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Workbook for Comparison of Air Quality Models

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Workbook for Comparison of Air Quality Models

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Monitoring and Data Analysis Division
Research Triangle Park, North Carolina 27711

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OAQPS GUIDELINE SERIES

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1 INTRODUCTION

A wide variety of air quality dispersion models are used by regulatory agencies, consulting firms and industry to estimate the air quality impacts of pollutant sources. It is often desired to compare two or more models to determine which is the most acceptable for a given application. It is particularly useful to be able to compare a given model with those which, by virtue of their extensive use, are familiar to most of the modeling community.

This workbook describes a technique for the qualitative comparison of modeling approaches on technical grounds. The methodology is based upon an applications approach. The results of the model comparison depend upon the application for which the model is to be used as well as upon the model characteristics. In each application of the technique, the model of interest (the "study" model) is compared with a "reference" model. Any models may be specified as study or reference models, as long as they are compatible with the application of interest.

The approach taken in this workbook is restricted to models that mathematically simulate the physical phenomena which determine atmospheric pollutant concentrations. Simulation models may require locally measured air quality data in order to fix the initial and boundary conditions or to determine appropriate background pollutant levels. Models excluded from that category are any that make use of locally measured air quality data to optimize or determine adjustable parameters unrelated to the physical processes being simulated. Thus, for example, calibration or averaging time conversion procedures are not considered as part of a simulation model but rather as statistical procedures which are applied to the calculations of a simulation model. Rollback models are also excluded from the category of simulation models. General considerations involved in the comparison of rollback and statistical or empirical models are discussed briefly in Section 7.

Although the amount and detail of the technical material, particularly that in Appendix A, may appear rather formidable to the user, it has been included for reference purposes and as an aid in dealing with unfamiliar treatments or situations. The user should refer to the examples in Appendix C.

If examples of the application of the methodology are examined, it should become clear that use of this workbook is not difficult.

It is important to understand that the methodology described in this workbook does not enable the user to evaluate the results obtained using a particular air quality model. That would require an evaluation of the quality and suitability of the input data as well as of the model. The methodology enables the user to determine only if the model used is as technically adequate as another model for the application of interest.

The workbook contains seven main sections and four appendices. Section 2 contains an overall description of the methodology and general instructions for its implementation. Sections 3-6 contain specific instructions and guidelines for carrying out various steps in the procedure. Section 3 deals with the classification of the user's application. Section 4 is concerned with the general suitability and compatibility of a model with the given application. It also considers the importance of various aspects of atmospheric dispersion in that application. Selected reference models for the various applications are also suggested in Section 4. Section 5 provides guidelines for identifying the treatments of various physical phenomena by a given model. Section 6 contains instructions and guidelines for making the comparative evaluation. Finally, Section 7 contains a discussion of some of the considerations involved in comparing rollback/statistical models.

The appendices contain general reference material useful in implementing the methodology. Appendix A contains technical discussions of the physical phenomena that determine atmospheric pollutant concentrations. It also contains a discussion of the importance of each phenomenon in different types of applications. Appendix B contains information on the treatments of these phenomena by selected reference models, including the working equations. Appendix C provides several examples of the use of the methodology in various common applications. Finally, copies of each of the various forms used in the methodology are provided for the user's convenience in Appendix D.

2 PROCEDURE

2.1 GENERAL

This section provides a general overview of the methodology, outlines the steps involved, and explains the types of information and decisions required at each step. The user is required to exercise judgment and to make qualitative decisions at each step, since model comparison is not, and cannot be made routine. Information and guidelines are provided for each step in the procedure. Prior to the initial use of the methodology, the user should read and understand the guidelines in this section. The experienced user can proceed directly to the comparison with occasional consultation of the reference materials.

The procedure is application-specific; that is, the results depend upon the specific situation to be modeled. Initially, the user identifies both the application of interest and an associated "reference model." This reference model serves as a standard of comparison against which the user gages the "study model" being evaluated. The way in which the study model treats twelve aspects of atmospheric dispersion called "application elements," or simply "elements" is determined. These application elements represent physical and chemical phenomena that govern atmospheric pollutant concentrations and include such aspects as horizontal and vertical dispersion, emission rate, and chemical reactions. The importance of each element to the application is defined in terms of an "importance rating." Tables giving the importance ratings for each element are provided, although the user may modify them under some circumstances. The heart of the procedure involves an element-by-element comparison of the way in which each element is treated by the two models. These individual comparisons, together with the importance ratings for each element in the given application, form the basis upon which the final comparative evaluation of the two models is made.

It is especially important that the user understand the physical phenomena involved, because the comparison of two models with respect to the way that they treat these phenomena is basic to the procedure. Sufficient information is provided in the text to permit these comparisons to be made and the availability of expert advice in the event of difficulties is assumed.

2.2 OVERVIEW

Comparison of a study model to a reference model is carried out in nine steps. Table 2.1 lists the section and tables to be used for each step in the comparison. Figure 2.1 illustrates schematically the steps in the comparison and their relation to each other. Greater detail, specific guidelines, and tables are given in Sections 3-6 and Appendices A and B. Forms for organizing and documenting a comparison are provided in Appendix D.

Table 2.1. Workbook Section and Form for Each Step in Comparison

Step		Workbook Sections	Form in Appendix D
Number	Action		
1	Classify application	3	Application Classification Form
	Record study model information	2.3	Evaluation Form A
2	Document study model equations	2.3	Reverse side of Evaluation Form A
3	Check study model compatibility	4.2	Evaluation Form A
4	Classify study model type[a]	4.3	Evaluation Form A
5	Identify reference model	4.4	Evaluation Form A
6	Review importance ratings	4.5	Evaluation Form B
7	Determine treatments of elements	5	Evaluation Form C
8	Compare treatments on element-by-element basis	6.2.1	Evaluation Form C
9	Synthesize individual comparisons into overall comparison	6.2.2	Evaluation Form D

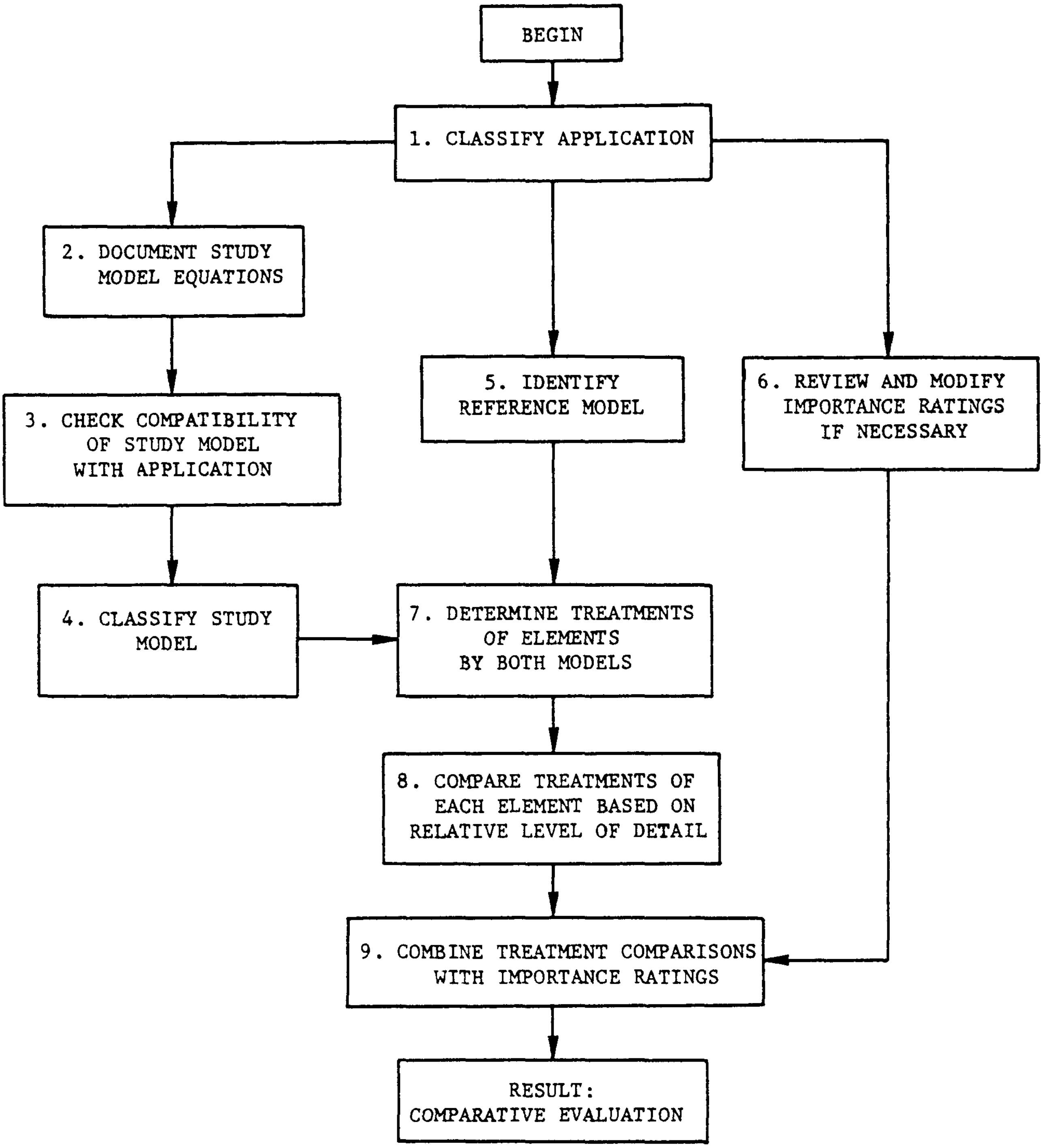
[a]If the study model has been classified as a rollback/statistical model, the user should proceed directly to Section 7 wherein such models are discussed.

2.3 STEP-BY-STEP INSTRUCTIONS

<u>Step 1 - Classify Application; Record Basic Information</u>

The user first classifies the application of interest. Specifically, the user considers each of the following four aspects of the application:

- Pollutant characteristics,
- Averaging time,
- Source characteristics, and
- Transport characteristics.



Note: Numbers in the boxes refer to the steps in the comparison procedure as given in Table 2.1.

Figure 2.1. Procedure for the Comparison of Air Quality Simulation Models

The classification is based on an application tree approach as described in Section 3. An Application Classification Form (see Figure 3.2 or Appendix D) is provided for carrying out this classification. Next, the four-digit "application index" is determined. This index identifies the application throughout the remainder of the comparison. The application must be classified with respect to the physical situation being modeled. Some basic background information about the study model is then recorded.

Step 2 - Document Study Model Equations

The element-by-element comparisons are facilitated by listing the major equations used by the study model on the back of the Evaluation Form - Part A. The user must examine the study model documentation carefully to determine the equations which are actually used. In some cases, when the study model documentation is inadequate or inconsistent, it may be necessary to examine the computer code itself to make the determination. The equations used by selected reference models are documented in Appendix B.

Step 3 - Check Model Compatibility

In this step the general compatibility of the study model with the application of interest is checked. Brief guidelines are given in Section 4.2 for determining whether

- Treatments of elements essential to the application of interest are incorporated in the study model and
- Output from the study model meets the user's requirements.

The documentation for the study model should contain the information to make the compatibility determination.

Step 4 - Classify Study Model Type

In this step, the study model is classified according to the general modeling approach adopted. This model classification is useful in identifying the way in which the model treats several application elements. Specific guidelines can be found in Section 4.3.

If the model is classified as a rollback/statistical model, or if it is found to involve both simulation and statistical estimation procedures, the methodology described in this workbook does not apply. A general discussion of some of the considerations involved in the comparison of such models may be found in Section 7. If the study model incorporates a calibration procedure which empirically adjust the estimates made by a simulation model, the user should consider only the simulation model and simply ignore the presence of the calibration procedure when applying the methodology.

Step 5 - Identify Reference Model

Table 4.1, Section 4.4, identifies suggested reference models for some of the indexed applications. This step only involves looking up the appropriate reference model for the application index determined in Step 1.

At this point, the Evaluation Form - Part A should be completely filled out. This form is shown in Figure 2.2.

Step 6 - Review and Modify Importance Ratings

This is the first step in which the user must consider the twelve application elements. Each element specifies a particular physical aspect of the overall processes by which the emission of pollutants into the atmosphere affects the air quality at some point. Figure 2.3 depicts the relationship between these application elements and the estimation of atmospheric pollutant levels. In order to compare the study model to the reference model, the user needs to know

- The importance of each element to the application of interest and
- How the treatment used by the study model compares to that used by the reference model.

An estimate of the importance of each element to each application can be found from Tables 4.2-4.13 in Section 4.5. Each element has been rated as being of HIGH, MEDIUM, or LOW importance to each application. The user should review these importance ratings. In light of the specific application, a particular rating may either be changed to another of the ratings given above or be designated as CRITICAL or IRRELEVANT. Critical elements are those to which it is desired to give extraordinary weight when the two models are compared. Irrelevant elements describe processes that are inoperative in the application of interest. Generally, with the exception of irrelevant elements, the user should expect to make very few modifications to the given ratings and, at most, one CRITICAL designation.

The Evaluation Form - Part B should now be completed by indicating the importance rating for each application element and any changes (see Figure 2.4).

EVALUATION FORM

Part A: Abstract and References

Study Model:

References:

Abstract:

Classification:

Application Index:

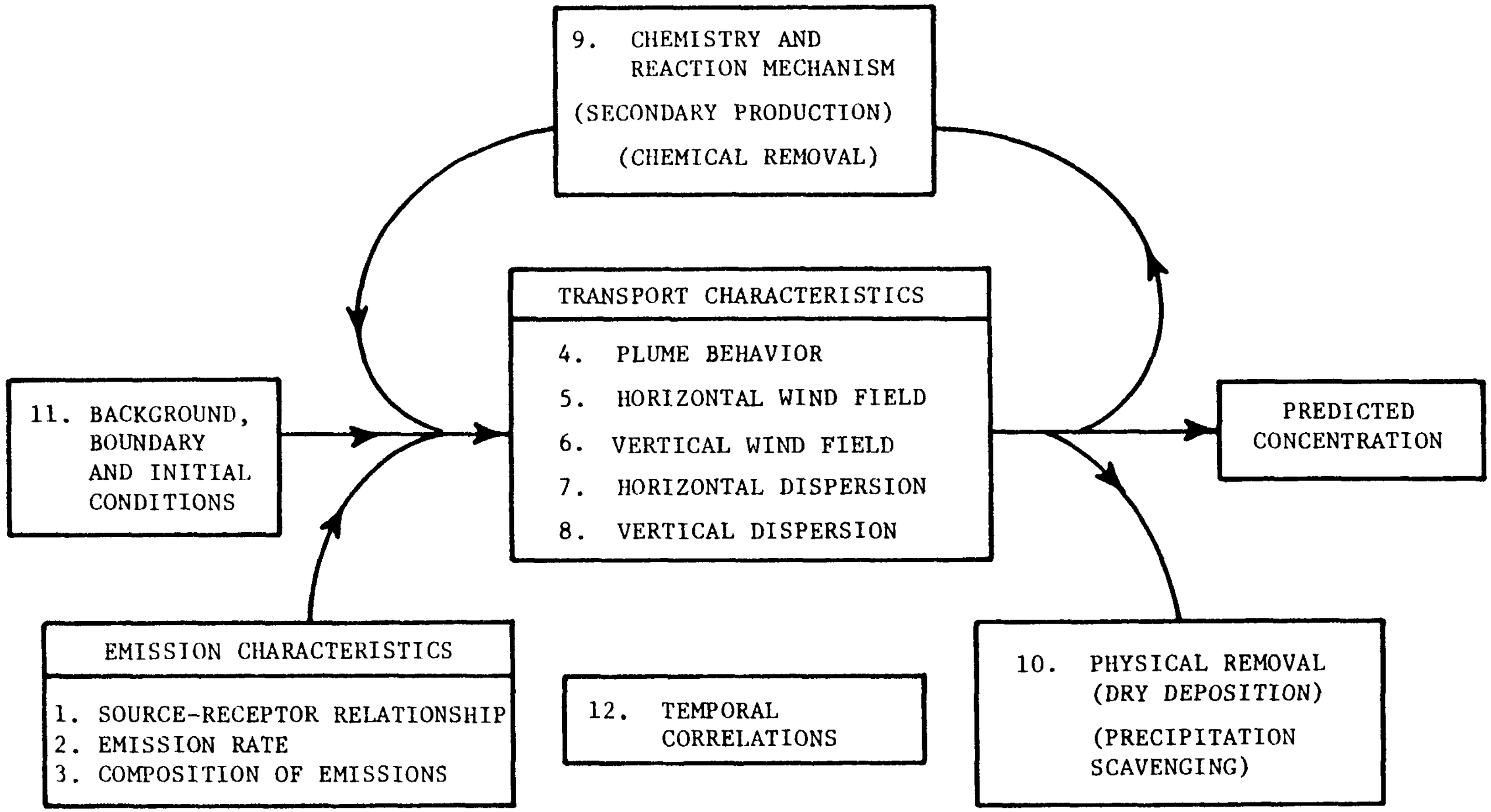
Reference Model:

Application Description:

Model Applicability: Applicable ☐ Not Applicable ☐

Note: The reverse side of this form for documenting the equations is not shown.

Figure 2.2. Evaluation Form - Part A



Note: Temporal correlations relate the time variations of all other application elements.

Figure 2.3. Application Elements as Major Factors Affecting Pollutant Concentrations

EVALUATION FORM

Part B: Importance Ratings

Application Index:

Application Element	Importance Rating Initial	Importance Rating Modified[a]
Source-Receptor Relationship		
Emission Rate		
Composition of Emissions		
Plume Behavior		
Horizontal Wind Field		
Vertical Wind Speed		
Horizontal Dispersion		
Vertical Dispersion		
Chemistry and Reaction Mechanism		
Physical Removal Processes		
Background, Boundary, Initial Conditions		
Temporal Correlations		

[a]With the exception of the designation of IRRELEVANT elements, it is expected that at most one CRITICAL designation and possibly one other modification may be made.

