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Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

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EPA

Guideline On Air Quality Models (Revised)

Draft

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DISCLAIMER

This report has been reviewed by the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

FOREWORD

This draft document contains proposed revisions to the Guideline on Air Quality Models. Until the regulatory process for revising the document is completed, including public review, Agency policy on the use of air quality models in regulatory programs will continue to be represented by:

1. Guideline on Air Quality Models, EPA-450/2-78-027, April 1978;
2. Regional Workshops on Air Quality Modeling: A Summary Report (with addenda), EPA-450/4-82-015, April 1981.

CAUTIONARY NOTE TO THE READER. The model summaries contained in Appendix A reflect proposed changes to some models. Algorithms and parameters dealing with wind speed profiles, stack tip downwash, urban dispersion coefficients, etc. may be affected. These changes are in response to earlier comments solicited by EPA and to recommendations from EPA's research programs. As a result, the summaries do not precisely reflect currently available versions of the models. Justifications for the proposed changes are detailed in "Summary of Comments and Responses on the October 1980 Proposed Revisions to the Guideline on Air Quality Models," February 1984 (Docket A-80-46, Reference No. II-G-5). A draft revision of the MPTER Model computer code (rural options) has been prepared to reflect the proposed changes and may be obtained for review and comment from Docket A-80-46, Reference No. II-G-12.

PREFACE

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 was first published in April 1978 to satisfy these requirements by specifying models and providing guidance for their use. This guideline provides a common basis for estimating the air quality concentrations used in assessing control strategies and developing emission limits.

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. Four primary on-going activities provide direct input to revisions of this modeling guideline. The first is a series of annual internal EPA workshops attended primarily by Regional Meteorologists and conducted for the purpose of ensuring consistency and providing clarification in the application of models. The second activity, directed toward the improvement of modeling procedures, is the cooperative agreement that EPA has with the scientific community represented by the American Meteorological Society. This agreement provides scientific assessment of procedures and proposed techniques and sponsors workshops on key technical issues. The third 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 this guideline. The fourth activity is the extensive on-going research efforts by EPA and others in air quality and meteorological modeling.

Based primarily on these four activities, this document embodies revisions to the "Guideline on Air Quality Models." Although the text has been revised from the 1978 guide, the present content and topics are similar. As necessary, new sections and topics are included. A new format has also been adopted in an attempt to lessen the time required to incorporate changes. The looseleaf notebook format allows future changes to be made on a page-by-page basis. Changes will not be scheduled, but announcements of proposed changes will be made in the Federal Register as needed. EPA believes that revisions to this guideline should be timely and responsive to user needs and should involve public participation to the greatest possible extent. Information on the current status of modeling guidance can always be obtained from EPA's Regional Offices.

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1.0 INTRODUCTION

This guideline recommends air quality modeling techniques that should be applied to State Implementation Plan (SIP)[1] revisions for existing sources and to new source reviews,[2] including prevention of significant deterioration (PSD).[3] 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. It serves to identify, for all interested parties, those techniques and data bases EPA considers acceptable. The guide is not intended to be a compendium of modeling techniques. Rather it provides air quality managers with a common basis for acceptable technical analyses.

Due to limitations in the spatial 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, and should be used in a complementary manner, to assess the accuracy of model estimates. The use of air quality measurements alone though would be suitable, 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.

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 judgment 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 judgment of experienced meteorologists and analysts is essential.

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 use of models and data bases should be sought even in case-by-case analyses. Such 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. This guide promotes that required consistency.

Recommendations are made in this guide 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 all air quality analyses relative to State Implementation Plans and in analyses required by EPA, State and local agency air programs. The EPA Regional Administrator 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 best simulates atmospheric transport and dispersion in the area of interest. However, to ensure consistency, deviations from this guide should be carefully documented and fully supported.

From time to time situations arise requiring clarification of the intent of the guidance on a specific topic. Periodic workshops are held with the EPA Regional Meteorologists to ensure consistency in modeling guidance. 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.

All changes to this guideline must follow rulemaking requirements since the guideline has been incorporated by reference in the PSD regulations. Changes will be proposed and noticed in the Federal Register. Ample opportunity for public comment will be provided for each proposed change and public hearings scheduled if requested. Published, final changes will be made available through the National Technical Information Service (NTIS).

A wide range of topics on modeling and data bases are discussed in the remainder of this guideline. Where specific recommendations are made, the recommendations are typed in a single-spaced format. 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 7 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 8 discusses issues common to many modeling analyses, including acceptable model components. Chapter 9 makes recommendations for data inputs to models including source, meteorological and background air quality data. Chapter 10 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.

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. Appendix B contains summaries of other refined models that may be considered with a case-specific justification. Appendix C contains a checklist of requirements for an air quality analysis.

2.0 OVERVIEW OF MODEL USE

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

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.

Air quality models are most successfully applied 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.

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 inappropriately chosen data, can lead to serious misjudgments regarding the source impact or the effectiveness of a control strategy.

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, consideration of these factors should not lead to selection of an inappropriate model.

2.2 Classes of Models

The air quality modeling procedures discussed in this guide can be categorized into four generic classes: Gaussian, numerical, statistical or empirical, and physical. Within these classes, especially Gaussian and numerical models, a large number of individual "computational algorithms" may exist, each with its own specific applications. While each of the algorithms may have the same generic basis, e.g., Gaussian, it is accepted practice to refer to them individually as models. For example, the CRSTER model and the RAM model are commonly referred to as individual models. In fact, they are both variations of a basic Gaussian model. In many cases the only real difference between models within the different classes is the degree of detail considered in the input or output data.

Gaussian models are the most widely used techniques for estimating the impact of nonreactive pollutants. Numerical models may be more appropriate than Gaussian models for area source urban applications that involve reactive pollutants, but they require much more extensive input data bases and resources and therefore are not as widely applied. Statistical or empirical techniques are frequently employed in situations where incomplete scientific understanding of the physical and chemical processes or lack of the required data bases make the use of a Gaussian or numerical model impractical. Various specific models in these three generic types are discussed in this guideline.

Physical modeling, the fourth generic type, involves the use of wind tunnel or other fluid modeling facilities. This class of modeling is a complex process requiring a high level of technical expertise, as well as access to the necessary facilities. Nevertheless, physical modeling may be very useful in evaluating the air quality impact of a source or group of sources in a geographic area limited to a few square kilometers. If physical modeling is available and its applicability demonstrated, it may be the best technique. A discussion of physical modeling is beyond the scope of this guide. The EPA publication "Guideline for Fluid Modeling of Atmospheric Diffusion,"[4] provides information on fluid modeling applications and the limitations of that method.

2.3 Levels of Sophistication of Models

In addition to the various classes of models, there are two levels of sophistication. The first level consists of general, relatively simple estimation techniques that provide conservative estimates of the air quality impact of a specific source, or source category. These are screening techniques or screening models. The purpose of such techniques is to eliminate from further consideration those sources that clearly will not cause or contribute to ambient concentrations in excess of either the National Ambient Air Quality Standards (NAAQS)[5] or the allowable prevention of significant deterioration (PSD) concentration increments.[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.

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.

The use of screening techniques followed 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.

3.0 RECOMMENDED AIR QUALITY MODELS

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, the Model Clearinghouse[6] and periodic Regional Meteorologists' workshops, are also briefly discussed here.

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 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 checklist, such as presented in Appendix C, and the preparation of a written protocol help to keep misunderstandings at a minimum.

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.

The 1980 solicitation of new or different models from the technical community[7] and the program whereby these models are 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 required. Thus, the solicitation of models is considered to be continuous.

3.1 Preferred Modeling Techniques

3.1.1 Discussion

EPA has developed approximately 10 models suitable for regulatory application. More than 20 additional models were submitted by private developers for possible inclusion in the guideline. These refined models have all been organized into eight categories of use: rural, urban industrial complex, reactive pollutants, mobile sources, complex terrain, visibility, and long range transport. They are undergoing an intensive evaluation by category. The evaluation exercises[8,9,10] include statistical measures of model performance suggested by the American Meteorological Society[11] and, where possible, peer scientific reviews.[12,13] If a single model is found to be superior to others in a given category, it is recommended for application in that category as a preferred model and listed in Appendix A. If no one model is found clearly superior 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. The models not specifically recommended for use in a particular category are summarized in Appendix B.

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 provisions outlined in the Federal Register notice of March 1980 (45 FR 20157)[7] will be evaluated as submitted. The evaluation process will include a determination of technical merit, in accordance with the six items listed in the above-mentioned Federal Register notice, 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 found to be clearly superior for wide use (not just an isolated case!) will be proposed for inclusion as preferred models in a future guideline revision.

3.1.2 Recommendations

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 this guide.

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.

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

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. An EPA document, "Interim Procedures for Evaluating Air Quality Models,"[14] has been prepared to assist in developing a consistent approach when justifying the use of other than the preferred modeling techniques recommended in this guide. These procedures provide a general framework for objective decision-making on the acceptability of an alternative model for a given regulatory application. The document contains procedures for conducting both the technical evaluation of the model and the field test or performance evaluation. An example problem that focuses on the design and execution of the protocol for conducting a field performance evaluation is also included in that document.

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

3.2.2 Recommendations

Determination of acceptability of a model is a Regional Office responsibility. Where the Regional Administrator or reviewing authority 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 is applicable.

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 will 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 application than a comparable model in Appendix A; and (3) if there is no preferred model for the specific application but a refined model is needed to satisfy regulatory requirements. Any one of these three separate conditions may warrant use of an alternative model. Some alternative models known to be available to the public that are applicable for selected situations are contained in Appendix B. However, inclusion there does not infer any unique status relative to other alternative models that are being or will be developed for the future.

Equivalency is established by demonstrating that the maximum or highest, second highest concentrations are within two 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, this demonstration is not intended to preclude the use of models that are not equivavalent. They may be used when one of two other conditions identified below are satisfied.

The procedures and techniques for determining the acceptability of a model for an individual case based on superior performance is contained in the document entitled "Interim Procedures for Evaluating Air Quality Models,"[14] 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.

When no Appendix A model is applicable to the modeling problem, an alternative refined model may be used provided that:

1. the model can be demonstrated to be applicable to the problem on a theoretical basis, and

2. the data bases which are necessary to perform the analysis are available and adequate, and

3a. performance evaluations of the model in similar circumstances have shown that the model is not biased toward underestimates, or

3b. after consultation with the EPA Regional Office, a second model is selected as a baseline or reference point for performance and the interim procedures[14] are then used to demonstrate that the proposed model is superior.

3.3 Availability of Supplementary Modeling Guidance

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 and also holds periodic workshops with headquarters and Regional Office modeling representatives.

3.3.1 The Model Clearinghouse

3.3.1.1 Discussion

The Model Clearinghouse is the single EPA focal point for review of air quality simulation models proposed for use in specific regulatory applications. Details concerning the Clearinghouse and its operation are found in the document, "Model Clearinghouse: Operational Plan."[6] Three primary functions of the Clearinghouse are:

(1) Review of decisions proposed by EPA Regional Offices on the use of modeling techniques and data bases.

(2) Periodic visits to Regional Offices to gather information pertinent to regulatory model usage.

(3) Preparation of an annual report summarizing activities of the Clearinghouse including specific determinations made during the course of the year.

3.3.1.2 Recommendations

The Regional Administrator 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. The Clearinghouse may also consider and evaluate the use of modeling techniques submitted in support of any regulatory action. Additional responsibilities are: (1) review proposed action for consistency with agency policy; (2) determine technical adequacy; and (3) make recommendations concerning the technique or data base.

3.3.2 Regional Meteorologists Workshops

3.3.2.1 Discussion

EPA conducts an annual in-house workshop for the purpose of mutual discussion and problem resolution among Regional Office modeling specialists, EPA research modeling experts and EPA Headquarters modeling and regulatory staff. A summary of the issues resolved at previous workshops was issued in 1981 as "Regional Workshops on Air Quality Modeling: A Summary Report."[15] That report clarified procedures not specifically defined in the 1978 guideline and was issued to ensure the consistent interpretation of model requirements from Region to Region. Similar in-house workshops for the purpose of clarifying guideline procedures or providing detailed instructions for the use of those procedures are anticipated in the future.

3.3.2.2 Recommendations

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.

4.0 SIMPLE-TERRAIN STATIONARY-SOURCE MODELS

4.1 Discussion

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. The models recommended in this section are most often used in the air quality impact analysis of stationary sources of SO_2 and particulates. The averaging time of the concentration estimates produced by these models ranges from 1 hour to an annual average.

Model evaluation exercises have been conducted to determine the "best, most appropriate point source model" for use in simple terrain.[8,12] However, no one model has been found to be clearly superior. Thus, based on past use, public familiarity, and availability CRSTER remains the recommended model for rural, simple terrain, single point source applications. Similar determinations were made for the other refined models that are identified in the following sections.

4.2 Recommendations

4.2.1 Screening Techniques

The EPA document "Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10R: Procedures for Evaluating Air Quality Impact of New Stationary Sources"[16] contains screening procedures that should be used if the source is in simple terrain. A computerized version of the Volume 10R screening technique for use in rural simple terrain is available in "UNAMAP"[17] as PTPLU; PTCITY* should be used for urban areas.

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 8.2.8. 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.

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*PTCITY, which contains urban dispersion coefficients will be made available in the next update of UNAMAP.

4.2.2 Refined Analytical Techniques

Table 4-1 lists preferred models for selected applications. These preferred models should be used for the sources, land use categories and averaging times indicated in the table. A brief description of each of these models is found in Appendix A. Also listed in that appendix are the model input requirements, the standard options that should be selected when running the program and output options.

Table 4-1

Preferred Models for Selected Applications in Simple Terrain

Short Term (1-24 hours)	Land Use	Model*
Single Source	Rural	CRSTER
	Urban	RAM
Multiple Source	Rural	MPTER
	Urban	RAM
Complicated Sources**	Rural/Urban	ISCST
Buoyant Industrial Line Sources	Rural	BLP
Long Term (monthly, seasonal or annual)		
Single Source	Rural	CRSTER
	Urban	RAM
Multiple Source	Rural	MPTER
	Urban	CDMQC*** or RAM****
Complicated Sources**	Rural/Urban	ISCLT
Buoyant Industrial Line Sources	Rural	BLP

*Several of these models contain options which allow them to be interchanged, e.g., ISCST can be substituted for CRSTER and equivalent, if not identical, concentration estimates obtained. Where a substitution is convenient to the user and equivalent estimates are assured, it may be made. The models as listed here reflect the applications for which they were originally intended.

**Complicated sources are sources with special problems such as aerodynamic downwash, particle deposition, volume and area sources, etc.

***Although CDMQC contains a method to convert from long-term to short term averages (Larsen's transform), this method is not acceptable in regulatory applications.

****If only a few sources in an urban area are to be modeled, RAM should be used.

5.0 MODEL USE IN COMPLEX TERRAIN

5.1 Discussion

For the purpose of this guideline, complex terrain is defined as terrain exceeding the height of the stack being modeled. Complex terrain dispersion models are normally applied to stationary sources of pollutants such as SO_2 and particulates.

Although the need for refined complex terrain dispersion models has been acknowledged for several years, adequate refined models have not been developed. The lack of detailed, descriptive data bases and basic knowledge concerning the behavior of atmospheric variables in the vicinity of complex terrain presents a considerable obstacle to the solution of the problem and the development of refined models.

A workshop[18] of invited complex terrain experts was held by the American Meteorological Society as a part of the AMS-EPA Cooperative Agreement in May of 1983. Several major complex terrain problems were identified at this workshop; among them were: (1) valley stagnation, (2) valley fumigation, (3) downwash on the leeside of terrain obstacles and (4) the identification of conditions under which plume impaction can occur.

A first step toward the solution of two of these problems has been taken in the multi-year EPA Complex Terrain Model Development project.[19,20,21] One product of this project is expected to be a model suitable for regulatory application to plume impaction problems in complex terrain. In addition, insight into the leeside effects problem is also anticipated. Completion of the project is not expected before 1986. Preliminary results have identified at least two concepts that have important implications for the regulatory application of models in complex terrain and will require further detailed study and evaluation. First, plume impaction resulting in high concentrations was observed to occur during the field study as well as in supporting fluid modeling studies.[19] Further, the occurrence of impaction was linked to a "critical streamline" that separates flow around an obstacle from flow over an obstacle. Second, high concentrations were also observed to occur in the lee of the obstacle and were of sufficient magnitude to indicate that this phenomenon should be considered, if appropriate, in the determination of source impacts.[20]

To date most projects have been designed to identify plume behavior in complex terrain and to define the meteorological variables influencing that behavior. Until such time as it is possible to develop and evaluate a model based on the quantification of the meteorological and plume parameters identified in these studies, existing algorithms adapted to site-specific complex terrain situations are all that are available. The methods discussed in this section should be considered screening, or "refined" screening, techniques and not refined dispersion models.

5.2 Recommendations

The following recommendations apply primarily to the situations where the impaction of plumes on terrain at elevations equal to or greater than the plume centerline during stable atmospheric conditions are determined to be the problem. The evaluation of other concentrations should be considered after consultation with the Regional Office. However, limited guidance on calculation of concentrations between stack height and plume centerline is provided.

Models developed for specific uses in complex terrain will be considered on a case-by-case basis after a suitable demonstration of their technical merits and an evaluation using measured on-site data following the procedures in "Interim Procedures for the Evaluation of Air Quality Models."[14] Since the location of plume centerline is as important a concern in complex terrain as dispersion rates, it should be noted that the dispersion models combined with a wind field analysis model should be superior to an assumption of straight-line plume travel. Such hybrid modeling techniques are also acceptable, after the appropriate demonstration and evaluation.

5.2.1 Screening Techniques

In the absence of an approved case-specific, refined, complex terrain model, three screening techniques are currently available to aid in the evaluation of concentrations due to plume impaction during stable conditions: the Valley Screening Technique as outlined in the Valley Model's User's Guide,[22] COMPLEX I,[17] and SHORTZ/LONGZ.[23] These methods should be used only to calculate concentrations at receptors whose elevations are greater than or equal to plume height. Receptors below stack height should be modeled using a preferred simple terrain model (see Chapter 4). Receptors between stack height and plume height should be modeled with both complex terrain and simple terrain models and the highest concentration used. (For the simple terrain models, terrain may have to be "chopped-off" at stack height, since these models are frequently limited to receptors no greater than stack height.)

5.2.1.1 Initial Screening Technique

The initial screen to determine 24-hour averages is the Valley Screening Technique. This technique uses the Valley Model with the following worst-case assumptions for rural areas: (1) P-G stability "F"; (2) wind speed of 2.5 m/s; and (3) 6 hours of occurrence. For urban areas the stability should be changed to "P-G stability E."

When using the Valley Screening Technique to obtain 24-hour average concentrations the following apply: (1) multiple sources should be treated individually and the concentrations for each wind direction summed; (2) only one wind direction should be used (see User's Guide,[22] page 2-15) even if individual runs are made for each source; (3) for buoyant sources, the BID option may be used, and the option to use the 2.6 stable plume rise factor should be selected; (4) if plume impaction is likely on any elevated terrain closer to the source than the distance from the source to the final plume rise, then the transitional (or gradual) plume rise option for stable conditions should be selected.

The receptor grid found in the Valley Model User's Guide may not be sufficient for all analyses if only one geographical scale factor is used. The Valley Model is very sensitive to the ground-level elevation at the receptor, and the use of the standard polar grid could miss the worst-case receptor. If this situation occurs, the user should choose an additional set of receptors at appropriate downwind distances whose elevations are equal to plume height minus 10 meters.

5.2.1.2 Second-Level Screening Technique (Rural)

If a violation of any NAAQS or the controlling increment is indicated by using the Valley Screening Technique, a second-level screening technique may be used. A site-specific data base of at least 1 full year of meteorological data is preferred for use with any second-level screening technique. Meteorological data used in the analysis should be reviewed for both spatial and temporal representativeness.

If the area is rural, the suggested second-level screening technique is COMPLEX I for all averaging times. COMPLEX I is a modification of the MPTER model that incorporates the plume impaction algorithm of the Valley Model. It is a multiple-source screening technique that accepts hourly meteorological data as input. The output is the same as the normal MPTER output. When using COMPLEX I the following options should be selected: (1) set terrain adjustment IOPT(1) = 1; (2) set buoyancy induced dispersion IOPT (4) = 1; (3) set IOPT (25) = 1; (4) set the terrain adjustment values to 0.5, 0.5, 0.5 0.5, 0.0, 0.0, (respectively for 6 stability classes); and (5) set Z MIN = 10.

If gradual plume rise is used to estimate concentrations at nearby elevated receptors, each of the concentrations listed in the model output table of high values should be carefully examined prior to regulatory application. The gradual plume rise option in COMPLEX I is not specific to stable conditions and the high concentrations could be the result of the larger dispersion coefficients assigned to unstable or neutral conditions and plume touchdown on other than elevated terrain. Only those concentrations specifically recorded at receptors above plume height should be used.

5.2.1.3 Second-Level Screening Technique (Urban)

In the event the source(s) is located in an urbanized (Section 8.2.8) complex terrain valley, then the screening technique of choice is SHORTZ for short term averages or LONGZ for long term averages. (SHORTZ and LONGZ may be used as screening techniques in these complex terrain applications without demonstration and evaluation. Application of these models in other than urbanized valley situations will require the same evaluation and demonstration procedures as are required for all Appendix B models.)

One full year of site-specific meteorological data is preferred when applying SHORTZ/LONGZ as a screening technique. If more data are available, they should be used.

Both SHORTZ and LONGZ have a number of options. When using these models as screening techniques for urbanized valley applications, the options listed in Table 5-1 should be selected.

5.2.1.4 Restrictions

For screening analyses using the Valley Screening Technique or Complex I, a sector greater than 22-1/2° should not be allowed and full ground reflection should always be used.

Table 5-1

Preferred Options for the SHORTZ/LONGZ Computer Codes When Used in a Screening Mode

Option	Selection
I Switch 9	If using NWS data, set = 0 If using site-specific data, check with the Regional Office
I Switch 17	Set = 1 (urban option)
GAMMA 1	Use default values (0.6 entrainment coefficient)
GAMMA 2	Always default to stable
XRY	Set = 0 (50 m rectilinear expansion distance)
NS, VS, FRQ (SHORTZ) NUS, VS, FRQ (LONGZ) (particle size, etc.)	Do not use (Applicable only in flat terrain)
ALPHA	Select 0.9
SIGEPU SIGAPU (dispersion parameters)	Use Cramer curves (default) If site-specific turbulence data are available, see the Regional Office for advice.
P (wind profile)	Select default values given in Table 2-2 of User's Instructions If site-specific data are available, see the Regional Office for advice.

5.2.2 Refined Analytical Techniques

When the results of the screening analysis demonstrate a possible violation of NAAQS or the controlling PSD increments, a more refined analysis should be conducted. Since there are no refined techniques currently recommended for complex terrain applications, any refined model used should be applied in accordance with Section 3.2. In particular, use of the "Interim Procedures for Evaluating Air Quality Models"[14] and a second model to serve as a baseline or reference point for the comparison should be used in a demonstration of applicability. Hybrid models which incorporate an accurate wind field analysis may provide a superior analysis tool.

In the absence of an appropriate refined model, screening results may need to be used to determine air quality impact and/or emission limits.

6.0 MODELS FOR OZONE, CARBON MONOXIDE AND NITROGEN DIOXIDE

6.1 Discussion

Models discussed in this section are generally applicable to mobile sources of pollutants. Those pollutants are typically ozone, carbon monoxide and nitrogen dioxide. Where stationary sources of those pollutants are of concern, the reader is referred to Sections 4 and 5.

A control agency whose jurisdiction contains areas with significant ozone problems and who has sufficient resources and data to use a photochemical dispersion model is encouraged to do so. Experience with and evaluations of the Urban Airshed Model show it to be an acceptable, refined approach. Better data bases are becoming available that support the more sophisticated analytical procedures. However, empirical models (e.g. EKMA) fill the gap between more sophisticated photochemical dispersion models and proportional (rollback) modeling techniques and may be the only applicable procedure if the data bases available are insufficient for refined dispersion modeling.

Carbon monoxide is generally considered to be a problem only in specific areas with high numbers of vehicles or slow moving traffic. For that reason, frequently only "hot spots" or project level analyses are needed in SIP revisions.

Nitrogen oxides are reactive and also an important contribution to the photochemical ozone problem. They are usually of most concern in areas of high ozone concentrations. Unless suitable photochemical dispersion models are used, assumptions regarding the conversion of NO to

NO_2 are required when modeling. Site-specific conversion factors may be developed. If site-specific conversion factors are not available or photochemical models are not used, NO_2 modeling should be considered only a screening procedure.

6.2 Recommendations

6.2.1 Models for Ozone

The Urban Airshed Model[24] is recommended for photochemical or reactive pollutant modeling applications involving entire urban areas. To ensure proper execution of this numerical model, users must satisfy the extensive input data requirements for the model as listed in Appendix A and the users guide. Users are also referred to the "Guideline for Applying the Airshed Model to Urban Areas"[25] for further information on data base requirements, kinds of tasks involved in the model application, and the overall level of resources required.

The empirical model, City-specific EKMA[26,27,28,29,30] is an acceptable approach for urban ozone applications.

Appendix B contains some additional models that may be applied on a case-by-case basis for photochemical or reactive pollutant modeling. Other photochemical models, including multi-layered trajectory models, that are available may be used if shown to be appropriate. Most photochemical dispersion models require emission data on individual hydrocarbon species and may require three dimensional meteorological information on an hourly basis. Reasonably sophisticated computer facilities are also often required. Because the input data are not universally available and studies to collect such data are very resource intensive, there are only limited evaluations of those models.

Proportional (rollback/forward) modeling is no longer an acceptable procedure for evaluating ozone control strategies.

6.2.2 Models for Carbon Monoxide

Carbon monoxide modeling for the development of SIP-required control strategies should follow the guidance provided in the "Carbon Monoxide Hot Spot Guidelines"[31] or in Volume 9 of the "Guidelines for Air Quality Maintenance Planning and Analysis."[32] These volumes provide screening techniques for locating and quantifying worst case carbon monoxide concentrations, and for establishing background values; they also provide methods for assessing areawide carbon monoxide concentrations. If results from screening techniques or measured carbon monoxide levels in an urban area are clearly well below the standards and expected to remain below the standard, or it can be demonstrated that the Federal Motor Vehicle Control Program will provide the needed CO reductions, then urban area-wide strategies may be evaluated using a modified rollback or proportional model approach.

Project analysis of mobile source emissions of carbon monoxide should first include an analysis using the screening techniques referenced above. If concentrations using these techniques exceed the NAAQS, then refined techniques are needed to determine compliance with the standards. CALINE3 (see Appendix A) is the preferred model for use when refined analyses are required.

Situations that require the use of refined techniques on an urban-wide basis should be considered on a case-by-case basis. If a suitable model is available and the data and technical competence required for its use are available, then such a model should be considered.

Where point sources of CO are of concern, they should be modeled using the screening and preferred techniques of Sections 4 or 5.

6.2.3 Models for Nitrogen Dioxide (Annual Average)

A three-tiered screening approach is recommended to obtain annual average estimates of NO_2 from point sources:

a. Initial screen: Use an appropriate Gaussian 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 for NO_2, proceed to the 2nd level screen.

b. 2nd level screen: Apply the Ozone Limiting Method[33] to the annual NO_x estimate obtained in (a) above using a representative average annual ozone concentration. If the result is still greater than the NAAQS, the more refined Ozone Limiting Method in the 3rd level screen should be applied.

c. 3rd level screen: Apply the Ozone Limiting Method separately for each hour of the year or multi-year period. Use representative hourly NO_2 background and ozone levels in the calculations.

In urban areas, a proportional model may be used as a preliminary assessment to evaluate control strategies for multiple sources (mobile and area) of NO_x; concentrations resulting from major point sources should be estimated separately as discussed above, then added to the impact of area 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 based on a spatially averaged NO_2/NO_x annual ratio determined from an existing air quality monitoring network.

Situations that require more refined techniques, such as those where there are sufficient hydrocarbons available that the assumptions implicit in the above procedure are no longer valid, should 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 it is 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.

