conditions using CALMET, as discussed in paragraphs 8.3(d) and 8.3.1.2(d) of Appendix W.

(2) CALPUFF may also be used on a case-by-case basis if it can be demonstrated using the criteria in Section 3.2 that the model is more appropriate for the specific application. The purpose of choosing a modeling system like CALPUFF is to fully treat stagnation, wind reversals, and time and space variations of meteorology effects on transport and dispersion, as discussed in paragraph 7.2.9(a).

(3) For regulatory applications of CALMET and CALPUFF, the regulatory default option should be used. Inevitably, some of the model control options will have to be set specific for the application using expert judgement and in consultation with the relevant reviewing authorities.

b. Input Requirements

Source Data:

1. Point sources: source location, stack height, diameter, exit velocity, exit temperature, base elevation, wind direction specific building dimensions (for building downwash calculations), and emission rates for each pollutant. Particle size distributions may be entered for particulate matter. Temporal emission factors (diurnal cycle, monthly cycle, hour/season, wind speed/stability class, or temperature-dependent emission factors) may also be entered. Arbitrarily-varying point source parameters may be entered from an external file.

2. Area sources: source location and shape, release height, base elevation, initial vertical distribution (σ_z) and emission rates for each pollutant. Particle size distributions may be entered for particulate matter. Temporal emission factors (diurnal cycle, monthly cycle, hour/season, wind speed/stability class, or temperature-dependent emission factors) may also be entered. Arbitrarily-varying area source parameters may be entered from an external file. Area sources specified in the external file are allowed to be buoyant and their location, size, shape, and other source characteristics are allowed to change in time.

3. Volume sources: source location, release height, base elevation, initial horizontal and vertical distributions (σ_y, σ_z) and emission rates for each pollutant. Particle size distributions may be entered for particulate matter. Temporal emission factors (diurnal cycle, monthly cycle, hour/season, wind speed/stability class, or temperature-dependent emission factors) may also be entered. Arbitrarily-varying volume source parameters may be entered from an external file.

4. Line sources: source location, release height, base elevation, average buoyancy parameter, and emission rates for each pollutant.

Particle size distributions may be entered for particulate matter. Temporal emission factors (diurnal cycle, monthly cycle, hour/season, wind speed/stability class, or temperature-dependent emission factors) may also be entered. Arbitrarily-varying line source parameters may be entered from an external file.

Meteorological Data (different forms of meteorological input can be used by CALPUFF):

1. Time-dependent three-dimensional meteorological fields generated by CALMET. This is the preferred mode for running CALPUFF. Inputs into CALMET include surface observations of wind speed, wind direction, temperature, cloud cover, ceiling height, relative humidity, surface pressure, and precipitation (type and amount), and upper air sounding data (wind speed, wind direction, temperature, and height). Optional large-scale model output (*e.g.,* from MM5) can be used by CALMET as well.

2. Single station surface and upper air meteorological data in CTDMPLUS data file formats (SURFACE.DAT and PROFILE.DAT files). This allows a vertical variation in the meteorological parameters but no spatial variability.

3. Single station meteorological data in ISCST3 data file format. This option does not account for variability of the meteorological parameters in the horizontal or vertical, except as provided for by the use of stability-dependent wind shear exponents and average temperature lapse rates.

Gridded terrain and land use data are required as input into CALMET when Option 1 is used. Geophysical processor programs are provided that interface the modeling system to standard terrain and land use data bases provided by the U.S. Geological Survey (USGS).

Receptor Data:

CALPUFF includes options for gridded and non-gridded (discrete) receptors. Special subgrid-scale receptors are used with the subgrid-scale complex terrain option.

Other Input:

CALPUFF accepts hourly observations of ozone concentrations for use in its chemical transformation algorithm. Subgrid-scale coastlines can be specified in its coastal boundary file. Optional, user-specified deposition velocities and chemical transformation rates can also be entered. CALPUFF accepts the CTDMPLUS terrain and receptor files for use in its subgrid-scale terrain algorithm.

c. Output

CALPUFF produces files of hourly concentrations of ambient concentrations for each modeled species, wet deposition fluxes, dry deposition fluxes, and for visibility applications, extinction coefficients. Postprocessing programs (PRTMET and CALPOST) provide options for analysis and display of the modeling results.

d. Type of Model

(1) CALPUFF is a non-steady-state time- and space-dependent Gaussian puff model. CALPUFF includes parameterized gas phase chemical transformation of SO_2, $SO_4^=$, NO, $NO_2^=$, HNO_3, NO_3-, and organic aerosols. A model for aqueous phase chemical transformation of SO_2 to $SO_4^=$ is included. CALPUFF can treat primary pollutants such as PM–10, toxic pollutants, ammonia, and other passive pollutants. The model includes a resistance-based dry deposition model for both gaseous pollutants and particulate matter. Wet deposition is treated using a scavenging coefficient approach. The model has detailed parameterizations of complex terrain effects, including terrain impingement, side-wall scrapping, and steep-walled terrain influences on lateral plume growth. A subgrid-scale complex terrain module based on a dividing streamline concept divides the flow into a lift component traveling over the obstacle and a wrap component deflected around the obstacle.