Figure 2.4. Evaluation Form - Part B

Step 7 - Determine Treatments of Application Elements

In this step the treatments of the application elements by both the study model and the reference model are determined. The treatments for each element should be described on the Evaluation Form - Part C. The user should consult that part of Section 5 that corresponds to each element. Section 5 gives guidelines, questions, and tables to aid the user in determining the study model's treatment of each element. If additional guidance is needed, Appendix A provides detailed discussions of various common treatments of the application elements.

The treatment of each element by selected reference models can be found in Tables B.2-B.13 in Appendix B.

It is strongly recommended that the sections of Appendix A appropriate to each element be read. The general discussion in each section provides information on the physical processes which are involved and hence builds a foundation for making the comparisons required in Step 8.

Step 8 - Compare the Two Treatments of Each Element

Once the treatment of a particular element has been determined, the next step is to determine whether the study model's treatment of that element is

- BETTER than,
- COMPARABLE to, or
- WORSE than

that of the reference model. Detailed guidance on making this comparison is given in Section 6.2.1. The required comparison is qualitative. Occasionally, the user may have some difficulty in deciding whether, for instance, the study model's treatment is better than or comparable to the reference model's. In such cases, it is suggested that the user enter the best estimate and note the other rating in parentheses for later consideration. In general, the user is urged to make a unique comparison whenever possible.

The Evaluation Form - Part C should be completed at this point (see Figure 2.5). Note that the form in Figure 2.5 contains room for describing the treatments of two elements only. Additional copies of this form up to a maximum total of six will be required in order to handle all relevant elements.

EVALUATION FORM

Part C: Treatment of Elements

Application Index:__________

Application Element: Reference Model: Treatment:	Application Element: Reference Model: Treatment:
Study Model: Importance Rating: Comparative Evaluation: Treatment:	Study Model: Importance Rating: Comparative Evaluation: Treatment:

Figure 2.5. Evaluation Form - Part C

Step 9 - Synthesize the Final Technical Comparison

The information required for the final technical comparison can be organized on the Evaluation Form - Part D (see Figure 2.6). As discussed in Section 6.2.2, the user first summarizes the results of the element-by-element comparisons. An initial evaluation is made by considering the relative treatments of the most important elements, and this initial evaluation is then modified or not according to the relative treatments of the elements of lesser importance. Elements of low importance are considered only in ambiguous cases. The final evaluation obtained in this way represents the final result of applying the methodology and at this point the comparison is complete.

EVALUATION FORM

Part D: Technical Comparison

Application Index:__________ Reference Model:__________ Study Model__________

Importance Rating of Application Elements	Number of Treatments				Comparative Rating of Study Model
	Total	BETTER	COMPARABLE	WORSE	
CRITICAL					________
HIGH					________
MEDIUM					________
LOW					
IRRELEVANT	____	XXX	XXX	XXX	
Total	(Should equal 12)				
			TECHNICAL EVALUATION		________

Figure 2.6. Evaluation Form - Part D

3 APPLICATION CLASSIFICATION

3.1 INTRODUCTION

The first step in the methodology is to suitably define the application as discussed in Sections 3.2-3.6. This workbook cannot treat all possible factors in detail. Thus, the user needs to consider the situation of interest and to exercise judgment at all stages of the evaluation. It is necessary, however, to classify the application in as much detail as practicable.

Four general aspects of air pollution simulation have been identified as being suitable for this purpose. In this section, the user classifies the application with respect to these four aspects. In the process, a four digit number is generated. This number serves to identify the class of applications to be considered in the comparison. This number, the application index, is used throughout the workbook for various purposes. The user should not consider in any way the details of the operation of either the reference or the study model in classifying the application. The classification should reflect only the characteristics of the problem at hand without regard to possible simulation techniques.

Note that meteorological concepts are not used in the classification scheme. Relevant aspects of meteorology comprise several of the application elements discussed in Section 5.

3.2 INSTRUCTIONS

The following procedure enables the user to classify the application of interest and to construct the application index. Figure 3.1 shows the classification process schematically. Decision trees and the accompanying guidelines are used to classify the application in the following four categories:

- Pollutant characteristics
- Averaging time,
- Source characteristics, and
- Transport characteristics.

The trees require definite decisions at each branch point. In cases of uncertainty, the user may follow multiple branches and refer to the application

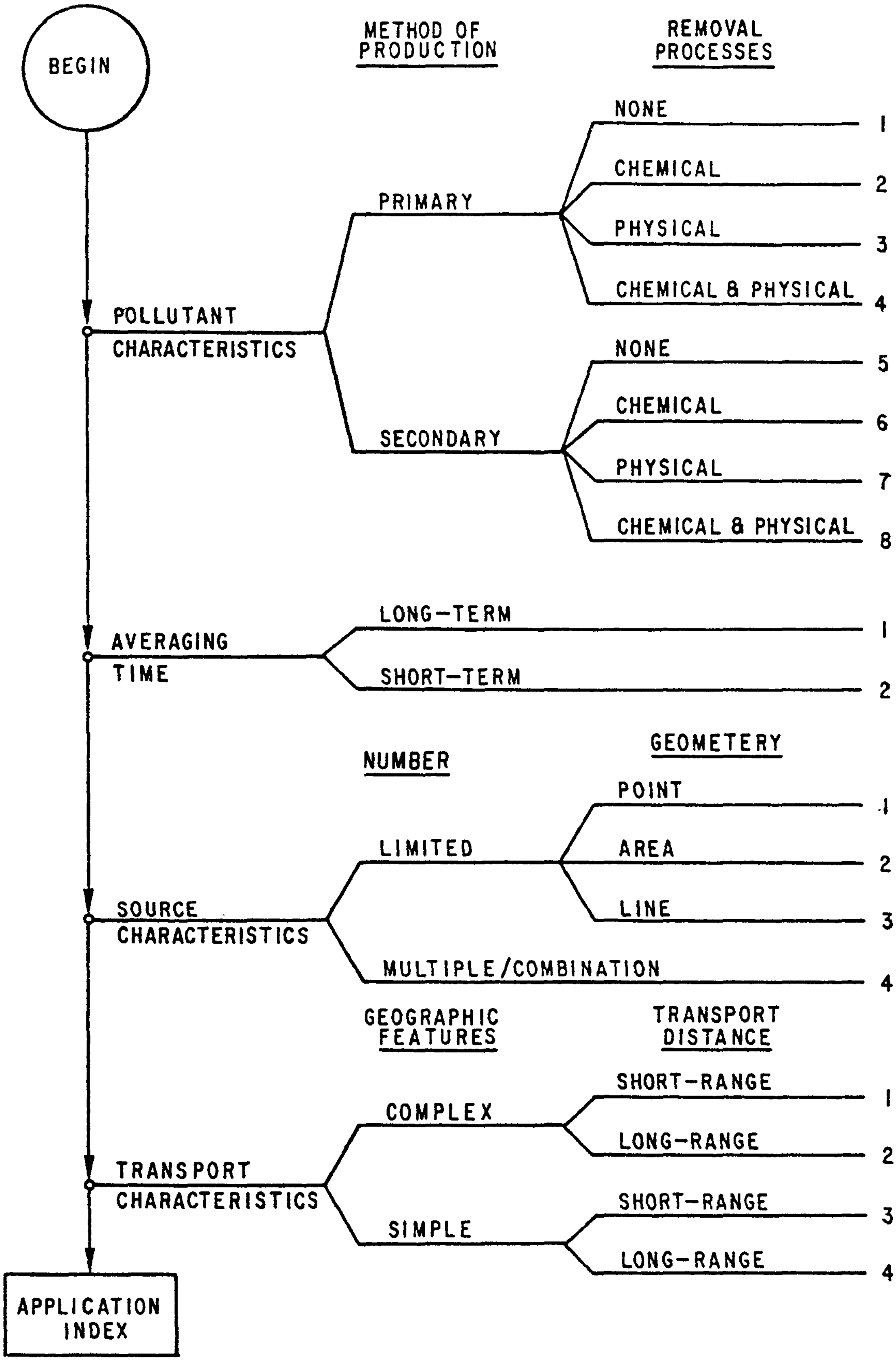


Figure 3.1. Scheme for Classifying Model Applications

element descriptions in Appendix A. The information in these detailed descriptions may facilitate the identification of the most pertinent classification. Each branch of each decision tree ends in a one-digit number that classifies the given application within the category being considered. After classifying the application in all four categories, the index numbers are combined into the four-digit composite application index.

The steps in classifying the application are listed below:

1. Classify the application within each of the four categories shown in Figure 3.1.

2. Determine the one-digit numbers corresponding to the specific classification chosen within each of the four categories.

3. Form the composite application index from these four one-digit numbers.

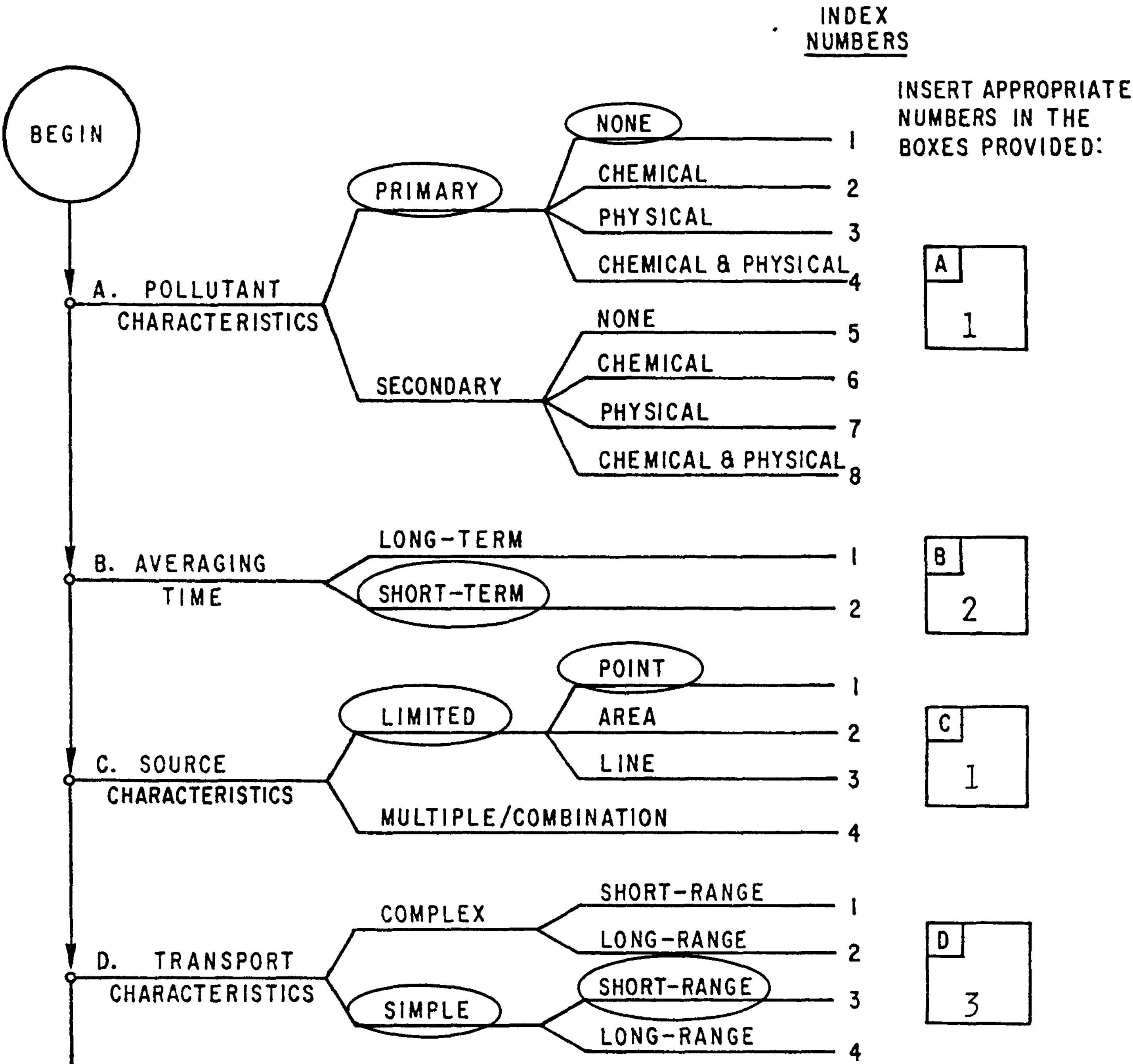
In classifying the application, the user should consult the guidelines for each descriptive category contained in Sections 3.3-3.6.

As an example, consider an application that involves estimating the short-term concentrations of total suspended particulate (a primary pollutant) due to a power plant (single point source) when (1) the interest is in the area close to the plant; (2) particulate removal by fallout, deposition, etc. can be ignored; and (3) the local geographic features are simple. The application index would be 1213, corresponding to the index numbers of 1, 2, 1 and 3 for the categories "pollutant characteristics," "averaging time," "source characteristics," and "transport characteristics" respectively. Figure 3.2 shows a completed sample Application Classification Form for this specific example.

3.3 CLASSIFICATION OF POLLUTANT CHARACTERISTICS

The decision tree for classifying pollutant characteristics is shown in Figure 3.3. The tree indicates processes by which pollutants are produced and/or removed from the atmosphere. The first step is to classify the pollutant as either primary or secondary. Primary pollutants are defined as those emitted directly into the atmosphere and secondary pollutants are defined as those produced in the atmosphere by chemical reactions. For example, if the application involves estimating the additional CO concentration caused

APPLICATION CLASSIFICATION FORM



Form the application index by transferring the four index numbers into the corresponding boxes below:

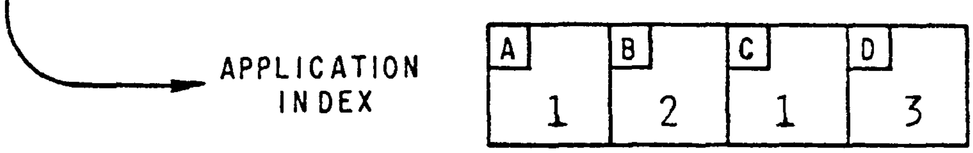


Figure 3.2. Sample Completed Application Classification Form

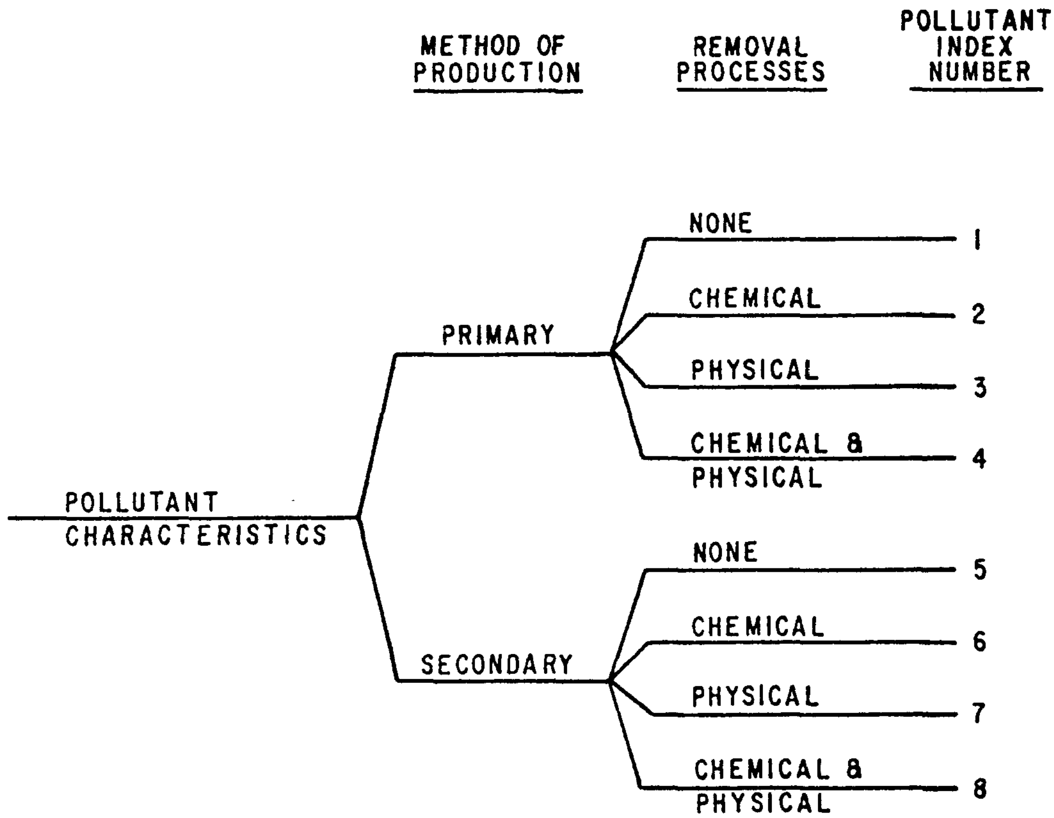


Figure 3.3. Decision Tree for Classifying Pollutant Characteristics

by a new highway link, CO is classified as a primary pollutant because it comes directly from the vehicular sources using the link. The most common example of a secondary pollutant is ozone, which is produced by photochemically initiated reactions involving reactive hydrocarbons and nitrogen oxides.

When the application involves a secondary pollutant, it eventually becomes necessary to determine the chemical identity of the primary precursors of that pollutant. Knowledge of the nature of the precursors and their sources is required by the nature of the modeling process; namely, to relate emissions from sources to atmospheric concentrations. Primary precursors are defined here as those substances that are emitted directly into the atmosphere, undergo chemical reaction, and whose ultimate reaction products include the pollutant of interest. Determination of the precursors often requires expert advice but is not required at this point in the classification. Knowledge of sources of the precursors is necessary when the source characteristics are classified.