7.0 OTHER MODEL REQUIREMENTS

7.1 Discussion

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.

Other Federal agencies have also developed specific modeling approaches for their own regulatory or other requirements. An example of this is the three-volume manual issued by the U. S. Department of Housing and Urban Development, "Air Quality Considerations in Residential Planning."[34] 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.

The need to estimate impacts at distances greater than 50 km (the nominal distance to which EPA considers most Gaussian models applicable) is an important one especially when considering the effects from secondary pollutants. Unfortunately, models submitted to EPA have not as yet undergone sufficient field evaluation to be recommended for general use. Existing data bases from field studies at mesoscale and long range transport distances are limited in detail. This limitation is a result of the expense to perform the field studies required to verify and improve mesoscale and long range transport models. Particularly important and sparse are meteorological data adequate for generating three dimensional wind fields. Application of models to complicated terrain compounds the difficulty.

A current EPA agreement with Argonne National Laboratory, scheduled for completion in FY 1985, will result in the development of evaluation procedures for long range transport models. Models submitted to EPA will be tested for currently available data bases with these procedures. Similar research in this area is also being performed by others in EPA and other organizations. For the time being, however, long range and mesoscale transport models must be evaluated for regulatory use on a case-by-case basis.

7.2 Recommendations

7.2.1 Fugitive dust/Fugitive emissions

Fugitive dust usually refers to the 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 are usually defined as emissions that come from an industrial source complex. They 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, the ISC model, with consideration of gravitational settling and dry deposition, is the recommended model. 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.

7.2.2 Particulate Matter

Currently a proposed NAAQS for particulate matter includes both provisions for particles in the size range less than 10 micrometers and for Total Suspended Particulates (TSP). State Implementation Plans will be developed by States to attain and maintain this new standard when the standard is promulgated.

Screening techniques like those identified in Section 4 are also applicable to PM_{10} and to large particles (TSP). It is recommended that subjectively determined values for "half-life" or pollutant decay not be used as a surrogate for particle removal. Conservative assumptions which do not allow removal or transformation are suggested for screening. Proportional models(rollback/forward) may not be applied for screening analysis, unless such techniques are used in conjunction with receptor modeling.

Refined models such as those in Section 4 are recommended for both PM_{10} and TSP. However, where possible, particle size, gas-to-particle formation and their effect on ambient concentrations may be considered. For urban-wide refined analyses CDMQC or RAM should be used. CRSTER and MPTER are recommended for point sources of small particles. For source-specific analyses of complicated sources, the ISC model is preferred. No model recommended for general use at this time accounts for secondary particulate formation or other transformations in a manner suitable for SIP control strategy demonstrations. Where possible, the use of receptor models[35,36] in conjunction with dispersion models is encouraged to more precisely characterize the emissions inventory and to validate source specific impacts calculated by the dispersion model.

For those cases where no recommended technique is available or applicable, modeling approaches should be approved by the appropriate Regional Office on a case-by-case basis. At this time analyses involving model calculations for distances beyond 50 km should also be justified on a case-by-case basis (see Section 7.2.6).

7.2.3 Lead

The air quality analyses required for lead implementation plans are given in Sections 51.83, 51.84 and 51.85 of 40 CFR Part 51. Sections 51.83 and 51.85 require the use of a modified rollback model as a minimum to demonstrate attainment of the lead air quality standard but the use of a dispersion model is the preferred approach. Section 51.83 requires the analysis of an entire urban area if the measured lead concentration in the urbanized area exceeds a quarterly (three month) average of 4.0 $\mu g/m^3$. Section 51.84 requires the use of a dispersion model to demonstrate attainment of the lead air quality standard around specified lead point sources. For other areas reporting a violation of the lead standard, Section 51.85 requires an analysis of the area in the vicinity of the monitor reporting the violation. The NAAQS for lead is a quarterly (three month) average, thus requiring the use of modeling techniques that can provide long-term concentration estimates.

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. For these applications the ISC model is preferred, since the model can account for deposition of particles and the impact of fugitive emissions. If the source is located in complicated terrain or is subject to unusual climatic conditions, a case-specific review by the appropriate Regional Office may be required.

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 APRAC-3 have been widely used for modeling carbon monoxide emissions from highways. However, none of these models accounts for deposition of particles. Where deposition is of concern, the line source treatment in ISC 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 (see Section 9.2); the point source and any nearby major roadways should be modeled separately using the ISC model.

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.

For further information concerning the use of models in the development of lead implementation plans, the documents "Supplementary Guidelines for Lead Implementation Plans,"[37] and "Updated Information on Approval and Promulgation of Lead Implementation Plans,"[38] should be consulted.

7.2.4 Visibility

The visibility regulations as promulgated in December 1980* require consideration of the effect of new sources on the visibility values of Federal Class I areas. The state of scientific knowledge concerning identifying, monitoring, modeling, and controlling visibility impairment is contained in an EPA report "Protecting Visibility: An EPA Report to Congress."[39] At the present time, "although information derived from modeling and monitoring can, in some cases, aid the States in development and implementation of the visibility program,"* the States are not currently required to establish monitoring networks or perform modeling analyses. However, a monitoring strategy is required. As additional knowledge is gained, guidance on "plume blight" and regional scale models will be provided, as appropriate.

References 40, 41, and 42 may also be useful when visibility evaluations are needed. Appendix B contains two models developed for application to visibility problems.

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*45 FR 80084.

7.2.5 Good Engineering Practice Stack Height

The use of stack heights in excess of Good Engineering Practice (GEP) stack height is prohibited in the development of emission limitations by 40 CFR 51.12 and 40 CFR 51.18. The definition of GEP stack height is contained in 40 CFR 51.1. Methods and procedures for making the appropriate stack height calculations, determining stack height credits and an example of applying those techniques are found in references 43, 44, and 45.

If stacks for new or existing major sources are found to be less than GEP height, then air quality impacts associated with cavity or wake effects due to the nearby building structures should be determined. Detailed downwash screening procedures[15] for both the cavity and wake regions should be followed. If more refined concentration estimates are required, the Industrial Source Complex (ISC) model contains algorithms for building wake calculations and should be used. Fluid modeling may also be used to evaluate and describe the cavity and wake effects.

7.2.6 Long Range Transport (beyond 50 km)

Suspected significant impacts on PSD Class I areas (as defined in the PSD Regulations) require that impact analyses be performed. However, the useful distance to which most Gaussian models are considered accurate for setting emission limits is 50 km. Since in many cases Class I areas may be threatened at distances greater than 50 km from new sources, some procedure is needed to (1) determine if a significant impact will occur, and (2) identify the model to be used in setting an emission limit if the Class I increments are threatened (models for this purpose should be approved for use on a case-by-case basis as required in Section 3.2). This procedure and the models selected for use should be determined in consultation with the EPA Regional Office and 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 models that may be affected.

Models for use beyond 50 km and not for PSD purposes also must be selected for use on a case-by-case basis. Normally, use of these models will require an acceptable demonstration of applicability and an evaluation of model performance if possible (see Section 3.2).

7.2.7 Modeling Guidance for Other Governmental Programs

When using the models recommended or discussed in this 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 that model. 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.

8.0 GENERAL MODELING CONSIDERATIONS

8.1 Discussion

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.

8.2 Recommendations

8.2.1 Design Concentrations

8.2.1.1 Design Concentrations for SO_2, Particulate Matter, Lead, and NO_2

If the air quality analyses are conducted using the period of meteorological input data recommended in Section 9.3.1.2 (e.g., 5 years of NWS data or one year of site-specific data), then the highest, second-highest short-term concentration should be used to determine emission limitations to assess compliance with the NAAQS and to determine PSD increments.

When sufficient and representative data exist for less than a 5-year period from a nearby NWS site, or when on-site data have been collected for less than a full continuous year, or when it has been determined that the on-site data may not be temporally representative, 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. This specifically applies to the use of techniques such as outlined in "Procedures for Evaluating Air Quality Impact of New Stationary Sources."[16]

If the design concentration is an annual average value and multiple years of data (on-site or NWS) are used, then the design value is the highest of the annual averages calculated for the individual years. If the design concentration is a quarterly average, then the highest individual quarterly period from a single year should be used.

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

8.2.1.2 Design Concentrations for Criteria Pollutants with Expected Exceedance Standards

Specific instructions for the determination of design concentrations for criteria pollutants with expected exceedance standards are contained in special guidance documents for the preparation of State Implementation Plans for those pollutants. 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.

8.2.1.3 Block Averaging Times

Concentration estimates should be based on block averaging times rather than running average times unless running averages are specifically included in the definition of the standard for the pollutant being modeled. The times for the blocked periods should be oriented to midnight unless specified otherwise in the standard. For example, 24-hour averages should be midnight to midnight, while 3-hour averages should be midnight-3, 3-6, 6-9, etc. Annual and quarterly averages should be on a calendar year basis.

8.2.2 Critical Receptor Sites

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. For large sources (those equivalent to a 500 MW power plant) and where violations of the NAAQS or PSD increment are likely, the selection of receptor sites should be a case-by-case determination taking into consideration the topography, the climatology, and the results of the initial screening procedure. Usually 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 10 km, are 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.

8.2.3 Dispersion Coefficients

Gaussian 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, and type of source (point vs. line) may dictate the selection of specific coefficients. Generally, coefficients used in Appendix A models are identical to, or at least based on, Pasquill-Gifford coefficients[46] in rural areas and McElroy-Pooler[47] coefficients in urban areas.

Research is continuing toward the development of methods to determine dispersion coefficients directly from measured or observed variables.[48] No method to date has proved to be widely applicable. Thus, direct measurement, as well as other dispersion coefficients related to distance and stability, may be used in Gaussian modeling only if a demonstration can be made that such parameters are more applicable and accurate for the given situation than are algorithms contained in the preferred models.

Buoyancy-induced dispersion (BID), as identified by Pasquill,[49] is included in the preferred models and should be used where buoyant sources, e.g., those involving fuel combustion, are involved.

8.2.4 Stability Categories

The Pasquill approach to classifying stability is generally required in all preferred models (Appendix A). The Pasquill method, as modified by Turner,[50] was developed for use with commonly observed meteorological data from the National Weather Service and is based on cloud cover, insolation and wind speed.

Procedures to determine Pasquill stability categories from other than NWS data are found in subsection 9.3. Any other method to determine Pasquill stability categories must be justified on a case-by-case basis.

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 generally acceptable only to determine long-term averages, such as seasonal or annual, and when the meteorological input data are statistically summarized as in the STAR summaries. Sector averaging is, however, commonly acceptable in complex terrain screening methods.

8.2.5 Plume Rise

The plume rise methods of Briggs[51,52] are incorporated in the preferred models and are recommended for use in all modeling applications. No provisions in these models are made for fumigation or multistack plume rise enhancement or the handling of such special plumes as flares; these problems should be considered on a case-by-case basis.

The algorithm for momentum plume rise, available in the preferred models, should be used where high velocity or nonbuoyant plumes are being considered.

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 rise is appropriate: (1) in complex terrain screening procedures to determine close-in impacts; (2) to identify the existence of building wake problems. These are automatically provided for in the complex terrain screening techniques and in the ISC building wake algorithms.

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 Bjorkland and Bowers[23] is the recommended technique for this situation and is found in the point source preferred models.

Where aerodynamic downwash occurs due to the adverse influence of nearby structures, the algorithms included in ISC[53] should be used.

8.2.6 Chemical Transformation

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[50] 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 Gaussian 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.

Complete conversion of NO to NO_2 should be assumed for all travel time when simple screening techniques are used to model point source emissions of nitrogen oxides. If a Gaussian model is used, and data are available on seasonal variations in maximum ozone concentrations, the Ozone Limiting Method[28] is recommended. In refined analyses, case-by case conversion rates based on technical studies appropriate to the site in question may be used. The use of more sophisticated modeling techniques should be justified for individual cases.

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.

8.2.7 Gravitational Settling and Deposition

An "infinite half-life" should be used for estimates of total suspended particulate concentrations when Gaussian models containing only exponential decay terms for treating settling and deposition are used.

Gravitational settling and deposition may be directly included in a model if either is a significant factor. At least one preferred model (ISC) contains settling and deposition algorithms and is recommended for use when particulate matter sources can be quantified and settling and deposition are problems.

8.2.8 Urban/Rural Classification

The selection of either rural or urban dispersion coefficients in a specific application should follow one of the procedures suggested by Irwin[54] 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.

Land Use Procedure: (1) Classify the land use within the total area, A_o, circumscribed by a 3 km radius circle about the source using the meteorological land use typing scheme proposed by Auer[55]; (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.

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

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.

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.

8.2.9 Fumigation

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 either 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 (see "Guidelines for Air Quality Maintenance Planning and Analysis Volume 10R: Procedures for Evaluating Air Quality Impact of New Stationary Sources")[16] that may be used to approximate the concentrations. Considerable care should be exercised in the use of the results obtained from the screening techniques.

Fumigation is also an important phenomenon on and near the shoreline of bodies of water. This can affect both individual plumes and area-wide emissions. Although models have been developed to address this problem, the evaluations so far do not permit the recommendation of any specific technique.

The Regional Office should be contacted to determine the appropriate model for applications where fumigation is of concern.

8.2.10 Stagnation

Although both short and long term periods of very light winds are important in the identification of worst-case conditions, the models identified in this guideline cannot adequately simulate such conditions. If stagnation conditions are determined to be important to the analysis, then techniques specific to the situation and location must be developed. Such techniques might include empirical models or box models. Assistance from the appropriate Regional Office should be obtained prior to embarking on the development of such a procedure.

8.2.11 Calibration of Models

Calibration of long-term multi-source models has been a widely used procedure even though the limitations imposed by statistical theory on the reliability of the calibration process for long-term estimates are well known.[56] In some cases, where a more accurate model is not available, calibration may be the best alternative for improving the accuracy of the estimated concentrations needed for control strategy evaluations. When calibration is warranted, the procedures described in the "Addendum to User's Guide for Climatological Dispersion Model"[57] should be followed.

Calibration of short-term models is not common practice and is subject to much greater error and misunderstanding. There have been attempts by some to compare short-term 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 short-term models of questionable benefit. Therefore, short-term model calibration is unacceptable.

9.0 MODEL INPUT DATA

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 inconsistencies 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 included as Appendix C. Specific data requirements and formats for individual models are described in detail in the users' guide for each model.

9.1 Source Data

9.1.1 Discussion

Sources of pollutants can be classified as point, line and area/volume sources. Point sources are defined in terms of size and may vary from program to program. 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.

Emission factors are compiled in an EPA publication commonly known as AP-42[58]; 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.

9.1.2 Recommendations

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* 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. The following example for a power plant 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.

a. 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.

b. Stack parameters. For all stacks, the stack height and 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.

c. 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).

d. 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.).

e. 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.

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*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.

f. 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.

g. 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 available for items (a) through (f) above following completion of construction or modification.

In multi-source applications for compliance with short term ambient standards, control strategies for point sources should be tested using allowable emission rates and design capacity (100 percent load). For quarterly and annual standards, historical maximum operating rates, based on the last 3 years of operation, can be used in the analysis. In the case where the physical characteristics of the source make it impossible to emit at the allowable rate, the achievable maximum emission rate may be used as long as this rate is restricted by an enforceable permit condition. 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 in Appendix C should be consulted for other possible emission data that could be helpful.

Line source modeling of streets and highways requires data on the width of the roadway and the median strip, the types and amounts (grams per second per meter) 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 available for line source modeling.

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.

9.2 Background Concentrations

9.2.1 Discussion

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.

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.[59] An appropriate data validation procedure should be applied to the data prior to use.

If the source is not isolated, it may be necessary to use a multi-source model to establish the impact of nearby sources. Background concentrations should be determined for each critical (concentration) averaging time.

9.2.2 Recommendations (Isolated Single Source)

Two options are available to determine background near isolated sources.

Option One: 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.

Option Two: 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 unidentified sources.

9.2.3 Recommendations (Multi-Source Areas)

In multi-source areas two components of background should be determined.

Nearby Sources: All sources expected to cause a significant concentration gradient in the vicinity of the source or sources under consideration should be explicitly modeled. For evaluation against annual standards these sources under consideration should be modeled at worst case actual emissions. For evaluation against short term standards these sources should be modeled at maximum allowable emissions. The nearby source inventory should be determined in consultation with the local air pollution control agency. It is envisioned that the nearby sources and the sources under consideration will be evaluated together using an appropriate Appendix A model.

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*For purposes of PSD, the location of monitors as well as data quality assurance procedures must satisfy requirements listed in the PSD Monitoring Guidelines.[54]

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.

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 9.2.2.

9.3 Meteorological Input Data

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.

Model input data are normally obtained either from the National Weather Service or as part of an on-site measurement program. Some recommendations for the use of each type of data are included in this subsection.

9.3.1 Length of Record of Meteorological Data

9.3.1.1 Discussion

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[60] 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 are prohibitively expensive. A recent study[61] compared various periods from a 17-year data set to determine the minimum number of years 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.

It should be noted that if less than 5 years of model input data are used in a modeling analysis to obtain a high second-high concentration, there is a degree of uncertainty that should be considered when applying those model results to the establishment of emission limits.

9.3.1.2 Recommendations

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 may be data collected either onsite or at the nearest National Weather Service (NWS) station. If the source is large, e.g., a 500 MW power plant, the use of 5 years of NWS meteorological data or at least 1 year of site-specific data is required. As many years, up to five, of site-specific data as are available should be used; such data should have been subjected to quality assurance procedures as described in Section 9.3.3.2.

9.3.2 National Weather Service Data

9.3.2.1 Discussion

The National Weather Service (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, most model applications still rely heavily on the NWS data.

There are two standard formats of the NWS data for use in air quality models. The short term 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. "STAR" summaries are available from NCDC for long term model use. These are joint frequency distributions of wind speed, direction and P-G stability category. They are used as direct input to models such as CDMQC.[57]

9.3.2.2 Recommendations

The preferred short term models listed in Appendix A all accept as input the NWS meteorological data preprocessed into model compatible form. Long-term (monthly seasonal or annual) preferred models use NWS "STAR" summaries. Summarized concentration estimates from the short-term models may also be used to develop long-term averages; however, concentration estimates based on the two separate input data sets may not necessarily agree.

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.

National Weather Service wind directions 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.

Data from FAA and military stations may be used if these data are equivalent in accuracy and detail to the NWS data.

9.3.3 Site-Specific Data

9.3.3.1 Discussion

Spatial or geographical representativeness is best achieved by collection of all of the needed model input data at the actual site of the source(s). Site-specific measured data are therefore preferred as model input, provided appropriate instrumentation and quality assurance procedures are followed and that the data collected are representative (free from undue local or "micro" influences) and compatible with the input requirements of the model to be used. However, direct measurements of all the needed model input parameters may not be possible. This section discusses suggestions for the collection and use of on-site data. Since the methods outlined in this section are still being tested, comparison of the model parameters derived using these site-specific data should be compared at least on a spot-check basis, with parameters derived from more conventional observations. Of particular concern are stability category determinations.

9.3.3.2 Recommendations

Site-specific Data Collection

Guidance provided in the "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)"[59] should be used for the establishment of special monitoring networks for PSD and other air quality modeling analyses. That guidance includes requirements and specifications for both pollutant and meteorological monitoring. Additional information is available in the EPA quality assurance handbooks and site selection guidance documents published on a pollutant-by-pollutant basis (see the Air Programs Report and Guidelines Index EPA-450/2-82-016). Volume IV of the series of reports "Quality Assurance Handbook for Air Pollution Measurement Systems"[62] contains such information for meteorological measurements. As a minimum, site-specific measurements of ambient air temperature, transport wind speed and direction, and the parameters to determine Pasquill-Gifford stability categories should be available in meteorological data sets to be used in modeling. Care should be taken to ensure that monitors are located to represent the area of concern and that they are not influenced by very localized effects. Site-specific data for model applications should cover as long a period of measurement as is possible to ensure adequate representation of "worst-case" meteorology. The Regional Office will determine the appropriateness of the measurement locations.

All site-specific data should be reduced to hourly averages. Table 9-1 lists the wind related parameters and the averaging time requirements.

Temperature Measurements

Temperature measurements should be made at standard shelter height in accordance with the guidance referenced above.

Wind Measurements

In addition to surface wind measurements, the transport wind direction should be measured at an elevation as close as possible to the plume height. To approximate this, if a source has a stack below 100 m, select the stack top height as the transport wind measurement height. For sources with stacks extending above 100 m, a 100 m tower is suggested unless the stack top is significantly above 100 meters (200 m or more). In cases with stacks 200 m or above, the Regional Office should determine the appropriate measurement height on a case-by-case basis. Remote sensing may be a feasible alternative. The dilution wind speed used in determining plume rise and also used in the Gaussian dispersion equation is, by convention, defined as the wind speed at stack top.

For routine tower measurements and surface measurements the wind speed should be measured using an anemometer and the wind direction measured using a horizontal vane. Specifications for wind measuring instruments and monitoring systems are contained in the "Ambient Air Monitoring Guidelines for Prevention of Significant Deterioration (PSD)"[59] and in the quality assurance handbook on meteorological measurements[62]. Irwin[63] provides additional guidance for processing wind data.

Stability Categories

The Pasquill-Gifford (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 observations. The wind speed measurements are made at or near 10 m. The insolation rate is typically assessed using the cloud cover and ceiling height criteria outlined by Turner[45]. Often the cloud cover data are not available in site-specific data sets. In the absence of such observations, it is recommended that the P-G stability category be estimated using Table 9-2. This table requires σ_E, the standard deviation of the vertical wind direction fluctuations. If the surface roughness of the area surrounding the source is different from the 15 cm roughness length upon which the table is based, an adjustment may be made as indicated in footnote 2 of Table 9-2. σ_E is computed from direct measurements of the elevation angle of the vertical wind directions.

If measurements of elevation angle are not available, σ_E may be determined using the transform:

$$\sigma_E = \sigma_W/u,$$

where: σ_E = the standard deviation of the vertical wind direction fluctuations over a one-hour period.

σ_W = the standard deviation of the vertical wind speed fluctuations over a one-hour period.

u = the average horizontal wind speed for a one-hour period.

Since both σ_W and u are in meters per second, σ_E is in radians. To use σ_E in Table 9-2, σ_E must be coverted to degrees. It is recommended that a vertically mounted propeller anemometer be used to measure the vertical wind speed fluctuations. The instrument should meet the specifications given in the Ambient Monitoring Guidelines referenced above. Compute σ_W directly each hour using at least 3600 values based on a recommended readout interval of 1 second. If σ_E is computed using the output of the anemometer by other than direct application of the formula for a variance, the method should be demonstrated to be equivalent to direct computation. Both the vertical wind speed fluctuations and the horizontal wind speed should be measured at the same level. Moreover, these measurements should be made at a height of 10 m for use in estimating the P-G stability category. Where trees or land use preclude measurements as low as 10 m, measurements should be made at a height above the obstructions.

If on-site measurements of either σ_E or σ_W are not available, stability categories may be determined using the horizontal wind direction fluctuation, σ_A, as outlined by Irwin[64]. Irwin includes the Mitchell and Timbre[65] method that uses categories of σ_A[66] listed in Table 9-2, as an initial estimate of the P-G stability category. This relationship is considered adequate for daytime use. During the nighttime (one hour prior to sunset to one hour after sunrise), the adjustments given in Table 9-3 should be applied to these categories. As with σ_A an hourly average σ_A may be adjusted for surface roughness by multiplying the table values of σ_A by a factor based on the average surface routhness length determined within 1 to 3 km of the source. The need for such adjustments should be determined on a case-by-case basis.

Wind direction meander may, at times, lead to an erroneous determination of P-G stability category based on σ_A. To minimize wind direction meander contributions, σ_A may be determined for each of four 15-minute periods in an hour. To obtain the σ_A for stability determinations in these situations, take the square root of one-quarter of the sum of the squares of the four 15-minute σ_A's, as illustrated in the footnote to Table 9-1. While this approach is acceptable for determining stability, σ_A's calculated in this manner are not likely to be suitable for input to models under development that are designed to accept on-site hourly σ's based on 60-minute periods.

There has not been a widespread use of σ_E and σ_A to determine P-G categories. As mentioned in the footnotes to Table 9-2, the techniques outlined have not been extensively tested. The criteria listed in Table 9-2, are for σ_E and σ_A values at 10 m. For best results, the σ_E and σ_A values should be for heights near the surface as close to 10 m as practicable. Obstacles and large roughness elements may preclude measurements as low as 10 m. If circumstances preclude measurements below 30 m, the Regional Meteorologist should be consulted to determine the appropriate measurements to be taken on a case-by-case basis. The criteria listed in Tables 9-2 and 9-3 result from studies conducted in relatively flat terrain in rather ideal circumstances. For routine applications where conditions are often less than ideal, it is recommended that a temporary program be initiated at each site to spot-check the stability class estimates. Irwin's method using σ_E or σ_A should be compare with P-G stability class estimates using on-site wind speed and subjective assessments of the insolation based on ceiling height and cloud cover. The Regional Meteorologist should be consulted when using the spot-check results to refine and adjust the preliminary criteria outlined in Tables 9-2 and 9-3.

In summary, when on-site data sets are being used, Pasquill-Gifford stability categories should be determined from one of the following schemes listed in the order of preference:

(1) Turner's 1964 method[50] using site-specific data which include cloud cover, ceiling height and surface ($\sim$ 10 m) wind speeds.

(2) σ_E from site-specific measurements and Table 9-2 (σ_E may be determined from elevation angle measurements or may be estimated from measurements of σ_W according to the transform: $\sigma_E = \sigma_W/u$ (see page 9-15)).

(3) σ_A from site-specific measurements and Tables 9-2 and 9-3.

(4) Turner's 1964 method using site-specific wind speed with cloud cover and ceiling height from a nearby NWS site.

Table 9-1

Averaging Times for Site-Specific Wind and Turbulence Measurements

Parameter	Averaging Time
Surface wind speed (for use in stability determinations)	1-hr
Transport direction	1-hr
Dilution wind speed	1-hr
Turbulence measurements (σ_E and σ_A) for use in stability determinations	1-hr*

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

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

Table 9-2

Wind Fluctuation Criteria For Estimating Pasquill Stability Categories*

Pasquill Stability Category	Standard Deviation of the Horizontal Wind Direction Fluctuations**, *** (in degrees)	Standard Deviation of the Vertical Wind Direction Fluctuations**, **** (in degrees)
A	Greater than 22.5°	Greater than 11.5°
B	17.5° to 22.5°	10.0° to 11.5°
C	12.5° to 17.5°	7.8° to 10.0°
D	7.5° to 12.5°	5.0° to 7.8°
E	3.8° to 7.5°	2.4° to 5.0°
F	Less than 3.8°	Less than 2.4°

Adapted from: Irwin, J., 1980[64].

*These criteria are appropriate for steady-state conditions, a measurement height of 10 m, for level terrain, and an aerodynamic surface roughness length of 15 cm. Care should be taken that the wind sensor is responsive enough for use in measuring wind direction fluctuations.[59]

**A surface roughness factor of $(z_0/15\ \text{cm})^{0.2}$, where z_0 is the average surface roughness in centimeters within a radius of 1-3 km of the source, may be applied to the table values. It should be noted that this factor, while theoretically sound, has not been subjected to rigorous testing and may not improve the estimates in all circumstances. A table of z_0 values that may be used as a guide to estimating surface roughness is given in Smedman-Hogstrom and Hogstrom.[67]

***These criteria are from a NRC proposal.[66] It would seem reasonable to restrict the possible categories to A through D during daytime hours with a restriction that for wind speeds above 6 m/s, conditions are neutral. Likewise, during the nighttime hours, some restrictions, as in Table 9-3, are needed to preclude occurrences of categories A through C.

****These criteria were adapted from those presented by Smith and Howard.[68] It would seem reasonable to restrict the possible categories to A through D during the daytime hours and to categories D through F during the nighttime hours. During the night, conditions are neutral for wind speeds equal to or greater than 5 m/s.