(2) The meteorological fields used by CALPUFF are produced by the CALMET meteorological model. CALMET includes a diagnostic wind field model containing objective analysis and parameterized treatments of slope flows, valley flows, terrain blocking effects, and kinematic terrain effects, lake and sea breeze circulations, and a divergence minimization procedure. An energy-balance scheme is used to compute sensible and latent heat fluxes and turbulence parameters over land surfaces. A profile method is used over water. CALMET contains interfaces to prognostic meteorological models such as the Penn State/NCAR Mesoscale Model (MM4, MM5; Section 11.0, ref. 100).

e. Pollutant Types

CALPUFF may be used to model gaseous pollutants or particulate matter that are inert or undergo linear chemical reactions, such as SO_2, $SO_4^=$, NO, NO_2, HNO_3, NO_3-, NH_3, PM–10, and toxic pollutants. For regional haze analyses, sulfate and nitrate particulate components are explicitly treated.

f. Source-Receptor Relationships

CALPUFF contains no fundamental limitations on the number of sources or receptors. Parameter files are provided that allow the user to specify the maximum number of sources, receptors, puffs, species, grid cells, vertical layers, and other model parameters. Its algorithms are designed to be suitable for source-receptor distances from tens of meters to hundreds of kilometers.

g. Plume Behavior

Momentum and buoyant plume rise is treated according to the plume rise equations of Briggs (1974, 1975) for non-downwashing point sources, Schulman and Scire (1980) for line sources and point sources subject to building downwash effects, and Zhang (1993) for buoyant area sources. Stack tip downwash effects and partial plume penetration into elevated temperature inversions are included.

h. Horizontal Winds

A three-dimensional wind field is computed by the CALMET meteorological model. CALMET combines an objective analysis procedure using wind observations with parameterized treatments of slope flows, valley flows, terrain kinematic effects, terrain blocking effects, and sea/lake breeze circulations. CALPUFF may optionally use single station (horizontally-constant) wind fields in the CTDMPLUS or ISC–PRIME data formats.

i. Vertical Wind Speed

Vertical wind speeds are not used explicitly by CALPUFF. Vertical winds are used in the development of the horizontal wind components by CALMET.

j. Horizontal Dispersion

Turbulence-based dispersion coefficients provide estimates of horizontal plume dispersion based on measured or computed values of σ_v. The effects of building downwash and buoyancy-induced dispersion are included. The effects of vertical wind shear are included through the puff splitting algorithm. Options are provided to use Pasquill-Gifford (rural) and McElroy-Pooler (urban) dispersion coefficients. Initial plume size from area or volume sources is allowed.

k. Vertical Dispersion

Turbulence-based dispersion coefficients provide estimates of vertical plume dispersion based on measured or computed values of σ_w. The effects of building downwash and buoyancy-induced dispersion are included. Vertical dispersion during convective conditions is simulated with a probability density function (pdf) model based on Weil *et al.* (1997). Options are provided to use Pasquill-Gifford (rural) and McElroy-Pooler (urban) dispersion coefficients. Initial plume size from area or volume sources is allowed.

l. Chemical Transformation

Gas phase chemical transformations are treated using parameterized models of SO_2 conversion to SO_4= and NO conversion to NO_2, HNO_3, and SO_4=. Aqueous phase oxidation of SO_2 to SO_4= by precipitating and non-precipitating clouds is included. Organic aerosol formation is treated.

m. Physical Removal

Dry deposition of gaseous pollutants and particulate matter is parameterized in terms of a resistance-based deposition model. Gravitational settling, inertial impaction, and Brownian motion effects on deposition of particulate matter is included. Wet deposition of gases and particulate matter is parameterized in terms of a scavenging coefficient approach.

n. Evaluation Studies

Berman, S., J.Y. Ku, J. Zhang, and S.T. Rao, 1977: Uncertainties in estimating the mixing depth—Comparing three mixing depth models with profiler measurements, Atmospheric Environment, 31: 3023–3039.

Environmental Protection Agency, 1998. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport Impacts. EPA publication No. EPA–454/R–98–019. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Irwin, J.S. 1997. A Comparison of CALPUFF Modeling Results with 1997 INEL Field Data Results. In *Air Pollution Modeling and its Application, XII.* Edited by S.E. Gyrning and N. Chaumerliac. Plenum Press, New York, NY.

Irwin, J.S., J.S. Scire, and D.G. Strimaitis, 1996. A Comparison of CALPUFF Modeling Results with CAPTEX Field Data Results. In *Air Pollution Modeling and its Application, XI.* Edited by S.E. Gyrning and F.A. Schiermeier. Plenum Press, New York, NY.

Strimaitis, D.G., J.S. Scire and J.C. Chang. 1998. Evaluation of the CALPUFF Dispersion Model with Two Power Plant Data Sets. Tenth Joint Conference on the Application of Air Pollution Meteorology, Phoenix, Arizona. American Meteorological Society, Boston, MA. January 11–16, 1998.