A particular pollutant can be both emitted directly into the atmosphere and produced by atmospheric chemical reactions; hence it can be both primary and secondary. For example, particulate sulfates are emitted directly from catalytic converters on automobiles and result as well from atmospheric reactions involving SO_2. In applications involving the total concentration of such a pollutant, it may be possible to choose a single classification. For example, if primary sources are known to be dominant, the pollutant should be classified primary. On the other hand, if secondary generation dominates, the secondary classification should be used. In situations where neither prevails, both branches should be explored. The model used must be able to handle both primary and secondary production. In such cases, the comparison will involve going through the evaluation process twice: identifying two applications, two reference models, two sets of importance ratings and making two independent evaluations. These evaluations can then be weighted by the relative importance of primary and secondary production and combined to arrive at the desired overall comparison.

In applications involving a specific source, the classification should be made based upon whether the pollutant emitted from that source is the pollutant of interest or a precursor.

After the method of production has been classified, the processes by which the pollutant is removed from the atmosphere must be classified. This second classification should be made by considering removal processes that are important over the range of time and distance involved in the application. In some situations, removal of the pollutant may be negligible and the branch labeled "None" is chosen. The determining factor is the relationship between the pollutant's removal rate under the conditions being studied and its residence time within the study area. Estimation of the appropriate removal rates may require expert advice. If roughly more than one-quarter to one-third of the pollutant could be removed within the study area, removal processes should be accounted for within a simulation model.

If removal is important, a decision is required as to the type of removal processes involved. Chemical removal processes are those in which the pollutant reacts chemically in the atmosphere as, for example, when SO_2 reacts to form sulfates and ceases to exist as the chemical species of interest. Physical removal processes produce a change in the amount of pollutant in the air without causing an immediate change in the chemical species of the material removed. They include such processes as gravitational settling, impaction, precipitation scavenging, and dry deposition. In cases where both chemical and physical removal processes are significant, the branch labeled "Chemical and Physical" should be chosen, even if the user is interested primarily in only one type. Of course, if one type of removal process is clearly predominant, that branch should be chosen.

Other terminology is frequently employed in discussing pollutant characteristics. Reactive pollutants are those that react chemically in the atmosphere. They thus belong on one of the four branches labelled "chemical" or "chemical and physical" removal. Pollutants that are not reactive are called stable even if physical processes remove them from the atmosphere. Conservative pollutants are those for which no removal process is significant enough to be considered.

Common characteristics of the criteria pollutants are given in Table 3.1. The indicated classifications are illustrative only and are not intended as an exhaustive list of all possibilities. In other circumstances, the classification might be different from those shown in the table.

3.4 CLASSIFICATION OF AVERAGING TIMES

The decision tree for classifying averaging times is shown in Figure 3.4. The time of interest is that over which the estimated concentrations are to be averaged. For a particular pollutant, averaging times from several minutes to a year may be of interest. Applications involving concentrations averaged for 24 hours or less should be considered as distinct from those in which seasonal or annual averages are estimated. The former are classified as short-term. Longer averaging times like a month, season, or year are classified as long-term. Table 3.2 classifies the averaging times specified in the NAAQS.

3.5 CLASSIFICATION OF SOURCE CHARACTERISTICS

In order to classify source characteristics, the number and the geometry of the sources involved in the application must be determined. The decision tree for classifying source characteristics is shown in Figure 3.5. The

Table 3.1 Classification of Criteria Pollutants[a]

Pollutant	Conditions	Method of Production	Removal Processes	Pollutant Index Number
TSP	Particles smaller than about 30μm.	Primary	None	1
	Particles larger than about 30μm.	Primary	Physical (gravitational settling)	3
SO_2	Residence time under 5-8 hrs.[b]	Primary	None	1
	Residence time over 5-8 hrs.[b]	Primary	Chemical and Physical	4
CO	Most conditions.	Primary	None	1
NO_2	Most sources emit mainly NO which reacts to form NO_2.	Secondary	Chemical	6
Oxidants	Primary sources are generally negligible.	Secondary	Chemical	6
Non-methane Hydrocarbons	-	Primary	Chemical	2

[a]These characteristics are for short-range urban situations without precipitation and could change under other circumstances.

[b]"Residence time" is approximated by the time taken to traverse the region of interest at a characteristic wind speed.

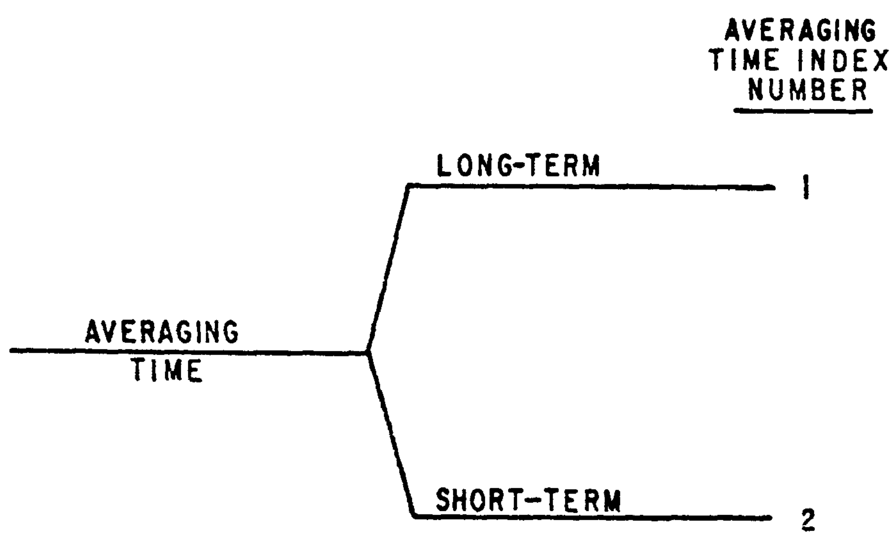


Figure 3.4. Decision Tree for Classifying Averaging Times

Table 3.2 Classification of NAAQS Averaging Times

Pollutant	Averaging Time	Classification	Averaging Time Index No.
TSP[a]	Annual	Long-term	1
	24-hour	Short-term	2
SO_2[a]	Annual	Long-term	1
	24-hour	Short-term	2
	3-hour	Short-term	2
CO	8-hour	Short-term	2
	1-hour	Short-term	2
Oxidants	1-hour	Short-term	2
Hydrocarbons	3-hour	Short-term	2
NO_2	Annual	Long-term	1

[a]These averaging times are also specified for the Prevention of Significant Deterioration (PSD) increments.

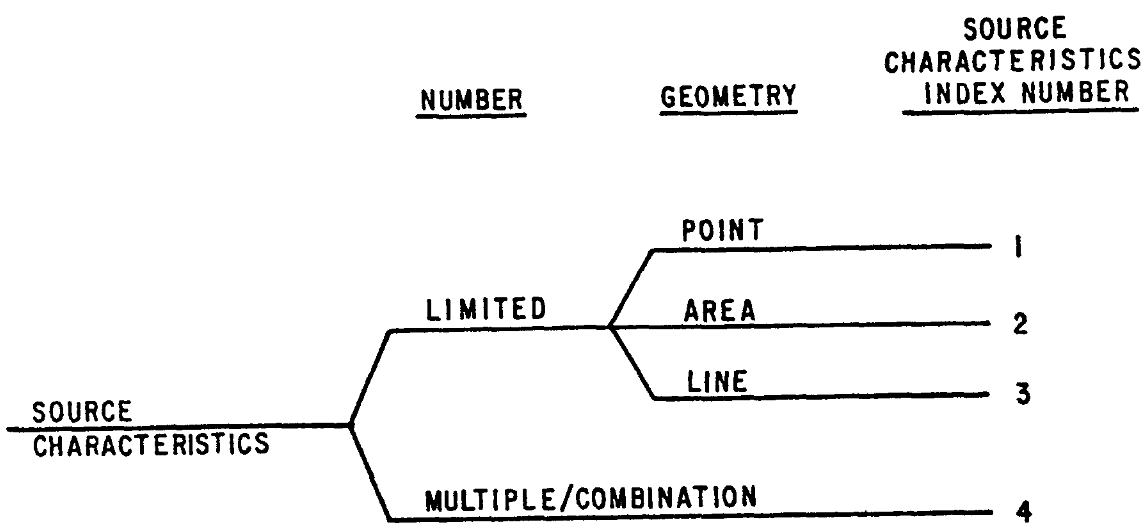


Figure 3.5. Decision Tree for Classifying Source Characteristics

proper branch of the tree is chosen by considering both the number and the geometry together. The user should choose the branch appropriate to the physical characteristics of the sources as inventoried for use in the model.

Whenever the dimensions of a stationary source are small compared to the distance at which concentrations are to be estimated, the source can be treated as a geometric point. Generally, sources are treated as points if they emit a substantial amount of any criteria pollutant, e.g. 100 tons per year. Some control agencies treat sources with as little as 1 ton per year of emissions as points.

Sources that emit small amounts of pollutant are usually aggregated and treated as uniform area sources. Their large number and highly variable emission rates preclude treating them as individual sources. In addition, some sources, such as open quarries or windblown fields, are "true" area sources due to their geometry. They are not aggregates of many point or line sources.

The line source designation is usually reserved for special problems involving aircraft or microscale analyses of vehicular impacts. As is the case with multiple point sources, closely packed line sources such as streets in downtown areas are frequently treated as uniform area sources. If individual line source data exists, the more appropriate line classification should be made; if the data base aggregates the lines to areas, the area classification should be made.

A small number of sources (generally less than 10-20) having the same geometry should be classified "limited" in number. Thus, if the impact of a power plant with five stacks were being estimated, the "limited" branch should be chosen. The same choice should also be made if five spatially separated sources are involved. However, in the latter case, the user should be aware that some models for treating a limited number of sources assume that these sources are coincident in space or equivalently that the separations between sources are small compared to the transport distances. The choice between the "limited" or the "multiple" branch should be based on the number of sources to be modeled, not the number of actual sources. Thus, if several hundred small incinerators have been inventoried as six area sources, the sources would be characterized as limited in number (six area sources), not multiple.

If either multiple sources or several source geometries are to be modeled, the "Multiple/Combination" branch is chosen. If a limited number of sources of a single geometry are to be modeled, the appropriate branch along the "Limited" path is chosen.

The source characteristics of some common source categories are given in Table 3.3. In particular applications, these general guidelines may be modified. For example, if the impact of a small number of industrial process sources is being investigated, the source characteristics should be classified as a limited number of point sources and not as part of an aggregated area source.

Table 3.3. Classification of Common Source Categories

Source Category	Number	Source Size[a]	Geometric Description	Source Characteristics Index Number
Industrial Process	Limited	Large	Point	1
	Multiple	Small	Area	4
Fuel Combustion (Internal and External)	Limited	Large	Point	1
	Multiple	Small	Area	4
Transportation	Limited		Line	3
	Multiple		Line or Area	4
Electricity Generation	Limited		Point	1
	Multiple		Point	4
Incineration	Limited		Point	1
	Multiple		Area	4
Urban Area	Multiple	Various	Combination	4

[a]Source size is measured relative to the point source size specified in the emission inventory. For example, major (large) sources are generally considered to be those that emit more than 100 tons per year.

3.6 CLASSIFICATION OF TRANSPORT CHARACTERISTICS

The decision tree for classifying transport characteristics is shown in Figure 3.6. This tree classifies the application with respect to geographic features and the transport distance from sources to receptors. One important general factor affecting transport has been omitted from the tree: meteorology. Meteorology has been omitted so that the application can be defined by relatively fixed or invariant characteristics of the application rather than by the variable factors which affect transport and dispersion.

The application is defined by specific pollutant characteristics, specific averaging times, well-defined source characteristics, well-defined geography, and a specific region. However, a wide range of meteorological conditions frequently must be analyzed. The relevant meteorological considerations and transport under certain specific adverse meteorological conditions are discussed in Appendices A.2 and A.4.

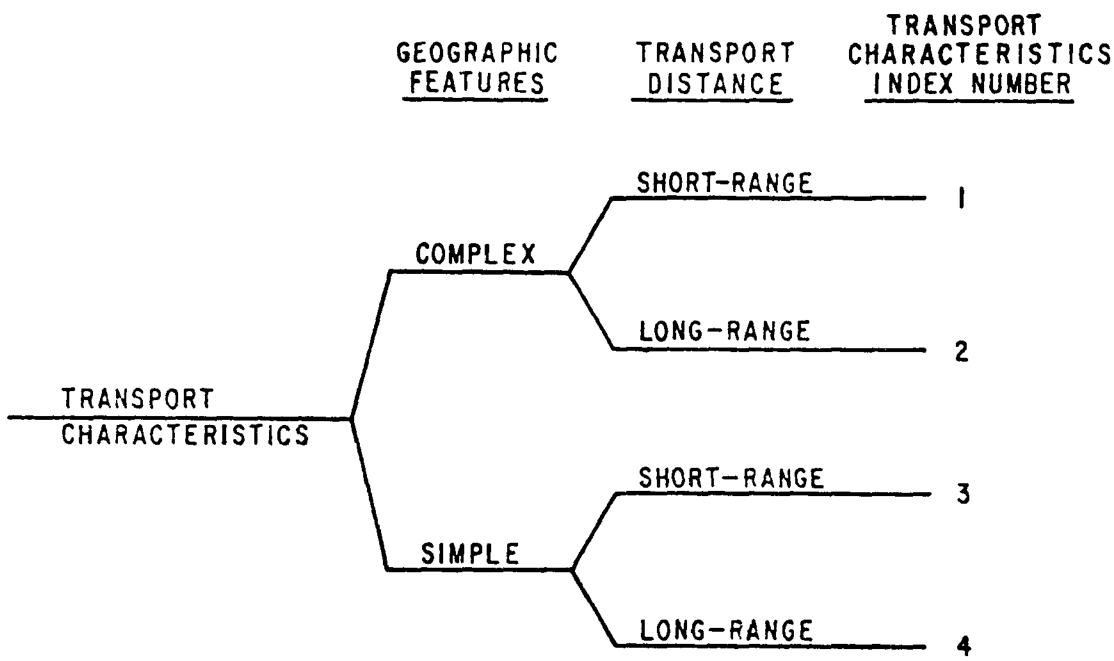


Figure 3.6. Decision Tree for Classifying Transport Characteristics

Geographic features should be classified as complex if their presence requires the consideration of point-to-point variations in the speed or direction of transport winds. Applications involving areas with rough terrain, areas containing or close to a large body of water, or areas in valleys or street canyons should generally be classified as having "complex" geographic features. Areas with level or gently rolling terrain should generally be classified as having "simple" geographic features. Determining the appropriate classification may require the advice of an expert air pollution meteorologist. The determination may also depend upon other features of the specific application. For example, variations in terrain that are significant when short-range transport is being considered might be insignificant when long-range transport is of interest. In coastal areas or near the Great Lakes, the potential effects of sea or lake breezes may require the complex classification. The precise distance inland over which the complex classification must be maintained cannot be specified without knowing the details of the application. If in doubt, the user should consult the technical material in Appendices A.3 and A.4 or obtain expert advice on the particular situation.

A different set of applications arises when the effects of sources are estimated over long rather than short distances. As a general rule-of-thumb, distances between sources and receptors that exceed 60-100 km (40-60 mi) should be classified long-range. The transport distance is also related to the residence time considered when the pollutant characteristics were classified. Care should be taken to see that the two choices are made on a consistent basis.

4 PRELIMINARY ANALYSIS

4.1 INTRODUCTION

In this section, guidelines and instructions are provided to enable the user to carry out steps 3-6 as given in Table 2.1 and shown in Figure 2.1. These steps involve a check to see that the study model is compatible with the application in certain essential respects, the classification of the study model, the identification of the reference model to be used in the comparison, and the review and possible modification of the importance ratings. These steps are considered in Sections 4.2-4.5, respectively. Sufficient guidelines for carrying out Step 2, the documentation of the study model equations, may be found in Section 2.3.

4.2 CHECK COMPATIBILITY OF STUDY MODEL WITH APPLICATION

It is desirable, before proceeding further, to determine that the study model meets two specific requirements of the application of interest and is therefore compatible with it. Generally, reference models can be used as standards for comparison even when they are not strictly compatible with the application of interest.

The first requirement is that the study model should contain treatments of all elements in which the user has a specific interest or which are required by the nature of the application. For example, if the user has determined that some specific physical removal process is important for the application of interest, and has as a result chosen the appropriate branch in the Application Tree, the study model should incorporate a treatment, however simplified, of that process. If the pollutant of interest is subject to chemical removal processes, and/or if it is a secondary pollutant, the study model should incorporate a treatment of the effects of the relevant chemical reactions. This may be extended to processes not covered in this workbook. If the user is interested in the effects of any process whatever, the study model must incorporate a treatment of that process.

The second requirement is that the study model should provide the user with the desired results. No attempt is made to list the various possibilities here. It is assumed that the user knows what estimates are desired and can determine whether or not the study model provides them. For example, the application might involve calculating the frequency distribution of twenty-four hour averages at some location. In this case, a model which gives only the maximum twenty-four hour average is not compatible with the user's application, because the desired information is not available as an output from the model.

4.3 CLASSIFICATION OF STUDY MODEL

The possible treatments of several application elements depend upon the general type of model being considered. It is, therefore, useful to classify the study model with regard to certain general characteristics. Guidelines are provided in this section to enable the user to carry out this classification; further discussion may be found in Appendix A.4.2.

The study model should first be categorized as either a simulation model or as a rollback/statistical model. The distinctions between these two broad categories are based upon

- The extent to which the model in question attempts to simulate the relevant physical and chemical processes which significantly affect atmospheric pollution levels and
- The degree to which locally measured air quality data are required for model usage or for the adjustment of model parameters.

A simulation model should attempt to describe mathematically the effects of all relevant physical phenomena expected to have a significant effect on air quality in the application of interest. It should not absolutely <u>require</u> the existence and use of locally measured air quality data except possibly to fix initial and boundary conditions. For example, a model which incorporates a model calibration procedure involving a statistical adjustment of concentration estimates should still be classified as a simulation model.