Table 9-3

Nighttime* P-G Stability Categories Based on σ_A from Table 9-2

If the σ_A Stability Category is	And the Wind Speed at 10 m is m/s	Then the Pasquill Stability Category is
A	<2.9	F
	2.9 to 3.6	E
	≥3.6	D
B	<2.4	F
	2.4 to 3.0	E
	≥3.0	D
C	<2.4	E
	≥2.4	D
D	wind speed not considered	D
E	wind speed not considered**	E
F	wind speed not considered***	F

Adapted from Irwin, J. 1980[64].

*Nighttime is considered to be from 1 hour prior to sunset to 1 hour after sunrise.

**The original Mitchell and Timbre[65] table had no wind speed restrictions; However, the original Pasquill criteria suggest that for wind speeds greater than 5 m/s, neutral conditions would be appropriate.

***The original Mitchell and Timbre[65] table had no wind speed restrictions; however, the original Pasquill criteria suggest that for wind speeds greater than or equal to 5 m/s, the D category would be appropriate, and for wind speeds between 3 m/s and 5 m/s, the E category would be appropriate.

9.3.4 Treatment of Calms

9.3.4.1 Discussion

Treatment of calm or light and variable wind poses a special problem in model applications since Gaussian models assume that concentration is inversely proportional to wind speed. The NWS generally lists all winds as calm when the wind speed indicator drops to approximately 1 m/s or below. Concentrations become unrealistically large when wind speeds less than 1 m/s are input to the model. A procedure has been developed for use with NWS data to prevent the occurrence of overly conservative concentration estimates during periods of calms. This procedure acknowledges that a Gaussian plume model does not apply during calm conditions and that our knowledge of plume behavior and wind patterns during these conditions does not, at present, permit the development of a better technique. Therefore, the procedure disregards hours when the speed is recorded as less than 1 m/s and concentration calculations using wind speed and direction cannot be made. The hour is treated as missing and a convention for handling missing hours is recommended.

9.3.4.2 Recommendations

Hourly concentrations calculated with Gaussian 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 concentration for the period by the number of valid or nonmissing 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. A post-processor computer program (CALMPRO) has been prepared following these instructions and is available through any EPA Regional Office.

The recommendations above apply to the use of calms for short-term averages and do not apply to the determination of long-term averages using "STAR" data summaries. Calms should continue to be included in the preparation of "STAR" summaries.

Stagnant conditions, including extended periods of calms, often produce high concentrations over wide areas for relatively long averaging periods. The standard short-term Gaussian 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 8.2.10)

Measured on-site wind speeds of less than 1 m/s should be set equal to 1 m/s when used as input to Gaussian models. Wind direction for these low wind speed hours may be determined on a case-by-case basis from the available site-specific records. If the wind is indeterminate with respect to speed or direction, it should be treated as missing data and short-term averages should then be calculated as above.

10.0 ACCURACY AND UNCERTAINTY OF MODELS

10.1 Discussion

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[11,69] 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,[70] was devoted to that subject.

10.1.1 Overview of Model Uncertainty

Dispersion models generally attempt to estimate conccentrations 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.[71]

Moreover, there is "reducible" uncertainty[72] 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--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.

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.[73] The statement of accuracy is based on statistical tests or performance measures such as bias, noise, correlation, etc.[11] 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.

10.1.2 Studies of Model Accuracy

A number of studies[74,75] 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 $\pm$ 10 to 40 percent are found to be typical,[76] 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.

As noted above, 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[77] 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.

10.1.3 Use of Uncertainty in Decision-Making

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.[69,70,72]

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 judgment to use of the "best estimate" provided by the modeler. This is an indication of the practical limitations imposed by current abilities of the technical community.

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.[78,79] 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.

10.1.4 Evaluation of Models

A number of actions are being taken to ensure that the best model is used correctly for each regulatory application and that a model is not arbitrarily imposed. First, this guideline clearly recommends that the most apropriate 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, all the models in eight categories (i.e., rural, urban, industrial complex, reactive pollutants, mobile source, complex terrain, visibility and long-range transport) that are candidates for inclusion in this guideline are being subjected to a systematic performance evaluation and a peer scientific review.[80] The same data bases are being used to evaluate all models within each of eight categories. 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,[11] are being followed. The results of the scientific review are being incorporated in this guideline and will be the basis for future revision.[12,13] Third, more specific information has been provided for justifying the site specific use of alternative models in the document "Interim Procedures for Evaluating Air Quality Models."[14] This document provides a method, following recommendations of the Woods Hole Workshop, that allows a judgment 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.

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.

10.2. Recommendations

No specific guidance on the consideration of model uncertainty in decision-making is being given at this time. There is incomplete technical information on measures of model uncertainty that are most relevant to the decision-maker. It is not clear how a decision-maker could use such information, particularly given limitations of the Clean Air Act. 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 and is consistent with CAA requirements.

11.0 REGULATORY APPLICATION OF MODELS

11.1 Discussion

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.

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. The same care should be given to the analysis of the air quality data as would be applied to a modeling analysis.

The current NAAQS for SO_2, TSP, and CO are all stated in terms of a concentration not to be exceeded more than once a year. There is only an annual standard for NO_2. The ozone standard was revised in 1979 and that standard permits the exceedance of a concentration on an average of not more than once a year, averaged over a 3-year period.[5,81] This represents a change from a deterministic to a more statistical form of the standard and permits some consideration to be given to unusual circumstances. The NAAQS are subjected to extensive review and possible revision every 5 years.

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; (2) the review of new sources and the prevention of significant deterioration (PSD); and (3) analyses of the emissions trades ("bubbles").

11.2 Recommendations

11.2.1 Analysis Requirements

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 included here as Appendix C. 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.

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 the NAAQS. It is recommended that the screening techniques found in "Procedures for Evaluating Air Quality Impact of New Stationary Sources"[16] be used for point source analyses. Screening procedures for area source analysis are discussed in "Applying Atmospheric Simulation Models to Air Quality Maintenance Areas."[82]

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, 5, 6 or 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.

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's impact. PSD air quality assessments should consider the amount of the allowable air quality increment that has already been granted to any other sources. The most recent source applicant should be allowed the prerogative to remodel 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.

11.2.2 Use of Measured Data in Lieu of Model Estimates

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 determination in flat terrain areas. 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.

There are circumstances where there is no applicable model, and measured data may need to be used. Examples of such situations are: (1) complex terrain locations; (2) land/water interface areas; and (3) urban locations with a large fraction of particulate emissions from nontraditional sources. However, only in the case of an existing source should monitoring data alone be a basis for emission limits. In addition, the following items should be considered prior to the acceptance of the measured data:

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

b. Has the monitoring network been designed to locate points of maximum concentration;

c. Do the monitoring network and the data reduction and storage procedures meet EPA monitoring and quality assurance requirements;

d. 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;

e. Is at least one full year of valid ambient data available; and

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

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. The Interim Procedures for Evaluating Air Quality Models[14] should be used in establishing criteria for demonstrating that a model is not applicable.

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.

11.2.3 Emission Limits

11.2.3.1 Design Concentrations

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.

To determine the averaging time for the design value, the most restrictive National Ambient Air Quality Standard (NAAQS) should be identified by calculating, for each averaging time, the ratio of the estimated concentration (including background) to the applicable NAAQS. The averaging time with the highest ratio of estimated concentration to NAAQS 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, the frequency of occurrence of the concentrations must be considered. 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 value that is not expected to be exceeded more than once per year over the period specified in the standard.

When the highest, second-highest concentration is used in assessing potential violations of a short-term NAAQS, criteria that are identified in "Guideline for Interpretation of Air Quality Standards"[83] should be followed. This guideline specifies that a violation of a short-term standard occurs at a site when the standard is exceeded a second time. Thus, emission limits that protect standards for averaging times of 24 hours or less are appropriately based on the highest, second-highest estimated concentration plus a background concentration which can reasonably be assumed to occur with the concentration.

11.2.3.2 Air Quality Standards

For new or modified sources to be located in areas where the SO_2, TSP, lead, NO_2, or CO NAAQS are being attained, the determination of whether or not 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 the highest, second-highest estimated concentration for averaging times of 24-hours or less. For lead, 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.

11.2.3.3 PSD Air Quality Increments and Impacts

The allowable PSD increments for criteria pollutants are established by regulation and cited in 40 CFR 51.24. 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.

Screening techniques defined in Sections 4 and 5 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 one year of on-site or five 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.).

The PSD regulations require an estimation of the SO_2 and TSP impact on any Class I area. Normally, Gaussian 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 Gaussian model application for regulatory purposes is generally considered to be 50 km. Beyond the 50 km 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 7.2.6. As previously noted in Sections 3 and 7, 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.

11.2.3.4 Emissions Trading Policy (Bubbles)

EPA's Emissions Trading Policy, commonly referred to as the "bubble policy," was proposed in the Federal Register on April 7, 1982.[84] Until a final policy is promulgated, principles contained in the proposal should be used to evaluate trading activities which become ripe for decision. Certain technical clarifications of the policy, including procedures for modeling bubbles, were provided to the Regional Offices in February, 1983.[85]

Emission increases and decreases within the bubble should result in ambient air quality equivalence. Two levels of analysis are defined for establishing this equivalence. In a Level I analysis the source configuration and setting must meet certain limitations (defined in the policy and clarification to the policy) that ensure ambient equivalence; no modeling is required. In a Level II analysis a modeling demonstration of ambient equivalence is required but only the sources involved in the emissions trade are modeled. The resulting ambient estimates of net increases/decreases are compared to a set of significance levels to determine if the bubble can be approved. A Level II analysis requires the use of a refined model and one year of representative meteoreolgical data. Sequential modeling must demonstrate that the significance levels are met temporally and spatially, i.e., for all receptors for each time period throughout the year (time period means the appropriate NAAQS averaging time, e.g., 3-hour, 24-hour, etc.)

For those bubbles that cannot meet the Level I or Level II requirements, the Emissions Trading Policy allows for a Level III analysis. A Level III analysis, from a modeling standpoint, is equivalent to the requirements for a standard SIP revision where all sources (and background) are considered and the estimates are compared to the NAAQS as in Section 11.2.3.2.

The Emissions Trading Policy allows States to adopt generic regulations for processing bubbles. The modeling procedures recommended in this guideline apply to such generic regulations. However, an added requirement is that the modeling procedures contained in any generic regulation must be replicable such that there is no doubt as to how each individual bubble will be modeled. In general this means that the models, the data bases and the procedures for applying the model must be defined in the regulation. The consequences of the replicability requirement are that bubbles for sources located in complex terrain and certain industrial sources where judgments must be made on source characterization cannot be handled generically.

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14.0 GLOSSARY OF TERMS

AIR QUALITY--Ambient pollutant concentrations and their temporal and spatial distribution.

ALGORITHM--A specific mathematical calculation procedure. A model may contain several algorithms.

BACKGROUND--Ambient pollutant concentrations due to (1) natural sources, (2) distant, unidentified man-made sources, and (3) nearby sources other than those currently under consideration.

CALIBRATE--An objective adjustment using measured air quality data (e.g., an adjustment based on least-squares linear regression).

CALM--For purposes of air quality modeling, calm is used to define the situation when the wind is indeterminate with regard to speed or direction.

COMPLEX TERRAIN--Terrain exceeding the height of the stack being modeled.

COMPUTER CODE--A set of statements that comprise a computer program.

EVALUATE--To appraise the performance and accuracy of a model based on a comparison of concentration estimates with observed air quality data.

MODEL--A quantitative or mathematical representation or simulation which attempts to describe the characteristics or relationships of physical events.

PREFERRED MODEL--A refined model that is recommended for a specific type of regulatory application.

RECEPTOR--A location at which ambient air quality is measured or estimated.

RECEPTOR MODELS--Procedures that examine an ambient monitor sample of particulate matter and the conditions of its collection to infer the types or relative mix of sources impacting on it during collection.

REFINED MODEL--An analytical technique that provides a detailed treatment of physical and chemical atmospheric processes and requires detailed and precise input data. Specialized estimates are calculated that are useful for evaluating source impact relative to air quality standards and allowable increments. The estimates are more accurate than those obtained from conservative screening techniques.

ROLLBACK--A simple model that assumes that if emissions from each source affecting a given receptor are decreased by the same percentage, ambient air quality concentrations decrease proportionately.

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

SIMPLE TERRAIN--An area were terrain features are all lower in elevation than the top of the stack of the source.

APPENDIX A

SUMMARIES

OF

PREFERRED AIR QUALITY MODELS

APPENDIX A

Table of Contents

A.0 INTRODUCTION

This appendix summarizes key features of refined air quality models preferred for specific regulatory applications. For each model, information is provided on availability*, costs, 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. The models are listed by name in alphabetical order.

Each of these models has been subjected to a performance evaluation using comparisons with observed air quality data. A summary of such comparisons for all models contained in this appendix is included in "A Survey of Statistical Measures of Model Performance and Accuracy for Several Air Quality Models," EPA-450/4-83-001. Where possible, several of the models contained herein have been subjected to rigorous 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.

*Where reference to UNAMAP (Version 6) is made, the assumption is implicit that the next update of UNAMAP will contain revisions of the models proposed in these descriptions. UNAMAP (Version 5) contains the current coding of these models.

A.1 BUOYANT LINE AND POINT SOURCE DISPERSION MODEL (BLP)

Reference: Schulman, Lloyd L., and Joseph S. Scire. "Buoyant Line and Point Source (BLP) Dispersion Model User's Guide," Document P-7304B. Environmental Research and Technology, Inc., Concord, Massachusetts, 1980.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

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

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.

The following options should be selected for regulatory applications:

rural (IRU=1) mixing height option

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).

terrain option (TERAN) set equal to 0., 0., 0., 0., 0., 0.

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.

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

Source data requirements are: 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.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program or input from punched cards (up to 24 hours). Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: locations and elevations of receptors, or location and size of receptor grid or request automatically generated receptor grid.

c. Output

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

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;

five highest 1-, 3-, and 24-hour average concentrations at each receptor; and

fifty highest 1-, 3-, and 24-hour concentrations over the receptor field.

d. Type of Model

BLP is a gaussian plume model.

e. <u>Pollutant Types</u>

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

f. <u>Source-Receptor Relationship</u>

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

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

g. <u>Plume Behavior</u>

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

Vertical potential temperature gradients of .02 Kelvin per meter for E stability and .035 Kelvin per meter are used for stable plume rise calculations. An option for user input values is included.

Transitional rise is used for line sources.

Option to not use transitional plume rise for point sources is included.

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

h. <u>Horizontal Winds</u>

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

Straight line plume transport is assumed to all downwind distances.

Wind speeds profile exponents of .10, .15, .20, .25, .30, and .30 are used for stability classes A through F, respectively. An option for user-defined values and an option to not use the wind speed profile feature are included.

i. <u>Vertical Wind Speed</u>

Vertical wind speed is assumed equal to zero.

j. <u>Horizontal Dispersion</u>

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

Six stability classes are used, with Turner class 7 treated as class 6.

k. <u>Vertical Dispersion</u>

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

Six stability are classes used, with Turner class 7 treated as class 6.

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform mixing is assumed beyond that point.

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. "Buoyant Line and Point Source (BLP) Dispersion Model User's Guide," P-7304B, Environmental Research and Technology, Inc., Concord, Massachusetts, 1980.

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

A.2 CALINE3

Reference: Benson, Paul E. "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, 1979.

Messina, A. D., J. A. Bullin, J. P. Nelli, and R. D. Moe. Estimates of Air Pollution Near Signalized Intersections. Report No. FHWA/TX-81/541-1, U.S. Department of Transportation, FHWA, Washington, D. C., 1983.

Availability: The CALINE3 model is available from the California Department of Transportation on an at-cost basis ($10 for documentation, approximately $50 for the model). Requests should be directed to:

Mr. Ebert Jung
Chief, Office of Computer Systems
California Department of Transportation
1120 N. Street
Sacramento, California 95814

Abstract: CALINE3 can be used to estimate the concentrations of non-reactive 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 appalications:

highway (line) sources;

urban or rural areas;

simple terrain;

transport distances less than 50 kilometers; and

one hour to 24 hours averaging times.

b. Input Requirements

Source data requirements are: 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.

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

Receptor data requirements are: 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

Up to 20 highway links are treated.

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

User-input hourly wind speed and direction are applied.

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

Six stability classes are used.

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

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

k. Vertical Dispersion

Six stability classes are used.

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

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

Adjustment for averaging time is included.

l. Chemical Transformation

Not treated.

m. Physical Removal

Optional deposition calculations are included.

n. Evaluation Studies

Bennis, G. R., et. al. "Air Pollution and Roadway Location, Design, and Operation - Project Overview," FHWA-CA-TL-7080-77-25, Federal Highway Administration, Washington, DC, 1977.

Cadle, S. H., et. al. "Results of the General Motors Sulfate Dispersion Experiment," General Motors Research Laboratories, GMR-2107, 1976.

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

Messina, A. D., J. A. Bullin, J. P. Nelli, and R. D. Moe, Estimates of Air Pollution Near Signalized Intersections, Report No. FHWA/TX-81/541-1, U. S. Department of Transportation, FHWA, Washington, D. C, 1983.

A.3 CLIMATOLOGICAL DISPERSION MODEL (CDM)

References: Busse, A. D. and J. R. Zimmerman. "User's Guide for the Climatological Dispersion Model." Publication No. EPA-R4-73-024 (NTIS PB 227346/AS), Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1973.

Brubaker, K. L., P. Brown, and R. R. Cirillo. "Addendum to User's Guide for Climatological Dispersion Model." Publication No. EPA-450/3-77-015 (NTIS PB 274-040), Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1977.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: CDM is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual) arithmetic average pollutant concentrations at any ground-level receptor in an urban area. An expanded version (CDMQC) includes the capability of producing a source contribution list and using a statistical model based on Larsen (1971) to transform the average concentration data from a limited number of receptors into expected geometric mean and maximum concentration values for several different averaging times.

a. Recommendations for Regulatory Use

CDM and CDMQC are appropriate for the following applications:

point and area sources;

urban areas;

flat terrain;

transport distances less than 50 kilometers;

long term averages over one month to one year or longer.

The following option should be selected for regulatory applications:

See Sections and 8.2.6 for 8.2.7 guidance on use of exponential

decay.

b. Input Requirements

Source data requirements are: location, average emissions rates and heights of emissions for point and area sources. Point source data requirements also include stack gas temperature, stack gas exit velocity, and stack inside diameter for plume rise calculations for point sources.

Meteorological data requirements are: stability wind rose (STAR deck day/night version), average afternoon mixing height, average morning mixing height, and average air temperature.

Receptor data requirements are: cartesian coordinates of each receptor. If the Larsen transform option is to be used to estimate short averaging time concentrations, measured standard geometric deviation of concentrations is required.

c. Output

Printed output includes:

one month to one year average concentrations (arithmetic mean only) at each receptor, and

optional point and area concentration rose for each receptor.

Printed output from the expanded version (CDMQC) includes:

optional arbitrary averaging time by Larsen (1971) procedure (typically 1-24 hr.), and

optional individual point, area source culpability list for each receptor.

d. Type of Model

CDM is a climatological Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

CDM applies user-specified locations for all point sources and receptors.

Area sources are input as multiples of a user-defined unit area source grid size.

User specified release heights are applied for individual point sources and the area source grid.

Actual separation between each source-receptor pair is used.

All receptors are assumed to be at ground level.

No terrain differences between source and receptor are treated.

g. Plume Behavior

CDM and CDMQC use Briggs (1971) neutral/unstable plume rise equations for final rise. Optionally a plume rise-wind speed product may be input for each point source.

Stack tip downwash equation from Bjorklund and Bowers (1982) is used.

No plume rise is calculated for area sources.

Does not treat fumigation or building downwash.

h. Horizontal Winds

Wind data are input as a stability wind rose (joint frequency distribution of 16 wind directions, 6 wind classes, and 5 stability classes).

Wind speed profile exponents for the urban case (Irwin, 1979) are used.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Pollutants are assumed evenly distributed across a 22.5 degree sector.

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

k. Vertical Dispersion

Urban dispersion coefficients from McElroy and Pooler (1968), as formulated by Briggs (1974) are used in CDM and CDMQC.

Mixing height has no effect until dispersion coefficient equals 0.8 times the mixing height; uniform vertical mixing is assumed beyond that point.

Buoyancy-induced disperion (Pasquill, 1976) is included.

Perfect reflection is assumed at the ground.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is not explicitly treated.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter and R. Fizz. "Evaluation of Urban Air Quality Simulation Models," EPA 450/4-83-020, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1983.

Turner, D. B., J. R. Zimmerman, and A. D. Busse. "An Evaluation of Some Climatological Dispersion Models," Third Meeting on the NATO/CCMS Panel on Modeling, Reproduced in Busse and Zimmerman, 1973.

Zimmerman, J. R. "Some Preliminary Results of Modeling from the Air Pollution Study of Ankara, Turkey," Proceedings of the Second Meeting of the Expert Panel on Air Pollution Modeling, NATO Committee on the Challenges of Modern Society, Paris, France, 1971.

Zimmerman, J. R. "The NATO/CCMS Air Pollution Study of St. Louis, Missouri." Presented at the Third Meeting of the Expert Panel on Air Pollution Modeling, NATO Committee on the Challenges of Modern Society, Paris, France, 1972.

A.4 GAUSSIAN-PLUME MULTIPLE SOURCE AIR QUALITY ALGORITHM (RAM)

<u>Reference:</u> Turner, D. B., and J. H. Novak, "User's Guide for RAM." EPA-600/8-78-016 Vol a, b. (NTIS PB 294791 and PB 294792). Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1978.

<u>Availability:</u> This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U. S. Department of Commerce
Springfield, Virginia 22161

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The accession number of the UNAMAP tape is PB

<u>Abstract:</u> RAM is a steady-state Gaussian plume model for estimating concentrations of relatively stable pollutants for averaging times from an hour to a day from point and area sources in an urban setting. Level or gently rolling terrain is assumed. Calculations are performed for each hour. A rural version exists but is not recommended for regulatory applications.

a. Recommendations for Regulatory Use

RAM is appropriate for the following applications:

point and area sources;

urban areas;

flat or rolling terrain;

transport distances less than 50 kilometers; and

one hour to one year averaging times.

The following option should be selected for regulatory applications:

see Sections 8.2.6 and 8.2.7 for guidance on use of exponential decay.

b. Input Requirements

Source data requirements are: location, emissions rate, physical stack height are required for point sources. Area source data requirements include location, size, emission rate, and height of emissions.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: coordinates of each receptor. Options for automatic placement of receptors near expected concentration maxima, and a gridded receptor array are included.

c. Output

Printed output includes:

hourly and average (up to 24 hours) concentrations at each receptor,

limited individual source contribution list, and

cumulative frequency distribution based on 24-hour averages and up to one year of data at a limited number of receptors.

d. Type of Model

RAM is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

RAM applies user-specified locations for all point sources and receptors.

Area sources are input as multiples of a user-defined unit area source grid size.

User specified release heights are applied for individual point sources.

Up to 3 effective release heights may be specified for the area sources. Area source release heights are assumed to be appropriate for a 5 meter per second wind and to be inversely proportional to wind speed.

Actual separation between each source-receptor pair is used.

All receptors are assumed to be at the same height above ground level, or at ground level.

No terrain differences between source and receptor are accounted for.

g. Plume Behavior

RAM uses Briggs (1969, 1971, 1972) plume rise equations for final rise.

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

Stack tip downwash equation from Bjorklund and Bowers (1982) is used.

No plume rise is calculated for area sources.

Fumigation and building downwash are not treated.

h. Horizontal Winds

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

Straight line plume transport is assumed to all downwind distances.

Wind speed profile exponents (Irwin, 1979) for the urban case are used.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Urban dispersion coefficients from McElroy and Pooler (1968), as formulated by Briggs (1974) are used in RAM.

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

Six stability classes are used, with Turner class 7 treated as class 6.

k. Vertical Dispersion

Urban dispersion coefficients from McElroy and Pooler (1969), as formulated by Briggs (1974) are used in RAM.

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

Six stability classes are used, with Turner class 7 treated as class 6.

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point.

Perfect reflection is assumed at the ground.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is not explicitly treated.

n. Evaluation Studies

Ellis, H., P. Lou, and G. Dalzell. "Comparison Study of Measured and Predicted Concentrations with the RAM Model at Two Power Plants Along Lake Erie," Second Joint Conference on Applications of Air Pollution Meteorology, New Orleans, Louisiana, 1980.

Guldberg, P. H., and C. W. Kern. "A Comparison Validation of the RAM and PTMTP Models for Short-Term Concentrations in Two Urban Areas," J. Air Poll. Control Assoc., Vol. 28, pp. 907-910, 1978.

Hodanbosi, R. R., and L. K. Peters. "Evaluation of RAM Model for Cleveland, Ohio," J. Air Poll. Control Assoc., Vol. 31, pp. 253-255, 1981.

Kummier, R. H., B. Cho, G. Roginski, R. Sinha and A. Greenburg. "A Comparative Validation of the RAM and Modified SAI Models for Short-Term SO2 Concentrations in Detroit," J. Air Poll. Control Assoc., Vol. 29, pp. 720-723, 1979.

Londergan, R. J., N. E. Bowne, D. R. Murray, H. Borenstein, and J. Mangano. "An Evaluation of Short-Term Air Quality Models Using Tracer Study Data," 4333, American Petroleum Institute, Washington, D. C. 20006, 1980.

Morgenstern, P., M. J. Geraghty, and A. McKnight. "A Comparative Study of the RAM (Urban) and RAMR (Rural) Models for Short-term SO2 Concentrations in Metropolitan Indianapolis," 79-2.2, 72nd Annual Meeting of the Air Pollution Control Association, Cincinnati, Ohio, 1979.

Ruff, R. E. "Evaluation of the RAM Using the RAPS Data Base," Contract 68-02-2770, SRI International, Menlo Park, California, 1980.

Londergan, R., D. Minott, D. Wackter, and R. Fizz. "Evaluation of Urban Air Quality Simulation Models," EPA 450/4-83-020, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1983.

A.5 INDUSTRIAL SOURCE COMPLEX MODEL (ISC)

Reference: Bowers, J. R., J. R. Bjorklund and C. S. Cheney. "Industrial Source Complex (ISC) Dispersion Model User's Guide, Volumes 1 and 2." Publication Nos. EPA-450/4-79-030, 031 (NTIS Numbers: Volume 1, PB-80-133044; Volume 2, PB-80-133051; Magnetic tape, PB-80-133036) Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1979.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

Abstract: The ISC model is a steady-state Gaussian plume model which can be used to access pollutant concentrations from a wide variety of sources associated with an industrial source complex. This model can account for settling and dry deposition of particulates, downwash area, line and volume sources, plume rise as a function of downwind distance, separation of point sources, and limited terrain adjustment. It operates in both long- and short-term modes.

a. Recommendations for Regulatory Use

ISC is appropriate for the following applications:

industrial source complexes;

rural or urban areas;

flat or rolling terrain; and

transport distances less than 50 kilometers;

one hour to annual averaging times.

The following options should be selected for regulatory applications:

concentration option (ISW(1)=1);

elevated terrain option (ISW(4)=1) if terrain is to be considered, or select flat terrain ISW(4)=0 if no terrain is to be considered;

rural option (ISW(20)=0) or urban option (ISW(20)=1) as specified in Section 8.2.8;

user-provided wind speed profile exponents (ISW(21)=2), or the recommended default exponents (ISW(21)=1) for the rural case, or the following values (ISW(21)=2) for the urban case:

.15, .15, .15, .15, .15, .15,
.15, .15, .15, .15, .15, .15,
.20, .20, .20, .20, .20, .20,
.25, .25, .25, .25, .25, .25,
.40, .40, .40, .40, .40, .40,
.60, .60, .60, .60, .60, .60;

default values for vertical potential temperature gradient option (ISW(22)=1);

final plume rise for all calçulations (ISW(24)=1), except when stack height is less than GEP then set ISW(24)=2;

default value for decay coefficient following guidance in Section 8.2.6. and 8.2.7 on use of exponential decay.

b. Input Requirements

Source data requirements are: location, emission rate, pollutant decay coefficient, elevation of source, stack height, stack exit velocity, stack inside diameter, stack exit temperature, particle size distribution with corresponding settling velocities, surface reflection coefficient, and dimensions of adjacent buildings.