A.5 Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS)

Reference

Perry, S.G., D.J. Burns, L.H. Adams, R.J. Paine, M.G. Dennis, M.T. Mills, D.G. Strimaitis, R.J. Yamartino and E.M. Insley, 1989. User's Guide to the Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS). Volume 1: Model Descriptions and User Instructions. EPA Publication No. EPA–600/8–89–041. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 89–181424)

Perry, S.G., 1992. CTDMPLUS: A Dispersion Model for Sources near Complex Topography. Part I: Technical Formulations. Journal of Applied Meteorology, 31(7): 633–645.

Availability

This model code is available on EPA's Internet SCRAM website and also on diskette (as PB 90–504119) from the National Technical Information Service (Section A.0).

Abstract

CTDMPLUS is a refined point source Gaussian air quality model for use in all stability conditions for complex terrain applications. The model contains, in its entirety, the technology of CTDM for stable and neutral conditions. However, CTDMPLUS can also simulate daytime, unstable conditions, and has a number of additional capabilities for improved user friendliness. Its use of meteorological data and terrain information is different from other EPA models; considerable detail for both types of input data is required and is supplied by preprocessors specifically designed for CTDMPLUS. CTDMPLUS requires the parameterization of individual hill shapes using the terrain preprocessor and the association of each model receptor with a particular hill.

a. Recommendation for Regulatory Use

CTDMPLUS is appropriate for the following applications:

- Elevated point sources;
- Terrain elevations above stack top;
- Rural or urban areas;
- Transport distances less than 50 kilometers; and
- One hour to annual averaging times when used with a post-processor program such as CHAVG.

b. Input Requirements

(1) Source data: For each source, user supplies source location, height, stack diameter, stack exit velocity, stack exit temperature, and emission rate; if variable emissions are appropriate, the user supplies hourly values for emission rate, stack exit velocity, and stack exit temperature.

(2) Meteorological data: For applications of CTDMPLUS, multiple level (typically three or more) measurements of wind speed and direction, temperature and turbulence (wind fluctuation statistics) are required to create the basic meteorological data file (''PROFILE''). Such measurements should be obtained up to the representative plume height(s) of interest (*i.e.,* the plume height(s) under those conditions important to the determination of the design concentration). The representative plume height(s) of interest should be determined using an appropriate complex terrain screening procedure (*e.g.,* CTSCREEN) and should be documented in the monitoring/modeling protocol. The necessary meteorological measurements should be obtained from an appropriately sited meteorological tower augmented by SODAR and/or RASS if the representative plume height(s) of interest is above the levels represented by the tower measurements. Meteorological preprocessors then create a SURFACE data file (hourly values of mixed layer heights, surface friction velocity, Monin-Obukhov length and surface roughness length) and a RAWINsonde data file (upper air measurements of pressure, temperature, wind direction, and wind speed).

(3) Receptor data: receptor names (up to 400) and coordinates, and hill number (each receptor must have a hill number assigned).

(4) Terrain data: user inputs digitized contour information to the terrain preprocessor which creates the TERRAIN data file (for up to 25 hills).

c. Output

(1) When CTDMPLUS is run, it produces a concentration file, in either binary or text format (user's choice), and a list file containing a verification of model inputs, *i.e.,*

- Input meteorological data from ''SURFACE'' and ''PROFILE''
- Stack data for each source
- Terrain information
- Receptor information
- Source-receptor location (line printer map).

(2) In addition, if the case-study option is selected, the listing includes:

- Meteorological variables at plume height
- Geometrical relationships between the source and the hill
- Plume characteristics at each receptor, *i.e.,*

—distance in along-flow and cross flow direction
—effective plume-receptor height difference
—effective σ_y & σ_z values, both flat terrain and hill induced (the difference shows the effect of the hill)
—concentration components due to WRAP, LIFT and FLAT.

(3) If the user selects the TOPN option, a summary table of the top 4 concentrations at each receptor is given. If the ISOR option is selected, a source contribution table for every hour will be printed.

(4) A separate disk file of predicted (1-hour only) concentrations (''CONC'') is written if the user chooses this option. Three forms of output are possible:

(i) A binary file of concentrations, one value for each receptor in the hourly sequence as run;

(ii) A text file of concentrations, one value for each receptor in the hourly sequence as run; or

(iii) A text file as described above, but with a listing of receptor information (names, positions, hill number) at the beginning of the file.

(5) Hourly information provided to these files besides the concentrations themselves includes the year, month, day, and hour information as well as the receptor number with the highest concentration.

d. Type of Model

CTDMPLUS is a refined steady-state, point source plume model for use in all stability conditions for complex terrain applications.

e. Pollutant Types

CTDMPLUS may be used to model non-reactive, primary pollutants.

f. Source-Receptor Relationship

Up to 40 point sources, 400 receptors and 25 hills may be used. Receptors and sources are allowed at any location. Hill slopes are assumed not to exceed 15°, so that the linearized equation of motion for Boussinesq flow are applicable. Receptors upwind of the impingement point, or those associated with any of the hills in the modeling domain, require separate treatment.

g. Plume Behavior

(1) As in CTDM, the basic plume rise algorithms are based on Briggs' (1975) recommendations.