Rollback/statistical models are also formulated mathematically and may require many of the same input variables, such as wind speed or mixing height, as do simulation models. They do not, however, attempt to describe the physical processes involved in the transport and dispersion of pollutants from source to receptor in order to estimate pollutant concentrations. Instead, the relationship between concentrations and the model input variables is determined empirically. This is usually done by assuming some simple functional relationship containing one or more adjustable parameters and then determining the values of these parameters that produce the best agreement with air quality data.

If the study model is classified as a rollback/statistical model, or if statistical conversion of averaging times is used by the model, the methodology described in this workbook does not apply. General guidelines regarding the comparison of rollback/statistical models may be found in Section 7 but the user should consult with an expert to determine the proper way to perform the evaluation in such cases.

If the study model is a simulation model, it may be categorized according to the following two additional features:

1. General modeling approach adopted

   - Numerical, involving the solution by numerical procedures of equations based upon the conservation of mass (K-theory), or

   - Semiempirical, involving the assumption of a particular functional form for the pollutant distribution; and

2. Treatment of the time dependence of pollutant concentrations

   - Steady-state, involving no time dependence; only a single constant set of conditions is used,

   - Dynamic, involving the estimation of pollutant concentrations as functions of time or as functions of position along a dynamic trajectory; evolution of the system in time is described in a causal manner,

   - Sequential, in which a sequence of conditions is considered; a separate independent calculation is done for each, or

   - Climatological, in which a number of different conditions are considered, each weighted by its frequency of occurrence; a separate calculation is done for each.

The user should be able to categorize the study model according to the general modeling approach from the definitions given and the study model documentation. If further discussion is needed, Appendix A.4.2 may be consulted. It should be pointed out that the first categorization relates to the treatment of dispersion by the study model and that different classifications may be needed for the treatments of horizontal and vertical dispersion.

The treatment of the time dependence of pollutant concentrations must be determined in order to carry out the second classification, and the user should be able to make this determination from the definitions provided together with the study model documentation. Again, further discussion is given in Appendix A.4.2.

Two points need to be made here regarding the classification of time dependence. The first relates to the difference between a dynamic model and a sequential model. Dynamic models often divide the total simulated time interval into a series of time steps and treat the pollutant distribution at the end of one step as the initial distribution for the next, thereby handling the time dependence in a causal manner. Sequential models also consider a series of time periods, but ignore the causal relation between pollutant distributions at each time step and do independent calculations for each.

The second point is that for sequential and climatological models, the individual calculations made for each of the conditions considered may be carried out using either dynamic or steady-state methods; a steady-state model is almost always used. This classification should also be indicated. Thus combinations like "climatological (steady-state)" or "sequential (steady-state)" arise.

Table B.1 in Appendix B gives the classification for selected reference models suggested for use in this workbook.

4.4 IDENTIFICATION OF REFERENCE MODEL

Table 4.1 suggests reference models that may be associated with some of the indexed applications. Each suggested reference model is briefly described in Appendix B. In the table, many applications do not have an associated reference model. In these cases, the user is encouraged to compare his model with some other applicable simulation model. If no such model is available, there is no reference model and no comparison can be made. Since not all aspects of an application have been classified by the foregoing procedure, footnotes have been provided where additional information is required in determining the appropriate reference model.

Table 4.1. Suggested Reference Models for Indexed Applications[a]

Index Number	Reference Model	Index Number	Reference Model	Index Number	Reference Model
1111	Valley, CRSTER (b,c)	2211	Valley	4111	Valley
1112		2212		4112	
1113	CDM, CRSTER (c,h)	2213	STRAM	4113	CDM
1114		2214	STRAM	4114	
1121	Valley	2221		4121	Valley
1122		2222		4122	
1123	CDM	2223	RAM	4123	CDM
1124		2224		4124	
1131		2231		4131	
1132		2232		4132	
1133		2233		4133	
1134		2234		4134	
1141	Valley	2241		4141	Valley
1142		2242		4142	
1143	CDM	2243	RAM	4143	CDM
1144		2244		4144	
1211	Valley, CRSTER (b,c)	3111	Valley	4211	Valley
1212		3112		4212	
1213	RAM, CRSTER (c,i)	3113	ATM	4213	STRAM
1214		3114		4214	STRAM
1221		3121	Valley	4221	
1222		3122		4222	
1223	RAM	3123		4223	RAM
1224		3124		4224	
1231		3131		4231	
1232		3132		4232	
1233	HIWAY, APRAC (d)	3133		4233	
1234		3134		4234	
1241		3141	Valley	4241	
1242		3142		4242	
1243	RAM, APRAC (e)	3143	CDM	4243	RAM
1244		3144		4244	
2111	Valley	3211	Valley	5111	
2112		3212		5112	
2113	CDM	3213	STRAM	5113	
2114		3214	STRAM	5114	
2121	Valley	3221		5121	
2122		3222		5122	
2123	CDM	3223	RAM	5123	
2124		3224		5124	
2131		3231		5131	
2132		3232		5132	
2133		3233		5133	
2134		3234		5134	
2141	Valley	3241		5141	
2142		3242		5142	
2143	CDM	3243	RAM	5143	
2144		3244		5144	

Table 4.1. (Contd.)

Index Number	Reference Model	Index Number	Reference Model	Index Number	Reference Model
5211	SAI, DIFKIN (f)	6223	SAI, DIFKIN (f)	7234	
5212		6224		7241	
5213	SAI, DIFKIN (f)	6231		7242	
5214		6232		7243	
5221	SAI, DIFKIN (f)	6233		7244	
5222		6234		8111	
5223	SAI, DIFKIN (f)	6241	SAI, DIFKIN (f)	8112	
5224		6242		8113	
5231		6243	SAI, DIFKIN (f)	8114	
5232		6244		8121	
5233		7111		8122	
5234		7112		8123	
5241	SAI, DIFKIN (f)	7113		8124	
5242		7114		8131	
5243	SAI, DIFKIN (f)	7121		8132	
5244		7122		8133	
6111		7123		8134	
6112		7124		8141	
6113		7131		8142	
6114		7132		8143	
6121		7133		8144	
6122		7134		8211	
6123		7141		8212	
6124		7142		8213	STRAM
6131		7143		8214	STRAM
6132		7144		8221	
6133		7211		8222	
6134		7212		8223	
6141		7213	STRAM	8224	
6142		7214	STRAM	8231	
6143		7221		8232	
6144		7222		8233	
6211	SAI, DIFKIN (f)	7223		8234	
6212		7224		8241	
6213	STRAM,SAI,DIFKIN(f,g)	7231		8242	
6214	STRAM	7232		8243	
6221	SAI, DIFKIN (f)	7233		8244	
6222					

Note: References to users' guides for each suggested reference model can be found in Appendix B.

[a] For applications for which no reference is listed, the user should compare his model with another applicable simulation model.

[b] Valley should be used when the receptor height exceeds the stack height (plume impaction case).

[c] CRSTER should be used only when receptor is below stack height.

Table 4.1 (Contd.)

[d]HIWAY is used for analysis of single highway link, APRAC for urban highway systems.

[e]Choose RAM for a combination of source types, APRAC for multiple line sources (highway systems).

[f]SAI is a regional grid model; DIFKIN is a trajectory model. Which to choose as a reference model depends upon aspects of the user's application not classified in the tree. SAI treats only photochemical smog. DIFKIN is also designed to treat photochemical smog, but provision is made for user-specification of an arbitrary chemical mechanism involving arbitrary, user-defined chemical species. Area sources may require other than emission data for preprocessor or preprocessing by user in both models.

[g]STRAM allows treatments of other than photochemical reactions. If the interest is in photochemistry choose SAI or DIFKIN.

[h]CRSTER assumes all sources are located at the same point. For a single source with multiple stacks, where this is a reasonable approximation, choose CRSTER rather than CDM as the reference model.

[i]CRSTER assumes all sources are located at the same point. For a single source with multiple stacks, where this is a reasonable approximation, choose CRSTER rather than RAM as the reference model.

4.5 REVIEW AND MODIFICATION OF IMPORTANCE RATINGS

As indicated in Section 2.1, the importance rating of an element is a measure of the importance of that element as a factor in determining atmospheric pollutant concentrations in the application of interest. The importance ratings are used as weighting factors in combining the individual element-by-element comparisons of the study and reference models into a final comparative evaluation.

Tables 4.2-4.13 at the end of this section give the importance rating of each element in each of the indexed applications. Brief discussions of these ratings may be found in Appendix A.9. At this point in the methodology, the user should review the importance ratings corresponding to the application index previously constructed and determine the need for modification of these ratings in the specific situation of interest.

Three types of situations arise that may justify modifying the importance ratings given in the tables at the end of this section:

- When the particular circumstances being modeled, or the particular interests of the user indicate that an element is either more or less important than the tabulated entry,

- When a particular element is of such overwhelming interest or importance that its treatment is critical to the application, and

- When a particular element has no bearing on the application and hence is irrelevant.

In the first situation, the decision to change a rating depends very much on the particular situation involved and the particular interests of the user. The user should review these ratings considering those aspects of the specific application not considered in the Application Tree. If necessary, the user should modify these ratings. Such changes should be made only after thoughtful reflection and consultation with an expert. For example, the user may be interested in estimating the amount of SO_2 removed by deposition in a region where deposition would usually be small and hence rated as of LOW importance. Given this particular interest, the importance rating for physical removal might be changed from LOW to MEDIUM or HIGH with the concurrence of an expert. The choice between MEDIUM and HIGH must be left to the user's discretion and depends upon how much weight it is felt that deposition deserves relative to the other application elements.

It may also be desirable to give one element exceptional weight in the technical evaluation. In this case, the element is designated CRITICAL to the overall technical evaluation. The comparison of the way that element is treated is weighted even more heavily than that of an element of HIGH importance. The CRITICAL designation should be used sparingly and then only when the user has a very strong interest in an effect associated specifically with that element. As an example, if it is desired to pick one of several alternative sites for a new source so as to give the "best" resulting air pollution estimates, source-receptor relationship might be treated as a CRITICAL element. In this example, the user needs to determine the differences in pollutant concentrations as the horizontal location of the source changes, perhaps by only relatively small amounts. Only models that handle horizontal location in a detailed manner would be acceptable. However, horizontal location is only one aspect of the application element "source-receptor relationship." In such situations, the user must identify clearly which aspect is critical in making the comparison between two models.

Lastly, some elements may be IRRELEVANT in the application of interest and should be so designated. These elements are not considered at all in the technical comparison. Examples of irrelevant elements include chemistry and reaction mechanism for primary conservative pollutants and physical removal in situations for which dry deposition and precipitation scavenging are unimportant. Although it may appear a rather simple matter to decide whether a given element is irrelevant, the user must be cautioned against the indiscriminate designation of irrelevant elements. Except in clear-cut instances such as the examples given above, most elements will have at least some LOW importance to the application and may need to be considered in cases where ambiguity exists. Irrelevant elements, however, are never considered in the comparison under any circumstances.

It bears repeating that changes in the importance ratings and especially the designation of an application element as CRITICAL should be undertaken only with expert advice and a firm conviction that the specific situation to be simulated clearly dictates such changes. Otherwise, the uniformity of evaluation that this workbook can provide is nullified. At most, no more than one or two changes in the tabulated importance ratings or a single critical designation, if any, should be made.

TABLES 4.2-4.13 - IMPORTANCE RATINGS

These ratings are based on the relative importance of each element to each class of applications as defined by the branches of the Application Tree.

For an interpretation of the Application Index as it applies to each table, see Fig. 3.1.

Brief discussions of these ratings are contained in Appendix A.9.

Table 4.2. Importance Ratings for Source-Receptor Relationship

1111	HIGH	3113	HIGH	5121	HIGH	7123	HIGH
1112	MEDIUM	3114	MEDIUM	5122	MEDIUM	7124	MEDIUM
1113	HIGH	3121	HIGH	5123	HIGH	7131	HIGH
1114	MEDIUM	3122	MEDIUM	5124	MEDIUM	7132	HIGH
1121	HIGH	3123	HIGH	5131	HIGH	7133	HIGH
1122	MEDIUM	3124	MEDIUM	5132	MEDIUM	7134	MEDIUM
1123	MEDIUM	3131	HIGH	5133	HIGH	7141	HIGH
1124	MEDIUM	3132	MEDIUM	5134	MEDIUM	7142	MEDIUM
1131	HIGH	3133	HIGH	5141	HIGH	7143	HIGH
1132	MEDIUM	3134	MEDIUM	5142	MEDIUM	7144	MEDIUM
1133	HIGH	3141	HIGH	5143	MEDIUM	7211	HIGH
1134	MEDIUM	3142	MEDIUM	5144	MEDIUM	7212	HIGH
1141	MEDIUM	3143	MEDIUM	5211	HIGH	7213	HIGH
1142	MEDIUM	3144	MEDIUM	5212	HIGH	7214	HIGH
1143	MEDIUM	3211	HIGH	5213	HIGH	7221	HIGH
1144	MEDIUM	3212	HIGH	5214	MEDIUM	7222	HIGH
1211	HIGH	3213	HIGH	5221	HIGH	7223	HIGH
1212	MEDIUM	3214	MEDIUM	5222	MEDIUM	7224	MEDIUM
1213	HIGH	3221	HIGH	5223	HIGH	7231	HIGH
1214	MEDIUM	3222	MEDIUM	5224	MEDIUM	7232	HIGH
1221	HIGH	3223	HIGH	5231	HIGH	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	HIGH	7234	HIGH
1223	HIGH	3231	HIGH	5233	HIGH	7241	HIGH
1224	MEDIUM	3232	HIGH	5234	MEDIUM	7242	MEDIUM
1231	HIGH	3233	HIGH	5241	HIGH	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	MEDIUM	7244	MEDIUM
1233	HIGH	3241	HIGH	5243	HIGH	8111	HIGH
1234	MEDIUM	3242	MEDIUM	5244	MEDIUM	8112	HIGH
1241	HIGH	3243	HIGH	6111	HIGH	8113	HIGH
1242	MEDIUM	3244	MEDIUM	6112	HIGH	8114	HIGH
1243	MEDIUM	4111	HIGH	6113	HIGH	8121	HIGH
1244	MEDIUM	4112	HIGH	6114	HIGH	8122	HIGH
2111	HIGH	4113	HIGH	6121	HIGH	8123	HIGH
2112	HIGH	4114	MEDIUM	6122	HIGH	8124	MEDIUM
2113	HIGH	4121	HIGH	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	MEDIUM	8132	HIGH
2121	HIGH	4123	HIGH	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	HIGH	4131	HIGH	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	HIGH	6134	HIGH	8142	MEDIUM
2131	HIGH	4133	HIGH	6141	HIGH	8143	HIGH
2132	HIGH	4134	MEDIUM	6142	MEDIUM	8144	MEDIUM
2133	HIGH	4141	HIGH	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	MEDIUM	8212	HIGH
2141	HIGH	4143	HIGH	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	HIGH	4211	HIGH	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	HIGH	6214	HIGH	8222	HIGH
2211	HIGH	4213	HIGH	6221	HIGH	8223	HIGH
2212	HIGH	4214	HIGH	6222	HIGH	8224	HIGH
2213	HIGH	4221	HIGH	6223	HIGH	8231	HIGH
2214	HIGH	4222	HIGH	6224	HIGH	8232	HIGH
2221	HIGH	4223	HIGH	6231	HIGH	8233	HIGH
2222	HIGH	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	HIGH	4231	HIGH	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	HIGH	6234	HIGH	8242	HIGH
2231	HIGH	4233	HIGH	6241	HIGH	8243	HIGH
2232	HIGH	4234	HIGH	6242	HIGH	8244	MEDIUM
2233	HIGH	4241	HIGH	6243	HIGH		
2234	HIGH	4242	MEDIUM	6244	MEDIUM		
2241	HIGH	4243	HIGH	7111	HIGH		
2242	MEDIUM	4244	MEDIUM	7112	HIGH		
2243	HIGH	5111	HIGH	7113	HIGH		
2244	MEDIUM	5112	MEDIUM	7114	MEDIUM		
3111	HIGH	5113	HIGH	7121	HIGH		
3112	MEDIUM	5114	MEDIUM	7122	MEDIUM		