Meteorological data requirements are: for short term modeling, hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. For long-term modeling, stability wind rose (STAR deck), average afternoon mixing height, average morning mixing height, and average air temperature.

Receptor data requirements are: coordinates of 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 combinations of sources;

concentration or deposition values calculated for any desired combinations of sources 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 receptor for each specified time period during an "N"-day period for any desired combinations of sources; and

tables of the maximum 50 concentration or deposition values calculated for any desired combinations of sources for each specified time period.

d. Type of Model

ISC is a Gaussian plume model.

e. Pollutant Types

ISC may be used to model primary pollutants. Settling and deposition are treated.

f. Source-Receptor Relationships

ISC applies user-specified locations for point, line, area and volume sources, and user-specified receptor locations or receptor rings.

Receptors are assumed to be at ground level, and must be at elevations not exceeding stack height.

Actual separation between each source-receptor pair is used.

g. Plume Behavior

ISC uses Briggs (1971, 1972) plume rise equations for final rise.

Stack tip downwash (Bjorklund and Bowers, 1982) and building downwash (Huber and Snyder, 1976) are used.

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

Fumigation is not treated.

h. Horizontal Winds

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

Straight line plume transport is assumed to all downwind distances.

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

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

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

Urban dispersion coefficients from McElroy and Pooler (1968), as formulated by Briggs (1974) are used.

Buoyancy induced dispersion (Pasquill, 1976) is included.

Six stability classes are used, with Turner class 7 treated as class 6.

k. Vertical Dispersion

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

Urban dispersion coefficients from McElroy and Pooler (1969), as formulated by Briggs (1974) are used.

Buoyancy induced dispersion (Pasquill, 1976) is included.

Six stability classes are used, with Turner class 7 treated as class 6.

Mixing height is accounted for with multiple reflections until the vertical coefficient equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point.

Perfect reflection is assumed at the ground.

l. Chemical Transformation

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

m. Physical Removal

Settling and dry deposition of particulates are treated.

n. Evaluation Studies

Bowers, J. F., and A. J. Anderson. "An Evaluation Study for the Industrial Source Complex (ISC) Dispersion Model," EPA-450/4-81-002, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1981.

Bowers, J. F., A. J. Anderson, and W. R. Hargraves. "Tests of the Industrial Source Complex (ISC) Dispersion Model at the Armco Middletown, Ohio Steel Mill," EPA-450/4-82-006 (NTIS PB 82-257-312), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1982.

Scire, J. S., and L. L. Schulman. "Evaluation of the BLP and ISC Models with SF6 Tracer Data and S02 Measurements at Aluminum Reduction Plants," APCA Specialty Conference on Dispersion Modeling for Complex Sources, 1981.

A.6 MULTIPLE POINT GAUSSIAN DISPERSION ALGORITHM WITH TERRAIN ADJUSTMENT (MPTER)

Reference: Pierce, Thomas D. and D. Bruce Turner. "User's Guide for MPTER." Publication No. EPA-600/8-80-016 (NTIS PB-80-197361). Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1980.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP Tape is PB

Abstract: MPTER is a Multiple Point Source Algorithm. This algorithm is useful for estimating air quality concentrations of relatively non-reactive pollutants. Hourly estimates are made using the Gaussian steady state model.

a. Recommendations for Regulatory Use

MPTER is appropriate for the following applications:

point sources;

rural or urban areas;

flat or rolling terrain (no terrain above stack height);

transport distances less than 50 kilometers; and

one hour to one year averaging times.

The following options should be selected for regulatory applications:

rural or urban as specified in Section 8.2.8;

default wind speed profile exponents or appropriate on site values; and

see Sections 8.2.6 and 8.2.7 for guidance on use of exponential decay.

b. Input Requirements

Source data requirements are: location, emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature, optional ground level elevation.

Meteorological data requirements are: hourly surface weather data from the EPA meterological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: coordinates and optional ground elevation for each receptor.

c. Output

Printed output includes:

Hourly and average (up to 24-hours) concentrations at each receptor;

Highest through fifth highest concentrations at each receptor for period, with the highest and high, second-high values flagged; and

Limited source contribution table.

d. Type of Model

MPTER is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

MPTER applies user-specified locations of point sources and receptors.

User input stack height and source characteristics for each source are used.

User input topographic elevation for each receptor is used.

g. Plume Behavior

MPTER uses Briggs (1969, 1971, 1972) plume rise equations for final rise.

Stack tip downwash equation from Bjorklund and Bowers (1982) is used.

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

Fumigation and building downwash are not treated.

h. Horizontal Winds

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

Straight line plume transport is assumed to all downwind distances.

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

i. Vertical Wind Speed

Vertical speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used in MPTER, with no adjustments made for variations in surface roughness or averaging times.

Urban dispersion coefficients from McElroy and Pooler (1968), as formulated by Briggs (1974), are used.

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

Six stability classes are used, with Turner class 7 treated as class 6.

k. Vertical Dispersion

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

Urban dispersion coefficients from McElroy and Pooler (1969), as formulated by Briggs (1974), are used.

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

Six stability classes are used, with Turner class 7 treated as class 6.

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point.

Perfect reflection is assumed at the ground.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is not explicitly treated.

n. Evaluation Studies

No specific studies for MPTER because regulatory editions of CRSTER and MPTER are equivalent. Studies for CRSTER are relevant to MPTER as well (See page A-32).

A.7 SINGLE SOURCE (CRSTER) MODEL

Reference: Environmental Protection Agency. "User's Manual for Single Source (CRSTER) Model." Publication No. EPA-450/2-77-013 (NTIS PB 271360). Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711, 1977.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: CRSTER is a steady state, Gaussian dispersion model designed to calculate concentrations from point sources at a single location in either a rural or urban setting. Highest and high-second high concentrations are calculated at each receptor for 1-hour, 3-hour, 24-hour, and annual averaging time.

a. Recommendations for Regulatory Use

CRSTER is appropriate for the following applications:

single point sources;

rural or urban areas;

transport distances less than 50 kilometers; and

flat or rolling terrain (no terrain above stack height).

The following options should be selected for regulatory applications:

rural (IUR=1) or urban (IUR=2) options as specified in Section 8.2.8; and

default wind speed profile exponents or appropriate on-site values.

see Sections 8.2.6 and 8.2.7 for guidance on use of exponential decay.

b. Input Requirements

Source data requirements are: emission rates, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: distance of each of the five receptor rings.

c. Output

Printed output includes:

highest and second highest concentrations for the year at each receptor for averaging times of 1, 3, and 24-hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours;

annual arithmetic average at each receptor;

for each day, the highest 1-hour and 24-hour concentrations over the receptor field; and

option for source contributions to concentrations at selected receptors.

d. Type of Model

CRSTER is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

CRSTER treats up to 19 point sources, no area sources.

All point sources are assumed collocated.

User input stack height is used for each source.

User input topographic elevation is used for each receptor, but must be below top of stack or program will terminate execution.

Receptors are assumed at ground level.

g. Plume Behavior

CRSTER uses Briggs (1969, 1971, 1972) plume rise equations for final rise.

Stack tip downwash equation from Bjorklund and Bowers (1982) is used.

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

Fumigation and building downwash are not treated.

h. Horizontal Winds

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

Straight line plume transport is assumed to all downwind distances.

Separate set of wind speed profile exponents (Irwin, 1979) for both rural and urban cases are used.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used in CRSTER with no adjustments made for variations in surface roughness or averaging times.

Urban dispersion coefficients from McElroy and Pooler (1968), as formulated by Briggs (1974), are used.

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

Six stability classes are used, with Turner class 7 treated as class 6.

k. Vertical Dispersion

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

Urban dispersion coefficients from McElroy and Pooler (1969), as formulated by Briggs (1974), are used.

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

Six stability classes are used, with Turner class 7 treated as class 6.

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform mixing is assumed beyond that point.

Perfect reflection is assumed at the ground.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is not explicitly treated.

n. Evaluation Studies

Klug, W. "Dispersion from Tall Stacks," 5th NATO/CCMS International Technical Meeting on Air Pollution Modeling, Denmark, 1974.

Londergan, R. J., N. E. Bowne, D. R. Murray, H. Borenstein, and J. Mangano. "An Evaluation of Short-Term Air Quality Models Using Tracer Study Data," 4333, American Petroleum Institute, Washington DC, 20006, 1980.

Mills, M. T., R. Caiazza, D. D. Hergert, and D. A. Lynn. "Evaluation of Point Source Dispersion Models," EPA-450/4-81-032, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1981.

Mills, M. T., and F. A. Record. "Comprehensive Analysis of Time-Concentration Relationships and the Validation of a Single Source Dispersion Model," EPA-450/3-75-083, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1975.

Mills, M. T., and R. W. Stern. "Model Validation and Time-Concentration Analysis of Three Power Plants," EPA-450/3-76-002, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1975.

Londergan, R., D. Minott, D. Wackter, T. Kincaid, and B. Bonitata. "Evaluation of Rural Air Quality Simulation Models," EPA-450/4-83-033, (NTIS PB 83-182-758), Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1983.

TRC-Environmental Consultants, Inc. "Overview, Results, and Conclusions for the EPRI Plume Model Validation and Development Project: Plains Site," EPRI EA-3074, Electric Power Research Institute, Palo Alto, California 94304, 1983.

A.8 URBAN AIRSHED MODEL (UAM)

References: Ames, J., T. C. Myers, L. E. Reid, D. C. Whitney, S. H. Golding, S. R. Hayes, and S. D. Reynolds. "The User's Manual for the SAI Urban Airshed Model," Document EM 78-89, Systems Applications, Inc., San Rafael, California, 1984.

Ames, J. S., R. Hayes, T. C. Myers, and D. C. Whitney. "Systems Manual for the SAI Urban Airshed Model," Document EM78-79R2, Systems Applications, Inc., San Rafael, California, 1984.

Environmental Protection Agency. "Guideline for Applying the Airshed Model to Urban Areas." EPA 450/4-80-020 (NTIS PB 81-200529). Environmental Protection Agency, Research Triangle Park, North Carolina, 1980.

Availability: Systems Application, Inc.
101 Lucas Valley Road
San Rafael, California 94903

Abstract: UAM is an urban scale, three dimensional, grid type, numerical simulation model. The model incorporates a condensed photochemical kinetics mechanism for urban atmospheres. The UAM is designed for computing ozone(O_3) concentrations under short-term, episodic conditions lasting one or two days resulting from emissions of oxides of nitrogen (NO_x) and volatile organic compounds (VOC). The model treats urban VOC emissions as their carbon-bond surrogates.

a. Recommendations for Regulatory Use

UAM is appropriate for the following applications: single urban areas having significant ozone attainment problems in the absence of interurban emission transport; and one hour averaging times.

UAM has many options but no specific recommendations can be made at this time on all options. The reviewing agency should be consulted on selection of options to be used in regulatory applications. At the present time, the following options should be selected for regulatory applications:

omit SO_2 and AEROSOLS from the SPECIES packet for the CHEMPARAM file;

set ROADWAY flag to FALSE in the SIMULATION packet for the SIMCONTROL file; and

set surface layer height to zero in the REGION packet for the AIRQUALITY, BOUNDARY, DIFFBREAK, METSCALARS, PTSOURCE, REGIONTOP, TEMPERATUR, TERRAIN, TOPCONC, and WIND files.

b. Input Requirements

Source data requirements are: gridded, hourly emissions of PAR, OLE, ETH, ARO, CARB, NO, and NO_2 for low-level sources. CO is optional. For major elevated point sources, hourly emissions, stack height, stack diameter, exit velocity, and exit temperature.

Meteorological data requirements are: hourly, gridded, divergence free, u and v wind components for each vertical level; hourly gridded mixing heights; hourly gridded surface temperatures; hourly exposure class; hourly vertical potential temperature gradient above and below the mixing height; hourly surface atmospheric pressure; hourly water mixing ratio; gridded surface roughness lengths.

Air quality data requirements are: concentration of O_3, NO, NO_2, PAR, OLE, ETH, ARO, CARB, PAN, and CO at the beginning of the simulation for each grid cell; hourly concentrations of each pollutant at each level along the inflow boundaries and top boundary of the modeling region.

Other data requirements are: hourly mixed layer average, NO_2 photolysis rates; and ozone surface uptake resistance along with associated gridded vegetation (scaling) factors.

c. Output

Printed output includes:

gridded instantaneous concentration fields at user-specified time intervals for user-specified pollutants and grid levels;

gridded time average concentration fields for user-specified time intervals, pollutants, and grid levels.

d. Type of Model

UAM is a three dimensional, numerical, photochemical grid model.

e. Pollutant Types

UAM may be used to model ozone (O_3) formation from oxides of nitrogen (NO_x) and volatile organic compound (VOC) emissions.

f. Source-Receptor Relationship

Low-level area and point source emissions are specified within each surface grid cell.

Up to 500 major point sources are allowed.

Hourly average concentrations of each pollutant are calculated for all grid cells at each vertical level.

g. Plume Behavior

Plume rise is calculated for major point sources using relationships recommended by Briggs (1971).

h. Horizontal Winds

See Input Requirements.

i. Vertical Wind Speed

Calculated at each vertical grid cell interface from the mass continuity relationship using the input gridded horizontal wind field.

j. Horizontal Dispersion

Horizontal eddy diffusivity is set to a user specified constant value (nominally 50 m^2/s).

k. Vertical Dispersion

Vertical eddy diffusivities for unstable and neutral conditions calculated using relationships of Lamb et al. (1977); for stable conditions, the relationship of Businger and Arya (1974) is employed. Stability class, friction velocity, and Monin-Obukhov length determined using procedure of Liu et al. (1976).

l. Chemical Transformation

UAM employs a simplified version of the Carbon-Bond II Mechanism (CBM-II) developed by Whitten, Killus, and Hogo (1980) employing various steady-state approximations. CBM-II is further simplified during nightime hours to improve computational efficiency. CBM-II utilizes five carbon-bond species (PAR-single bonded carbon atoms; OLE-terminal double bonded carbon atoms; ETH-ethylene; ARO-alkylated aromatic rings; and CARB-aldehydes, ketones, and surrogate carbonyls) which serve as surrogates for the large variety of emitted organic compounds in the urban atmosphere.

m. Physical Removal

Dry deposition of ozone and other pollutant species are calculated. Vegetation (scaling) factors are applied to the reference surface uptake resistance of each species depending on land use type.

n. Evaluation Studies

Builtjes, P. J. H., K. D. van der Hurt, and S. D. Reynolds. "Evaluation of the Performance of a Photochemical Dispersion Model in Practical Applications," 13th International Technical Meeting on Air Pollution Modeling and Its Application," Ile des Embiez, France, September 1982.

Cole, H. S., D. E. Layland, G. K. Moss, and C. F. Newberry. "The St. Louis Ozone Modeling Project," EPA 450/4-83-019 (NTIS PB 84-236611), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

Dennis, R. L., M. W. Downton, and R. S. Keil. "Evaluation of Performance Measures for an Urban Photochemical Model," EPA 450/4-83-021 (NTIS PB 84-115062), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina ,1983.

Layland, D. E. and H. S. Cole. "A Review of Recent Applications of the SAI Urban Airshed Model," EPA 450/4-84-004 (NTIS PB-185255), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

Layland, D. E., S. D. Reynolds, H. Hogo and W. R. Oliver. "Demonstration of Photochemical Grid Model Usage for Ozone Control Assessment," Paper 83-31.6, 76th Annual Meeting of the Air Pollution Control Association, Atlanta, Georgia, 1983.

Schere, K. L. and J. H. Shreffler. "Final Evaluation of Urban-Scale Photochemical Air Quality Simulation Models," EPA 600/3-82-094 (NTIS PB 83-147991), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1982.

Seigneur C., T. W. Tesche, C. E. Reid, P. M. Roth, W. R. Oliver, and J. C. Cassmassi. "The Sensitivity of Complex Photochemical Model Estimates to Detail In Input Information, Appendix A - A Compilation of Simulation Results," EPA 450/4-81-031b (NTIS PB 82-234220), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1981.

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APPENDIX B

SUMMARIES

OF

ALTERNATIVE AIR QUALITY MODELS

APPENDIX B

TABLE OF CONTENTS

B.0 INTRODUCTION

This appendix summarizes key features of refined air quality models that may be considered on a case-by-case basis for individual regulatory applications. For each model, information is provided on availability,* regulatory use, data input, output format and options, simulation of atmospheric physics and accuracy. The Models are listed by name in alphabetical order.

There are three separate conditions under which these models will normally be approved for use: first, if a demonstration can be made that the model produces concentration estimates equivalent to the estimates obtained using a preferred model (e.g. the maximum or highest second highest concentration is within 2% of the estimate using the comparable preferred model); second, if a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the model in Appendix B performs better for the application than a comparable model in Appendix A; and third, if there is no preferred model for the specific application but a refined model is needed to satisfy regulatory requirements. Any one of these three separate conditions may warrant use of these models. See Section 3.2, Use of Alternative Models, for additional details.

Many of these models have been subjected to a performance evaluation by comparison with observed air quality data. A summary of such comparisons for models contained in this appendix is included in "A Survey of Statistical Measures of Model Performance and Accuracy for Several Air Quality Models," EPA-450/4-83-001. Where possible, several of the models contained herein have been subjected to rigorous evaluation exercises, including (1) statistical performance measures recommended by the American Meteorological Society and (2) peer scientific reviews.

*Where reference is made to UNAMAP (Version 6), the assumption is implicit that that update of UNAMAP will contain the model identified.

B.1 AIR QUALITY DISPLAY MODEL (AQDM)

<u>Reference</u>: TRW Systems Group. "Air Quality Display Model." Prepared for National Air Pollution Control Administration, DHEW, U.S. Public Health Service, Washington, D.C., 1969, (NTIS PB 198194).

<u>Availability</u>: This model is available in the form of a punched card deck from:

Library Services
MD-35
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Attn: Ann Ingram

<u>Abstract</u>: AQDM is a climatological steady state Gaussian plume model that estimates annual arithmetic average sulfur dioxide and particulate concentrations at ground level in urban areas. A statistical model based on Larsen (1971) is used to transform the average concentration data from a limited number of receptors into expected geometric mean and maximum concentration values for several different averaging times.

a. Recommendations for Regulatory Use

AQDM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. AQDM must be executed in the equivalent mode.

AQDM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that AQDM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: average emissions rates and heights of emissions for point and area sources; stack gas temperature, stack gas exit velocity, and stack inside diameter for plume rise calculations for point sources.

Meteorological data requirements are: stability wind rose (STAR deck), average afternoon mixing height, average morning mixing height, and average air temperature.

Receptor data requirements are: number and locations of receptors. If the Larsen transform option is to be used to estimate short averaging time concentrations, measured standard geometric deviation of concentrations is required.

c. Output

Printed output includes:

one month to one year average concentrations (arithmetic mean only) at each receptor;

optional arbitrary averaging time by Larsen (1971) procedure (typically 1-24 hr); and

optional individual point, area source culpability list for each receptor.

d. Type of Model

AQDM is a Gaussian plume model.

e. Pollutant Types

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

f. Source Receptor Relationship

AQDM applies user-specified locations stack height for each point source.

AQDM uses any location and size for each area source.

Up to 225 receptors may be located on uniform rectangular grid.

Up to 12 user-specified receptor locations are permitted.

Unique release height is used for each point, area source.

Receptors are assumed to be at ground level.

No terrain differences between source and receptor are treated.

g. Plume Behavior

AQDM uses Briggs (1969) plume rise formulas.

No plume rise is calculated for area sources.

Fumigation and downwash are not treated.

Zero concentration is assumed when plume height is greater than mixing height.

h. Horizontal Winds

Wind data are input as stability wind rose (joint frequency distribution) of 16 wind directions, six wind speed classes, and five stability classes.

No variation in wind speed with height is assumed.

Constant, uniform (steady-state) wind is assumed.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Pollutants are assumed evenly distributed across a 22.5 degree sector.

Frequency of occurrence of a meteorological state is interpolated between sector center lines.

Averaging times from 1 month to 1 year or longer are treated.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used.

Five stability classes are as defined by Turner (1964). Stability classes E and F are combined, and assigned dispersion values equivalent to stability class D.

Neutral stability is split internally into 60% day, 40% night, with the two differing only in the treatment of mixing height.

Mixing height is a function of a single input afternoon mixing height, a single input morning mixing height, modified by the stability class.

l. Chemical Transformations

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

McNidar, R. R. (1977). "Variability Analysis of Long-term Dispersion Models," Joint Conf. on Applications of Air Pollution Meteorology, American Meteorology Society, 29 Nov.-2 Dec., 1977, Salt Lake City, Utah.

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B.2 AIR RESOURCES REGIONAL POLLUTION ASSESSMENT (ARRPA) MODEL

Reference: Mueller, S. F., R. J. Valente, T. L. Crawford, A. L. Sparks, and L. L. Gautney, Jr. "Description of the Air Resources Regional Pollution Assessment (ARRPA) Model: September 1983." TVA/ONR/AQB-83/14. Tennessee Valley Authority, Muscle Shoals, Alabama 35660, 1983.

Availability: The computer code and sample input for this model are available on magnetic tape from:

Computer Services Development Branch
Office of Natural Resources and Economic Development
Tennessee Valley Authority
OSWHA
Muscle Shoals, Alabama 35660.

Phone (205) 386-2985

A hard copy of the model output corresponding with the sample input is also available.

Abstract: The ARRPA model is a medium/long-range segmented-plume model. It is designed to compute air concentrations and surface dry mass deposition of sulfur dioxide and sulfate. A unique feature of the model is its use of prognostic meteorological output from the National Weather Service Boundary Layer Model (BLM). Boundary layer conditions are computed by the BLM on a grid with a spatial resolution of 80 km, and are archieved in intervals of 3 hours. BLM output used by this model includes three dimensional wind field components and potential temperature at 10 height levels from the surface through 2000 m above the surface.

a. Recommendations for Regulatory Use

There is no specific recommendation at this time. The ARRPA model may be used when transport distances are greater than 50 km on a case-by-case basis.

b. Input Requirements

Source data requirements: location (latitude and longitude), stack height, stack diameter, stack gas exit velocity, stack gas temperature, SO_2 emission rate, $SO_4^=$ emission rate, stack base elevation.

Meteorological data requirements: Hourly wind field components (u,v,w), potential temperature (θ), Pasquill-Gifford stability class and mixing height. These data are obtained as output from the

BLM output preprocessing program called MDPP [S.F. Mueller and R. J. Valente. "Meteorological Data Preprocessing Manual for the Air Resources Regional Pollution Assessment Model (Generic Version)." TVA/ONR/AQB-83/13. Tennessee Valley Authority, September 1983.] Required input to MDPP is BLM output (in three-hour intervals) of u, v, w, and θ, surface layer friction velocity (u_*) and surface layer values of the inverse Monin-Obukhov length (L^{-1}).

Receptor data requirements: gridded receptor array coordinates (x and y) and receptor heights (z) from a receptor preprocessing program called HEIGHT. HEIGHT produces a user-designed array of points which may be skewed up to ± 90 degrees relative to the model x axis. The elevation of each receptor is adjusted to give height above smoothed model terrain.

c. Output

Printed output includes:

listings of input parameters (except for meteorological data);

listing of hours processed and flags for missing data periods.

Disk output: parameters for controlling analysis and printout options in the postprocessing program called ANALYSIS; hourly SO_2 and $SO_4^=$ air concentrations and dry deposition amounts at each receptor.

Optional printed output: two programs are available for displaying model output - DISPLAY and ANALYSIS; DISPLAY prints out hourly gridded concentration and/or deposition fields for a user-specified time periods; ANALYSIS prints out (1) the five highest concentrations of SO_2 and/or $SO_4^=$ at each receptor for 1-hour, 3-hour (optional) and 24-hour (optional) averaging periods, (2) average SO_2 and/or $SO_4^=$ concentrations at each receptor for the entire analysis period and (3) gridded SO_2 and/or $SO_4^=$ dry deposition amounts for the day having the greatest dry deposition and for the entire analysis period.

d. Type of Model

The ARRPA model is a Gaussian segmented-plume model.

e. Pollutant Types

SO_2 and $SO_4^=$ are treated.

f. Source-Receptor Relationship

One source is treated per model run, though results from several sources may be superimposed.

Emission rates are constant.

Receptors (up to 100) in gridded network may have different elevations.

Height of receptors above ground is variable.

g. Plume Behavior

Plume rise is computed in a piecewise-continuous manner through discrete model layers (Mueller, et al., 1983).

Plume can be isolated from the ground (lofting).

Plume height varies in time and space.

h. Horizontal Winds

Hourly horizontal wind components, specified at 80-km intervals across the model grid, are spatially interpolated and vertically averaged through the plume depth to get plume transport vectors. A model option is available that uses the wind vector near the vertical plume center instead of computing a vertically-averaged vector.

i. Vertical Wind Speed

The mass-conserving BLM wind field used in this model provides vertical wind components that vary horizontally and vertically, and are used to adjust plume height.

j. Horizontal Dispersion

Plume half-width (σ_y) growth goes through four stages:

(1) growth follows Turner curves for $\sigma_y < 1000$ m;
(2) a transition in growth behavior from Turner curves to dynamical-statistical (Langevin) theory occurs for $1000 \text{ m} < \sigma_y < 6000$ m;
(3) growth is based on dynamical-statistical theory for $\sigma_y > 6000$ m; eddy diffusivity computed from Pasquill-Gifford stability class;
(4) growth approaches that described by Taylor's statistical theory (limit of dynamical-statistical theory for time much larger than the Lagrangian time correlation) for $\sigma_y > 10000$ m.

k. Vertical Dispersion

Plume half-depth (σ_z) growth is based on combination of Brookhaven curves for elevated plumes and Turner curves for near-ground plumes.

Vertical plume structure is Gaussian, with superimposed reflection terms, until σ_z becomes sufficiently large that a vertically uniform plume assumption is appropriate.

Plume is assumed to be isolated above the ground when the plume centerline height is more than a distance σ_Z above the mixing height.

Maximum depth of a plume is 2000 m.

l. Chemical Transformation

SO_2 oxidation to $SO_4^=$ is treated using a first-order chemical reaction rate constant which is parameterized to vary hourly following diurnal and seasonal cycles.

m. Physical Removal

Dry deposition is computed using the source depletion equation. Dry deposition velocities vary according to the stability of the surface layer.

n. Evaluation Studies

Studies are in progress.

B.3 APRAC-3/MOBILE2

Reference: Simmon, P. B., R. M. Patterson, F. L. Ludwig, and L. B. Jones. "The APRAC-3/Mobile 1 Emissions and Diffusion Modeling Package". EPA 909-9-81-002. Environmental Protection Agency, Region IX, San Francisco, California 94104, 1981. NTIS PB82-103763.

User's Guide to MOBILE2 (Mobile Source Emissions Model). EPA-460/3-81-006, 1981.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U. S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: APRAC-3 is a model which computes hourly average carbon monoxide concentrations for any urban location. The model calculates contributions from dispersion on various scales: extraurban, mainly from sources upwind of the city of interest; intraurban, from freeway, arterial, and feeder street sources; and local, from dispersion within a street canyon. APRAC-3 requires an extensive traffic inventory for the city of interest. An emissions module incorporating Mobile 2 is used to compute emission factors. The APRAC-3 documentation now contains a revised Table 9, Inputs for Preprocessor Program, for accommodating additional MOBILE2 inputs.

a. Recommendations for Regulatory Use

APRAC-3 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. APRAC-3 must be executed in the equivalent mode.

APRAC-3 can be used in a case-by-case basis in lieu of a preferred model if it can be demonstrated using the criteria in Section 3.2, that APRAC-3 is more appropriate for the specific application. In this case the model options/mode which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: line source (traffic link) end points, road type and daily traffic volume.