(2) A central feature of CTDMPLUS for neutral/stable conditions is its use of a critical dividing-streamline height (H_c) to separate the flow in the vicinity of a hill into two separate layers. The plume component in the upper layer has sufficient kinetic energy to pass over the top of the hill while streamlines in the lower portion are constrained to flow in a horizontal plane around the hill. Two separate components of CTDMPLUS compute ground-level concentrations resulting from plume material in each of these flows.

(3) The model calculates on an hourly (or appropriate steady averaging period) basis how the plume trajectory (and, in stable/neutral conditions, the shape) is deformed by each hill. Hourly profiles of wind and temperature measurements are used by CTDMPLUS to compute plume rise, plume penetration (a formulation is included to handle penetration into elevated stable layers, based on Briggs (1984)), convective scaling parameters, the value of H_c, and the Froude number above H_c.

h. Horizontal Winds

CTDMPLUS does not simulate calm meteorological conditions. Both scalar and vector wind speed observations can be read by the model. If vector wind speed is unavailable, it is calculated from the scalar wind speed. The assignment of wind speed (either vector or scalar) at plume height is done by either:

• Interpolating between observations above and below the plume height, or

• Extrapolating (within the surface layer) from the nearest measurement height to the plume height.

i. Vertical Wind Speed

Vertical flow is treated for the plume component above the critical dividing streamline height (H_c); see ''Plume Behavior''.

j. Horizontal Dispersion

Horizontal dispersion for stable/neutral conditions is related to the turbulence velocity scale for lateral fluctuations, σ_v, for which a minimum value of 0.2 m/s is used. Convective scaling formulations are used to estimate horizontal dispersion for unstable conditions.

k. Vertical Dispersion

Direct estimates of vertical dispersion for stable/neutral conditions are based on observed vertical turbulence intensity, *e.g.,* σ_w (standard deviation of the vertical velocity fluctuation). In simulating unstable (convective) conditions, CTDMPLUS relies on a skewed, bi-Gaussian probability density function (pdf) description of the vertical velocities to estimate the vertical distribution of pollutant concentration.

l. Chemical Transformation

Chemical transformation is not treated by CTDMPLUS.

m. Physical Removal

Physical removal is not treated by CTDMPLUS (complete reflection at the ground/hill surface is assumed).

n. Evaluation Studies

Burns, D.J., L.H. Adams and S.G. Perry, 1990. Testing and Evaluation of the CTDMPLUS Dispersion Model: Daytime Convective Conditions. Environmental Protection Agency, Research Triangle Park, NC.

Paumier, J.O., S.G. Perry and D.J. Burns, 1990. An Analysis of CTDMPLUS Model Predictions with the Lovett Power Plant Data Base. Environmental Protection Agency, Research Triangle Park, NC.

Paumier, J.O., S.G. Perry and D.J. Burns, 1992. CTDMPLUS: A Dispersion Model for Sources near Complex Topography. Part II: Performance Characteristics. Journal of Applied Meteorology, 31(7): 646–660.

A.6 Emissions and Dispersion Modeling System (EDMS) 3.1

Reference

Benson, Paul E., 1979. CALINE3—A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets. Interim Report, Report Number FHWA/CA/TL–79/23. Federal Highway Administration, Washington, D.C. (NTIS No. PB 80–220841)

Federal Aviation Administration, 1997. Emissions and Dispersion Modeling System (EDMS) Reference Manual. FAA Report No. FAA–AEE–97–01, USAF Report No. AL/EQ–TR–1997–0010, Federal Aviation Administration, Washington, D.C. 20591. See Availability below. (Note: this manual includes supplements that are available on the EDMS Internet website: http://www.aee.faa.gov/aee-100/aee-120/edms/banner.htm)

Petersen, W.B. and E.D. Rumsey, 1987. User's Guide for PAL 2.0—A Gaussian-Plume Algorithm for Point, Area, and Line Sources. EPA Publication No. EPA–600/8–87–009. Office of Research and Development, Research Triangle Park, NC. (NTIS No. PB 87–168 787/AS)

Availability

EDMS is available for $200 from: Federal Aviation Administration, Attn: Ms. Julie Ann Draper, AEE, 800 Independence Avenue, S.W., Washington, D.C. 20591, Phone: (202) 267–3494.