Table 4.3. Importance Ratings for Emission Rate

1111	MEDIUM	3113	MEDIUM	5121	HIGH	7123	HIGH
1112	MEDIUM	3114	MEDIUM	5122	MEDIUM	7124	MEDIUM
1113	MEDIUM	3121	MEDIUM	5123	HIGH	7131	HIGH
1114	MEDIUM	3122	MEDIUM	5124	MEDIUM	7132	MEDIUM
1121	MEDIUM	3123	MEDIUM	5131	HIGH	7133	HIGH
1122	MEDIUM	3124	MEDIUM	5132	MEDIUM	7134	MEDIUM
1123	MEDIUM	3131	MEDIUM	5133	HIGH	7141	MEDIUM
1124	MEDIUM	3132	MEDIUM	5134	MEDIUM	7142	MEDIUM
1131	MEDIUM	3133	MEDIUM	5141	MEDIUM	7143	MEDIUM
1132	MEDIUM	3134	MEDIUM	5142	MEDIUM	7144	MEDIUM
1133	MEDIUM	3141	MEDIUM	5143	MEDIUM	7211	HIGH
1134	MEDIUM	3142	MEDIUM	5144	MEDIUM	7212	HIGH
1141	MEDIUM	3143	MEDIUM	5211	HIGH	7213	HIGH
1142	MEDIUM	3144	MEDIUM	5212	HIGH	7214	HIGH
1143	MEDIUM	3211	HIGH	5213	HIGH	7221	HIGH
1144	MEDIUM	3212	MEDIUM	5214	HIGH	7222	HIGH
1211	HIGH	3213	HIGH	5221	HIGH	7223	HIGH
1212	MEDIUM	3214	MEDIUM	5222	HIGH	7224	HIGH
1213	HIGH	3221	HIGH	5223	HIGH	7231	HIGH
1214	MEDIUM	3222	MEDIUM	5224	HIGH	7232	HIGH
1221	HIGH	3223	HIGH	5231	HIGH	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	HIGH	7234	HIGH
1223	HIGH	3231	HIGH	5233	HIGH	7241	HIGH
1224	MEDIUM	3232	MEDIUM	5234	HIGH	7242	MEDIUM
1231	HIGH	3233	HIGH	5241	HIGH	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	MEDIUM	7244	MEDIUM
1233	HIGH	3241	MEDIUM	5243	HIGH	8111	HIGH
1234	MEDIUM	3242	MEDIUM	5244	MEDIUM	8112	HIGH
1241	MEDIUM	3243	MEDIUM	6111	HIGH	8113	HIGH
1242	MEDIUM	3244	MEDIUM	6112	HIGH	8114	HIGH
1243	MEDIUM	4111	HIGH	6113	HIGH	8121	HIGH
1244	MEDIUM	4112	MEDIUM	6114	HIGH	8122	HIGH
2111	HIGH	4113	HIGH	6121	HIGH	8123	HIGH
2112	MEDIUM	4114	MEDIUM	6122	HIGH	8124	HIGH
2113	HIGH	4121	HIGH	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	HIGH	8132	HIGH
2121	HIGH	4123	HIGH	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	HIGH	4131	HIGH	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	MEDIUM	6134	HIGH	8142	MEDIUM
2131	HIGH	4133	HIGH	6141	HIGH	8143	HIGH
2132	MEDIUM	4134	MEDIUM	6142	MEDIUM	8144	MEDIUM
2133	HIGH	4141	MEDIUM	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	MEDIUM	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	MEDIUM	4211	HIGH	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	HIGH	6214	HIGH	8222	HIGH
2211	HIGH	4213	HIGH	6221	HIGH	8223	HIGH
2212	HIGH	4214	HIGH	6222	HIGH	8224	HIGH
2213	HIGH	4221	HIGH	6223	HIGH	8231	HIGH
2214	HIGH	4222	HIGH	6224	HIGH	8232	HIGH
2221	HIGH	4223	HIGH	6231	HIGH	8233	HIGH
2222	HIGH	4224	HIGH	6232	HIGH	8234	HIGH
2223	HIGH	4231	HIGH	6233	HIGH	8241	HIGH
2224	HIGH	4232	HIGH	6234	HIGH	8242	HIGH
2231	HIGH	4233	HIGH	6241	HIGH	8243	HIGH
2232	HIGH	4234	HIGH	6242	HIGH	8244	HIGH
2233	HIGH	4241	HIGH	6243	HIGH		
2234	HIGH	4242	MEDIUM	6244	HIGH		
2241	HIGH	4243	HIGH	7111	HIGH		
2242	MEDIUM	4244	MEDIUM	7112	MEDIUM		
2243	HIGH	5111	HIGH	7113	HIGH		
2244	MEDIUM	5112	MEDIUM	7114	MEDIUM		
3111	MEDIUM	5113	HIGH	7121	HIGH		
3112	MEDIUM	5114	MEDIUM	7122	MEDIUM		

Table 4.4. Importance Ratings for Chemical Composition of Emissions[a]

1111	LOW	3113	LOW	5121	MEDIUM	7123	MEDIUM
1112	LOW	3114	LOW	5122	MEDIUM	7124	MEDIUM
1113	LOW	3121	LOW	5123	MEDIUM	7131	MEDIUM
1114	LOW	3122	LOW	5124	MEDIUM	7132	MEDIUM
1121	LOW	3123	LOW	5131	MEDIUM	7133	MEDIUM
1122	LOW	3124	LOW	5132	MEDIUM	7134	MEDIUM
1123	LOW	3131	LOW	5133	MEDIUM	7141	MEDIUM
1124	LOW	3132	LOW	5134	MEDIUM	7142	MEDIUM
1131	LOW	3133	LOW	5141	MEDIUM	7143	MEDIUM
1132	LOW	3134	LOW	5142	MEDIUM	7144	MEDIUM
1133	LOW	3141	LOW	5143	MEDIUM	7211	MEDIUM
1134	LOW	3142	LOW	5144	MEDIUM	7212	MEDIUM
1141	LOW	3143	LOW	5211	MEDIUM	7213	MEDIUM
1142	LOW	3144	LOW	5212	MEDIUM	7214	MEDIUM
1143	LOW	3211	LOW	5213	MEDIUM	7221	MEDIUM
1144	LOW	3212	LOW	5214	MEDIUM	7222	MEDIUM
1211	LOW	3213	LOW	5221	MEDIUM	7223	MEDIUM
1212	LOW	3214	LOW	5222	MEDIUM	7224	MEDIUM
1213	LOW	3221	LOW	5223	MEDIUM	7231	MEDIUM
1214	LOW	3222	LOW	5224	MEDIUM	7232	MEDIUM
1221	LOW	3223	LOW	5231	MEDIUM	7233	MEDIUM
1222	LOW	3224	LOW	5232	MEDIUM	7234	MEDIUM
1223	LOW	3231	LOW	5233	MEDIUM	7241	MEDIUM
1224	LOW	3232	LOW	5234	MEDIUM	7242	MEDIUM
1231	LOW	3233	LOW	5241	MEDIUM	7243	MEDIUM
1232	LOW	3234	LOW	5242	MEDIUM	7244	MEDIUM
1233	LOW	3241	LOW	5243	MEDIUM	8111	HIGH
1234	LOW	3242	LOW	5244	MEDIUM	8112	HIGH
1241	LOW	3243	LOW	6111	HIGH	8113	HIGH
1242	LOW	3244	LOW	6112	HIGH	8114	HIGH
1243	LOW	4111	MEDIUM	6113	HIGH	8121	HIGH
1244	LOW	4112	MEDIUM	6114	HIGH	8122	HIGH
2111	MEDIUM	4113	MEDIUM	6121	HIGH	8123	HIGH
2112	MEDIUM	4114	MEDIUM	6122	HIGH	8124	HIGH
2113	MEDIUM	4121	MEDIUM	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	HIGH	8132	HIGH
2121	MEDIUM	4123	MEDIUM	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	MEDIUM	4131	MEDIUM	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	MEDIUM	6134	HIGH	8142	HIGH
2131	MEDIUM	4133	MEDIUM	6141	HIGH	8143	HIGH
2132	MEDIUM	4134	MEDIUM	6142	HIGH	8144	HIGH
2133	MEDIUM	4141	MEDIUM	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	HIGH	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	MEDIUM	4211	MEDIUM	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	MEDIUM	6214	HIGH	8222	HIGH
2211	MEDIUM	4213	MEDIUM	6221	HIGH	8223	HIGH
2212	MEDIUM	4214	MEDIUM	6222	HIGH	8224	HIGH
2213	MEDIUM	4221	MEDIUM	6223	HIGH	8231	HIGH
2214	MEDIUM	4222	MEDIUM	6224	HIGH	8232	HIGH
2221	MEDIUM	4223	MEDIUM	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	MEDIUM	4231	MEDIUM	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	MEDIUM	6234	HIGH	8242	HIGH
2231	MEDIUM	4233	MEDIUM	6241	HIGH	8243	HIGH
2232	MEDIUM	4234	MEDIUM	6242	HIGH	8244	HIGH
2233	MEDIUM	4241	MEDIUM	6243	HIGH		
2234	MEDIUM	4242	MEDIUM	6244	HIGH		
2241	MEDIUM	4243	MEDIUM	7111	MEDIUM		
2242	MEDIUM	4244	MEDIUM	7112	MEDIUM		
2243	MEDIUM	5111	MEDIUM	7113	MEDIUM		
2244	MEDIUM	5112	MEDIUM	7114	MEDIUM		
3111	LOW	5113	MEDIUM	7121	MEDIUM		
3112	LOW	5114	MEDIUM	7122	MEDIUM		

[a]When a particulate size distribution is required, consult an expert to determine the importance of this application element.

Table 4.5. Importance Ratings for Plume Behavior

1111	HIGH	3113	HIGH	5121	MEDIUM	7123	MEDIUM
1112	MEDIUM	3114	MEDIUM	5122	LOW	7124	LOW
1113	MEDIUM	3121	MEDIUM	5123	MEDIUM	7131	HIGH
1114	LOW	3122	LOW	5124	LOW	7132	MEDIUM
1121	MEDIUM	3123	MEDIUM	5131	MEDIUM	7133	MEDIUM
1122	LOW	3124	LOW	5132	LOW	7134	LOW
1123	MEDIUM	3131	HIGH	5133	MEDIUM	7141	HIGH
1124	LOW	3132	MEDIUM	5134	LOW	7142	MEDIUM
1131	MEDIUM	3133	MEDIUM	5141	MEDIUM	7143	MEDIUM
1132	LOW	3134	LOW	5142	LOW	7144	LOW
1133	MEDIUM	3141	HIGH	5143	MEDIUM	7211	HIGH
1134	LOW	3142	MEDIUM	5144	LOW	7212	MEDIUM
1141	MEDIUM	3143	MEDIUM	5211	HIGH	7213	HIGH
1142	LOW	3144	LOW	5212	MEDIUM	7214	MEDIUM
1143	MEDIUM	3211	HIGH	5213	HIGH	7221	HIGH
1144	LOW	3212	MEDIUM	5214	MEDIUM	7222	MEDIUM
1211	HIGH	3213	HIGH	5221	HIGH	7223	HIGH
1212	MEDIUM	3214	MEDIUM	5222	MEDIUM	7224	MEDIUM
1213	HIGH	3221	HIGH	5223	MEDIUM	7231	HIGH
1214	MEDIUM	3222	MEDIUM	5224	LOW	7232	MEDIUM
1221	HIGH	3223	HIGH	5231	HIGH	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	MEDIUM	7234	MEDIUM
1223	MEDIUM	3231	HIGH	5233	HIGH	7241	HIGH
1224	LOW	3232	MEDIUM	5234	MEDIUM	7242	MEDIUM
1231	HIGH	3233	HIGH	5241	HIGH	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	MEDIUM	7244	MEDIUM
1233	HIGH	3241	HIGH	5243	HIGH	8111	HIGH
1234	MEDIUM	3242	MEDIUM	5244	MEDIUM	8112	MEDIUM
1241	HIGH	3243	HIGH	6111	HIGH	8113	HIGH
1242	MEDIUM	3244	MEDIUM	6112	MEDIUM	8114	MEDIUM
1243	HIGH	4111	HIGH	6113	MEDIUM	8121	MEDIUM
1244	MEDIUM	4112	MEDIUM	6114	LOW	8122	LOW
2111	HIGH	4113	HIGH	6121	MEDIUM	8123	MEDIUM
2112	MEDIUM	4114	MEDIUM	6122	LOW	8124	LOW
2113	MEDIUM	4121	MEDIUM	6123	MEDIUM	8131	HIGH
2114	LOW	4122	LOW	6124	LOW	8132	MEDIUM
2121	MEDIUM	4123	MEDIUM	6131	MEDIUM	8133	MEDIUM
2122	LOW	4124	LOW	6132	LOW	8134	LOW
2123	MEDIUM	4131	HIGH	6133	MEDIUM	8141	HIGH
2124	LOW	4132	MEDIUM	6134	LOW	8142	MEDIUM
2131	MEDIUM	4133	MEDIUM	6141	MEDIUM	8143	MEDIUM
2132	LOW	4134	LOW	6142	LOW	8144	LOW
2133	MEDIUM	4141	HIGH	6143	MEDIUM	8211	HIGH
2134	LOW	4142	MEDIUM	6144	LOW	8212	MEDIUM
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	LOW	4144	LOW	6212	MEDIUM	8214	MEDIUM
2143	MEDIUM	4211	HIGH	6213	HIGH	8221	HIGH
2144	LOW	4212	MEDIUM	6214	MEDIUM	8222	MEDIUM
2211	HIGH	4213	HIGH	6221	HIGH	8223	HIGH
2212	MEDIUM	4214	MEDIUM	6222	MEDIUM	8224	MEDIUM
2213	HIGH	4221	HIGH	6223	MEDIUM	8231	HIGH
2214	MEDIUM	4222	MEDIUM	6224	LOW	8232	MEDIUM
2221	HIGH	4223	HIGH	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	MEDIUM	8234	MEDIUM
2223	MEDIUM	4231	HIGH	6233	HIGH	8241	HIGH
2224	LOW	4232	MEDIUM	6234	MEDIUM	8242	MEDIUM
2231	HIGH	4233	HIGH	6241	HIGH	8243	HIGH
2232	MEDIUM	4234	MEDIUM	6242	MEDIUM	8244	MEDIUM
2233	HIGH	4241	HIGH	6243	HIGH		
2234	MEDIUM	4242	MEDIUM	6244	MEDIUM		
2241	HIGH	4243	HIGH	7111	HIGH		
2242	MEDIUM	4244	MEDIUM	7112	MEDIUM		
2243	HIGH	5111	HIGH	7113	HIGH		
2244	MEDIUM	5112	MEDIUM	7114	MEDIUM		
3111	HIGH	5113	MEDIUM	7121	MEDIUM		
3112	MEDIUM	5114	LOW	7122	LOW		

Table 4.6. Importance Ratings for Horizontal Wind Field

1111	MEDIUM	3113	MEDIUM	5121	MEDIUM	7123	MEDIUM
1112	HIGH	3114	HIGH	5122	HIGH	7124	HIGH
1113	MEDIUM	3121	MEDIUM	5123	MEDIUM	7131	HIGH
1114	HIGH	3122	HIGH	5124	HIGH	7132	HIGH
1121	MEDIUM	3123	MEDIUM	5131	HIGH	7133	MEDIUM
1122	HIGH	3124	HIGH	5132	HIGH	7134	HIGH
1123	MEDIUM	3131	MEDIUM	5133	MEDIUM	7141	MEDIUM
1124	HIGH	3132	HIGH	5134	HIGH	7142	HIGH
1131	MEDIUM	3133	MEDIUM	5141	MEDIUM	7143	MEDIUM
1132	HIGH	3134	HIGH	5142	HIGH	7144	HIGH
1133	MEDIUM	3141	MEDIUM	5143	MEDIUM	7211	HIGH
1134	HIGH	3142	HIGH	5144	HIGH	7212	HIGH
1141	MEDIUM	3143	MEDIUM	5211	HIGH	7213	HIGH
1142	HIGH	3144	HIGH	5212	HIGH	7214	HIGH
1143	MEDIUM	3211	HIGH	5213	HIGH	7221	HIGH
1144	HIGH	3212	HIGH	5214	HIGH	7222	HIGH
1211	HIGH	3213	HIGH	5221	HIGH	7223	MEDIUM
1212	HIGH	3214	HIGH	5222	HIGH	7224	HIGH
1213	HIGH	3221	HIGH	5223	MEDIUM	7231	HIGH
1214	HIGH	3222	HIGH	5224	HIGH	7232	HIGH
1221	HIGH	3223	MEDIUM	5231	HIGH	7233	HIGH
1222	HIGH	3224	HIGH	5232	HIGH	7234	HIGH
1223	MEDIUM	3231	HIGH	5233	HIGH	7241	HIGH
1224	HIGH	3232	HIGH	5234	HIGH	7242	HIGH
1231	HIGH	3233	MEDIUM	5241	HIGH	7243	MEDIUM
1232	HIGH	3234	HIGH	5242	HIGH	7244	HIGH
1233	MEDIUM	3241	HIGH	5243	MEDIUM	8111	HIGH
1234	HIGH	3242	HIGH	5244	HIGH	8112	HIGH
1241	HIGH	3243	MEDIUM	6111	HIGH	8113	MEDIUM
1242	HIGH	3244	HIGH	6112	HIGH	8114	HIGH
1243	MEDIUM	4111	HIGH	6113	MEDIUM	8121	HIGH
1244	HIGH	4112	HIGH	6114	HIGH	8122	HIGH
2111	HIGH	4113	MEDIUM	6121	HIGH	8123	MEDIUM
2112	HIGH	4114	HIGH	6122	HIGH	8124	HIGH
2113	MEDIUM	4121	MEDIUM	6123	MEDIUM	8131	HIGH
2114	HIGH	4122	HIGH	6124	HIGH	8132	HIGH
2121	MEDIUM	4123	MEDIUM	6131	HIGH	8133	MEDIUM
2122	HIGH	4124	HIGH	6132	HIGH	8134	HIGH
2123	MEDIUM	4131	HIGH	6133	MEDIUM	8141	HIGH
2124	HIGH	4132	HIGH	6134	HIGH	8142	HIGH
2131	HIGH	4133	MEDIUM	6141	HIGH	8143	MEDIUM
2132	HIGH	4134	HIGH	6142	HIGH	8144	HIGH
2133	MEDIUM	4141	MEDIUM	6143	MEDIUM	8211	HIGH
2134	HIGH	4142	HIGH	6144	HIGH	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	HIGH	4144	HIGH	6212	HIGH	8214	HIGH
2143	MEDIUM	4211	HIGH	6213	HIGH	8221	HIGH
2144	HIGH	4212	HIGH	6214	HIGH	8222	HIGH
2211	HIGH	4213	HIGH	6221	HIGH	8223	HIGH
2212	HIGH	4214	HIGH	6222	HIGH	8224	HIGH
2213	HIGH	4221	HIGH	6223	HIGH	8231	HIGH
2214	HIGH	4222	HIGH	6224	HIGH	8232	HIGH
2221	HIGH	4223	MEDIUM	6231	HIGH	8233	HIGH
2222	HIGH	4224	HIGH	6232	HIGH	8234	HIGH
2223	MEDIUM	4231	HIGH	6233	HIGH	8241	HIGH
2224	HIGH	4232	HIGH	6234	HIGH	8242	HIGH
2231	HIGH	4233	HIGH	6241	HIGH	8243	HIGH
2232	HIGH	4234	HIGH	6242	HIGH	8244	HIGH
2233	HIGH	4241	HIGH	6243	HIGH		
2234	HIGH	4242	HIGH	6244	HIGH		
2241	HIGH	4243	MEDIUM	7111	HIGH		
2242	HIGH	4244	HIGH	7112	HIGH		
2243	MEDIUM	5111	HIGH	7113	MEDIUM		
2244	HIGH	5112	HIGH	7114	HIGH		
3111	MEDIUM	5113	MEDIUM	7121	MEDIUM		
3112	HIGH	5114	HIGH	7122	HIGH		