Meteorological data requirements are: hourly wind direction (nearest 10 degrees), hourly wind speed, and hourly cloud cover for stability calculations

Receptor data requirements are: coordinates for up to 10 receptors for any single day and up to 8 receptors for the intersection submodel.

c. Output

Printed ouput includes:

hourly calculations at each receptor.

d. Type of Model

APRAC-3 is a Gaussian plume model.

e. Pollutant Types

APRAC-3 may be used to model primary pollutants.

f. Source-Receptor Relationship

The traffic links may have arbitrary length and orientation off-link traffic allocated to two-mile square grid. Link traffic emissions are aggregated into a receptor oriented area source array.

The boundaries of the area sources actually treated are (1) arcs at radial distances from the receptor which increase in geometric progression, (2) the sides of a 22.5^{o} sector oriented upwind for distances greater than 1000 m, and (3) the sides of a 45^{o} sector oriented upwind for distances less than 1000 m.

A similar area source array is established for each receptor.

Sources are assumed to be at ground level.

Up to 10 receptors are accepted for any single day.

Up to 625 receptors are accepted for a single-hour.

Up to 8 receptors are accepted for the intersection submodel.

Receptors are at ground level.

Receptor locations are arbitrary.

Four internally defined receptor locations on each user-designated street are used in a special street canyon sub-model.

A box model is used to estimate contribution from upwind sources beyond 32 km based on wind speed, mixing height, annual fuel consumption.

In street canyon sub-model, contribution from other streets is included in background.

g. Plume Behavior

Plume rise is not treated.

Fumigation and downwash are not treated except in street canyon sub-model.

In street canyon sub-model, a helical circulation pattern is assumed.

h. Horizontal Winds

User input hourly wind speed and direction in tens of degrees are used.

No variation of wind speed or direction with height is assumed.

Constant, uniform (steady-state) wind is assumed within each hour.

The model can interpolate winds at receptors if more than one wind is provided.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero except in street canyon sub-model.

Helical circulation assumed by street canyon sub-model.

j. Horizontal Dispersion

Sector averaging is used with uniform distribution within sectors. Sector size is 22.5 degrees beyond 1 km and 45.0 degrees within 1 km.

k. Vertical Dispersion

Six stability classes are used. Stability class is determined internally from user-supplied meteorological data modified from Turner (1964).

Dispersion coefficients are adapted from McElroy and Pooler (1968).

No adjustments are made for variations in surface roughness

Downwind distance variation of σ_z is assumed to be ax^b for purposes of doing analytical integration.

In street canyon sub-model, an empirical function of wind speed and street width and direction is used

Perfect reflection at the surface is assumed.

Mixing height is ignored until concentration equals that calculated using box model. A box model (uniform vertical distribution) is used beyond that distance.

l. <u>Chemical Transformation</u>

Not treated.

m. <u>Physical Removal</u>

Not treated.

n. <u>Evaluation Studies</u>

None for APRAC-3/MOBILE2.

B.4 COMPTER

Reference: State of Alabama. "COMPTER Model Users Guide," Alabama Air Pollution Control Commission, Montgomery, Alabama 36130-1701.

Availability: This model is available to users for tape reproduction charges. Send tape and desired format and specifications to:

Alabama Air Pollution Control Commission
465 South McDonough
Montgomery, Alabama 36130

Abstract: COMPTER is based on the Gaussian steady-state technique applicable to both urban and rural areas. The model contains the following attributes: (a) determines maximum 24-hour, 3-hour, 1-hour and variable hour concentrations for both block and running averages; (b) elevated terrain considered with the standard plume-chopping technique or stability dependent plume path trajectory; (c) uses annual hourly meteorological data in the CRSTER preprocessor format; (d) uses Pasquill-Gifford stability curves; (e) allows for stability class substitution in the stable categories. Typical model use is in rural areas with moderate to low terrain features.

a. Recommendations for Regulatory Use

COMPTER can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. COMPTER must be executed in the equivalent mode.

COMPTER can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that COMPTER is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: annual or hourly values of emission rate, exit velocity, stack gas temperature, stack height, and stack diameter.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is optional.

Receptor data requirements are: individual receptor coordinates; or a location, dimension, and spacing of a rectangular grid; or a location and distance from the center of five rings of receptors; or a combination of individual receptors and either the rectangular grid or the rings of receptors. Elevations of all receptors may be input.

c. Output

Printed output includes:

Highest and second highest concentrations for the year at each receptor for averaging times of 1, 3 and 24-hours, a user-selected averaging time which may be 2-12 hours, and a 50 high table for 1, 3, and 24-hours;

Annual arithmetic average at each receptor; and the highest 1-hour and 24-hour concentrations over the receptor field for each day considered.

Computer readable output includes:

Hourly, 3-hourly, variable hourly, and 24-hourly concentrations for each receptor on magnetic storage device.

d. Type of Model

COMPTER is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

A maximum 50 sources and 200 receptors are treated.

COMPTER applies user-specified locations of sources and recetors.

user input stack height and source characteristics for each source are applied.

User input topographic elevation for each receptor is applied.

Receptors are assumed to be at ground level.

g. Plume Behavior

Briggs' (1969, 1971, 1972) plume rise equations with limited mixing are used.

Plume height is adjustable according to stability with use of plume path coefficient.

h. Horizontal Winds

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

Straight line plume transport is assumed to all downwind distances.

Power law wind profile exponents used are .10, .15, .20, .25, .30, and .30, for stability classes A through F, respectively. Anemometer height is assumed to be 10 meters.

i. Vertical Wind Speed

Vertical wind speeds assumed equal to zero.

j. Horizontal Dispersion

Dispersion coefficients are from Turner (1969), with no further adjustments made for variations in surface roughness or averaging time.

Optionally, stability class 7 may be treated as Class 6.

Other options for stable class substitution include changing stabilities F and G to E, and reducing E, F, and G to D, E, and F, respectively.

k. Vertical Dispersion

Dispersion coefficients are from Turner (1969), with no further adjustments made for variations in surface roughness.

Optionally, stability class 7 may be treated as class 6.

Other options for stable class substitution include changing stabilities F and G to E; and reducing E, F, and G to D, E, and F, respectively.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. "Evaluation of Rural Air Quality Simulation Models." EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

B.5 ERT AIR QUALITY MODEL (ERTAQ)

Reference: Environmental Research & Technology, Inc., ERTAQ Users' Guide. ERT Document No. M-0186-001E. Environmental Research & Technology, Inc., Concord, Massachusetts, 1980.

Availability: The ERTAQ model is available from:

Environmental Research & Technology, Inc.
ATTN: Mr. Joseph A. Curreri
Air Quality Center
696 Virginia Road
Concord, Massachusetts 01742

No cost has been specified.

Abstract: ERTAQ is a multiple point, line and area source dispersion model which utilizes the univariate Gaussian formula with multiple reflections.

With the fugitive dust option, entrainment of particulates from ground-level sources and subsequent deposition are accountable. The model offers an urban/rural option, and calculates long-term or worst-case concentrations due to arbitrarily located sources for arbitrarily located receptors above or at ground level. Background concentrations and calibration factors at each receptor can be user specified. Unique flexibility is afforded by postprocessing storage and manipulation capability.

a. Recommendations for Regulatory Use

ERTAQ can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. ERTAQ must be executed in the equivalent mode.

ERTAQ can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that ERTAQ is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: up to six pollutants may be specified, citing quantity and calibration factor for each (and particle size, if appropriate); heat rate and height of emissions per source for determining plume height.

Meteorological data requirements are: stability wind rose, plus annual average ambient air temperature and mixing height.

Receptor data requirements are: cartesian coordinates for each receptor.

c. <u>Output</u>

Printed output includes:

> Mean concentrations at designated receptors for long-term mode. In worst-case mode, concentrations for user-specified meteorological conditions.

d. <u>Type of Model</u>

ERTAQ is a climatological Gaussian plume model.

e. <u>Pollutant Types</u>

ERTAQ treats primary pollutants with or without significant settling velocities.

f. <u>Source-Receptor Relationship</u>

Up to 501 user-specified locations for point, area, and line sources, and up to 128 arbitrarily located receptors are permitted.

User-specified release heights are applied for all sources.

Simple terrain relief is treated.

Receptors may be at or above ground level.

g. <u>Plume Behavior</u>

Briggs (1975) plume rise formulas final rise only, are used.

Briggs calm formula is used when wind speed is less than 1.37 meters per second.

Plume rise may be calculated for point and area sources.

Top of mixed layer is perfect reflector (full or no plume penetration).

Fumigation and downwash are not treated.

Buoyancy-induced dispersion is not treated.

h. <u>Horizontal Winds</u>

Steady state and homogeneous winds are assumed.

Sixteen wind directions and six speed classes are treated.

Exponential vertical profile extrapolates observed wind to release height for plume rise and to plume height for downwind dilution.

The exponents used are .10, .15, .20, .25, and .30 for stability classes A through E, respectively.

i. Vertical Wind Speed

Vertical wind speed is assumed to be zero.

j. Horizontal Dispersion

Uniform distribution in 22.5 degree sector, or triangular distribution in 45 degree sector (user specified).

k. Vertical Dispersion

Gaussian plume with initial mixing specification is assumed.

Five stability categories are treated (converts all stability class F to class E).

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

Urban case is treated by shifting the stability one class toward unstable.

Top of mixed layer is perfect reflector (full or no plume penetration).

Ground surface is total reflector.

Surface deposition reduces entire plume concentration using a source depletion factor.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Particle deposition for ground-level sources is treated.

n. Evaluation Studies

Londergan, R. J., D. H. Minott, D. J. Wachter and R. R. Fizz. "Evaluation of Urban Air Quality Simulation Models." EPA-450/4-83-020. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1983.

B.6 ERT VISIBILITY MODEL

Reference: Drivas, Peter J., Savithri Machiraju, and David W. Heinold. "ERT Visibility Model: Version 3; Technical Description and User's Guide." Document M2020-001. Environmental Research & Technology, Inc., Concord, Massachusetts, 1980.

Availability: Anyone wishing to review the Visibility model should contact Environmental Research & Technology, Inc. (ERT). At present no cost has been identified for the user manual or the model. Requests should be directed to:

Mr. Joseph A. Curreri
Air Quality Studies Division
Environmental Research & Technology, Inc.
696 Virginia Road
Concord, Massachusetts 01742

Abstract: The ERT Visibility model is a Gaussian dispersion model designed to estimate visibility impairment for arbitrary lines of sight due to isolated point source emissions by simulating gase-to-particle conversion, dry deposition, NO to NO_2 conversion and linear radiative transfer.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The ERT visibility model may be used on a case by case basis.

b. Input Requirements

Source data requirements are: stack height, stack temperature, emissions of SO_2, NO_x, TSP, fraction of NO_x as NO_2, fraction of TSP which are carbonaceous, exit velocity, and exit radius.

Meteorological data requirements are: hourly ambient temperature, mixing depth, wind speed at stack height, stability class, potential temperature gradient, and wind direction.

Receptor data requirements are: observer coordinates with respect to source, latitude, longitude, time zone, date, time of day, elevation, relative humidity, background visual range, line-of-sight azimuth and elevation angle, inclination angle of the observed object, distance from observer to object, object reflectivity, surface reflectivity, number and spacing of integral receptor points along line-of-sight.

Other data requirements are: ambient concentrations of O_3 and NO_x, deposition velocity of TSP, sulfate, nitrate, SO_2 and NO_x, first-order transformation rate for sulfate and nitrate.

c. Output

Printed output includes both summary and detailed results as follows: Summary output: page 1 - site, observer and object parameters; page 2 - optical pollutants and associated extinction coefficients; page 3 - plume model input parameters; page 4 - total calculated visual range reduction, and each pollutant's contribution; page 5 - calculated plume contrast, object contrast and object contrast degradation at the 550 nm wavelength; page 6 - calculated blue/red ratio and ΔE (U*V*W*) values for both sky and object discoloration.

Detailed output: phase functions for each pollutant in four wavelengths (400, 450, 550, 650 nm), concentrations for each pollutant along sight path, solar geometry, contrast parameters at all wavelengths, intensities, tristimulus values and chromaticity coordinates for views of the object, sun, background sky and plume.

d. Type of Model

ERT Visibility is a Gaussian plume model for estimating visibility impairment.

e. Pollutant Types

Optical activity of sulfate, nitrate, (derived from SO_2 and NO_x emissions) primary TSP and NO_2 is simulated.

f. Source Receptor Relationship

Single source and hour is simulated. Unlimited number of lines-of-sight (receptors) is permitted per model run.

g. Plume Behavior

Briggs (1971) plume rise equations for final rise are used.

h. Horizontal Wind Field

A single wind speed and direction is specified for each case study. The wind is assumed to be spatially uniform.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used. Mixing height is accounted for with multiple reflection handled by summation of series near the source, and Fourier representation farther downwind.

l. Chemical Transformation

First order transformations of sulfates and nitrates are used.

m. Physical Removal

Dry deposition is treated by the source depletion method.

n. Evaluation Studies

White, Warren H. et al. "An Intercomparison of Plume Visibility Models with VISTTA Observations at the Navajo Generating Station," 1983.

Seigneur, C., R. W. Bergstrom, and A. B. Hudischewskyj. "Evaluation of the EPA PLUVUE Model and the ERT Visibility Model Based on the 1979 VISTTA Data Base" EPA-450/4-82-008, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1982.

B.7 HIWAY-2

Reference: Petersen, W. B. User's Guide for HIWAY-2. Publication No. EPA-600/8-80-018 (NTIS PB 80-227-556) Environmental Protection Agency, ESRL, Research Triangle Park, North Carolina 27711, 1980.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: HIWAY-2 can be used to estimate the concentrations of non-reactive pollutants from highway traffic. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of "at-grade" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation, and receptor location. The model was developed for situations where horizontal wind flow dominates. The model cannot consider complex terrain or large obstructions to the flow such as buildings or large trees.

a. Recommendations for Regulatory Use

HIWAY-2 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. HIWAY-2 must be executed in the equivalent mode.

HIWAY-2 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that HIWAY-2 is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: a uniform emission rate by lane, roadway end points; height of emission; length, width, and number of lanes; and width of center strip.

Meteorological data requirements are: one set at a time of hourly averages of wind speed, wind direction, and mixing height and the Pasquill-Gifford stability class. Wind speed and direction are preferred to be at 2 meters above ground.

Receptor data requirements are: coordinates of each receptor.

c. Output

Printed output includes:

> one hourly average concentration at each specified receptor location.

d. Type of Model

HIWAY-2 is a Gaussian plume model.

e. Pollutant Types

HIWAY-2 may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

HIWAY-2 applies user-specified end points for a single roadway segment, and user-specified receptor locations.

Plume impact on receptor is calculated by finite difference integration of a point source along each lane of the roadway.

g. Plume Behavior

HIWAY-2 does not treat plume rise.

h. Horizontal Winds

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

Straight line plume transport is assumed to all downwind distances.

An aerodynamic drag factor is applied when winds are parallel to the roadway and speeds are less than 2 m/sec.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

The total horizontal dispersion is that due to ambient turbulence plus the turbulence generated by the vehicles on the roadway.

Beyond 300 m downwind total turbulence is considered to be dominated by atmospheric turbulence, with plume dispersion as described by Turner (1969).

Three stability classes are considered: unstable, neutral and stable.

k. Vertical Dispersion

The total horizontal dispersion is that due to ambient turbulence plus the turbulence generated by the vehicles on the roadway.

Beyond 300 m downwind total turbulence is considered to be dominated by atmospheric turbulence, with plume dispersion as described by Turner (1969).

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point.

Three stability classes are considered: unstable, neutral and stable.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Rao, S. T., and J. R. Visalli. "On the Comparative Assessment of the Performance of Air Quality Models," J. Air Poll. Control Assoc., Vol. 31, pp. 851-860, 1981.

B.8 INTEGRATED MODEL FOR PLUMES AND ATMOSPHERIC CHEMISTRY IN COMPLEX TERRAIN (IMPACT) (Fabrick)

Reference: Fabrick, Allan J. and Peter J. Haas. "User Guide to IMPACT: An Integrated Model for Plumes and Atmospheric Chemistry in Complex Terrain." DCN 80-241-403-01. Radian Corporation, 8501 Mo-Pac Blvd., Austin, Texas 78766, 1980.

Availability: Both a magnetic tape containing the IMPACT model and a set of test data and a copy of the IMPACT User's Guide may be obtained directly from Radian Corporation. The total cost is $500.

Requests should be sent to:

Radian Corporation
Atmospheric Science Division
8501 Mo-Pac Blvd.
Austin, Texas 78766

Abstract: IMPACT is an Eulerian, three-dimensional, finite difference grid model designed to calculate the impact of pollutants, either inert or reactive, in simple or complex terrain, emitted from either point or area sources. It automatically treats single or multiple point or area sources, the effects of vertical temperature stratifications on the wind and diffusion fields, shear flows caused by the atmospheric boundary layer or by terrain effects, and chemical transformations.

a. Recommendations for Regulatory Use

IMPACT can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. IMPACT must be executed in the equivalent mode.

IMPACT can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that IMPACT is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

There is no specific recommendation concerning the use of IMPACT for photochemical applications. IMPACT may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: for point sources--location (I, J), stack height, exit temperature, volume flow rate or stack diameter and exit velocity, hourly emission rates for all pollutants for area sources location, of corners, and hourly emission rates for each pollutant.

Meteorological data requirements are: Hourly wind speed and direction, surface and elevated, from meteorological stations within and surrounding the modeling area, temperature, pressure, humidity and insolation (the three last variables are optional).

Receptor data requirements are: none since concentrations are output for cells in the computational grid.

Air quality data (optional): One or more vertical concentration profiles for each pollutant.

Other data: 2-D array of terrain heights, 2-D array of surface roughness values (optional).

c. Output

Printed output options include:

surface and elevated horizontal cross sections of pollutant concentrations (instantaneous, or averages over N hours where N=1, 2,3,. . .);

horizontal cross sections of diffusivities and wind velocities; and

arbitrary vertical and horizontal cross sections of pollutant concentrations and diffusivities, and CALCOMP wind field vector plots are generated by the POST post-processor program.

Computer readable output includes:

Concentration, wind field and diffusivity data for each hour.

d. Type of Model

IMPACT is an Eulerian finite difference model.

e. Pollutant Types

IMPACT may be used to model any inert pollutant.

IMPACT may be used to model SO_2, $SO_4^=$, NO_x, NO_2, O_3, hydrocarbons (depends upon chemistry mechanism selected).

f. Source-Receptor Relationship

Up to 20 point sources and 20 area sources may be treated (greater number of sources may be treated by increasing common block storage allocation).

Concentrations are calculated at the center of each cell in the grid.

g. Plume Behavior

Briggs (1975) formulation for plume rise is used.

Elevated inversions are considered.

h. Horizontal Winds

A three dimensional stability and terrain dependent nondivergent wind field is interpolated from single or multiple wind data measurements using a Poisson technique.

i. Vertical Wind Speed

Vertical wind speed is treated at each wind site, user specified or extrapolated from surface data. Interpolated is accomplished as part of the three dimensional wind field interpolation.

j. Horizontal Dispersion

A three dimensional diffusivity field is calculated using either the technique of Myrup/Ranzieri or the DEPICT method (see User Guide, Fabrick and Haas, 1980).

k. Vertical Dispersion

A three dimensional diffusivity field is calculated using either the technique of Myrup/Ranzieri or the DEPICT method (see User Guide, Fabrick and Haas, 1980).

l. Chemical Transformation

Either 3, 6, 8 or 15-species mechanisms are currently available (see User Guide). Calculations are also performed for inert pollutants.

m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

n. Evaluation Studies

Fabrick, A. J., R. Sklarew, and J. Wilson. Point Source Model Evaluation and Development Study, report prepared for the California Air Resources Board, 1977.

Sklarew, R., and V. Mirabella. "Experience in IMPACT Modeling of Complex Terrain," Fourth Symposium on Turbulence Diffusion and Air Pollution, Reno, Nevada, 1979.

Sklarew, R., J. Wilson, A. J. Fabrick and V. Mirabella. "Rough Terrain Modeling," presented at Geothermal Environmental Seminar '76, Clear Lake California, 1976.

Sklarew, R., and K. Tran. "The NEWEST Wind Field Model with Applications to Thermally Driven Drainage Wind in Mountainous Terrain," presentd at the AMS Meeting, Lake Tahoe, 1978.

Fabrick, A. J., and P. J. Haas. "Analysis of Dispersion Models used for Complex Terrain Simulation," presented at the Symposium on Intermediate Range Transport Processes and Technology Assessment, Gatlinburg, Tennessee, 1980.

B.9 INTEGRATED MODEL FOR PLUMES AND ATMOSPHERIC CHEMISTRY IN COMPLEX TERRAIN (IMPACT)(Sklarew)

Reference: User Guide to Impact: An Integrated Model for Plumes and Atmospheric Chemistry in Complex Terrain, by Khanh T. Tran and Ralph C. Sklarew, Form and Substance, Inc., Westlake Village, California, 1979.

Availability: Available at a cost of $1720 (1981).

Form & Substance, Inc.
875 Westlake Boulevard
Westlake Village, California 91361.

Abstract: IMPACT is a three-dimensional numerical grid model. Terrain is represented by blockages in the grid. IMPACT solves the conservation of mass equation for each pollutant by time splitting for each dimension and by one-dimensional finite differencing. The three dimensional wind field is developed from sparse inputs by an iterative three-dimensional poisson solver that matches inputs, terrain and stability effects on the wind in response to terrain as well as thermally generated downslope drainage winds. Diffusion is simulated using k-theory with diffusivities computed consistent with the computed wind field. IMPACT also can perform chemical reaction simulation for each cell by a predictor corrector solution of kinetics rate equations and contains chemical mechanisms for photochemical O_3/NO_2 and for $SO_2/SO_4^=$

a. Recommendations for Regulatory Use

IMPACT can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. IMPACT must be executed in the equivalent mode.

IMPACT can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that IMPACT is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

There is no specific recommendation concerning the use of IMPACT for photochemical applications. IMPACT may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: all standard point, line and area source parameters.

Meteorological data requirements are: hour by hour data for wind speed and direction and stability or temperature at one or more locations at ground level or vertical profile. (The more data the better but IMPACT can run with the same minimal data used in a Gaussian model.)

Receptor data requirements are: none. Concentrations are calculated for cells in the computational grid.

c. Output

Printed output includes:

> One or multiple hour-averaged or instantaneous, concentration for each grid cell. Summary edits for ground level, specfied receptors and contour plots.

d. Type of Model

IMPACT is an Eulerian, finite difference model.

e. Pollutant Types

IMPACT treats inert and reactives species such as CO, O_3, NO, NO_2, SO_2, $SO_4^=$, etc.

f. Source-Receptor Relationship

Concentrations are calculated at the center of each grid cell.

Up to 50 point sources and 50 area sources are printed.

g. Plume Behavior

Briggs (1975) plume rise is used. Optionally, Briggs (1969) plume rise can be used. Fumigation and plume height above mixing height are treated.

h. Horizontal Winds

Horizontal wind fields calculated self consistently from input data and terrain.

i. Vertical Wind Field

Vertical wind fields calculated self consistently from input data and terrain.

j. Horizontal Dispersion

A three dimensional diffusivity field is calculated using either the technique of Myrup and Ranzieri, or the DEPICT method as described in the User's Guide.

k. Vertical Dispersion

A three dimensional diffusivity field is calculated using either the technique of Myrup and Ranzieri, or the DEPICT method as described in the User's Guide.

l. Chemical Transformation

Two mechanisms are included for photochemical O_3/NO_2: the five species GRC mechanism (Eschenroeder, 1972) and the 14 species Hecht-Seinfeld-Dodge mechanism (Hecht and Seinfeld, 1974).

One mechanism is included for $SO_2/SO_4^=$, a simplified method described by Sklarew, et al. (1979).

m. Physical Removal

Fallout and surface absorption is included.

n. Evaluation Studies

Fabrick, A. J., R. Sklarew and J. Wilson. Point Source Model Evaluation and Development Study, report prepared for the California Air Resources Board, 1977.

Sklarew, R., and V. Mirabella. "Experience in IMPACT Modeling of Complex Terrain," Fourth Symposium on Turbulence Diffusion and Air Pollution, Reno, Nevada, 1979.

Sklarew, R., J. Wilson, A. J. Fabrick, and V. Mirabella. "Rough Terrain Modeling," presented at Geothermal Environmental Siminar '76, Clear Lake, California, 1976.

Sklarew, R., and K. Tran. "The NEWEST Wind Field Model with Applications to Thermally Driven Drainage Wind in Mountainous Terrain," presented at the AMS Meeting, Lake Tahoe, 1978.

Fabrick, A. J, and P. J. Haas. "Analysis of Dispersion Models used for Complex Terrain Simulation," presented at the Symposium on Intermediate Range Transport Processes and Technology Assessment, Gatlinburg, Tennessee, 1980.

B.10 LONGZ

Reference: Bjorklund, J. R., and J. F. Bowers. "User's Instructions for the SHORTZ and LONGZ Computer Programs. Volumes 1 and 2," EPA 903/9-82-004, U.S. Environmental Protection Agency, Region III, Philadelphia, Pennsylvania 19106, 1982.

Availability: The model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: LONGZ utilizes the steady-state univariate Gaussian plume formulation for both urban and rural areas in flat or complex terrain to calculate long-term (seasonal and/or annual) ground-level ambient air concentratins attributable to emissions from up to 14,000 arbitrarily placed sources (stacks, buildings and area sources). The output consists of the total concentration at each receptor due to emissions from each user-specified source or group of sources, including all sources. An option which considers losses due to deposition (see the description of SHORTZ) is deemed inappropriate by the authors for complex terrain, and is not discussed here.

a. Recommendations for Regulatory Use

LONGZ can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. LONGZ must be executed in the equivalent mode.

LONGZ can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that LONGZ is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: for point, building or area, sources, location, elevation, total emission rate (optionally classified by gravitational settling velocity) and decay coefficient; for stack soruces, stack height, effluent temperature, effluent exit velocity, stack radius (inner), emission rate, and ground elevation (optional);

for building sources, height, length and width, and orientation; for area sources, characteristic vertical dimension, and length, width and orientation.

Meteorological data requirements are: wind speed and measurement height, wind profile exponents, wind direction standard deviations (turbulent intensities), mixing height, air temperature, vertical potential temperature gradient.

Receptor data requirements are: coordinates, ground elevation.

c. Output

Printed output includes:

> Total concentration due to emissions from user-specified source groups, including the combined emissions from all sources (with optional allowance for depletion by deposition).

d. Type of Model

LONGZ is a climatological Gaussian plume model.

e. Pollutant Types

LONGZ may be used to model primary pollutants. Settling and deposition are treated.

f. Source-Receptor Relationships

LONGZ applies user specified locations for sources and receptors.

Receptors are assumed to be at ground level.

g. Plume Behavior

Plume rise equations of Bjorklund and Bowers (1982) are used.

Stack tip downwash (Bjorklund and Bowers, 1982) is included.

All plumes move horizontally and will fully intercept elevated terrain.

Plumes above mixing height are ignored.

Perfect reflection at mixing height is assumed for plumes below the mixing height.

Plume rise is limited when the mean wind at stack height approaches or exceeds stack exit velocity.

Perfect reflection at ground is assumed for pollutants with no settling velocity.

Zero reflection at ground is assumed for pollutants with finite settling velocity.

LONGZ does not simulate fumigation.

Tilted plume is used for pollutants with settling velocity specified.

Buoyancy-induced dispersion is treated (Briggs, 1972).

h. Horizontal Winds

Wind field is homogeneous and steady-state.

Wind speed profile exponents are functions of both stability class and wind speed. Default values are specified in Bjorklund and Bowers (1982).

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Pollutants are initially uniformly distributed within each wind direction sector. A smoothing function is then used to remove discontinuities at sector boundaries.

k. Vertical Dispersion

Vertical dispersion is derived from input vertical turbulent intensities using adjustments to plume height and rate of plume growth with downwind distance specified in Bjorklund and Bowers (1982).

l. Chemical Transformation

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

m. Physical Removal

Gravitational settling and dry deposition of particulates are treated.

n. Evaluation Studies

Bjorklund, J. R., and J. F. Bowers. "User's Instructions for the SHORTZ and LONGZ Computer Programs," EPA-903/9-82-004, Environmental Protection Agency, Region III, Philadelphia, Pennsylvania 19106, 1982.