Abstract

EDMS is a combined emissions/dispersion model for assessing pollution at civilian airports and military air bases. This model, which was jointly developed by the Federal Aviation Administration (FAA) and the United States Air Force (USAF), produces an emission inventory of all airport sources and calculates concentrations produced by these sources at specified receptors. The system stores emission factors for fixed sources such as fuel storage tanks and incinerators and also for mobile sources such as aircraft or automobiles. The EDMS emissions inventory module incorporates methodologies described in AP–42 for calculating aircraft emissions, on-road and off-road vehicle emissions, and stationary source emissions. The dispersion modeling module incorporates PAL2 and CALINE3 (Section A.3) for the various emission source types. Both of these components interact with the database to retrieve and store data. The dispersion module, which processes point, area, and line sources, also incorporates a special meteorological preprocessor for processing up to one year of National Climatic Data Center (NCDC) hourly data.

a. Recommendations for Regulatory Use

EDMS is appropriate for the following applications:

• Cumulative effect of changes in aircraft operations, point source and mobile source emissions at airports or air bases;

• Simple terrain;

• Non-reactive pollutants;

• Transport distances less than 50 kilometers; and

• 1-hour to annual averaging times.

b. Input Requirements

(1) All data are entered through the EDMS graphical user interface. Typical entry items are annual and hourly source activity, source and receptor coordinates, etc. Some point sources, such as heating plants, require stack height, stack diameter, and effluent temperature inputs.

(2) Wind speed, wind direction, hourly temperature, and Pasquill-Gifford stability category (P–G) are the meteorological inputs. They can be entered manually through the EDMS data entry screens or automatically through the processing of previously loaded NCDC hourly data.

c. Output

Printed outputs consist of:

• A summary emission inventory report with pollutant totals by source category and detailed emission inventory reports for each source category; and

• A concentration summary report for up to 8760 hours (one year) of meteorological data that lists the number of sources, receptors, and the five highest concentrations for applicable averaging periods for the respective primary NAAQS.

d. Type of Model

For its emissions inventory calculations, EDMS uses algorithms consistent with the EPA Compilation of Air Pollutant Emission Factors, AP–42 (Section 11.0, ref. 96). For its dispersion calculations, EDMS uses the Point Area & Line (PAL2) model and the CALifornia LINE source (CALINE3) model, both of which use Gaussian algorithms.

e. Pollutant Types

EDMS includes emission factors for carbon monoxide, nitrogen oxides, sulfur oxides, hydrocarbons, and suspended particles and calculates the dispersion for all except hydrocarbons.

f. Source-Receptor Relationship

(1) Within hardware and memory constraints, there is no upper limit to the number of sources and receptors that can be modeled simultaneously.

(2) The Gaussian point source equation estimates concentrations from point sources after determining the effective height of emission and the upwind and crosswind distance of the source from the receptor. Numerical integration of the Gaussian point source equation is used to determine concentrations from line sources (runways). Integration over area sources (parking lots), which includes edge effects from the source region, is done by considering finite line sources perpendicular to the wind at intervals upwind from the receptor. The crosswind integration is done analytically; integration upwind is done numerically by successive approximations. Terrain elevation differences between sources and receptors are neglected.

(3) A reasonable height above ground level may be specified for each receptor.

g. Plume Behavior

(1) Briggs final plume rise equations are used. If plume height exceeds mixing height, concentrations are assumed equal to zero. Surface concentrations are set to zero when the plume centerline exceeds mixing height.

(2) For roadways, plume rise is not treated.

(3) Building and stack tip downwash effects are not treated.

h. Horizontal Winds

(1) Steady state winds are assumed for each hour. Winds are assumed to be constant with altitude.

(2) Winds are entered manually by the user or automatically by reading previously loaded NCDC annual data files.

i. Vertical Wind Speed

Vertical wind speed is assumed to be zero.

j. Horizontal Dispersion

(1) Six stability classes are used (P–G classes A through F).

(2) Aircraft runways, vehicle parking lots, stationary sources, and training fires are modeled using PAL2. Either rural (Pasquill-Gifford) or urban (Briggs) dispersion settings may be specified globally for these sources.

(3) Vehicle roadways, aircraft taxiways, and aircraft queues are modeled using CALINE3. CALINE3 assumes urban dispersion curves. The user specifies terrain roughness.

k. Vertical Dispersion

(1) Six stability classes are used (P–G classes A through F).

(2) Aircraft runways, vehicle parking lots, stationary sources, and training fires are modeled using PAL2. Either rural (Pasquill-Gifford) or urban (Briggs) dispersion settings may be specified globally for these sources.

(3) Vehicle roadways, aircraft taxiways, and aircraft queues are modeled using CALINE3. CALINE3 assumes urban dispersion curves. The user specifies terrain roughness.

l. Chemical Transformation

Chemical transformations are not accounted for.

m. Physical Removal

Deposition is not treated.

n. Evaluation Studies

None cited.

A.7 Industrial Source Complex Model With Prime Downwash Algorithm (ISC–PRIME)

Reference

Environmental Protection Agency, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volumes 1 and 2. EPA Publication Nos. EPA–454/B–95–003a & b. Environmental Protection Agency, Research Triangle Park, NC. (NTIS Nos. PB 95–222741 and PB 95–222758, respectively)

Schulman, L.L., D.G. Strimaitis, and J.S. Scire, 1997. Addendum to ISC3 User's Guide, *The PRIME Plume Rise and Building Downwash Model.* Prepared for the Electric Power Research Institute, Palo Alto, CA., Earth Tech Document A287. A–99–05, II–A–12)

Schulman, L.L., D.G. Strimaitis, and J.S. Scire, 1998. Development and Evaluation of the PRIME Plume Rise and Building Downwash Model. (submitted to Journal of the Air & Waste Management Association) 34pp. + 10 figures (A–99–05, II–A–13)

Availability

The model code and its documentation are available for download from EPA's SCRAM Internet website (Section A.0).