Table 4.7. Importance Ratings for Vertical Wind Field

1111	HIGH	3113	LOW	5121	HIGH	7123	LOW
1112	MEDIUM	3114	LOW	5122	MEDIUM	7124	LOW
1113	LOW	3121	HIGH	5123	LOW	7131	HIGH
1114	LOW	3122	MEDIUM	5124	LOW	7132	MEDIUM
1121	HIGH	3123	LOW	5131	HIGH	7133	LOW
1122	MEDIUM	3124	LOW	5132	MEDIUM	7134	LOW
1123	LOW	3131	HIGH	5133	LOW	7141	HIGH
1124	LOW	3132	MEDIUM	5134	LOW	7142	MEDIUM
1131	HIGH	3133	LOW	5141	HIGH	7143	LOW
1132	MEDIUM	3134	LOW	5142	MEDIUM	7144	LOW
1133	LOW	3141	HIGH	5143	LOW	7211	HIGH
1134	LOW	3142	MEDIUM	5144	LOW	7212	HIGH
1141	HIGH	3143	LOW	5211	HIGH	7213	LOW
1142	MEDIUM	3144	LOW	5212	HIGH	7214	LOW
1143	LOW	3211	HIGH	5213	LOW	7221	HIGH
1144	LOW	3212	MEDIUM	5214	LOW	7222	HIGH
1211	HIGH	3213	LOW	5221	HIGH	7223	LOW
1212	MEDIUM	3214	LOW	5222	HIGH	7224	LOW
1213	LOW	3221	HIGH	5223	LOW	7231	HIGH
1214	LOW	3222	MEDIUM	5224	LOW	7232	HIGH
1221	HIGH	3223	LOW	5231	HIGH	7233	LOW
1222	MEDIUM	3224	LOW	5232	HIGH	7234	LOW
1223	LOW	3231	HIGH	5233	LOW	7241	HIGH
1224	LOW	3232	MEDIUM	5234	LOW	7242	HIGH
1231	HIGH	3233	LOW	5241	HIGH	7243	LOW
1232	MEDIUM	3234	LOW	5242	HIGH	7244	LOW
1233	LOW	3241	HIGH	5243	LOW	8111	HIGH
1234	LOW	3242	MEDIUM	5244	LOW	8112	HIGH
1241	HIGH	3243	LOW	6111	HIGH	8113	LOW
1242	MEDIUM	3244	LOW	6112	HIGH	8114	LOW
1243	LOW	4111	HIGH	6113	LOW	8121	HIGH
1244	LOW	4112	MEDIUM	6114	LOW	8122	HIGH
2111	HIGH	4113	LOW	6121	HIGH	8123	LOW
2112	MEDIUM	4114	LOW	6122	HIGH	8124	LOW
2113	LOW	4121	HIGH	6123	LOW	8131	HIGH
2114	LOW	4122	MEDIUM	6124	LOW	8132	HIGH
2121	HIGH	4123	LOW	6131	HIGH	8133	LOW
2122	MEDIUM	4124	LOW	6132	HIGH	8134	LOW
2123	LOW	4131	HIGH	6133	LOW	8141	HIGH
2124	LOW	4132	MEDIUM	6134	LOW	8142	HIGH
2131	HIGH	4133	LOW	6141	HIGH	8143	LOW
2132	MEDIUM	4134	LOW	6142	HIGH	8144	LOW
2133	LOW	4141	HIGH	6143	LOW	8211	HIGH
2134	LOW	4142	MEDIUM	6144	LOW	8212	HIGH
2141	HIGH	4143	LOW	6211	HIGH	8213	LOW
2142	MEDIUM	4144	LOW	6212	HIGH	8214	LOW
2143	LOW	4211	HIGH	6213	LOW	8221	HIGH
2144	LOW	4212	HIGH	6214	LOW	8222	HIGH
2211	HIGH	4213	LOW	6221	HIGH	8223	LOW
2212	HIGH	4214	LOW	6222	HIGH	8224	LOW
2213	LOW	4221	HIGH	6223	LOW	8231	HIGH
2214	LOW	4222	HIGH	6224	LOW	8232	HIGH
2221	HIGH	4223	LOW	6231	HIGH	8233	LOW
2222	HIGH	4224	LOW	6232	HIGH	8234	LOW
2223	LOW	4231	HIGH	6233	LOW	8241	HIGH
2224	LOW	4232	HIGH	6234	LOW	8242	HIGH
2231	HIGH	4233	LOW	6241	HIGH	8243	LOW
2232	HIGH	4234	LOW	6242	HIGH	8244	LOW
2233	LOW	4241	HIGH	6243	LOW		
2234	LOW	4242	HIGH	6244	LOW		
2241	HIGH	4243	LOW	7111	HIGH		
2242	HIGH	4244	LOW	7112	MEDIUM		
2243	LOW	5111	HIGH	7113	LOW		
2244	LOW	5112	MEDIUM	7114	LOW		
3111	HIGH	5113	LOW	7121	HIGH		
3112	MEDIUM	5114	LOW	7122	MEDIUM		

Table 4.8. Importance Ratings for Horizontal Dispersion

1111	MEDIUM	3113	HIGH	5121	MEDIUM	7123	HIGH
1112	MEDIUM	3114	MEDIUM	5122	MEDIUM	7124	MEDIUM
1113	MEDIUM	3121	MEDIUM	5123	MEDIUM	7131	HIGH
1114	MEDIUM	3122	MEDIUM	5124	MEDIUM	7132	MEDIUM
1121	MEDIUM	3123	MEDIUM	5131	HIGH	7133	HIGH
1122	MEDIUM	3124	MEDIUM	5132	MEDIUM	7134	MEDIUM
1123	MEDIUM	3131	MEDIUM	5133	HIGH	7141	HIGH
1124	MEDIUM	3132	MEDIUM	5134	MEDIUM	7142	MEDIUM
1131	MEDIUM	3133	MEDIUM	5141	HIGH	7143	HIGH
1132	MEDIUM	3134	MEDIUM	5142	MEDIUM	7144	MEDIUM
1133	MEDIUM	3141	MEDIUM	5143	HIGH	7211	HIGH
1134	MEDIUM	3142	MEDIUM	5144	MEDIUM	7212	HIGH
1141	MEDIUM	3143	MEDIUM	5211	HIGH	7213	HIGH
1142	MEDIUM	3144	MEDIUM	5212	HIGH	7214	HIGH
1143	MEDIUM	3211	HIGH	5213	HIGH	7221	HIGH
1144	MEDIUM	3212	HIGH	5214	HIGH	7222	HIGH
1211	HIGH	3213	HIGH	5221	HIGH	7223	HIGH
1212	MEDIUM	3214	HIGH	5222	MEDIUM	7224	HIGH
1213	HIGH	3221	HIGH	5223	HIGH	7231	HIGH
1214	MEDIUM	3222	MEDIUM	5224	MEDIUM	7232	HIGH
1221	MEDIUM	3223	HIGH	5231	HIGH	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	HIGH	7234	HIGH
1223	MEDIUM	3231	HIGH	5233	HIGH	7241	HIGH
1224	MEDIUM	3232	MEDIUM	5234	HIGH	7242	HIGH
1231	HIGH	3233	HIGH	5241	HIGH	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	HIGH	7244	HIGH
1233	HIGH	3241	HIGH	5243	HIGH	8111	HIGH
1234	MEDIUM	3242	MEDIUM	5244	HIGH	8112	HIGH
1241	HIGH	3243	HIGH	6111	HIGH	8113	HIGH
1242	MEDIUM	3244	MEDIUM	6112	HIGH	8114	HIGH
1243	HIGH	4111	HIGH	6113	HIGH	8121	HIGH
1244	MEDIUM	4112	MEDIUM	6114	HIGH	8122	MEDIUM
2111	HIGH	4113	HIGH	6121	HIGH	8123	HIGH
2112	MEDIUM	4114	MEDIUM	6122	MEDIUM	8124	MEDIUM
2113	HIGH	4121	MEDIUM	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	MEDIUM	8132	HIGH
2121	MEDIUM	4123	MEDIUM	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	MEDIUM	4131	HIGH	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	MEDIUM	6134	HIGH	8142	HIGH
2131	HIGH	4133	HIGH	6141	HIGH	8143	HIGH
2132	MEDIUM	4134	MEDIUM	6142	HIGH	8144	HIGH
2133	HIGH	4141	HIGH	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	HIGH	8212	HIGH
2141	HIGH	4143	HIGH	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	HIGH	4211	HIGH	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	HIGH	6214	HIGH	8222	HIGH
2211	HIGH	4213	HIGH	6221	HIGH	8223	HIGH
2212	HIGH	4214	HIGH	6222	HIGH	8224	HIGH
2213	HIGH	4221	HIGH	6223	HIGH	8231	HIGH
2214	HIGH	4222	MEDIUM	6224	HIGH	8232	HIGH
2221	HIGH	4223	HIGH	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	HIGH	4231	HIGH	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	HIGH	6234	HIGH	8242	HIGH
2231	HIGH	4233	HIGH	6241	HIGH	8243	HIGH
2232	HIGH	4234	HIGH	6242	HIGH	8244	HIGH
2233	HIGH	4241	HIGH	6243	HIGH		
2234	HIGH	4242	HIGH	6244	HIGH		
2241	HIGH	4243	HIGH	7111	HIGH		
2242	HIGH	4244	HIGH	7112	HIGH		
2243	HIGH	5111	HIGH	7113	HIGH		
2244	HIGH	5112	MEDIUM	7114	HIGH		
3111	HIGH	5113	HIGH	7121	HIGH		
3112	MEDIUM	5114	MEDIUM	7122	MEDIUM		

Table 4.9. Importance Ratings for Vertical Dispersion

1111	HIGH	3113	HIGH	5121	HIGH	7123	HIGH
1112	MEDIUM	3114	MEDIUM	5122	MEDIUM	7124	HIGH
1113	HIGH	3121	HIGH	5123	HIGH	7131	HIGH
1114	MEDIUM	3122	MEDIUM	5124	MEDIUM	7132	HIGH
1121	HIGH	3123	HIGH	5131	HIGH	7133	HIGH
1122	MEDIUM	3124	MEDIUM	5132	MEDIUM	7134	HIGH
1123	HIGH	3131	HIGH	5133	HIGH	7141	HIGH
1124	MEDIUM	3132	MEDIUM	5134	MEDIUM	7142	HIGH
1131	HIGH	3133	HIGH	5141	HIGH	7143	HIGH
1132	MEDIUM	3134	MEDIUM	5142	MEDIUM	7144	HIGH
1133	HIGH	3141	HIGH	5143	HIGH	7211	HIGH
1134	MEDIUM	3142	MEDIUM	5144	MEDIUM	7212	HIGH
1141	HIGH	3143	HIGH	5211	HIGH	7213	HIGH
1142	MEDIUM	3144	MEDIUM	5212	MEDIUM	7214	HIGH
1143	HIGH	3211	HIGH	5213	HIGH	7221	HIGH
1144	MEDIUM	3212	MEDIUM	5214	MEDIUM	7222	HIGH
1211	HIGH	3213	HIGH	5221	HIGH	7223	HIGH
1212	MEDIUM	3214	MEDIUM	5222	MEDIUM	7224	HIGH
1213	HIGH	3221	HIGH	5223	HIGH	7231	HIGH
1214	MEDIUM	3222	MEDIUM	5224	MEDIUM	7232	HIGH
1221	HIGH	3223	HIGH	5231	HIGH	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	MEDIUM	7234	HIGH
1223	HIGH	3231	HIGH	5233	HIGH	7241	HIGH
1224	MEDIUM	3232	MEDIUM	5234	MEDIUM	7242	HIGH
1231	HIGH	3233	HIGH	5241	HIGH	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	MEDIUM	7244	HIGH
1233	HIGH	3241	HIGH	5243	HIGH	8111	HIGH
1234	MEDIUM	3242	MEDIUM	5244	MEDIUM	8112	HIGH
1241	HIGH	3243	HIGH	6111	HIGH	8113	HIGH
1242	MEDIUM	3244	MEDIUM	6112	HIGH	8114	HIGH
1243	HIGH	4111	HIGH	6113	HIGH	8121	HIGH
1244	MEDIUM	4112	MEDIUM	6114	HIGH	8122	HIGH
2111	HIGH	4113	HIGH	6121	HIGH	8123	HIGH
2112	MEDIUM	4114	MEDIUM	6122	HIGH	8124	HIGH
2113	HIGH	4121	HIGH	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	HIGH	8132	HIGH
2121	HIGH	4123	HIGH	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	HIGH	4131	HIGH	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	MEDIUM	6134	HIGH	8142	HIGH
2131	HIGH	4133	HIGH	6141	HIGH	8143	HIGH
2132	MEDIUM	4134	MEDIUM	6142	HIGH	8144	HIGH
2133	HIGH	4141	HIGH	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	HIGH	8212	HIGH
2141	HIGH	4143	HIGH	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	HIGH	4211	HIGH	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	MEDIUM	6214	HIGH	8222	HIGH
2211	HIGH	4213	HIGH	6221	HIGH	8223	HIGH
2212	MEDIUM	4214	MEDIUM	6222	HIGH	8224	HIGH
2213	HIGH	4221	HIGH	6223	HIGH	8231	HIGH
2214	MEDIUM	4222	MEDIUM	6224	HIGH	8232	HIGH
2221	HIGH	4223	HIGH	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	HIGH	4231	HIGH	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	MEDIUM	6234	HIGH	8242	HIGH
2231	HIGH	4233	HIGH	6241	HIGH	8243	HIGH
2232	MEDIUM	4234	MEDIUM	6242	HIGH	8244	HIGH
2233	HIGH	4241	HIGH	6243	HIGH		
2234	MEDIUM	4242	MEDIUM	6244	HIGH		
2241	HIGH	4243	HIGH	7111	HIGH		
2242	MEDIUM	4244	MEDIUM	7112	HIGH		
2243	HIGH	5111	HIGH	7113	HIGH		
2244	MEDIUM	5112	MEDIUM	7114	HIGH		
3111	HIGH	5113	HIGH	7121	HIGH		
3112	MEDIUM	5114	MEDIUM	7122	HIGH		

Table 4.10. Importance Ratings for Chemistry and Reaction Mechanism

1111	LOW	3113	LOW	5121	MEDIUM	7123	MEDIUM
1112	LOW	3114	LOW	5122	MEDIUM	7124	MEDIUM
1113	LOW	3121	LOW	5123	MEDIUM	7131	MEDIUM
1114	LOW	3122	LOW	5124	MEDIUM	7132	MEDIUM
1121	LOW	3123	LOW	5131	MEDIUM	7133	MEDIUM
1122	LOW	3124	LOW	5132	MEDIUM	7134	MEDIUM
1123	LOW	3131	LOW	5133	MEDIUM	7141	MEDIUM
1124	LOW	3132	LOW	5134	MEDIUM	7142	MEDIUM
1131	LOW	3133	LOW	5141	MEDIUM	7143	MEDIUM
1132	LOW	3134	LOW	5142	MEDIUM	7144	MEDIUM
1133	LOW	3141	LOW	5143	MEDIUM	7211	MEDIUM
1134	LOW	3142	LOW	5144	MEDIUM	7212	MEDIUM
1141	LOW	3143	LOW	5211	MEDIUM	7213	MEDIUM
1142	LOW	3144	LOW	5212	MEDIUM	7214	MEDIUM
1143	LOW	3211	LOW	5213	MEDIUM	7221	MEDIUM
1144	LOW	3212	LOW	5214	MEDIUM	7222	MEDIUM
1211	LOW	3213	LOW	5221	MEDIUM	7223	MEDIUM
1212	LOW	3214	LOW	5222	MEDIUM	7224	MEDIUM
1213	LOW	3221	LOW	5223	MEDIUM	7231	MEDIUM
1214	LOW	3222	LOW	5224	MEDIUM	7232	MEDIUM
1221	LOW	3223	LOW	5231	MEDIUM	7233	MEDIUM
1222	LOW	3224	LOW	5232	MEDIUM	7234	MEDIUM
1223	LOW	3231	LOW	5233	MEDIUM	7241	MEDIUM
1224	LOW	3232	LOW	5234	MEDIUM	7242	MEDIUM
1231	LOW	3233	LOW	5241	MEDIUM	7243	MEDIUM
1232	LOW	3234	LOW	5242	MEDIUM	7244	MEDIUM
1233	LOW	3241	LOW	5243	MEDIUM	8111	HIGH
1234	LOW	3242	LOW	5244	MEDIUM	8112	HIGH
1241	LOW	3243	LOW	6111	HIGH	8113	HIGH
1242	LOW	3244	LOW	6112	HIGH	8114	HIGH
1243	LOW	4111	MEDIUM	6113	HIGH	8121	HIGH
1244	LOW	4112	MEDIUM	6114	HIGH	8122	HIGH
2111	MEDIUM	4113	MEDIUM	6121	HIGH	8123	HIGH
2112	MEDIUM	4114	MEDIUM	6122	HIGH	8124	HIGH
2113	MEDIUM	4121	MEDIUM	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	HIGH	8132	HIGH
2121	MEDIUM	4123	MEDIUM	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	MEDIUM	4131	MEDIUM	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	MEDIUM	6134	HIGH	8142	HIGH
2131	MEDIUM	4133	MEDIUM	6141	HIGH	8143	HIGH
2132	MEDIUM	4134	MEDIUM	6142	HIGH	8144	HIGH
2133	MEDIUM	4141	MEDIUM	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	HIGH	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	MEDIUM	4211	MEDIUM	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	MEDIUM	6214	HIGH	8222	HIGH
2211	MEDIUM	4213	MEDIUM	6221	HIGH	8223	HIGH
2212	MEDIUM	4214	MEDIUM	6222	HIGH	8224	HIGH
2213	MEDIUM	4221	MEDIUM	6223	HIGH	8231	HIGH
2214	MEDIUM	4222	MEDIUM	6224	HIGH	8232	HIGH
2221	MEDIUM	4223	MEDIUM	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	MEDIUM	4231	MEDIUM	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	MEDIUM	6234	HIGH	8242	HIGH
2231	MEDIUM	4233	MEDIUM	6241	HIGH	8243	HIGH
2232	MEDIUM	4234	MEDIUM	6242	HIGH	8244	HIGH
2233	MEDIUM	4241	MEDIUM	6243	HIGH		
2234	MEDIUM	4242	MEDIUM	6244	HIGH		
2241	MEDIUM	4243	MEDIUM	7111	MEDIUM		
2242	MEDIUM	4244	MEDIUM	7112	MEDIUM		
2243	MEDIUM	5111	MEDIUM	7113	MEDIUM		
2244	MEDIUM	5112	MEDIUM	7114	MEDIUM		
3111	LOW	5113	MEDIUM	7121	MEDIUM		
3112	LOW	5114	MEDIUM	7122	MEDIUM		