B.11 MARYLAND POWER PLANT SITING PROGRAM (PPSP) MODEL

References: Brower, R. The Maryland Power Plant Siting Program (PPSP) Air Quality Model User's Guide. Prepared by Environmental Center, Martin Marietta Corporation, Baltimore, Maryland for Maryland Department of Natural Resources, 1982. Ref. No. PPSP-MP-38 (NTIS No. PB82-238387).

Weil, J. C. and R. P. Brower. The Maryland PPSP Dispersion Model for Tall Stacks. Prepared by Environmental Center, Martin Marietta Corporation, Baltimore, Maryland, for Maryland Department of Natural Resources, 1982. Ref. No. PPSP-MP-36 (NTIS No. PB82-219155).

Availability: Two reports referenced above are available from NTIS. Tape of source code and test data not currently available.

Abstract: PPSP is a Gaussian dispersion model applicable to tall stacks in either rural or urban areas, but in terrain that is essentially flat (on a scale large compared to the ground roughness elements). The PPSP model follows the same general formulation and computer coding as CRSTER, also a Gaussian model, but it differs in four major ways. The differences are in the scientific formulation of specific ingredients or "sub-models" to the Gaussian model, and are based on recent theoretical improvements as well as supporting experimental data. The differences are: (1) stability during daytime is based on convective scaling instead of the Turner criteria; (2) Briggs' dispersion curves for elevated sources are used; (3) Briggs plume rise formulas for convective conditions are included; and (4) plume penetration of elevated stable layers is given by Briggs' (1982) model.

a. Recommendations for Regulatory Use

PPSP can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. PPSP must be executed in the equivalent mode.

PPSP can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that PPSP is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: emission rate (monthly rates optional), physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: distance of each of the five receptor rings.

c. Output

Printed output includes:

highest and second highest concentrations for the year at each receptor for averaging times of 1, 3, and 24-hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours;

annual arithmetic average at each receptor; and

for each day, the highest 1-hour and 24-hour concentrations over the receptor field.

d. Type of Model

PPSP is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

Up to 19 point sources are treated.

All point sources are assumed at the same location.

Unique stack height and stack exit conditions are applied for each source.

Receptor are locations restricted to 36 azimuths (every 10 degrees) and five user-specified radial distances.

g. Plume Behavior

Briggs (1975) final rise formulas for buoyant plumes are used. Momentum rise is not considered.

Transitional or distance-dependent plume rise is not modeled.

Penetration (complete, partial, or zero) of elevated inversions is treated with Briggs (1983) model; ground-level concentrations are dependent on degree of plume penetration.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law variation, with different exponents for different stability classes and variable reference height (7 meters is default). Wind speed power law exponents are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Constant, uniform (steady-state) wind assumed within each hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion parameters are Briggs (Gifford, 1975), with stability class defined by u/w* during daytime, and by the method of Turner (1964) at night.

Urban dispersion is treated by changing all stable cases to stability class D.

Buoyancy-induced dispersion (Pasquill, 1976) is included (using $\Delta H/3.5$).

k. Vertical Dispersion

Rural dispersion parameters are Briggs (Gifford, 1975), with stability class defined by u/w* during daytime, and by the method of Turner (1964).

Urban dispersion treated by changing all stable cases to stability class D.

Buoyancy-induced dispersion (Pasquill, 1976) is included (using $\Delta H/3.5$).

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Weil, J. C. and R. P. Brower. The Maryland PPSP dispersion model for tall stacks. Prepared by Environmental Center, Martin Marietta Corporation, Baltimore, Maryland, for Maryland Department of Natural Resources, 1982. Ref. No. PPSP MP-36 (NTIS No. PB 82-219155).

B.12 MESOSCALE PLUME SEGMENT MODEL (MESOPLUME)

Reference: Benkley, C. W. and A. Bass. "Development of Mesoscale Air Quality Models: Volume 2. User's Guide to MESOPLUME (Mesoscale Plume Segment) Model." EPA-600/7-80-057. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1980.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: MESOPLUME is a mesoscale plume segment (or "bent plume") model designed to calculate concentrations of SO_2 and SO_4 over large distances. Plume growth is calculated by finite difference methods with plume growth parameters fitted to Turner's plume size (sigma) curves.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The MESOPLUME Model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: location (x and y coordinates), stack height, emission rate for SO_2, emission rate for $SO_4^=$, buoyancy flux for plume rise, multipliers, by hour of the day, for the emission rate and for the buoyancy flux; each for up to 10 sources.

Meteorological data requirements are: spatially variable, gridded fields of horizontal (u,v) wind components, mixing height, and Pasquill stability class. These data are normally, though not necessarily, obtained from the output of the MESOPAC program (Volume 6, EPA 600/7-80-061). MESOPAC requires, as input, radiosonde observations from one or more stations, plus the wind components at the most relevant level.

Receptor data requirements are: gridded array plus up to 10 optional arbitrary receptors.

c. Output

Optional printed output includes:

a table that lists all input parameters used in run;

optional arrays of ground-level concentrations of SO_2 and $SO_4^=$ for user-specified intervals;

tables as above for specified receptors only;

arrays of maximum grid point concentration values of the period of the run;

arrays of concentration values averaged over entire run span; and

table listing of the time when the first plume segment from each source reached the edge of the computational grid.

Optional Disk Output:

the concentrations array may be output to disk for each time step; and

the optional MESOFILE postprocessing program (Volume 5, EPA 600/7-80-060) line printer plots and calcomp plots are available.

d. Type of Model

MESOPLUME is a Gaussian plume segment model.

e. Pollutant Types

SO_2 and $SO_4^=$ are treated.

f. Source-Receptor Relationship

Up to 10 sources are permitted.

MESOPLUME uses optional 24-hour cycle of emission rate multipliers.

MESOPLUME uses optional 24-hour cycle of buoyancy flux multipliers.

Calculations are made over a gridded network of receptors.

Up to 10 arbitrary receptors are permitted.

g. Plume Behavior

Briggs (1975) plume rise equations are used, with buoyancy flux, F, input to the model.

Fumigation is treated.

h. Horizontal Winds

Derived gridded wind field specified for each grid square. MESOPAC derives the values by interpolation between stations and hours.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Incremental puff growth is calculated over discrete time steps with puff growth parameters reform chosen to approximate σ_y curves of Turner out to 100 km. At distances greater than 100 km, plume growth parameters after Heffter (1965) are used.

Plume growth is a function of stability class.

Alternate plume growth coefficients may be used.

k. Vertical Dispersion

If plume element centerline is below the mixing height, the pollutant is uniformly mixed through the mixing depth with the mixing lid and ground (unless dry deposition is used) acting as perfect reflectors.

If plume element centerline is above the mixing height, no mixing to the ground is assumed.

Optional: σ_z is approximated in manner similar to σ_y (see item j). With this option, no mixing lid is allowed.

Alternate plume growth coefficients may be used.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Dry deposition is treated.

n. Evaluation Studies

Bass, A., C. W. Benkley, J. S. Scire, and C. S. Morris. "Development of Mesoscale Air Quality Simulation Models. Volume 1: Comparative Studies of Puff, Plume, and Grid Models for Long Distance Dispersion," EPA 600/7-80-056, Environmental Protection Agency, Research Triangle Park, North Carolina 1979.

B.13 MESOSCALE PUFF MODEL (MESOPUFF)

Reference: Benkley, C. W. and A. Bass. "Development of Mesoscale Air Quality Simulation Models, Volume 3, User's Guide to MESOPUFF (Mesoscale Puff) Model." EPA 600/7-80-058. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1980.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: MESOPUFF is a mesoscale puff model designed to calculate concentrations of SO_2 and $SO_4^=$ over long distances. Plume growth is calculated by finite difference techniques with plume growth parameters fitted to Turner's plume size (sigma) curves.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The MESOPUFF Model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: location (x and y coordinates), stack height, emission rate for SO_2, emission rate for $SO_4^=$, buoyancy flux for plume rise; optional multipliers, by hour of the day, for the emission rate and for the buoyancy flux; each for up to 10 sources.

Meteorological data requirements: spatially variable, gridded fields of horizontal (u,v) wind components, mixing height, and Pasquill stability class. These data are normally, though not necessarily, obtained from the output of the MESOPAC program (Volume 6, EPA-600/7-80-061). MESOPAC requires, as input, radiosonde observations from one or more stations, plus the wind components at the most relevant level.

Receptor data requirements: up to a 40 x 40 grid.

c. Output

Printed output includes:

all input parameters;

optionally, arrays of ground-level concentrations of SO_2 and $SO_4^=$ for user-specified averaging times at user-specified intervals;

line printer plots and calcomp plots through the MESOFILE postprocessing program (Volume 5, EPA 600/7-80-060).

Computer readable output includes:

The concentrations array may be output to disk for each time step.

d. Type of Model

MESOPUFF is a Gaussian puff model.

e. Pollutant types

SO_2 and $SO_4^=$ are treated.

f. Source-Receptor Relationship

Up to 10 point sources are permitted.

Calculations are made over a gridded network of receptors.

g. Plume Behavior

Briggs (1975) plume rise equations are used, including plume penetration, with buoyancy flux, F, input to the model.

Fumigation is included.

Fumigation may produce immediate mixing or multiple reflection calculations at user's option.

h. Horizontal Winds

Derived gridded wind field is specified for each grid square. A preprocessor program called MESOPAC derives the values by interpolation between stations and hours.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Incremental puff growth is calculated over discrete time steps with puff growth parameters chosen to approximate σ_y curves of Turner out to 100 kilometers. At distances greater than 100 km, growth is based on plume growth rates given by Heffter (1965).

Plume growth is a function of stability class.

Optionally, alternate plume growth coefficients may be used.

k. Vertical Dispersion

For a puff element emitted at an effective stack height which is less than the mixing height, uniform mixing of the pollutant within the mixed layer is assumed.

For a puff element emitted above the mixing height, no effect of the puff is felt at the grouind.

MESOPUFF includes an option to ignore mixing height.

Optionally, puff growth in the vertical (σ_z) may be simulated in a manner similar to horizontal dispersion (see item j). Multiple reflection effects are accounted for with this option.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Dry deposition is treated.

n. Evaluation Studies

Bass, A., C. W. Benkley, J. S. Scire, and C. S. Morris. "Development of Mesoscale Air Quality Simulation Models. Volume 1: Comparative Studies of Puff, Plume, and Grid Models for Long Distance Dispersion," EPA 600/7-80-056, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1979.

B.14 MESOSCALE TRANSPORT DIFFUSION AND DEPOSITION MODEL FOR INDUSTRIAL SOURCES (MTDDIS)

<u>Reference</u>: Wang, I. T. and T. L. Waldron. "User's Guide for MTDDIS Mesoscale Transport, Diffusion, and Deposition Model for Industrial Sources." EMSC6062.1UR(R2). Rockwell International, Environmental Monitoring & Services Center, Newbury Park, California 91320, 1980.

<u>Availability</u>: Contact I. T. Wang or T. L. Waldron at:
Rockwell International
Environmental Monitoring and Services Center
242 West Hillcrest Drive
Newberry Park, California 19320

<u>Abstract</u>: MTDDIS is a variable-trajectory Gaussian puff model applicable to long-range transport of point source emissions over level or rolling terrain. It can be used to determine 3-hour maximum and 24-hour average concentrations of relatively nonreactive pollutants from up to 10 separate stacks.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The MTDDIS Model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature, and location.

Meteorological data requirements are: hourly surface weather data, from up to 10 stations, including cloud ceiling, wind direction, wind speed; temperature, opaque cloud cover and precipitation. For long-range applications, user-analyzed daily mixing heights are recommended. If these are not available, the NWS daily mixing heights will be used by the program. A single upper air sounding station for the region is assumed. For each model run, air trajectories are generated for a 48-hour period, and therefore, the afternoon mixing height of the day before and the mixing heights of the day after are also required by the model as input, in order to generate hourly mixing heights for the modeled period.

Receptor data requirements are: up to three user-specified rectangular grids.

c. Output

Printed output includes:

tabulations of hourly meteorological parameters include both input surface observations and calculated hourly stability classes and mixing heights for each station;

printed air trajectories for the two consecutive 24-hour periods for air parcels generated 4 hours apart starting at 0000 LST; and

3-hour maximum and 24-hour average grid concentrations over user-specified rectangular grids are output for the second 24-hour period.

d. Type of Model

MTDDIS is a Gaussian puff model.

e. Pollutant Types

MTDDIS can be used to model primary pollutants. Dry deposition is treated.

Exponential decay can account for some reactions.

f. Source-Receptor Relationship

MTDDIS treats up to 10 point sources.

Up to three user-specified rectangular receptor grids may be specified by the user.

g. Plume Behavior

Briggs (1971, 1972) plume rise formulas are used.

If plume height exceeds mixing height, ground level concentration is assumed zero.

Fumigation and downwash are not treated.

h. Horizontal Winds

Wind speeds and wind directions at each station are first corrected for release height. Speed conversions are based on power law variation and direction conversions are based on linear height dependence as recommended by Irwin (1979).

Converted wind speeds and wind directions are then weighted according to the algorithms of Heffter (1980) to calculate the effective transport wind speed and direction.

i. Vertical Wind Field

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Transport-time-dependent dispersion coefficients from Heffter (1980) are used.

k. Vertical Dispersion

Transport-time-dependent dispersion coefficients from Heffter (1980) are used.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Dry deposition is treated. User input deposition velocity is required.

Wet deposition is treated. User input hourly precipitation rate and precipitation layer depth or cloud ceiling height are required.

n. Evaluation Studies

None cited.

B.15 MODELS 3141 and 4141

Reference: Enviroplan, Inc. "User's Manual for Enviroplan's Model 3141 and Model 4141." Enviroplan, Inc., West Orange, New Jersey, 1981.

Availability: Requests should be directed to:

Environplan, Inc.
59 Main Street
West Orange, New Jersey 07052

Abstract: Models 3141 and 4141 are modifications of CRSTER (UNAMAP VERSION 3) and are applicable to complex terrain particularly where receptor elevation approximately equals or exceeds the stack top elevation. The model utilizes intermediate ground displacement procedures and dispersion enchancements developed from an aerial tracer study and ground level concentrations measured for a power plant located in complex terrain.

a. Recommendations for Regulatory Use

3141 and 4141 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. 3141 and 4141 must be executed in the equivalent mode.

3141 and 4141 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that 3141 and 4141 is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas exit temperature.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor data requirements are: distance of each of five receptor rings.

c. Output

Printed output includes:

Highest and second highest concentrations for the year at each receptor for averaging times of 1, 3, and 24-hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours.

Annual arithmetic average at each receptor.

For each day, the highest 1-hour and 24-hour concentrations over the receptor field.

d. Type of Model

3141 and 4141 are Gaussian plume models.

e. Pollutant Types

3141 and 4141 may be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

Up to 19 point sources are treated.

No area sources are treated.

All point sources are assumed to be collocated.

Unique stack height is used for each source.

Receptor locations are restricted to 36 azimuths (every 10 degrees) and 5 user-specified radial distances.

Unique topographic elevation is used for each receptor.

g. Plume Behavior

Briggs (1969, 1971, 1972) final plume rise formulas are used.

If plume height exceeds mixing height at a receptor location after terrain adjustment, concentration is assumed equal to zero.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law variation exponents from DeMarrais (1959), different exponents for different stability classes, reference height = 7 meters. Exponents used are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Constant, uniform (steady-state) wind is assumed within each hour.

i. <u>Vertical Wind Speed</u>

Vertical wind speed is assumed equal to zero.

j. <u>Horizontal Dispersion</u>

Dispersion coefficients are Pasquill-Gifford coefficients from Turner (1969).

Dispersion is adjusted to 60 minute averaging time by one-fifth power rule (Gifford, 1975)

Buoyancy-induced dispersion (Briggs, 1975) is included.

k. <u>Vertical Dispersion</u>

Dispersion coefficients are Pasquill-Gifford coefficients from Turner (1969).

Buoyancy-induced dispersion (Briggs, 1975) is included.

l. <u>Chemical Transformation</u>

Not treated.

m. <u>Physical Removal</u>

Not treated.

n. <u>Evaluation Studies</u>

Ellis, H. M., P. C. Liu, and C. Runyon. "Comparison of Predicted and Measured Concentrations for 54 Alternative Models of Plume Transport in Complex Terrain," Presented in APCA Annual Conference, June 26-28, 1979, Cincinnati, Ohio.

Ellis, H. M., P. C. Liu, and C. Runyon. "Comparison of Predicted and Measured Concentations for 58 Alternative Models of Plume Transport in Complex Terrain," APCA Journal, Vol. 30, No. 6, 1980.

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. "Evaluation of Rural Air Quality Simulation Models." EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

B.16 MULTIMAX

Reference: Moser, J. H. "MULTIMAX: An Air Dispersion Modeling Program for Multiple Sources, Receptors, and Concentration Averages." Shell Development Company, Westhollow Research Center, P. O. Box 1380, Houston. Texas 77001, 1979.

Availability: The NTIS accession number for "MULTIMAX: An Air Dispersion Modeling Program for Multiple Sources, Receptors, and Concentration Averages" is PB80-170178, and is available at a cost of $12.50. The accession number for the computer tape for MULTIMAX is PB80-170160, and the cost is $300.00.

Requests should be sent to:

Computer Products
National Technical Information Service
U. S. Department of Commerce
5825 Port Royal Road
Springfield, Virginia 22161

Abstract: MULTIMAX is a Gaussian plume model applicable to both urban and rural areas. It can be used to calculate highest and second-highest concentrations, for each of several averaging times due to up to 100 sources arbitrarily located.

a. Recommendations for Regulatory Use

MULTIMAX can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. MULTIMAX must be executed in the equivalent mode.

MULTIMAX can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Secition 3.2, that MULTIMAX is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, and stack gas temperature.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual enemometer height (a single value) is also required. Wind speed profile exponents (one for each stability class) are required if on-site data are input.

Receptor requirements are: individual receptor points, circles of receptors, or lines of receptors may be input, with receptor point locations, receptor line end points, and receptor circle center and radius defined in either cartesian or polar coordinates.

c. Output

Printed output includes:

highest and second-highest concentrations for the year at each receptor for averaging time of 1, 3, and 24 hours.
annual arithmetic average at each receptor.

Computer readable output includes:

input data and results.

d. Type of Model

MULTIMAX is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

Up to 100 point sources may be input.

Area sources are not treated.

Point sources may be at any location.

Unique stack height is used for each source.

Unique topographic elevation is used for each receptor; must be below top of stack.

Receptors can be described individually, as lines, or as arcs.

g. Plume Behavior

MULTIMAX uses Briggs (1969, 1971, 1972) final plume rise formulas.

If plume height exceeds mixing height, concentrations downwind are assumed equal to zero.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law variation exponents from DeMarrais (1959), different exponents for different stability classes, reference height = 10 meters. The exponents are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Constant, uniform (steady-state) wind is assumed within each hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used in MULTIMAX with no adjustments made for variations in surface roughness.

Six stability classes are used, with Turner class 7 treated as Class 6.

Averaging time adjustment is optional.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used in MULTIMAX with no adjustments made for variations in surface roughness.

Six stability classes are used, with Turner class 7 treated as Class 6.

Perfect reflection at the ground is assumed.

Mixing height is accounted for with multiple reflections until the vertical plume size equals 1.6 times the mixing height; uniform mixing is assumed beyond that point.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. "Evaluation of Rural Air Quality Simulation Models." EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

B.17 MULTIPLE POINT SOURCE DIFFUSION MODEL (MPSDM)

Reference: Environmental Research & Technology, Inc. User's Guide to MPSDM. ERT Document No. M-186-001-630. Environmental Research & Technology, Inc., Concord, Massachusetts, 1980.

Availability: Available only from:

Environmental Research & Technology, Inc.
ATTN: Mr. Joseph A. Curreri
Air Quality Center
696 Virginia Road
Concord, Massachusetts 01742

No cost has been specified.

Abstract: MPSDM is a steady-state Gaussian dispersion model designed to calculate, in sequential model or in "case-by-case" mode, concentrations of nonreactive pollutants resulting from single or multiple source emissions. The MPSDM model may be used for sources located in flat or complex terrain, in a univariate (σ_z) or bivariate (σ_y, σ_z) mode. Sufficient flexibility is allowed in the specification of model parameters to enable the MPSDM user to duplicate results that would be obtained from many other Gaussian point-source models. A number of features are incorporated to facilitate site-specific model validation studies.

a. Recommendations for Regulatory Use

MPSDM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. MPSDM must be executed in the equivalent mode.

MPSDM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that MPSDM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: Hourly or constant emission rate, stack gas temperature, exit velocity, and stack inside diameter.

Meteorological data requirements are: Hourly wind speed, wind direction, air temperature and mixing height; and vertical temperature difference or stability class.

Receptor data requirements are: Northing, easting, and ground level elevation of each receptor.

Air quality data requirements are: Observed concentrations at any monitor for any or all hours ("case-by-case" mode only) will be compared with estimates, or (sequential mode only) will be used to determine background levels. Background is calculated as the average of those monitors more than ±i radians from the plume centerline defined in the model. Default for i is the equivalent of 60°. User input for i is optional.

c. Output

Printed output includes:

"Case-by-case" mode: Printed output includes hourly centerline, off centerline, sector averaged and observed concentrations at all monitors; downwind profiles of centerline concentrations; and a statistical summary of all cases addressed.

Sequential mode: Printed output limited to ratio of predicted maximum concentration to maximum concentration measured at each monitor. Primary output is a file output containing hourly averaged concentrations.

A post-processing program, ANALYSIS, is used to produce averages for longer periods. For a user-specified average period a ranked order of peak concentrations, the cumulative frequency of occurrence of user specified concentration levels or a summary of hourly meteorological characteristics and concentrations contributing to levels above a user-specified value can also be obtained with the ANALYSIS post-processor.

d. Type of Model

MPSDM is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

Arbitrary locations for sources and receptors are used.

Actual terrain elevations may be specified and accounted for by plume-height adjustments.

Actual separation between each source receptor pair is used.

Receptors at assumed to be at ground level.

Unique stack height is used for each source.

g. Plume Behavior

Briggs (1969, 1973, 1975) plume rise equations are used.

Partial (or total) penetration of plume into elevated inversions (Briggs, 1975) is included.

Stack tip downwash (Briggs, 1975) is treated.

Fumigation (Turner, 1969) is treated.

h. Horizontal Winds

User-supplied hourly wind speed and direction are assumed to specify horizontally homogeneous, steady-state conditions.

Wind speeds vary with height according to user-designated profiles for each stability.

Wind direction is specifiable in whole degrees from 1° to 360°.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

ASME (Brookhaven) diffusion coefficients (ASME, 1968) are used.

Options are Pasquill-Gifford coefficients or user input horizontal plume with coefficients of the form ax^b, or sector average with user-input sector width.

Hourly stability (five classes--very unstable through slightly stable) is determined internally from input vertical temperature gradient and mean wind speed or stability classes.

A buoyancy-induced dispersion algorithm (Pasquill, 1976) is optional.

k. Vertical Dispersion

ASME (Brookhaven) diffusion coefficients (ASME, 1968) are used. Options are Pasquill-Gifford coefficients or user input horizontal plume with coefficients of the form ax^b.

Hourly stability (five classes--very unstable through slightly stable) are determined internally from input vertical temperature gradient and mean wind speed or stability classes.

A buoyancy-induced dispersion algorithm (Pasquill, 1976) is optional.

Perfect reflection at ground is assumed.

Perfect reflection is assumed at the mixing height of pollutant above or below top of mixing layer (except for partial plume penetration).

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Lavery, T. F., and L. L. Schulman. "The Validity of a Gaussian Plume Point Source Diffusion Model for Predicting Short-Term SO2 Levels in the Vicinity of Electric Generating Plants in New York State," Joint Conference on Applications of Air Pollution Meteorology, AMS/APCA, November 29 - December 2, 1977, Salt Lake City, Utah.

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. "Evaluation of Rural Air Quality Simulation Models." EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

B.18 MULTI-SOURCE (SCSTER) MODEL

Reference: Program Documentation EN7408SS Southern Company Services, Inc., Technical Engineering Systems, 64 Perimeter Center East, Atlanta, Georgia 30346.

Availability: The SCSTER model and user's manual are available at no charge to a limited number of persons through Southern Company Services. A magnetic tape must be provided to Southern Company Services by those desiring the model.

Requests should be directed to:

Mr. Bryan Baldwin
Research Specialist
Southern Company Services
Post Office Box 2625
Birmingham, Alabama 35202

Abstract: SCSTER is a modified version of the EPA CRSTER model. The primary distinctions of SCSTER are its capability to consider multiple sources that are not necessarily collocated, its enhanced receptor specifications, its variable plume height terrain adjustment procedures and plume distortion from directional wind shear.

a. Recommendations for Regulatory Use

SCSTER can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. SCSTER must be executed in the equivalent mode.

SCSTER can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that SCSTER is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: emission rate, stack gas exit velocity, stack gas temperature, stack exit diameter, physical stack height, elevation of stack base, and coordinates of stack location. The variable emission data can be monthly or annual averages.

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is optional. Wind speed profile exponents (one for each stability class) are optional.

Receptor data requirements are: cartesian coordinates and elevations of individual receptors; distances of receptor rings, with elevation of each receptor; receptor grid networks, with elevation of each receptor.

c. Output

Printed output includes:

> tables are given for each averaging time and the highest 50 concentrations or source contributions of individual point sources at up to 20 receptor locations for each averaging period;
>
> listing of daily maximum 1-hour and 24-hour concentrations; and
>
> tables of both highest and second-highest concentrations.

Optional magnetic tape output includes:

> all 1-hour concentrations.

d. Type of Model

SCSTER is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

SCSTER can handle up to 60 separate stacks at varying locations and 15 receptor rings.

SCSTER provides four terrain adjustments including the CRSTER full terrain height adjustment and a half-height for receptors above stack height.

g. Plume Behavior

SCSTER uses Briggs (1969, 1971, 1972) final plume rise formulas.

Transitional plume rise is optional.

SCSTER contains options to incorporate wind shear with a method described in Appendix A of the User's Guide.

SCSTER provides four terrain adjustments including the CRSTER full terrain height adjustment and a half-height for receptors above stack height.

Provides for Transitional plume rise at receptors close to source.

h. Horizontal Winds

Wind speeds are corrected for release height based on power law exponents from DeMarrais (1959), different exponents for different stability classes; reference height of 7 m. Exponents are .10, .15, .20, .25, .30, and .30 for stability classes A through F, respectively.

Steady-state wind is assumed within a given hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Rural dispersion coefficients from Turner (1969) are used.

Six stability classes are used, with Turner class seven treated as class six.

k. Vertical Dispersion

Rural dispersion coefficients from Turner (1969) are used.

Six stability classes are used, with Turner Class seven treated as class six.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. "Evaluation of Rural Air Quality Simulation Models," EPA 450/4-83-003, Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

B.19 PACIFIC GAS AND ELECTRIC PLUME5 MODEL

Reference: User's Manual for Pacific Gas and Electric PLUME5 Model, March 1, 1981, Pacific Gas and Electric, San Francisco, California.

Availability: Contact: Pacific Gas and Electric Company
245 Market Street
San Francisco, California 94106

Abstract: PLUME5 is a steady-state Gaussian plume model applicable to both rural and urban areas in uneven terrain. Pollutant concentrations at 500 receptors from up to 10 sources with up to 15 stacks each can be calculated using up to 5 meteorological inputs. The model in its "basic" mode is similar to CRSTER and MPTER. Several options are available that allow better simulation of atmospheric conditions and improved model outputs. These options allow plume rise into or through a stable layer and crosswind spread of the plume by wind directional shear with height, initial plume expansion, mean (advective) wind speed, terrain considerations, and chemical transformation of pollutants.

Differences that exist between PLUME5 and CRSTER are in the following areas: Stability class determination, hourly mixing height schemes, hourly stable layer data, randomization of wind direction, extent of data set required for preprocessing, meteorological data inputs.

a. Recommendations for Regulatory Use

PLUME5 can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. PLUME5 must be executed in the equivalent mode.