Abstract

The ISC–PRIME model is a steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex. The model is based on ISC3, with the PRIME (Plume RIse Model Enhancements) algorithm added for improved treatment of building downwash. This model can account for the following: settling and dry deposition of particles; building downwash; area, line, and volume sources; plume rise as a function of downwind distance, building dimensions and stack placement with respect to a building; separation of point sources; and limited terrain adjustment.

a. Recommendations for Regulatory Use

(1) ISC–PRIME is appropriate for the following applications:

- Industrial source complexes where aerodynamic downwash or deposition is important;
- Rural or urban areas;
- Flat or rolling terrain;
- Transport distances less than 50 kilometers;
- 1-hour to annual averaging times; and
- Continuous toxic air emissions.

(2) The following options should be selected for regulatory applications: For short term or long term modeling, set the regulatory ''default option''; *i.e.,* use the keyword DFAULT, which automatically selects stack tip downwash, final plume rise, buoyancy induced dispersion (BID), the vertical potential temperature gradient, a treatment for calms, the appropriate wind profile exponents, and the appropriate value for pollutant half-life; set the ''rural option'' (use the keyword RURAL) or ''urban option'' (use the keyword URBAN); and set the ''concentration option'' (use the keyword CONC).

b. Input Requirements

(1) Source data: location, emission rate, physical stack height, stack gas exit velocity, stack inside diameter, and stack gas temperature. Optional inputs include source elevation, building dimensions, particle size distribution with corresponding settling velocities, and surface reflection coefficients.

(2) Meteorological data: ISC–PRIME requires hourly surface weather data from the preprocessor program PCRAMMET, which provides hourly stability class, wind direction, wind speed, temperature, and mixing height.

(3) Receptor data: coordinates and optional ground elevation for each receptor.

c. Output

Printed output options include:

- Program control parameters, source data, and receptor data;
- Tables of hourly meteorological data for each specified day;
- ''N''-day average concentration or total deposition calculated at each receptor for any desired source combinations;
- Concentration or deposition values calculated for any desired source combinations at all receptors for any specified day or time period within the day;
- Tables of highest and second highest concentration or deposition values calculated at each receptor for each specified time period during a(n) ''N''-day period for any desired source combinations, and tables of the maximum 50 concentration or deposition values calculated for any desired source combinations for each specified time period.

d. Type of Model

ISC–PRIME is a Gaussian plume model. It has been revised to perform a double integration of the Gaussian plume kernel for area sources. The PRIME algorithm modifies plume rise and dispersion during downwash conditions.

e. Pollutant Types

ISC–PRIME may be used to model primary pollutants and continuous releases of toxic and hazardous waste pollutants. Settling and deposition are treated.

f. Source-Receptor Relationships

(1) ISC–PRIME applies user-specified locations for point, line, area and volume

sources, and user-specified receptor locations or receptor rings.

(2) User input topographic evaluation for each receptor is used. Elevations above stack top are reduced to the stack top elevation, *i.e.,* ''terrain chopping''.

(3) User input height above ground level may be used when necessary to simulate impact at elevated or ''flag pole'' receptors, *e.g.,* on buildings.

(4) Actual separation between each source-receptor pair is used.

g. Plume Behavior

(1) ISC–PRIME uses Briggs (1969, 1971, 1975) plume rise equations for final rise.

(2) Stack tip downwash equation from Briggs (1974) is used.

(3) For plume rise affected by the presence of a building, the PRIME downwash algorithm is used. Plume rise is computed using a numerical solution of the mass, energy and momentum conservation laws (Zhang and Ghoniem, 1993). Streamline deflection and the position of the stack relative to the building affect plume trajectory and dispersion. Enhanced dispersion is based on the approach of Weil (1996). Plume mass captured by the cavity is well-mixed within the cavity. The captured plume mass is re-emitted to the far wake as a volume source. For GEP height stacks, buildings downwash is not used.

(4) For rolling terrain (terrain not above stack height), plume centerline is horizontal at height of final rise above source.

(5) Fumigation is not treated.

h. Horizontal Winds

(1) For each source, a constant, uniform (steady-state) stack-top wind is assumed for each hour except for PRIME downwash calculations, which use a power-law speed profile with height and account for velocity deficits in building wakes.

(2) Straight line plume transport is assumed to all downwind distances.

(3) Separate wind speed profile exponents (Irwin, 1979; EPA, 1980) for both rural and urban cases are used.

(4) An optional treatment for calm winds is included for short term modeling.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

(1) Rural dispersion coefficients from Turner (1969) are used, with no adjustments for surface roughness or averaging time.