Table 4.11. Importance Ratings for Physical Removal Processes

1111	LOW	3113	MEDIUM	5121	LOW	7123	MEDIUM
1112	MEDIUM	3114	HIGH	5122	MEDIUM	7124	HIGH
1113	LOW	3121	HIGH	5123	LOW	7131	HIGH
1114	MEDIUM	3122	HIGH	5124	MEDIUM	7132	HIGH
1121	LOW	3123	MEDIUM	5131	LOW	7133	MEDIUM
1122	MEDIUM	3124	HIGH	5132	MEDIUM	7134	HIGH
1123	LOW	3131	HIGH	5133	LOW	7141	HIGH
1124	MEDIUM	3132	HIGH	5134	MEDIUM	7142	HIGH
1131	LOW	3133	MEDIUM	5141	LOW	7143	MEDIUM
1132	MEDIUM	3134	HIGH	5142	MEDIUM	7144	HIGH
1133	LOW	3141	HIGH	5143	LOW	7211	MEDIUM
1134	MEDIUM	3142	HIGH	5144	MEDIUM	7212	HIGH
1141	LOW	3143	MEDIUM	5211	LOW	7213	MEDIUM
1142	MEDIUM	3144	HIGH	5212	MEDIUM	7214	HIGH
1143	LOW	3211	MEDIUM	5213	LOW	7221	MEDIUM
1144	MEDIUM	3212	HIGH	5214	LOW	7222	HIGH
1211	LOW	3213	MEDIUM	5221	LOW	7223	MEDIUM
1212	MEDIUM	3214	HIGH	5222	MEDIUM	7224	HIGH
1213	LOW	3221	MEDIUM	5223	LOW	7231	MEDIUM
1214	LOW	3222	HIGH	5224	LOW	7232	HIGH
1221	LOW	3223	MEDIUM	5231	LOW	7233	MEDIUM
1222	MEDIUM	3224	HIGH	5232	MEDIUM	7234	HIGH
1223	LOW	3231	MEDIUM	5233	LOW	7241	MEDIUM
1224	LOW	3232	HIGH	5234	LOW	7242	HIGH
1231	LOW	3233	MEDIUM	5241	LOW	7243	MEDIUM
1232	MEDIUM	3234	HIGH	5242	MEDIUM	7244	HIGH
1233	LOW	3241	MEDIUM	5243	LOW	8111	HIGH
1234	LOW	3242	HIGH	5244	LOW	8112	HIGH
1241	LOW	3243	MEDIUM	6111	MEDIUM	8113	MEDIUM
1242	MEDIUM	3244	HIGH	6112	HIGH	8114	HIGH
1243	LOW	4111	HIGH	6113	MEDIUM	8121	HIGH
1244	LOW	4112	HIGH	6114	MEDIUM	8122	HIGH
2111	MEDIUM	4113	MEDIUM	6121	MEDIUM	8123	MEDIUM
2112	HIGH	4114	HIGH	6122	HIGH	8124	HIGH
2113	MEDIUM	4121	HIGH	6123	MEDIUM	8131	HIGH
2114	MEDIUM	4122	HIGH	6124	MEDIUM	8132	HIGH
2121	MEDIUM	4123	MEDIUM	6131	MEDIUM	8133	MEDIUM
2122	HIGH	4124	HIGH	6132	HIGH	8134	HIGH
2123	MEDIUM	4131	HIGH	6133	MEDIUM	8141	HIGH
2124	MEDIUM	4132	HIGH	6134	MEDIUM	8142	HIGH
2131	MEDIUM	4133	MEDIUM	6141	MEDIUM	8143	MEDIUM
2132	HIGH	4134	HIGH	6142	HIGH	8144	HIGH
2133	MEDIUM	4141	HIGH	6143	MEDIUM	8211	MEDIUM
2134	MEDIUM	4142	HIGH	6144	MEDIUM	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	MEDIUM	8213	MEDIUM
2142	HIGH	4144	HIGH	6212	MEDIUM	8214	HIGH
2143	MEDIUM	4211	MEDIUM	6213	LOW	8221	MEDIUM
2144	MEDIUM	4212	HIGH	6214	MEDIUM	8222	HIGH
2211	MEDIUM	4213	MEDIUM	6221	MEDIUM	8223	MEDIUM
2212	MEDIUM	4214	HIGH	6222	MEDIUM	8224	HIGH
2213	LOW	4221	MEDIUM	6223	LOW	8231	MEDIUM
2214	MEDIUM	4222	HIGH	6224	MEDIUM	8232	HIGH
2221	MEDIUM	4223	MEDIUM	6231	MEDIUM	8233	MEDIUM
2222	MEDIUM	4224	HIGH	6232	MEDIUM	8234	HIGH
2223	LOW	4231	MEDIUM	6233	LOW	8241	MEDIUM
2224	MEDIUM	4232	HIGH	6234	MEDIUM	8242	HIGH
2231	MEDIUM	4233	MEDIUM	6241	MEDIUM	8243	MEDIUM
2232	MEDIUM	4234	HIGH	6242	MEDIUM	8244	HIGH
2233	LOW	4241	MEDIUM	6243	LOW		
2234	MEDIUM	4242	HIGH	6244	MEDIUM		
2241	MEDIUM	4243	MEDIUM	7111	HIGH		
2242	MEDIUM	4244	HIGH	7112	HIGH		
2243	LOW	5111	LOW	7113	MEDIUM		
2244	MEDIUM	5112	MEDIUM	7114	HIGH		
3111	HIGH	5113	LOW	7121	HIGH		
3112	HIGH	5114	MEDIUM	7122	HIGH		

Table 4.12. Importance Ratings for Background, Boundary and Initial Conditions

1111	MEDIUM	3113	MEDIUM	5121	MEDIUM	7123	HIGH
1112	MEDIUM	3114	MEDIUM	5122	MEDIUM	7124	HIGH
1113	MEDIUM	3121	MEDIUM	5123	MEDIUM	7131	HIGH
1114	MEDIUM	3122	MEDIUM	5124	MEDIUM	7132	HIGH
1121	MEDIUM	3123	MEDIUM	5131	MEDIUM	7133	HIGH
1122	MEDIUM	3124	MEDIUM	5132	MEDIUM	7134	HIGH
1123	MEDIUM	3131	MEDIUM	5133	MEDIUM	7141	HIGH
1124	MEDIUM	3132	MEDIUM	5134	MEDIUM	7142	HIGH
1131	MEDIUM	3133	MEDIUM	5141	MEDIUM	7143	HIGH
1132	MEDIUM	3134	MEDIUM	5142	MEDIUM	7144	HIGH
1133	MEDIUM	3141	MEDIUM	5143	MEDIUM	7211	HIGH
1134	MEDIUM	3142	MEDIUM	5144	MEDIUM	7212	HIGH
1141	MEDIUM	3143	MEDIUM	5211	MEDIUM	7213	HIGH
1142	MEDIUM	3144	MEDIUM	5212	MEDIUM	7214	HIGH
1143	MEDIUM	3211	MEDIUM	5213	MEDIUM	7221	HIGH
1144	MEDIUM	3212	MEDIUM	5214	MEDIUM	7222	HIGH
1211	MEDIUM	3213	MEDIUM	5221	MEDIUM	7223	HIGH
1212	MEDIUM	3214	MEDIUM	5222	MEDIUM	7224	HIGH
1213	MEDIUM	3221	MEDIUM	5223	MEDIUM	7231	HIGH
1214	MEDIUM	3222	MEDIUM	5224	MEDIUM	7232	HIGH
1221	MEDIUM	3223	MEDIUM	5231	MEDIUM	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	MEDIUM	7234	HIGH
1223	MEDIUM	3231	MEDIUM	5233	MEDIUM	7241	HIGH
1224	MEDIUM	3232	MEDIUM	5234	MEDIUM	7242	HIGH
1231	MEDIUM	3233	MEDIUM	5241	MEDIUM	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	MEDIUM	7244	HIGH
1233	MEDIUM	3241	MEDIUM	5243	MEDIUM	8111	HIGH
1234	MEDIUM	3242	MEDIUM	5244	MEDIUM	8112	HIGH
1241	MEDIUM	3243	MEDIUM	6111	HIGH	8113	HIGH
1242	MEDIUM	3244	MEDIUM	6112	HIGH	8114	HIGH
1243	MEDIUM	4111	MEDIUM	6113	HIGH	8121	HIGH
1244	MEDIUM	4112	MEDIUM	6114	HIGH	8122	HIGH
2111	MEDIUM	4113	MEDIUM	6121	HIGH	8123	HIGH
2112	MEDIUM	4114	MEDIUM	6122	HIGH	8124	HIGH
2113	MEDIUM	4121	MEDIUM	6123	HIGH	8131	HIGH
2114	MEDIUM	4122	MEDIUM	6124	HIGH	8132	HIGH
2121	MEDIUM	4123	MEDIUM	6131	HIGH	8133	HIGH
2122	MEDIUM	4124	MEDIUM	6132	HIGH	8134	HIGH
2123	MEDIUM	4131	MEDIUM	6133	HIGH	8141	HIGH
2124	MEDIUM	4132	MEDIUM	6134	HIGH	8142	HIGH
2131	MEDIUM	4133	MEDIUM	6141	HIGH	8143	HIGH
2132	MEDIUM	4134	MEDIUM	6142	HIGH	8144	HIGH
2133	MEDIUM	4141	MEDIUM	6143	HIGH	8211	HIGH
2134	MEDIUM	4142	MEDIUM	6144	HIGH	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	MEDIUM	6212	HIGH	8214	HIGH
2143	MEDIUM	4211	MEDIUM	6213	HIGH	8221	HIGH
2144	MEDIUM	4212	MEDIUM	6214	HIGH	8222	HIGH
2211	MEDIUM	4213	MEDIUM	6221	HIGH	8223	HIGH
2212	MEDIUM	4214	MEDIUM	6222	HIGH	8224	HIGH
2213	MEDIUM	4221	MEDIUM	6223	HIGH	8231	HIGH
2214	MEDIUM	4222	MEDIUM	6224	HIGH	8232	HIGH
2221	MEDIUM	4223	MEDIUM	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	MEDIUM	4231	MEDIUM	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	MEDIUM	6234	HIGH	8242	HIGH
2231	MEDIUM	4233	MEDIUM	6241	HIGH	8243	HIGH
2232	MEDIUM	4234	MEDIUM	6242	HIGH	8244	HIGH
2233	MEDIUM	4241	MEDIUM	6243	HIGH		
2234	MEDIUM	4242	MEDIUM	6244	HIGH		
2241	MEDIUM	4243	MEDIUM	7111	HIGH		
2242	MEDIUM	4244	MEDIUM	7112	HIGH		
2243	MEDIUM	5111	MEDIUM	7113	HIGH		
2244	MEDIUM	5112	MEDIUM	7114	HIGH		
3111	MEDIUM	5113	MEDIUM	7121	HIGH		
3112	MEDIUM	5114	MEDIUM	7122	HIGH		

Table 4.13. Importance Ratings for Temporal Correlations

1111	LOW	3113	MEDIUM	5121	MEDIUM	7123	MEDIUM
1112	LOW	3114	LOW	5122	MEDIUM	7124	MEDIUM
1113	LOW	3121	MEDIUM	5123	MEDIUM	7131	HIGH
1114	LOW	3122	MEDIUM	5124	LOW	7132	MEDIUM
1121	LOW	3123	MEDIUM	5131	MEDIUM	7133	MEDIUM
1122	LOW	3124	LOW	5132	MEDIUM	7134	MEDIUM
1123	LOW	3131	MEDIUM	5133	MEDIUM	7141	HIGH
1124	LOW	3132	MEDIUM	5134	LOW	7142	MEDIUM
1131	LOW	3133	MEDIUM	5141	MEDIUM	7143	MEDIUM
1132	LOW	3134	LOW	5142	MEDIUM	7144	MEDIUM
1133	LOW	3141	MEDIUM	5143	MEDIUM	7211	HIGH
1134	LOW	3142	MEDIUM	5144	LOW	7212	HIGH
1141	LOW	3143	MEDIUM	5211	HIGH	7213	HIGH
1142	LOW	3144	LOW	5212	MEDIUM	7214	HIGH
1143	LOW	3211	HIGH	5213	MEDIUM	7221	HIGH
1144	LOW	3212	MEDIUM	5214	MEDIUM	7222	HIGH
1211	MEDIUM	3213	MEDIUM	5221	HIGH	7223	HIGH
1212	MEDIUM	3214	MEDIUM	5222	MEDIUM	7224	HIGH
1213	MEDIUM	3221	HIGH	5223	MEDIUM	7231	HIGH
1214	LOW	3222	MEDIUM	5224	MEDIUM	7232	HIGH
1221	MEDIUM	3223	MEDIUM	5231	HIGH	7233	HIGH
1222	MEDIUM	3224	MEDIUM	5232	MEDIUM	7234	HIGH
1223	MEDIUM	3231	HIGH	5233	MEDIUM	7241	HIGH
1224	LOW	3232	MEDIUM	5234	MEDIUM	7242	HIGH
1231	MEDIUM	3233	MEDIUM	5241	HIGH	7243	HIGH
1232	MEDIUM	3234	MEDIUM	5242	MEDIUM	7244	HIGH
1233	MEDIUM	3241	HIGH	5243	MEDIUM	8111	HIGH
1234	LOW	3242	MEDIUM	5244	MEDIUM	8112	MEDIUM
1241	MEDIUM	3243	MEDIUM	6111	HIGH	8113	MEDIUM
1242	MEDIUM	3244	MEDIUM	6112	MEDIUM	8114	MEDIUM
1243	MEDIUM	4111	MEDIUM	6113	MEDIUM	8121	HIGH
1244	LOW	4112	MEDIUM	6114	MEDIUM	8122	MEDIUM
2111	MEDIUM	4113	MEDIUM	6121	HIGH	8123	MEDIUM
2112	MEDIUM	4114	LOW	6122	MEDIUM	8124	MEDIUM
2113	MEDIUM	4121	MEDIUM	6123	MEDIUM	8131	HIGH
2114	LOW	4122	MEDIUM	6124	MEDIUM	8132	MEDIUM
2121	MEDIUM	4123	MEDIUM	6131	HIGH	8133	MEDIUM
2122	MEDIUM	4124	LOW	6132	MEDIUM	8134	MEDIUM
2123	MEDIUM	4131	MEDIUM	6133	MEDIUM	8141	HIGH
2124	LOW	4132	MEDIUM	6134	MEDIUM	8142	MEDIUM
2131	MEDIUM	4133	MEDIUM	6141	HIGH	8143	MEDIUM
2132	MEDIUM	4134	LOW	6142	MEDIUM	8144	MEDIUM
2133	MEDIUM	4141	MEDIUM	6143	MEDIUM	8211	HIGH
2134	LOW	4142	MEDIUM	6144	MEDIUM	8212	HIGH
2141	MEDIUM	4143	MEDIUM	6211	HIGH	8213	HIGH
2142	MEDIUM	4144	LOW	6212	HIGH	8214	HIGH
2143	MEDIUM	4211	HIGH	6213	HIGH	8221	HIGH
2144	LOW	4212	MEDIUM	6214	HIGH	8222	HIGH
2211	HIGH	4213	MEDIUM	6221	HIGH	8223	HIGH
2212	MEDIUM	4214	MEDIUM	6222	HIGH	8224	HIGH
2213	MEDIUM	4221	HIGH	6223	HIGH	8231	HIGH
2214	MEDIUM	4222	MEDIUM	6224	HIGH	8232	HIGH
2221	HIGH	4223	MEDIUM	6231	HIGH	8233	HIGH
2222	MEDIUM	4224	MEDIUM	6232	HIGH	8234	HIGH
2223	MEDIUM	4231	HIGH	6233	HIGH	8241	HIGH
2224	MEDIUM	4232	MEDIUM	6234	HIGH	8242	HIGH
2231	HIGH	4233	MEDIUM	6241	HIGH	8243	HIGH
2232	MEDIUM	4234	MEDIUM	6242	HIGH	8244	HIGH
2233	MEDIUM	4241	HIGH	6243	HIGH		
2234	MEDIUM	4242	MEDIUM	6244	HIGH		
2241	HIGH	4243	MEDIUM	7111	HIGH		
2242	MEDIUM	4244	MEDIUM	7112	MEDIUM		
2243	MEDIUM	5111	MEDIUM	7113	MEDIUM		
2244	MEDIUM	5112	MEDIUM	7114	MEDIUM		
3111	MEDIUM	5113	MEDIUM	7121	HIGH		
3112	MEDIUM	5114	LOW	7122	MEDIUM		

5 TREATMENT OF APPLICATION ELEMENTS

5.1 INTRODUCTION

This section gives specific guidelines for determining, for each application element, the treatment used by a given model. In making these determinations, reference to the dispersion equation and the other working equations documented on Evaluation Form-Part A is useful. The user must be careful in determining the treatments used by the study model. Model documentation is often inadequate and occasionally inconsistent, and in some cases it may be necessary to examine the computer code itself to determine what the real treatment of some element is. The list of input variables should be examined and checked for consistency with the working equations and general formulation to insure that sufficient information is input and that no seemingly irrelevant data are required. If these general guidelines are followed, the effort involved in determining the treatments of the application elements will be minimized.