PLUME5 can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that PLUME5 is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: cartesian or polar coordinates of each source with stack height, diameter, gas temperature, and exit velocity for each stack.

Meteorological data requirements are: Surface data--hourly meteorological data including wind direction, wind speed, temperature, and either ceiling height and total sky cover or sigma A or Delta T depending on how stability is computed; stable layer data--either NCC data or site specific user supplied data.

Receptor data requirements are: cartesian or polar coordinates of each receptor.

c. Output

Printed output includes:

highest and second highest concentrations for the year printed out at each receptor for averaging times of 1, 3, and 24-hours, plus a user-selected averaging time which may be 2, 4, 6, 8, or 12 hours.

annual arithmetic average at each receptor.

for each day, the highest 1-hour and 24-hour concentrations over the receptor field is printed.

hourly effective stack height and effective stack height distributions.

vertical profiles of maximum pollutant concentrations above a designated height (Z_0) for the data period processed.

cumulative number of exceedances of 1 hour and 24-hour specified values for all receptors during the entire meteorological data period. These specified values will normally be National and State Ambient Air Quality Standards.

Computer readable output includes:

hourly concentrations for each receptor on magnetic tape.

computer file for input to plotting routine. The file stores the highest 1-hour (or other specified time period) concentration at each receptor for the entire meteorological data period for input into a user supplied plotting routine.

d. Type of Model

PLUME5 is a Gaussian plume model.

e. Pollutant Types

PLUME5 may be used to model primary pollutants.
Chemical transformations of pollutants are treated by exponential decay and/or ozone limiting procedures.

f. Source-Receptor Relationship

Can input up to 10 separate sources with up to 15 stacks per source.

Unique stack height for each source. Rectangular or circular receptor locations (up to 500) can be either model generated or user input.

Terrain Considerations:

When plume rise, H, is above the stable layer top concentration estimates will only be calculated for receptors at or above the stable layer top. If the receptor is below the stable layer top, then the concentration is zero.

When plume rise falls within the stable layer, concentration estimates will be only calculated for receptors located within this region. If the receptor height is above or below the stable top, then the concentration is zero.

When plume rise falls below the stable layer and the receptor height is above the stable layer base, then the concentration is zero. If the receptor height is below the stable layer base, the receptor height is redefined.

g. Plume Behavior

PLUME5 uses Briggs (1975) final plume rise formulas.

Expansion of plumes within and above a stable layer is treated.

h. Horizontal Winds

User-supplied hourly wind directions are read to nearest 1, 5, 10, and 22.5 degrees. (The 5, 10 and 22.5 degree values are randomly modified to nearest whole degree within the intervals).

PLUME5 employs the extrapolated mean wind speed at stack height when the effective stack height is equal to or less than the height of the inversion base above ground. If the plume rises into a stable layer, a separate algorithm is used.

Constant, uniform (steady state) wind assumed within each hour.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Six stability classes are defined by either radiation index and wind speed (STAR), wind direction fluctuation, or temperature lapse rate.

Nighttime stability class is based on wind direction fluctuations or temperature lapse rate and may be modified according to the method of Mitchell and Timbre (1979).

Dispersion curves are from Turner (1969).

k. Vertical Dispersion

Six stability classes are defined by either radiation index and wind speed (STAR), wind direction fluctuations, or temperature lapse rate.

Nighttime stability class is based on wind direction fluctuations or temperature laspe rate and modified according to the method of Mitchell-Timbre (1979).

Dispersion curves are from Turner (1969).

l. Chemical Transformation

Chemical transformations are treated using exponential decay and/or ozone limiting procedures.

m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter, T. Kincaid and B. Bonitata. "Evaluation of Rural Air Quality Simulation Models," EPA-450/4-83-033, (NTIS PB 83-182-758), Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1983.

B.20 PLUMSTAR AIR QUALITY SIMULATION MODEL

Reference: Lurmann, F. W. and D. A. Godden 1983. "User's Guide to the PLMSTAR Air Quality Simulation Model." ERT Document No. M-2206, Environmental Research & Technology, Inc., Westlake Village, California 91361.

Abailiability: The model is not currently in the public domain; however, requests for the model are considered on an individual basis. Requests for the model should be sent to:

Mr. Frederick W. Lurmann
Environmental Research & Technology, Inc.
2625 Townsgate Road
Westlake Village, California 91361

Abstract: PLMSTAR (pronounced plume star) is a photochemical trajectory model designed for urban scale and mesoscale applications involving the impact of point and area source reactive hydrocarbon (RHC), NO_x, and SO_x emissions on downwind short-term concentrations of O_3, NO_2, HNO_3, PAN, SO_2, and $SO_4^=$. The model's Lagrangian air parcel is subdivided into a 5 layer/9 column domain of computational cells. The approach allows for realistic simulation of the combined effects of atmospheric chemical reactions and pollutant dispersion in the horizontal and vertical directions. Other key features of the model include: the capability for generation of trajectories at any level of a three-dimensional, divergence-free wind field; the capability for calculating the utilizing time and space varying surface deposition of pollutants; an up-to-date O_3/RHC/NO_x/SO_x chemical mechanism that utilizes eight classes of reactive hydrocarbons; and the capability for simultaneously handling both point and area source emissions.

a. Recommendation for Regulatory Use

There is no specific recommendation at the present time. The PLUMSTAR Model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: emssion rates, stack parameters, diurnal emission profiles, and RHC, NO_x, and SO_x partitioning profiles.

Meteorological data requirements are: station location, grid geometry, surface winds, surface roughness, surface temperature, temperature profiles, mixing heights (optional), cloud cover, solar radiation, and winds aloft.

Receptor data requirements are: receptor locations and topography.

c. Output

Printed output includes:

computed concentrations at specified times and receptors along the trajectory.

d. Type of Model

PLMSTAR is a photochemical trajectory model.

e. Pollutant Types

The key chemical species included in the model are O_3, NO, NO_2, HNO_3, PAN, SO_2, $SO_4^=$, CO, and eight classes of reactive hydrocarbons. Twenty additional intermediate species are included in the chemical mechanism.

f. Source-Receptor Relationships

Source-receptor relationships for individual sources are calculated using a differencing technique. That is, simulations are made with and without an individual source (or group of collocated sources) in addition to the RHC/NO_x/SO_x emissions from all other sources in the region. The emission processors allow for up to 250 point sources and an unlimited number of area sources(allocated to a grid of 36 x 36 squares) to be included in the simulation.

g. Plume Behavior

Plume rise calculations are based on Briggs (1975).

h. Horizontal Winds

Gridded hourly multi-level horizontal wind fields are generated using techniques similar to those reported by Goodin et al. (1979). These involve wind data interpolation, divergence minimization, and terrain adjustment. Trajectory path segments are then generated by interpolation from the gridded horizontal wind fields in 15 minute steps at the user selected vertical level. Either source or receptor oriented trajectory may be generated.

i. Vertical Wind speed

Vertical speed is produced by WINDMOD, but is not utilized in the trajectory calculation or the pollutant advection algorithm.

j. Vertical Dispersion

Vertical eddy diffusivities (K_z) are calculated as a function of wind speed, stability, surface roughness, and boundary layer height.

The effects of vertical dispersion on pollutant concentrations are calculated by numerically integrating finite difference approximations to the diffusion equation.

Mixing heights can be internally calculated or externally specified.

k. Horizontal Dispersion

Horizontal eddy diffusivities (K_y) are calculated either as a function of K_z and stability class or as a function of σ_y. Urban or rural σ_y's may be selected. The effects of horizontal dispersion on pollutant concentrations are calculated by numerically integrating finite difference approximations to the diffusion equation.

l. Chemical Transformation

PLMSTAR incorporates a slightly condensed version of the Atkinson et al. (1982) photochemical mechanism for O_3/RHC/NO_x/SO_x/air mixtures. The mechanism contains 62 reactions involving 38 species, including 8 classes of organic precursors. The effects of chemical transformations on pollutant concentrations are computed by numerically integrating the nonlinear kinetic rate equations.

m. Physical Removal

Dry deposition of O_3, NO_2, HNO_3, PAN, SO_2, and $SO_4^=$ is based on the model of Wesely and Hicks (1977).

n. Evaluation Studies

Lurmann, F. W., D. A. Godden and A. C. Lloyd. "The Development and Selected Sensitivity, Tests of the PLMSTAR Reactive Plume Model," presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, Texas, 1982.

Godden, D. and F. Lurmann. Development of the PLMSTAR Model and its Application to Ozone Episode Conditions in the South Coast Air Basin, ERT Document No. P-A702-200, Environmental Research & Technology, Inc., Westlake Village, California, 1983.

B.21 PLUME VISIBILITY MODEL (PLUVUE II)

<u>Reference</u>: Seigneur, C., C. D. Johnson, D. A. Latimer, R. W. Bergstrom and H. Hogo. "User's Manual for the Plume Visibility Model (PLUVUE II)." SYSAPP-83/097, Systems Applications, Inc. San Rafael, California, 1983.

<u>Availability</u>: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

<u>Abstract</u>: The Plume Visibility Model (PLUVUE II) is a computerized model used for estimating visual range reduction and atmospheric discoloration caused by plumes resulting from the emissions of particles, nitrogen oxides and sulfur oxides from a single emission source. PLUVUE II predicts the transport, dispersion, chemical reactions, optical effects and surface deposition of point or area source emissions.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The Plume Visibility Model (PLUVUE II) may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: location and elevation; emission rates of SO_2, NO_x, and particulates; flue gas flow rate, exit velocity, and exit temperature; flue gas oxygen content; properties (including density, mass median and standard geometric deviation of radius) of the emitted aerosols in the accumulation (0.1-1.0 μm) and coarse (1.0-10.0 μm) size modes; and deposition velocities for SO_2, NO_x, coarse mode aerosol, and accumulations mode aerosol.

Meteorological data requirements are: stability class, wind direction (for an observer-based run) wind speed, lapse rate, air temperature, relative humidity, and mixing height.

Other data requirements are: ambient background concentrations of NO_x, NO_2, O_3, and SO_2, background visual range or sulfate and nitrate concentrations.

Receptor (observer) data requirements are: location, elevation, terrain which will be observed through the plume (for observer based run with white, gray, and black viewing backgrounds).

c. Output

Printed output includes:

Plume concentrations and visual effects at specified downwind distances for calculated or specified lines of sight.

d. Type of Model

PLUVUE is a Gaussian plume model.

e. Pollutant Types

PLUVUE II treats NO, NO_2, SO_2, H_2SO_4, HNO_3, O_3, primary and secondary particles to calculate effects on visibility.

f. Source Receptor Relationship

PLUVUE treats a single point or area source.

Predicted concentrations and visual effects are obtained at user specified downwind distances.

g. Plume Behavior

PLUVUE uses Briggs (1969, 1971, 1972) final plume rise equations.

h. Horizontal Winds

User-specified wind speed (and direction for an observer-based run) are assumed constant for the calculation.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

User specified plume widths, or widths computed from either Pasquill-Gifford-Turner curves (Turner, 1969) or TVA curves (Carpenter, et al., 1971) are used in PLUVUE.

k. Vertical Dispersion

User specified plume depths, or computer from Pasquill-Gifford-Turner curves (Turner, 1969) or TVA curves (Carpenter, et al., 1971) are used in PLUVUE.

l. Chemical Transformation

PLUVUE II treats the chemistry of NO, NO_2, O_3, OH, $O(^1D)$, SO_2, HNO_3, and H_2SO_4, by means of nine reactions. Steady state approximations are used for radicals and for the $NO/NO_2/O_3$ reactions.

m. Physical Removal

Dry deposition of gaseous and particulate pollutants is treated using deposition velocities.

n. Evaluation Studies

Bergstrom, R. W., C. Seigneur, B. L. Babson, H. Y. Holman and M. A. Wojcik. "Comparison of the Observed and Predicted Visual Effects Caused by Power Plant Plumes," Atmospheric Environment, Vol. 15, pp. 2135-2150, 1981.

Bergstrom, R. W., Seigneur, C. D. Johnson, and L. W. Richards. "Measurements and Simulations of the Visual Effects of Particulate Plumes," Systems Applications, Inc. San Rafael, California.

Seigneur, C., R. W. Bergstrom, and A. B. Hudischewskyj. "Evaluation of the EPA PLUVUE Model and the ERT Visibility Model Based on the 1979 VISTTA Data Base," EPA-450/4-82-008, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1982.

B.22 POINT, AREA, LINE SOURCE ALGORITHM (PAL)

<u>Reference:</u> Petersen, W. B. "User's Guide for PAL - A Gaussian-Plume Algorithm for Point, Area, and Line Sources." Publication No. EPA-600/4-78-013 (NTIS PB 281306). Office of Research and Development, Research Triangle Park, North Carolina 27711, 1978.

<u>Availability:</u> This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

<u>Abstract:</u> PAL is an acronym for this point, area, and line source algorithm. PAL is a method of estimating short-term dispersion using Gaussian-plume steady-state assumptions. The algorithm can be used for estimating concentrations of non-reactive pollutants at 99 receptors for averaging times of from 1 to 24 hours, and for a limited number of point, area, and line sources (99 of each type). This algorithm is not intended for application to entire urban areas but is intended, rather, to assess the impact on air quality, on scales of tens to hundreds of meters, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed. 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 conce ntrations from the four types of line sources. Subroutines are included that estimate concentrations for multiple lane line and curved path sources, special line sources (line sources with endpoints at different heights above ground), and special curved path sources. Integration over the area source, 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.

a. Recommendations for Regulatory Use

PAL can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. PAL must be executed in the equivalent mode.

PAL can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that PAL is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: point-sources--emission rate, physical stack height, stack gas temperature, stack gas velocity, stack diameter, stack gas volume flow, coordinates of stack, initial σ_y and σ_z; area sources--source strength, size of area source, coordinates of S.W. corner, and height of area source; and line sources--source strength, number of lanes, height of source, coordinates of end points, initial σ_y and σ_z, width of line source, and width of median. Diurnal variations in emissions are permitted.

Meteorological data: wind profile exponents, anemometer height, wind direction and speed, stability class, mixing height, air temperature, and hourly variations in emission rate.

Receptor data requirements are: receptor coordinates.

c. Output

Printed output includes:

Hourly concentration for each source type at each receptor; and

Average concentration for up to 24 hrs for each source type at each receptor.

d. Type of Model

PAL is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationships

Up to 99 sources of each of 6 source types: point, area, and 4 types of line sources.

Source and receptor coordinates are uniquely defined.

Unique stack height for each source.

Coordinates of receptor locations are user defined.

g. Plume Behavior

Briggs final plume rise equations.

Does not treat fumigation or downwash.

If plume height exceeds mixing height, concentrations assumed equal to zero.

Surface concentrations are set to zero when the plume centerline exceeds mixing height.

h. Horizontal Winds

Uses user-supplied hourly wind data.

Constant, uniform (steady-state) wind assumed within each hour.

Wind increase with height, diurnal variation of emissions.

i. Vertical Wind Speeds

Assumed equal to zero.

j. Horizontal Dispersion

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

6 stability classes are used.

Dispersion coefficients (Pasquill-Gifford) based on 3 cm roughness height.

k. Vertical Dispersion

6 stability classes used.

Rural dispersion coefficients from Turner (1969); no further adjustments made for variation in surface roughness, transport or averaging time.

Multiple reflection handled by summation of series until σ_Z = 1.6 times mixing height. Uniform vertical distribution thereafter.

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

None.

B.23 RANDOM-WALK ADVECTION AND DISPERSION MODEL (RADM)

References: Austin, D. I., A. W. Bealer, and W. R. Goodin. Random-Walk Advection and Dispersion Model (RADM), User's Manual. Dames & Moore, Los Angeles, California, 1981.

Runchal, A. K., W. R. Goodin, A. W. Bealer, D. I. Austin. Technical Description of the Random-Walk Advection and Dispersion Model (RADM). Dames & Moore, Los Angeles, California, 1981.

Availability: A. W. Bealer
Dames and Moore
222 East Anapamu Street
Santa Barbara, California 93101

Abstract: RADM is a Lagrangian dispersion model which uses the random-walk method to simulate atmospheric dispersion. The technical procedure involves tracking tracer particles having a given mass through advection by the mean wind and diffusion by the random motions of atmospheric turbulence. Turbulent movement is calculated by determining the probability distribution of particle movement for a user-defined time step. A random number between 0 and 1 is then computed to determine the distance of particle movement according to the probability distribution. A large number of particles is used to statistically represent the distribution of pollutant mass. Concentrations are calculated by summing the mass in a volume around the receptor of interest and dividing the total mass by the volume. Concentrations can be calculated for any averaging time. RADM is applicable to point and area sources.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The RADM model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature. Hourly rates may be specified.

Meteorological data requirements are: Gridded wind field including wind speed, wind direction, stability class, temperature and mixing height.

Receptor data requirements are: coordinates, ground elevation, and receptor cell dimensions.

c. Output

Printed output includes:

average concentration by receptor for user-specified averaging time (concentrations are printed for each block of n hours).

average concentrations for the entire period of the run.

d. Type of Model

RADM is a random-walk Lagrangian dispersion model.

e. Pollutant Types

RADM may be used to model inert gases and particles, and pollutants with exponential decay or formation rates.

f. Source-Receptor Relationship

Multiple point and area sources may be specified at independent locations.

Unique stack characteristics are used for each source.

No restriction is placed on receptor locations.

Perfect reflection at the surface is assumed for the portion not removed by dry deposition.

Particles leaving the gridded area are removed from simulation.

g. Plume Behavior

Briggs (1975) final plume rise equations are used.

Inversion penetration by the plume is allowed.

Fumigation may occur as mixing height rises above a plume which has penetrated an inversion.

h. Horizontal Winds

Wind speed, wind direction, stability class, temperature and mixing height are supplied on a gridded array.

Any wind field may be used as long as output is in correct format for RADM input.

Wind field is updated at user-specified intervals, which may be less than one hour if data are available.

Vertical wind speed profile is used based on surface roughness and stability using Monin-Obukhov length.

i. Vertical Wind Speed

Assumed equal to zero.

j. Horizontal Dispersion

Dispersion is based on diffusivity values calculated from surface roughness, stability class and Monin-Obukhov length.

Diffusivity is a function of height.

k. Vertical Dispersion

Dispersion is based on diffusivity values calculated from surface roughness, stability class and Monin-Obkhov length.

Diffusivity is a function of height.

l. Chemical Transformations

Simple exponential decay or formation is used.

m. Physical Removal

Dry deposition is treated.

n. Evaluation Studies

Runchal, A. K., A. W. Bealer, and G. S. Segal. A completely Lagrangian Random-Walk Model for Atmospheric Dispersion. Proceedings of the Thirteenth International Colloquim on Atmospheric Pollution, National Institute for Applications of Chemical Research, Paris, pp. 137-142, 1978.

Goodin, W. R., A. K. Runchal and G. Y. Lou. Evaluation and Application of the Random-Walk Advection and Dispersion Model (RADM). Symposium on Intermediate Range Atmospheric Transport Processes and Technology Assessment, DOE/NOAA/ORNL, Gatlinburg, Tennessee, 1980.

Goodin, W. R., D. I. Austin and A. K. Runchal. A Model Verification and Prediction Study of $SO_2/SO_4^=$ Concentrations in the San Francisco Bay Area. Second Joint Conference on Applications of Air Pollution Meteorology, AMS/APCA, New Orleans, Louisiana, 1980.

B.24 REACTIVE PLUME MODEL (RPM-II)

Reference: "User's Guide to the Reactive Plume Model--RPM-II," D. Stewart, M. Yocke, and M-K Liu, 1980. SAI No. EF80-75.

Availability: Contact: Systems Applications, Inc.
101 Lucas Valley Road
San Rafael, California 94903

Abstract: The Reactive Plume Model, RPM-II, is a computerized model used for estimating short-term concentrations of primary and secondary pollutants resulting from point or area source emissions. The model is capable of simulating the complex interaction of plume dispersion and non-linear photochemistry. Two main features of the model are: (1) the horizontal resolution within the plume, which offers a more realistic treatment of the entrainment process, and (2) its flexibility with regards to choices of chemical kinetic mechanisms.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The RPM-II Model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: emission rate, name, and molecular weight of each species of pollutant emitted; ambient pressure, ambient temperature, stack height, stack diameter, stack exit velocity, stack gas temperature, and location.

Meteorological data requirements are: wind speeds, plume widths or stability classes, photolysis rate constants, and plume depths or stability classes.

Receptor data requirements are: downwind distances or travel times at which calculations are to be made.

c. Output

Short-term concentrations of primary and secondary pollutants at either user specified time increments, or user specified downwind distances.

d. Type of Model

Reactive plume model.

e. Pollutant Types

Currently, using the Carbon Bond Mechanism (CBM-II), 35 species are simulated (68 reactions), including NO, NO_2, O_3, SO_2, $SO_4^=$, five categories of reactive hydrocarbons, secondary nitrogen compounds, organic aerosols, and radical species.

f. Source-Receptor Relationships

Single point source.

Single area or volume source.

Multiple sources can be simulated if they are lined up along the wind trajectory.

Predicted concentrations are obtained at a user specified time increment, or at user specified downwind distances.

g. Plume Behavior

Briggs (1971) plume rise equations are used.

h. Horizontal Winds

User specifies wind speeds as a function of time.

i. Vertical Wind Speed

Not treated.

j. Horizontal Dispersion

User specified plume widths, or user may specify stability and widths will be computed using Turner (1969).

k. Vertical Dispersion

User specified plume depths, or user may specify stability in which case depths will be calculated using Turner (1969). Note that vertical uniformity in plume concentration is assumed.

l. Chemical Transformation

The RPM-II has the flexibility of using any user input chemical kinetic mechanism. Currently it is run using the chemistry of the Carbon Bond Mechanism, CBM-II (Whitten, Killus, and Hogo, 1980. "Modeling of Simulated Photochemical Smog with Kinetic Mechanisms: Volume 1. Final Report," Systems Applications Inc.). The CBM-II, as incorporated in the RPM-II, contains 35 species and 68 reactions focusing primarily on hydrocarbon-nitrogen oxides-ozone photochemistry.

m. Physical Removal

Not treated.

n. Evaluation Studies

Stewart, D. A. and M-K Liu, "Development and Application of a Reactive Plume Model," Atmospheric Environment, Vol. 15, 2377-2393, 1981.

B.25 REGIONAL TRANSPORT MODEL (RTM-II)

Reference: Morris, R. E., D. A. Stewart, and M-K Liu. "Revised User's Guide to the Regional Transport Model--Version II" (RTM-II), Publication No. SYSAPP-83/022, Systems Applications Inc., San Rafael, California, 1982.

Availability: Contact: Systems Applications, Inc.
101 Lucas Valley Road
San Raphael, California 94903

Abstract: The Regional Transport Model (RTM-II) is a computer based air quality grid model whose primary use is estimating the distribution of air pollution from multiple point sources at large distances (on the scale of several hundred to a thousand kilometers). It may also be applied to a limited number of area sources. RTM-II offers significant advantages over other long-range transport models because it is a quasi-three dimensional hybrid (grid plus Lagrangian puff) approach to the solution of the advection-diffusion equation. Furthermore, its formulation allows the treatment of spatially and temporally varying wind, mixing depths, diffusivity, and transformation rate fields. It is also capable of treating spatially varying surface depletion processes. While the modeling concept is capable of predicting concentration distributions of many pollutant species (e.g., NO_x, CO, TSP, etc.), the most notable applications of the model to date focus on the long-range transport and transformation of SO_2 and sulfates.

a. Recommendations for Regulatory Use

There is no specific recommendation at the present time. The RTM Model may be used on a case-by-case basis.

b. Input Requirements

Source data requirements are: major point source SO_2 and primary sulfate emissions, including stack height, diameter, exit velocity, exit temperature, and hourly emission factors; area source of SO_2 and primary $SO_4^=$ emissions in gridded format with hourly emission factors.

Meteorological data requirements are: gridded u, v wind fields at 3-hour intervals (model configured for separate wind fields in each layer), derived from twice daily radiosonde data, time variation linear between a maximum convectively driven boundary layer and a minimum mechanically driven boundary layer, spatial interpolation by an inverse distance weighted objective scheme; gridded hourly precipitation fields determined either by averaging precipitation rate of all stations in grid (if high density), or by inverse distance weighted interpolation (if low density).

Other data requirements are: parameter file, containing region definition, starting time, output and averaging time intervals, region top specifications, and various operational flags; horizontal diffusivity fields calculated from wind fields; land use type file; deposition velocities and roughness length determined internally from tabulated values associated with land use types; initial conditions and boundary conditions for both layers (boundary conditions may be time varying).

c. Output

Printed output includes:

Diagnostic information.

Instantaneous SO_2 and sulfate concentration fields for lower and upper layers at pre-specified time intervals.

Average SO_2 and sulfate concentration fields for upper and lower layer, over pre-specified time intervals. Accumulated dry and wet deposition for each species over pre-selected time intervals.

d. Type of Model

RTM-II is a hybrid Eulerian grid and Lagrangian puff model.

e. Pollutant Types

RTM-II is configured for SO_2 and sulfate only. Primary sulfate emissions may be included.

f. Source Receptor Relationships

Area sources and minor point sources are specified at each grid within the modeling domain.

Up to 500 major point sources (modeled with the Gaussian puff submodel) are allowed.

Grid average concentration and deposition totals are provided at each grid within the modeling domain (deposition for lower layer grid only). All lower grid average concentration values are assumed to be representative of ground-level receptors.

g. Plume Behavior

Plume rise (Briggs, 1971) is calculated for all major point sources regardless of whether they are treated in the Gaussian puff submodel.

h. Horizontal Winds

Gridded u, v wind fields are used at 3-hour interval for each layer.

Gaussian puff submodel tracks puff centroids horizontally at user specified time intervals.

i. Vertical Wind Speed

Considered implicitly if convergent or divergent winds are provided.

j. Horizontal Dispersion

Plume dispersion is based on σ_y differentials derived from a power law fit to Turner (1969) dispersion curves. Variable stabilities within adjacent cells are considered.

Horizontal eddy diffusivities are proportional to the wind field deformation and are calculated from the gridded wind fields as ancilliary input. Maximum and minimum constraints are imposed on the magnitude of the diffusivities.

k. Vertical Dispersion

Plume dispersion is based on σ_z differentials derived from a power law fit to Turner (1969) dispersion curves. Variable stabilities within adjacent cells are considered.

Vertical dispersion across the mixed layer-surface layer interface is considered when calculating pollutant deposition.

l. Chemical Transformation

Linear SO_2 oxidation is treated. Rate constant is diurnally and latitudinally variable. A minimum oxidation rate constant is specified to account for heterogeneous oxidation during the nighttime.

m. Physical Removal

Dry deposition of SO_2 and sulfate is treated.
Precipitation scavenging of SO_2 (reversible) and sulfate (irreversible) is treated.

n. Evaluation Studies

Stewart, D. A., R. E. Morris, M-K Liu, and D. Henderson, "Evaluation of an Episodic Regional Transport Model for a Multiple Day Episode," Atmos. Environ., 17, 1225-1252, 1983.

B.26 ROUGH TERRAIN DIFFUSION MODEL (RTDM)

Reference: Environmental Research & Technology, Inc., Users' Guide for to the Rough Terrain Diffusion Model (RTDM, Rev. 3.00). ERT Report No. M2209-585. Environmental Research & Technology, Inc., 696 Virginia Road, Concord, Massachusetts 01742, 1982.

Availability: The RTDM model is available from:

Environmental Research & Technology, Inc.
ATTN: Mr. Joseph A. Curreri
696 Virginia Road
Concord, Massachusetts 01742

Abstract: The Rough Terrain Diffusion Model (RTDM) version 3.00 is a sequential Gaussian plume model designed to estimate ground level concentrations in rough (or flat terrain in the vicinity of one or more co-located point sources. It is specifically designed for applications involving chemically stable atmospheric pollutants and is best suited for evaluation of buoyant plume behavior within about 15 km from the source(s). Model results for receptors beyond 15 km can be used with caution to 50 km, and RTDM can be used as a screening model for distances beyond 50 km. RTDM has special algorithms to deal with plume behavior in complex terrain, and is especially suited for rough terrain applications.