(2) Urban dispersion coefficients from Briggs (Gifford, 1976) are used.

(3) Buoyancy induced dispersion (Pasquill, 1976) is included.

(4) Six stability classes are used.

(5) Dispersion is enhanced by the presence of a building.

k. Vertical Dispersion

(1) Rural dispersion coefficients from Turner (1969) are used, with no adjustments for surface roughness.

(2) Urban dispersion coefficients from Briggs (Gifford, 1976) are used.

(3) Buoyancy induced dispersion (Pasquill, 1976) is included.

(4) Six stability classes are used.

(5) Mixing height is accounted for with multiple reflections until the vertical plume standard deviation equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point.

(6) Perfect reflection is assumed at the ground.

(7) Dispersion is enhanced by the presence of a building.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Time constant is input by the user.

m. Physical Removal

Dry deposition effects for particles are treated using a resistance formulation in which the deposition velocity is the sum of the resistances to pollutant transfer within the surface layer of the atmosphere, plus a gravitational settling term (EPA, 1994), based on the modified surface depletion scheme of Horst (1983).

n. Evaluation Studies

Bowers, J.F. and A.J. Anderson, 1981. An Evaluation Study for the Industrial Source Complex (ISC) Dispersion Model, EPA Publication No. EPA–450/4–81–002. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Environmental Protection Agency, 1992. Comparison of a Revised Area Source Algorithm for the Industrial Source Complex Short Term Model and Wind Tunnel Data. EPA Publication No. EPA–454/R–92–014. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 93–226751)

Environmental Protection Agency, 1992. Sensitivity Analysis of a Revised Area Source Algorithm for the Industrial Source Complex Short Term Model. EPA Publication No. EPA–454/R–92–015. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 93–226769)

Environmental Protection Agency, 1992. Development and Evaluation of a Revised Area Source Algorithm for the Industrial Source Complex Long Term Model. EPA Publication No. EPA–454/R–92–016. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 93–226777)

Environmental Protection Agency, 1994. Development and Testing of a Dry Deposition Algorithm (Revised). EPA Publication No. EPA–454/R–94–015. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS No. PB 94–183100)

Paine, R.J. and F. Lew, 1997. Results of the Independent Evaluation of ISCST3 and ISC–PRIME. Prepared for the Electric Power Research Institute, Palo Alto, CA. ENSR Document Number 2460–026–440. (NTIS No. PB 98–156524)

Paine, R.J. and F. Lew, 1997. Consequence Analysis for ISC–PRIME. Prepared for the Electric Power Research Institute, Palo Alto, CA. ENSR Document Number 2460–026–450. (NTIS No. PB 98–156516)

Schulman, L.L., D.G. Strimaitis, and J.S. Scire, 1998. Development and Evaluation of the PRIME Plume Rise and Building Downwash Model. {submitted to Journal of the Air & Waste Management Association} 34pp. + figures (A–99–05, II–A–13)

Scire, J.S. and L.L. Schulman, 1981. Evaluation of the BLP and ISC Models with SF_6 Tracer Data and SO_2 Measurements at Aluminum Reduction Plants. Air Pollution Control Association Specialty Conference on Dispersion Modeling for Complex Sources, St. Louis, MO.

Scire, J.S., L.L. Schulman and D.G. Strimaitis, 1995. Observations of Plume Descent Downwind of Buildings. 88th Annual Meeting of the Air & Waste Management Association, Paper 95-WP75B.01, AWMA, Pittsburgh, PA.

A.8 Offshore and Coastal Dispersion Model (OCD)

Reference

DiCristofaro, D.C. and S.R. Hanna, 1989. OCD: The Offshore and Coastal Dispersion Model, Version 4. Volume I: User's Guide, and Volume II: Appendices. Sigma Research Corporation, Westford, MA. (NTIS Nos. PB 93–144384 and PB 93–144392)

Availability

This model code is available on the Support Center for Regulatory Air Models Bulletin Board System and also on diskette (as PB 91–505230) from the National Technical Information Service (see Section A.0).

Technical Contact

Minerals Management Service, Attn: Mr. Dirk Herkhof, Parkway Atrium Building, 381 Elden Street, Herndon, VA 22070–4817, Phone: (703) 787–1735.

Abstract

(1) OCD is a straight-line Gaussian model developed to determine the impact of offshore emissions from point, area or line sources on the air quality of coastal regions. OCD incorporates overwater plume transport and dispersion as well as changes that occur as the plume crosses the shoreline. Hourly meteorological data are needed from both offshore and onshore locations. These include water surface temperature, overwater air temperature, mixing height, and relative humidity.