While RTDM version 3.00 is specifically designed for use with with sequential data sets, it can also be run in a case-study mode. Various optional features of the model make it useful for either research/sensitivity applications or routine evaluations of source compliance. RTDM has the ability to use hourly on-site measurements of turbulence intensity, vertical temperature difference, horizontal wind shear, and wind speed profile exponents. However, RTDM version 3.00 retains sufficient flexibility in the specification of model inputs to enable the user to obtain results similar to many other Gaussian point source models (including RTDM.WC). The ability of RTDM to read hourly emissions data makes it useful for sitespecific model evaluation studies.

a. Recommendations for Regulatory Use

RTDM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. RTDM must be executed in the equivalent mode.

RTDM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that RTDM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: physical stack height, stack inner radius, stack-gas temperature and exit velocity, and pollutant emission rate; a single ground elevation can be entered since all sources are colocated.

Meteorological data requirements are: Range of atmospheric stability classes (maximum of six); range of wind directions (maximum of 16); range of wind speed classes (maximum of six); wind speed for each speed class; mean ambient temperature; angular plume width for stable (optional for nonstable).

Receptors data requirements are: downwind distances; terrain elevations.

c. Output

Printed output includes:

a list of input parameters;

if the case-study mode is used, a detailed output of plume orientation and size, and concentrations associated with each source-receptor pair.

a concentration file is written to disk or tape for all RTDM runs. This output file is used as input to the ANALYSIS postprocessor, which gives information concerning the highest concentrations for each receptor, input meteorology for peak concentration events, and cumulative frequency distributions.

d. Type of Model

RTDM is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

All sources are collocated.

Up to 400 receptors may be placed arbitrarily with respect to the source.

Receptors are assumed to be at ground level.

g. Plume Behavior

Under all conditions, a partial reflection factor can be calculated; thus, full doubling of ground-level concentrations is not necessarily permitted if a plume impinges upon terrain. A stagnation streamline height, H_{crit}, is calculated in stable conditions. Plumes below H_{crit} are allowed to impinge upon terrain, otherwise, plumes pass over terrain obstacles with a relative height computed from plume path coefficients.

Plume path coefficients (user specified) determines plume-terrain interaction (from full lift to direct impingement), as a function of stability.

Briggs (1975) formulas are used; calm formula is used for wind speeds < 1.37 meters per second.

Fumigation and building downwash are not treated.

Stack-tip downwash is treated (ERT, 1982).

h. Horizontal Winds

Primary hourly wind speed is used to calculate plume rise and possibly plume dilution.

A second wind speed may be used to compute plume dilution.

Hourly or stability-dependent wind speed profile exponents may be specified. The default values are .09, .11, .12, .14, .20, and .30 for stability classes A through F, respectively.

The base elevation of the wind speed profile is adjustable.

i. Vertical Wind speed

Vertical wind speed is assumed equal to zero.

j. Horizontal Dispersion

Default is 22.5 degree sector averaging. Optionally, other sector widths may be specified by the user.

Other options are: Gaussian distribution for all stabilities; and Gaussian distribution for stabilities A through D combined with sector averaging for stable cases.

If Gaussian distribution is selected the default σ_y is fit to the ASME(1979) curves using the form ax^b in three distance ranges.

Other options for Gaussian distribution selection are a fit to the P-G σ_y values, and user input values of the form ax^b up to three distance ranges.

Another option is to use hourly measured turbulence intensity (I_y).

Plume growth equation parallels Briggs (1974).

k. Vertical Dispersion

Gaussian distribution is assumed.

Default σ_z values are a fit to ASME (1979).

Optionally, σ_z is fit to Pasquill-Gifford curves (Turner, 1969), or user may input curves of the form ax^b in up to three distance ranges.

Another option is to use hourly measured turbulence intensity (I_z).

Plume growth equation parallels Briggs (1974).

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Egan, B. A., R. D'Errico, C. Vaudo. "Estimating Air Quality Levels in Regions of High Terrain Under Stable Atmospheric Conditions," presented at the Fourth Symposium on Turbulence, Diffusion, and Air Pollution at Reno, Nevada, American Meteorological Society, Boston, Massachusetts, 1979.

Corkum, D. A., and J. W. Bradstreet. "A Sulfur Dioxide Modeling Comparison Study in the Rough Terrain of Nothern New Hampshire Near a Paper Mill," presented at the 73rd Annual Meeting of the Air Pollution Control Association at Montreal, Quebec, Canada, 1980.

B.27 SHORTZ

Reference: Bjorklund, J. R., and J. F. Bowers. "User's Instructions for the SHORTZ and LONGZ Computer Programs, Volumes 1 and 2," EPA 903/9-82-004, U.S. Environmental Protection Agency, Region III, Philadelphia, Pennsylvania 19106, 1982.

Availability: This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: SHORTZ utilizes the steady state bivariate Gaussian plume formulation for both urban and rural areas in flat or complex terrain to calculate ground-level ambient air concentrations. It can calculate 1-hour, 2-hour, 3-hour etc. average concentrations due to emissions from stacks, buildings and area sources for up to 300 arbitrarily placed sources. The output consists of total concentration at each receptor due to emissions from each user-specified source or group of sources, including all sources. If the option for gravitational settling is invoked, analysis cannot be accomplished in complex terrain without violating mass continuity.

a. Recommendations for Regulatory Use

SHORTZ can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. SHORTZ must be executed in the equivalent mode.

SHORTZ can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that SHORTZ is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: for point, building or area sources, location, elevation, total emission rate (optionally classified by gravitational settling velocity) and decay coefficient; for stack sources, stack height, effluent temperature, effluent exit velocity, stack radius (inner), actual volumetric flow rate, and ground elevation (optional); for building sources, height, length and width, and orientation; for area sources, characteristic vertical dimension, and length, width and orientation.

Meteorological data requirements are: wind speed and measurement height, wind profile exponents, wind direction, standard deviations of vertical and horizontal wind directions, (i.e., vertical and lateral turbulent intensities), mixing height, air temperature, and vertical potential temperature gradient.

Receptor data requirements are: coordinates, ground elevation.

c. Output

Printed output includes:

> Total concentration due to emissions from user-specified source groups, including the combined emissions from all sources (with optional allowance for depletion by deposition).

d. Type of Model

SHORTZ is a Gaussian plume model.

e. Pollutant Types

SHORTZ may be used to model primary pollutants. Settling and deposition of particulates are treated.

f. Source-Receptor Relationships

User specified locations for sources and receptors are used.

Receptors are assumed to be at ground level.

g. Plume Behavior

Plume rise equations of Bjorklund and Bowers (1982) are used.

Stack tip downwash (Bjorklund and Bowers, 1982) is included.

All plumes move horizontally and will fully intercept elevated terrain.

Plumes above mixing height are ignored.

Perfect reflection at mixing height is assumed for plumes below the mixing height.

Plume rise is limited when the mean wind at stack height approaches or exceeds stack exit velocity.

Perfect reflection at ground is assumed for pollutants with no settling velocity.

Zero reflection at ground is assumed for pollutants with finite settling velocity.

Tilted plume is used for pollutants with settling velocity specified.

Buoyancy-induced dispersion (Briggs, 1972) is included.

h. Horizontal Winds

Winds are assumed homogeneous and steady-state.

Wind speed profile exponents are functions of both stability class and wind speed. Default values are specified in Bjorklund and Bowers (1982).

i. Vertical Wind Speed

Vertical winds are assumed equal to zero.

j. Horizontal Dispersion

Horizontal plume size is derived from input lateral turbulent intensities using adjustments to plume height, and rate of plume growth with downwind distance specified in Bjorklund and Bowers (1982).

k. Vertical Dispersion

Vertical plume size is derived from input vertical turbulent intensities using adjustments to plume height and rate of plume growth with downwind distance specified in Bjorklund and Bowers (1982).

l. Chemical Transformation

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

m. Physical Removal

Settling and deposition of particulates are treated.

n. Evaluation Studies

Bjorklund, J. R., and J. F. Bowers. "User's Instructions for the SHORTZ and LONGZ Computer Programs," EPA-903/9-82-004, Environmental Protection Agency, Region III, Philadelphia, Pennsylvania 19106, 1982.

B.28 SIMPLE LINE-SOURCE MODEL (SLSM)

Reference: Chock, D. P. "User's Guide for the Simple Line-Source Model for Vehicle Exhaust Dispersion Near a Road," Environmental Science Department, General Motors Research Laboratories, Warren, Michigan 48090, 1980.

Availability: Copies of the above reference are available from:

Dr. D. P. Chock
Environmental Sciences Department
General Motors Research Laboratories
General Motors Technical Center
Warren, Michigan 48090

No information available on the cost or availability of a tape or other direct computer input.

Abstract: SLSM is a simple steady-state Gaussian plume model which can be used to determine hourly (or half-hourly) averages of exhaust concentrations within 100m from a roadway on a relatively flat terrain. The model allows for plume rise due to the heated exhaust, which can be important when the crossroad wind is very low. It also utilizes a new set of vertical dispersion parameters which reflects the influence of traffic-induced turbulence.

a. Recommendations for Regulatory Use

SLSM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. SLSM must be executed in the equivalent mode.

SLSM can be used on a casd-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that SLSM is more appropriate fo the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: emission rate per unit length per lane, the number of lanes on the road, distances from lane centers to the receptor, source and receptor heights.

Meteorological data requirements are: buoyancy flux, ambient stability condition, ambient wind and its direction relative to the road.

Receptor data requirements are: distance and height above ground.

c. Output

Printed output includes:

> Hourly or (half-hourly) concentrations at the receptor due to exhaust emission from a road (or a system of roads by summing the results from repeated model applications).

d. Type of Model

SLSM is a Gaussian plume model.

e. Pollutant Types

SLSM can be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

SLSM treats arbitrary location of line sources and receptors.

g. Plume Behavior

Plume-rise formula adequate for a heated line source is used.

h. Horizontal Winds

SLSM uses user-supplied hourly or (or half-hourly) ambient wind speed and direction. The wind measurements are from a height of 5 to 10 m.

i. Vertical Wind Speed

Vertical wind speed is assumed equal to zero.

j. Dispersion Parameters

Horizontal dispersion parameter is not used.

k. Vertical Dispersion

A vertical dispersion parameter is used which is a function of stability and wind-road angle. Three stability classes are used: unstable, neutral and stable. The parameters take into account the effect of traffic-generated turbulence (Chock, 1980).

l. Chemical Transformation

Not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Chock, D. P. "A Study of Pollutant Dispersion Near Highways," Atmospheric Environment 12, 823-829, 1978.

Sistla, G., P. Samson, M. Keenan, and S. T. Ras. "A Study of Pollutant Dispersion Near Highways," Atmospheric Environment 13, 669-685, 1979.

B.29 TEXAS CLIMATOLOGICAL MODEL (TCM-2)

Reference: Staff of the Texas Air Control Board, Users' Guide to the TEXAS CLIMATOLOGICAL MODEL (TCM). Texas Air Control Board, Permits Section, 6330 Highway 290 East, Austin, Texas 78723.

Availability: The TCM-2 model is available from the Texas Air Control Board at the following cost:

User's Manual only	$ 20.00
User's Manual and Model (Magnetic Tape)	$ 80.00

Requests should be directed to:

Data Processing Division
Texas Air Control Board
6330 Highway 290 East
Austin, Texas 78723

This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: TCM is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual arithmetic) average pollutant concentrations of non-reactive pollutants.

a. Recommendations for Regulatory Use

TCM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. TCM must be executed in the equivalent mode.

TCM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that TCM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the appliction should be used.

b. Input Requirements

Source data requirements are: point source coordinates emission rates (by pollutant), stack height, stack diameter, stack gas exit velocity, stack gas temperature; area source coordinates (southwest corner), size, emission rate.

Meteorological data requirements are: stability wind rose and average temperature.

Receptor data requirements are: size and spacing of the rectangular receptor grid.

c. Output

Printed output includes:

period average concentrations listed, displayed in map format, or punched on cards at the user's option.

culpability list option provides the contributions of the five highest contributors at each receptor.

maximum concentration option provides the maximum concentration for each scenario (run).

d. Type of Model

TCM is a Gaussian plume model.

e. Pollutant Types

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

f. Source-Receptor Relationship

Arbitrary location of point sources and area sources are treated.

Arbitrary location and spacing of rectangular grid of receptors are used. (Area source grid is best defined in terms of the receptor grid, so that the receptors fall in the center of the area source).

Receptors located in simple terrain may be modeled.

g. Plume Behavior

Briggs (1975) plume rise equations, including momentum rise, are used for point sources.

Two-thirds power law is used when transitional rise option is selected.

Flares are treated.

Building downwash is treated using the Huber-Snyder (1976) technique.

h. Horizontal Winds

Characteristic wind speed is calculated for each direction-stability class combination.

This characteristic speed is the inverse of the average inverse speed for the stability-wind direction combination.

Wind speed is adjusted to stack height by a power law using exponents of .10, .15, .20, .25, .30, and .30 for stabilities A through F, respectively.

i. Vertical Wind Speed

Vertical wind speed is assumed to be zero.

j. Horizontal Dispersion

Uniform distribution within each 22.5 degree sector is assumed.

k. Vertical Dispersion

Dispersion parameters for point sources are fit to Turner (1969); for area sources in the urban mode the fit is to Gifford and Hanna (1970).

Seven stability classes are used.

Pasquill A through F are treated, with daytime "D" and nighttime "D" given separately.

In the urban mode, E and F stability classes are treated as D-night.

Perfect reflection at the ground is assumed.

l. Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

n. Evaluation Studies

Londergan, R. J., D. H. Minott, D. J. Wachter and R. R. Fizz. "Evaluation of Urban Air Quality Simulation Models." EPA-450/4-83-020. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1983.

Durrenberger, C. S., B. A. Braberg, and K. Zimmermann. "Development of a Protocol to be Used for Dispersion Model Comparison Studies," presented at the 76th Annual Meetiog of the Air Pollution Control Association at Atlanta, Georgia, 1983.

B.30 TEXAS EPISODIC MODEL (TEM-8)

Reference: Staff of the Texas Air Control Board. User's Guide to the TEXAS EPISODIC MODEL. Texas Air Control Board, Permits Section, 6330 Highway 290 East, Austin, Texas 78723.

Availibility: The TEM -8 model is available from the Texas Air Control Board at the following costs:

User's Manual only	$ 20.00
User's Manual and Model (Magnetic Tape)	$ 80.00

Requests should be directed to:

Data Processing Division
Texas Air Control Board
6330 Highway 290 East
Austin, Texas 78723

This model is available as part of UNAMAP (Version 6). The computer code is available on magnetic tape from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Phone (703) 487-4763

The accession number of the UNAMAP tape is PB

Abstract: TEM is a short-term, steady-state Gaussian plume model for determining short-term concentrations of non-reactive pollutants.

a. Recommendations for Regulatory Use

TEM can be used if it can be demonstrated to estimate concentrations equivalent to those provided by the preferred model for a given application. TEM must be executed in the equivalent mode.

TEM can be used on a case-by-case basis in lieu of a preferred model if it can be demonstrated, using the criteria in Section 3.2, that TEM is more appropriate for the specific application. In this case the model options/modes which are most appropriate for the application should be used.

b. Input Requirements

Source data requirements are: locations, average emission rates and heights of emissions for both point and area sources; stack gas temperature, stack gas exit velocity, and stack inside diameter for point sources for plume rise calculations.

Any combination of hourly meteorological data up to 24 hours may be used, (e.g. 1, 3, 5, 8, 24 hours).

Meteorological data requirements are: hourly surface weather data from the EPA meteorological preprocessor program. Preprocessor output includes hourly stability class, wind direction, wind speed, temperature, and mixing height.

Receptor requirements are: size, spacing and location of rectangular grid of receptors.

c. Output

Printed output includes:

concentration list;

spatial array (concentrations displayed as on a map);

punched cards of the concentration list;

culpability list (percent contributions) of the five highest contributors to each receptor;

maximum concentration; and

point source list.

d. Type of Model

TEM is a Gaussian plume model.

e. Pollutant Types

TEM can be used to model primary pollutants. Settling and deposition are not treated.

f. Source-Receptor Relationship

Arbitrary locations of point sources and area sources are treated.

Arbitrary location and spacing of rectangular grid of receptors is treated. Area source grid is best defined in terms of the receptor grid so that the receptors fall in the centers of the area sources.

Receptors located in simple terrain may be modeled.

g. Plume Behavior

Briggs (1975) plume rise equations are used, including momentum rise, for point sources.

Transitional rise is calculated.

Stack-tip downwash and building downwash (Huber and Snyder, 1976) may be evaluated.

h. Horizontal Winds

Wind speeds are adjusted to release height by power law formula, using exponents of .10, .15, .20, .25, .30 and .30 for stabilities A through F respectively.

Steady-state wind is assumed.

i. Vertical Wind Speed

Vertical wind is assumed equal to zero.

j. Horizontal Dispersion

Gaussian plume coefficients are fitted to Turner (1969).

In the urban mode, stable cases are shifted to neutral nighttime (D-night) conditions and urban mixing heights are used.

k. Vertical Dispersion

Dispersion parameters for point sources are fit to Turner (1969); for area sources, in the urban mode, the fit is to Gifford and Hanna (1970).

Total reflection of the plume at the ground is assumed.

In the urban mode, coefficients are shifted from E and F to D-nighttime coefficients.

l. Chemical Transformation

Chemical transformation is treated using exponential decay. Half-life is input by the user.

m. Physical Removal

Physical removal is treated using exponential decay. Half-life is input by the user.

n. Evaluation Studies

Londergan, R., D. Minott, D. Wachter, T. Kincaid and D. Bonitata. "Evaluation of Rural Air Quality Simulation Models." EPA-450/4-83-003, Environmental Protection Agency, Research Triangle Park, North Carolina, 1983.

Durrenberger, C. J., B. A. Broberg, and K. Zimmermann. "Development of a Protocol to be Used for Dispersion Model Comparison Studies," presented at the 76th Annual Meeting of the Air Pollution Control Association at Atlanta, Georgia, 1983.

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APPENDIX C

EXAMPLE AIR QUALITY ANALYSIS CHECKLIST

C.0 INTRODUCTION

This checklist recommends a standardized set of data and a standard basic level of analysis needed for PSD applications and SIP revisions. The checklist implies a level of detail required to assess both PSD increments and the NAAQS. Individual cases may require more or less information and the Regional Meteorologist should be consulted at an early stage in the development of a data bases for a modeling analysis.

At pre-application meetings between source owner and reviewing authority, this checklist should prove useful in developing a concensus on the data base, modeling techniques and overall technical approach prior to the actual analyses. Such agreement will help avoid misunderstandings concerning the final results and may reduce the later need for additional analyses.

EXAMPLE AIR QUALITY ANALYSIS CHECKLIST*

1. Source location map(s) showing location with respect to:

   ° Urban areas**

   ° PSD Class I areas

   ° Nonattainment areas**

   ° Topographic features (terrain, lakes, river valleys, etc.)**

   ° Other major existing sources**

   ° Other major sources subject to PSD requirements

   ° NWS meteorological observations (surface and upper air)

   ° On-site/local meteorological observations (surface and upper air)

   ° State/local/on-site air quality monitoring locations**

   ° Plant layout on a topographic map covering a 1-km radius of the source with information sufficient to determine GEP stack heights

2. Information on urban/rural characteristics:

   ° Land use within 3 km of source classified according to Auer, A. H. (1978): Correlation of land use and cover with meteorological anomalies, J. of Applied Meteorology, 17:636-643.

   ° Population

     - total
     - density

   ° Based on current guidance determination of whether the area should be addressed using urban or rural modeling methodology

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*The "Guidelines for Air Quality Maintenance and Analysis," Volume 10R, EPA-450/4-77-001, October 1977 should be used as a screening tool to determine whether modeling analyses are required. Screening procedures should be refined by the user to be site/problem specific.

**Within 50 km or distance to which source has a significant impact, whichever is less.

3. Emission inventory and operating/design parameters for major sources within region of significant impact of proposed site (same as required for applicant)

- Actual and allowable annual emission rates (g/s) and operating rates*

- Maximum design load short-term emission rate (g/s)*

- Associated emissions/stack characteristics as a function of load for maximum, average, and nominal operating conditions if stack height is less than GEP or located in complex terrain. Screening analyses as footnoted on page 1 or detailed analyses, if necessary, must be employed to determine the constraining load condition (e. g., 50%, 75%, or 100% load) to be relied upon in the short-term modeling analysis.

  - location (UTM's)
  - height of stack (m) and grade level above MSL
  - stack exit diameter (m)
  - exit velocity (m/s)
  - exit temperature (°K)

- Area source emissions (rates, size of area, height of area source)*

- Location and dimensions of buildings (plant layout drawing)

  - to determine GEP stack height
  - to determine potential building downwash considerations for stack heights less than GEP

- Associated parameters

  - boiler size (megawatts, pounds/hr. steam, fuel consumption, etc.)
  - boiler parameters (% excess air, boiler type, type of firing, etc.)
  - operating conditions (pollutant content in fuel, hours of operation, capacity factor, % load for winter, summer, etc.)
  - pollutant control equipment parameters (design efficiency, operation record, e.g., can it be bypassed?, etc.)

- Anticipated growth changes

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*Particulate emissions should be specified as a function of particulate diameter and density ranges.

4. Air quality monitoring data:

   ° Summary of existing observations for latest five years (including any additional quality assured measured data which can be obtained from any state or local agency or company)*

   ° Comparison with standards

   ° Discussion of background due to uninventoried sources and contributions from outside the inventoried area and description of the method used for determination of background (should be consistent with the Guideline on Air Quality Models)

5. Meteorological data:

   ° Five consecutive years of the most recent representative sequential hourly National Weather Service (NWS) data, or one or more years of hourly sequential on-site data

   ° Discussion of meteorological conditions observed (as applied or modified for the site-specific area, i.e., identify possible variations due to difference between the monitoring site and the specific site of the source)

   ° Discussion of topographic/land use influences

6. Air quality modeling analyses:

   ° Model each individual year for which data are available with a recommended model or model demonstrated to be acceptable on a case-by-case basis

     - urban dispersion coefficients for urban areas
     - rural dispersion coefficients for rural areas

   ° Evaluate downwash if stack height is less than GEP

   ° Define worst case meteorology

   ° Determine background and document method

     - long-term
     - short-term

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*See **on page 1 of checklist.

- ° Provide topographic map(s) of receptor network with respect to location of all sources
- ° Follow current guidance on selection of receptor sites for refined analyses
- ° Include receptor terrain heights (if applicable) used in analyses
- ° Compare model estimates with measurements considering the upper ends of the frequency distribution
- ° Determine extent of significant impact--provide maps
- ° Define areas of maximum and highest, second-highest impacts due to applicant source (refer to format suggested in Air Quality Summary Tables)
  - long-term
  - short-term

7. Comparison with acceptable air quality levels:
   - ° NAAQS
   - ° PSD increments
   - ° Emission offset impacts if nonattainment

8. Documentation and guidelines for modeling methodology:
   - ° Follow guidance documents
     - Guideline on Air Quality Models, EPA-450/2-78-027R,
     - Workbook for Comparison of Air Quality Models, EPA-450/2-78-028a,b, May 1978
     - Guidelines for AQMPA, Vol. 10R, EPA-450/4-77-001, October 1977
     - Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations), EPA-450/4-80-023, July 1981
     - Ambient Air Monitoring Guidelines for PSD, EPA-450/2-78-019, November 1980
     - "Requirements for Preparation, Adoption and Submittal of Implementation Plans; Approval and Promulgation of Implementation Plans," Federal Register, Vol. 43, No. 119, pp. 52676-52748, August 1980 (Prevention of Significant Deterioration)

AIR QUALITY SUMMARY

For All New Sources

Pollutant ________ *	________ **		________ **		
	Highest	Highest 2nd High	Highest	Highest 2nd High	Annual
Concentration Due to Modeled Source ($\mu g/m^3$)					
Background Concentration ($\mu g/m^3$)					
Total Concentration ($\mu g/m^3$)					
Receptor Distance (Km) (or UTM Easting)					
Receptor Direction (°) (or UTM Northing)					
Receptor Elevation (m)					
Wind Speed (m/s)					
Wind Direction (°)					
Mixing Depth (m)					
Temperature (°K)					
Stability					
Day/Month/Year of Occurrence					

*Use separate sheet for each pollutant (SO_2, TSP, CO, NO_x, HC, Pb, Hg, Asbestos, etc.)

**List all appropriate averaging periods (1-hr, 3-hr, 8-hr, 24-hr, 30-day, 90-day, etc.) for which an air quality standard exists

Surface Air Data From ________ Surface Station Elevation (m) ________

Anemometer Height Above Local Ground Level (m) ________

Upper Air Data From ________

Period of Record Analyzed ________

Model Used ________

Recommended Model ________

AIR QUALITY SUMMARY

For All Sources

Pollutant ________ *	________ **		________ **		
	Highest	Highest 2nd High	Highest	Highest 2nd High	Annual
Concentration Due to Modeled Source ($\mu g/m^3$)					
Background Concentration ($\mu g/m^3$)					
Total Concentration ($\mu g/m^3$)					
Receptor Distance (Km) (or UTM Easting)					
Receptor Direction (°) (or UTM Northing)					
Receptor Elevation (m)					
Wind Speed (m/s)					
Wind Direction (°)					
Mixing Depth (m)					
Temperature (°K)					
Stability					
Day/Month/Year of Occurrence					

*Use separate sheet for each pollutant (SO_2, TSP, CO, NO_x, HC, Pb, Hg, Asbestos, etc.)

**List all appropriate averaging periods (1-hr, 3-hr, 8-hr, 24-hr, 30-day, 90-day, etc.) for which an air quality standard exists

Surface Air Data From ______ Surface Station Elevation (m) ________

Anemometer Height Above Local Ground Level (m) ____________________

Upper Air Data From ______________________________________

Period of Record Analyzed ________________________________

Model Used ____

Recommended Model _______________________________________

AIR QUALITY SUMMARY

For All Sources

Pollutant ________*	________**		________**		
	Highest	Highest 2nd High	Highest	Highest 2nd High	Annual
Concentration Due to Modeled Source ($\mu g/m^3$)					
Background Concentration ($\mu g/m^3$)					
Total Concentration ($\mu g/m^3$)					
Receptor Distance (Km) (or UTM Easting)					
Receptor Direction (°) (or UTM Northing)					
Receptor Elevation (m)					
Wind Speed (m/s)					
Wind Direction (°)					
Mixing Depth (m)					
Temperature (°K)					
Stability					
Day/Month/Year of Occurrence					

*Use separate sheet for each pollutant (SO_2, TSP, CO, NO_x, HC, Pb, Hg, Asbestos, etc.)

**List all appropriate averaging periods (1-hr, 3-hr, 8-hr, 24-hr, 30-day, 90-day, etc.) for which an air quality standard exists

Surface Air Data From ________ Surface Station Elevation (m) ________

Anemometer Height Above Local Ground Level (m) ________________

Upper Air Data From ________________________________

Period of Record Analyzed ________________________________

Model Used ________________________________

Recommended Model ________________________________

STACK PARAMETERS FOR ANNUAL MODELING

Stack No.	Serving	Emission Rate for each Pollutant (g/s)	Stack Exit Diameter (m)	Stack Exit Velocity (m/s)	Stack Exit Temperature (°K)	Physical Stack Height (m)	GEP Stack Height (m)	Stack Base Elevation (m)	Building Dimensions (m) Height	Width	Length

STACK PARAMETERS FOR SHORT-TERM MODELING*

Stack No.	Serving	Emission Rate for each Pollutant (g/s)	Stack Exit Diameter (m)	Stack Exit Velocity (m/s)	Stack Exit Temperature (°K)	Physical Stack Height (m)	GEP Stack Height (m)	Stack Base Elevation (m)	Building Dimensions (m) Height	Width	Length

*Separate tables for 50%, 75%, 100% of full load operating condition (and any other operating conditions as determined by screening or detailed modeling analyses to represent constraining operating conditions) should be provided.