(2) Some of the key features include platform building downwash, partial plume penetration into elevated inversions, direct use of turbulence intensities for plume dispersion, interaction with the overland internal boundary layer, and continuous shoreline fumigation.

a. Recommendations for Regulatory Use

OCD has been recommended for use by the Minerals Management Service for emissions located on the Outer Continental Shelf (50 FR 12248; 28 March 1985). OCD is applicable for overwater sources where onshore receptors are below the lowest source height. Where onshore receptors are above the lowest source height, offshore plume transport and dispersion may be modeled on a case-by-case basis in consultation with the EPA Regional Office.

b. Input Requirements

(1) Source data: point, area or line source location, pollutant emission rate, building height, stack height, stack gas temperature, stack inside diameter, stack gas exit velocity,

stack angle from vertical, elevation of stack base above water surface and gridded specification of the land/water surfaces. As an option, emission rate, stack gas exit velocity and temperature can be varied hourly.

(2) Meteorological data (over water): wind direction, wind speed, mixing height, relative humidity, air temperature, water surface temperature, vertical wind direction shear (optional), vertical temperature gradient (optional), turbulence intensities (optional).

(3) Meteorological data (over land): wind direction, wind speed, temperature, stability class, mixing height.

(4) Receptor data: location, height above local ground-level, ground-level elevation above the water surface.

c. Output

(1) All input options, specification of sources, receptors and land/water map including locations of sources and receptors.

(2) Summary tables of five highest concentrations at each receptor for each averaging period, and average concentration for entire run period at each receptor.

(3) Optional case study printout with hourly plume and receptor characteristics. Optional table of annual impact assessment from non-permanent activities.

(4) Concentration files written to disk or tape can be used by ANALYSIS postprocessor to produce the highest concentrations for each receptor, the cumulative frequency distributions for each receptor, the tabulation of all concentrations exceeding a given threshold, and the manipulation of hourly concentration files.

d. Type of Model

OCD is a Gaussian plume model constructed on the framework of the MPTER model.

e. Pollutant Types

OCD may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

(1) Up to 250 point sources, 5 area sources, or 1 line source and 180 receptors may be used.

(2) Receptors and sources are allowed at any location.

(3) The coastal configuration is determined by a grid of up to 3600 rectangles. Each element of the grid is designated as either land or water to identify the coastline.

g. Plume Behavior

(1) As in ISC, the basic plume rise algorithms are based on Briggs' recommendations.

(2) Momentum rise includes consideration of the stack angle from the vertical.

(3) The effect of drilling platforms, ships, or any overwater obstructions near the source are used to decrease plume rise using a revised platform downwash algorithm based on laboratory experiments.

(4) Partial plume penetration of elevated inversions is included using the suggestions of Briggs (1975) and Weil and Brower (1984).

(5) Continuous shoreline fumigation is parameterized using the Turner method where complete vertical mixing through the thermal internal boundary layer (TIBL) occurs as soon as the plume intercepts the TIBL.

h. Horizontal Winds

(1) Constant, uniform wind is assumed for each hour.

(2) Overwater wind speed can be estimated from overland wind speed using relationship of Hsu (1981).

(3) Wind speed profiles are estimated using similarity theory (Businger, 1973). Surface layer fluxes for these formulas are calculated from bulk aerodynamic methods.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

(1) Lateral turbulence intensity is recommended as a direct estimate of horizontal dispersion. If lateral turbulence intensity is not available, it is estimated from boundary layer theory. For wind speeds less than 8 m/s, lateral turbulence intensity is assumed inversely proportional to wind speed.

(2) Horizontal dispersion may be enhanced because of obstructions near the source. A virtual source technique is used to simulate the initial plume dilution due to downwash.

(3) Formulas recommended by Pasquill (1976) are used to calculate buoyant plume enhancement and wind direction shear enhancement.

(4) At the water/land interface, the change to overland dispersion rates is modeled using a virtual source. The overland dispersion rates can be calculated from either lateral turbulence intensity or Pasquill-Gifford curves. The change is implemented where the plume intercepts the rising internal boundary layer.

k. Vertical Dispersion

(1) Observed vertical turbulence intensity is not recommended as a direct estimate of vertical dispersion. Turbulence intensity should be estimated from boundary layer theory as default in the model. For very stable conditions, vertical dispersion is also a function of lapse rate.

(2) Vertical dispersion may be enhanced because of obstructions near the source. A virtual source technique is used to simulate the initial plume dilution due to downwash.

(3) Formulas recommended by Pasquill (1976) are used to calculate buoyant plume enhancement.

(4) At the water/land interface, the change to overland dispersion rates is modeled using a virtual source. The overland dispersion rates can be calculated from either vertical turbulence intensity or the Pasquill-Gifford coefficients. The change is implemented where the plume intercepts the rising internal boundary layer.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Different rates can be specified by month and by day or night.

m. Physical Removal

Physical removal is also treated using exponential decay.

n. Evaluation Studies

DiCristofaro, D.C. and S.R. Hanna, 1989. OCD: The Offshore and Coastal Dispersion Model. Volume I: User's Guide. Sigma Research Corporation, Westford, MA.

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Hanna, S.R. and D.C. DiCristofaro, 1988. Development and Evaluation of the OCD/API Model. Final Report, API Pub. 4461, American Petroleum Institute, Washington, D.C.

A.REF References

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