5.2 TREATMENT OF SOURCE-RECEPTOR RELATIONSHIP

There are six factors to be considered:

- Horizontal location of sources,
- Release heights,
- Downwind and crosswind distances,
- Orientation of area and line sources,
- Horizontal location of receptors, and
- Height of receptors.

Guidance to aid the user in determining the treatment of these factors is given below.* This guidance and Table 5.1 listing the various treatments assume a multiple source application. In the context of source location, receptor location, release height, and receptor height, the user should not compare treatments solely on their respective levels of detail. Consideration should also be given to whether the level of detail employed is required for the application of interest. For example, if a single source-receptor pair is of interest,

*Refer to Appendix A.1.2 for detailed discussion of the treatment of the source-receptor relationship.

Table 5.1. Treatment of Source-Receptor Relationship[a]

a. Horizontal Source Location

Source Type	Method of Treatment
Point	1. Sources located at specific, arbitrary points.
	2. Sources aggregated onto many subareas.
	3. Sources aggregated onto only a few subareas.
	4. Sources aggregated on a basis other than location. No information on location.
	5. Not treated explicitly; all sources treated alike regardless of location.
Area	1. Sources located at arbitrary locations; not located as blocks on a grid network.
	2. Sources located as blocks on grid network. User can change scale of grid.
	3. Sources located as blocks on a grid network. User cannot change scale of grid.
	4. Sources aggregated on a basis other than location. No information on location.
	5. Not treated explicitly.
Line	1. Line located at any desired position; line treated as volume source with width and height as well as length.
	2. Lines treated as one-dimensional (i.e., no width or height) with arbitrary location.
	3. Sources aggregated onto many subareas.
	4. Sources aggregated onto only a few subareas.
	5. Sources aggregated on a basis other than location. No information on location.
	6. Not treated explicitly.

Table 5.1. (Contd.)

b. Release Height	
Source Type	Method of Treatment
Point	1. Accounts for both elevation of stack base and physical stack height.
	2. Assumes flat terrain; no elevation corrections. Release at any physical stack height.
	3. Several representative release heights can be specified for each grid cell or category when sources have been aggregated.
	4. Model assumes all releases take place at same user-defined height.
	5. Model assumes all releases take place at same height which user cannot change.
	6. Not treated explicitly.
Area	1. Accounts for both average elevation of area and allows several arbitrary release heights.
	2. Assumes flat terrain; no elevation corrections. Several arbitrary release heights for each area.
	3. Assumes flat terrain. Only one release height for each area.
	4. Only one release height may be specified for all areas.
	5. Model assumes all releases take place at same height which user cannot change.
	6. Not treated explicitly.
Line	1. Release height and elevation may both be specified.
	2. Flat terrain assumed, arbitrary release height for each source.
	3. Several representative release heights can be specified for each grid square when sources have been aggregated.
	4. Assumes all releases at same height which user cannot change.
	5. Not treated explicitly.

Table 5.1. (Contd.)

c. Downwind/Crosswind Distances		
Source Type		Method of Treatment
Point	1.	Precise downwind and crosswind distances calculated for each source-receptor pair.
	2.	Single representative or average value used for aggregate of several point sources.
	3.	Not treated explicitly.
Area	1.	Calculated for various points within each area source.
	2.	Single representative or average value used for each area source.
	3.	Not treated explicitly.
Line	1.	Single value calculated for each segment along line.
	2.	Single representative or average value used for entire line.
	3.	Single representative or average value used for aggregate of several line sources.
	4.	Not treated explicitly.

d. Source Orientation		
Source Type		Method of Treatment
Point	1.	Not applicable.
Area	1.	Areas can assume any orientation; sides not restricted to lie along specific directions.
	2.	Sides of areas restricted to be along specific grid directions.
	3.	Not treated explicitly.
Line	1.	Line can assume any orientation with respect to receptor and may be inclined.
	2.	Line assumed to be horizontal; orientation arbitrary.
	3.	Applies to only a restricted range of orientations.
	4.	Not treated explicitly.

Table 5.1. (Contd.)

e. Receptor Location

Method of Treatment

1. Receptor located at specific, arbitrary location.
2. Receptor located at specific, arbitrary location within some specific area, commonly an area source emission grid.
3. Receptors located at points on a separate user-defined grid.
4. Receptors located only at points defined within the model.
5. Receptor locations defined only as being within certain boundaries smaller than the entire region of interest, e.g., within a given grid cell.
6. Receptor location not treated explicitly. Concentration estimate independent of receptor location within region of interest.

f. Receptor Height

Method of Treatment

1. Receptor located at specific, arbitrary height above ground.
2. Receptor located at specific, arbitrary height above ground subject to upper limit constraint, e.g., effective stack height.
3. Receptor located at one of several discrete user-defined heights.
4. Receptor located at one of several model-defined heights.
5. Receptor heights defined only as being within certain ranges.
6. Receptors constrained to be all at the same height.
7. Receptors constrained to be all at gound level.
8. Not treated explicitly.

[a] Within each source type, treatments are listed in order of decreasing level of detail. Various combinations of the treatments for each aspect of the source-receptor may be used; the user can arrive at an overall comparison by determining how the models compare in their treatment of each aspect.

a model need not be able to locate many sources and receptors as long as a single pair can be treated in its true relationship.

Horizontal Location

The treatment of the horizontal location of point sources can be found by determining:

- Whether each source can be located arbitrarily at its true location.
- If not, the level of aggregation imposed by the model as distinct from that imposed by the emission inventory.
- The basis for this aggregation.

The key consideration is the level or degree of aggregation required. Little or none implies a relatively detailed treatment in contrast to treatments that require a lot. Some treatments aggregate on the basis of a parameter such as source type and hence convey little information on source location.

For area sources, the considerations are similar:

- Whether each source can be located arbritarily or must be blocks in a fixed grid network.
- Whether the user can change the scale of the grid to suit the detail available in the inventory.
- Whether the model imposes aggregation in addition to any imposed by the inventory in developing the area sources.
- The basis for the model's aggregation.

The major difference between the point and area sources comes from the two-dimensional nature of the area sources. They must be located as blocks rather than as points; otherwise the progression from the most to the least detailed treatments is the same for both types.

For line sources, the situation is similar except that the line may be treated as an elongated volume source having length, width, and height. For the location of a line the user should determine:

- Whether the line can have width and/or height or is truly considered a one-dimensional source.
- If the receptor height is arbitrary or if only one height (usually ground level) is assumed.

- Whether the line can be uniquely located, usually by the location of its endpoints.
- If not, the degree of aggregation imposed by the model.
- The basis for that aggregation.

Release Height

As used here, release height means the height above ground level at which emissions are physically released into the atmosphere and does not include any considerations of plume rise or other types of plume behavior, which are dealt with in Section 5.5. The user should be aware, however, that some effective plume rise may frequently be included in the user-specified release height supplied as input to models that do not treat plume rise explicitly. This approach is discussed in Section 5.5; the comparison of treatments of release height should proceed as if the release heights were the heights at which emissions actually enter the atmosphere. There are three considerations in determining the level of detail with which release height is treated for point, area, and line sources:

- Whether the model treats elevation differences due to terrain.
- Whether the model allows the physical stack height (or height of release above ground level for area and line sources) to vary between different sources or source categories.
- Whether release heights can be specified arbitrarily by the user or whether specific values or sets of values are imposed by the model.

Receptor Location and Receptor Height

Since receptors are generally taken to be points, the user should be able to describe the treatment of receptor location and height by making the same considerations as outlined above. Specifically, the user should determine:

- Whether the receptors can be located arbitrarily or are limited to specific points within the given area.
- If the receptor height is arbitrary or if only one height (usually ground level) is assumed.

With these considerations and the entries in Table 5.1, the user should be able to describe and compare treatments of receptor location and receptor height.

Downwind/Crosswind Distances

Some models contain parameters whose values depend explicitly on downwind or crosswind distances between source-receptor pairs. In such cases, these treatments must be described and compared. In other cases, it should simply be noted on the technical evaluation form that this aspect of the source-receptor relationship is "not applicable." The key consideration for all source types is whether the treatment causes a loss in the precision with which the downwind and crosswind distances can be specified. Aspects for the user to consider are:

- Whether precise downwind/crosswind distances are calculated for each point source-receptor pair or for various points within area sources or along line sources.
- Whether, for area and line sources, single representative or average distances are used.

It should be noted that when the model aggregates sources, the values of downwind/crosswind distance are representative of the grid blocks used in the aggregation and not of the sources themselves.

Orientation

Orientation does not apply to point sources. For area sources, the user needs to consider:

- Whether the sides of the area sources can be arbitrarily oriented, or
- Whether they are restricted to lie along specific directions specified by a grid.

For line sources, the situation is slightly more complex, because a line presents a significantly different appearance depending upon the angle from which it is viewed. The considerations are:

- Whether the line can be inclined or must be horizontal.
- Whether the line can be arbitrarily oriented with respect to the wind direction; some models can treat only a restricted range of orientations.

When these considerations have been made, the user should have little trouble in locating the study model's treatment of each aspect of the source-receptor relationship in Table 5.1 and in briefly describing that treatment on the Evaluation Form-Part C. In applications involving several source types, an overall evaluation must be reached based upon the comparative treatment of each source type individually. Each treatment must be weighted by the expected importance of that source type in the application of interest.

Table 5.1 gives the treatment of the source-receptor relationship by models in general. Table B.2 gives the treatment of the source-receptor relationship by selected reference models.

5.3 TREATMENT OF EMISSION RATE

The degree of spatial and temporal resolution must both be assessed in determining the treatment of emission rate.* Regardless of the aspect or type of source, the user is basically interested in determining:

- Whether an emission rate and emission pattern unique to each source can be specified, or
- Whether average emission rates and general patterns must be used.

For the spatial aspect of point sources, the user need only determine whether each source can have an arbitrary emission rate or whether all sources must have identical rates.

For area sources, there are several methods for treating the emission rate, depending on how the concentration estimates are made. The user must determine:

- Whether variation in the emission rate is allowed within a single source or whether each area is assumed to emit uniformly.
- If the areas must be uniform, whether the emission rates are arbitrary or whether they must be the same or selected from a specific set of values.
- Whether concentration estimates are obtained by numerical integration over the area or by replacing the area by a small number of effective point sources.

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*Refer to Appendix A.1.3 for detailed discussion of the treatment of emission rate.

- Whether contributions from all individual area sources are estimated.
- Whether a single estimate of the total area source contribution is made.

Similarly, for line sources the considerations are:

- Whether the emission rate can vary along the line or whether the line is assumed to be a uniform source.
- If the line must be uniform, whether the emission rate is arbitrary.
- Whether concentration estimates are obtained by integration or by replacing the line by a small number of effective point sources.

For the temporal aspect, the considerations are the same for all types of sources:

- Whether the emissions can vary with time, or
- Whether constant emission rates are assumed.
- If the emissions can vary with time, whether the model uses
  - An actual time sequence of emission rates,
  - A sampled set of emission rates, or
  - A set of rates partially arranged in sequence or correlated with other variables.

With these considerations, the user should be able to determine a model's treatment of emission rate and to describe it on the evaluation Form-Part C.

Table 5.2 gives the general treatment of emission rate. Table B.3 gives the treatment of emission rate by the reference models.

5.4 TREATMENT OF COMPOSITION OF EMISSIONS

The user must deal with two aspects of the composition of emissions. For all types of emissions, the chemical composition must be treated <u>except</u> when dealing with primary, stable pollutants. In addition, for particulate matter, the size distribution may need to be considered.*

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*Refer to Appendix A.1.4 for detailed discussion of the treatment of composition of emissions.

Table 5.2. Treatment of Emission Rate

Variation	Source Type		Method of Treatment
Spatial	Point	1.	Allows arbitrary emission rate for each source.
		2.	All sources assumed to have identical emission rates.
	Area	1.	Allows variation over each area source. Total contribution estimated by summing all individual contributions. Individual contributions estimated by integration.
		2.	Assumes uniform area sources with arbitrary emission rates. Total contribution estimated by summing all individual contributions. Individual contributions estimated by integration.
		3.	Assumes uniform area sources with arbitrary emission rates. Total contribution estimated by integration without estimating individual source contributions.
		4.	Assumes uniform area sources with arbitrary emission rates. Total contribution estimated by summing all individual contributions. Individual contributions estimated by replacing each area source by a small number of effective point sources.
		5.	Assumes uniform area sources, all with the same emission rate. Total contribution estimated by replacing entire area source distribution by a small number of effective point sources.
	Line	1.	Allows variation along the line. Integrates to obtain concentration.
		2.	Assumes arbitrary emission rate is uniform along the line. Integrates to obtain concentration.
		3.	Allows variation along the line. Replaces line by a small number of effective point sources with emission rates dependent upon position along line.
		4.	Assumes uniform lines with arbitrary emission rates. Replaces line by small number of effective point sources.
		5.	Assumes all lines have the same uniform emission rate. Replaces line by small number of effective point sources.
Temporal[b]	All	1.	Treats an actual time sequence of emission rates averaged over a short interval (typically one hour).
		2.a.	Treats a sampled set of the possible emission rates appropriate to a short interval.
		b.	Treats time sequence of short-term emission rates derived by model from input emission rates appropriate to longer term.
		3.	Treats a time sequence of emission rates averaged over a long interval (e.g., one day).
		4.	Uses a set of emission rates which are at most partially arranged in sequence.
		5.	Treats only constant emission rates.

[a]Within each source type, the treatments are listed in order of decreasing level of detail.

[b]In addition to the level of detail, the suitability of the technique of treating the variations must be assessed as discussed in Appendix A.1.3 whenever the treatment allows temporal variations to be specified.

If treatment of chemical composition of emissions is required by the application, the user should consider:

- Whether all relevant compounds are treated individually or whether certain compounds are lumped into classes with each class treated by a representative or hypothetical compound. The specific compounds or classes treated should be listed or described on the Evaluation Form-Part C.

- If lumping is used, the number of classes considered and whether these classes are appropriate to the application of interest.

- Whether the model determines emissions of certain compounds as fixed fractions of input emissions regardless of source type.

- Whether further assumptions are made regarding the composition of user-input emissions.

- Whether the model treats only one of many compounds known to interact.

In making these determinations, expert advice may be required.

When fallout, deposition, or precipitation scavenging (rainout or washout) are involved, the size distribution of particulate matter is important. The treatment used may be found by determining:

- Whether a size distribution is used and if so, whether it is continuous or discrete.

    - If continuous, whether the functional form can be specified or whether parameters are input for a fixed distribution.

    - If discrete, whether there are many narrow size ranges or a few broad ranges.

- If a size distribution is not used, whether some given fraction of the emissions is affected by the size-dependent mechanism.

- If so, whether the fraction is arbitrary.

These considerations should enable the user to determine the treatment of composition of emissions.

Table 5.3 gives the general treatments of the composition of emissions. Table B.4 gives the treatments used by the selected reference models.

Table 5.3. Treatment of Composition of Emissions[a]

Aspect Treated	Method of treatment
Chemical Composition[b]	1. Emissions of all relevant compounds treated individually.
	2. Lumps some emissions into a large number of classes appropriate to the application of interest; other emissions treated as individual compounds. All members of each class treated by a representative or hypothetical compound. All relevant emissions treated.
	3. Uses a gross lumping of *some* of the emissions *into only a few* classes. Other emissions treated as individual compounds. All relevant emissions treated.
	4. Treats emissions of only some of the compounds known to take part in relevant reactions.
	5. Places fixed fractions of input emissions into a small number of classes. Uses same fractions for all sources.
	6. Treats only one of many compounds known to interact or one lumped class of emissions.
	7. Same as No. 6 but the model places a fixed fraction of input emissions into the single class.
Size Distribution[c]	1. Treats continuous size distribution and allows the functional form to be specified by the user.
	2. Treats continuous size distribution. Parameters of a fixed distribution specified by the user.
	3. Treats all particles within various size ranges by a corresponding set of representative sizes; uses a large number of narrow ranges.
	4. Same as No. 3 but treats a small number of broad ranges.
	5. Assumes a given user-input fraction of emissions are affected by the size-dependent mechanism of interest.
	6. Same as 5 but fraction is set by the model.
	7. Not treated explicitly.

[a]Within each aspect, the treatments are listed in order of decreasing level of detail.

[b]Important only in cases involving secondary or reactive pollutants.

[c]Important only in cases involving fallout, deposition, or precipitation scavenging (washout or rainout) of particulates.

5.5 TREATMENT OF PLUME BEHAVIOR

By considering the following, the user should be able to determine the study model's treatment of plume behavior:*

- Whether a plume rise formula is used by the model.
- If so, whether the formula has been extensively validated for the specific application of interest or for similar applications.
- Whether the formula is one of the common ones: Briggs' 2/3, Holland, CONCAWE, CONCAWE simplified, or the ASME formula.
- If the formula has not been validated and is not one of the four common formulae:
  - To what power of the inverse wind speed the plume rise is proportional.
  - Whether there is a buoyancy term and the power to which it is raised.
  - Whether there is a momentum term.
  - Whether the formula accounts for differences in atmospheric stability.
  - Whether plume rise is a function of downwind distance.
- If no plume rise formula used, whether the product of wind speed and plume rise is assumed constant.
- If so, whether the constant can be changed from source to source.
- Upon what other parameters, like stability, the constant can depend.
- Whether downwash and/or fumigation are treated.

In comparing treatments of plume rise, the main consideration should be validation in either the application of interest or similar applications. A properly validated formula should always be considered better than an unvalidated formula.

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*Refer to Appendix A.2.2 for detailed discussion of the treatment of plume behavior.

As pointed out in Section 5.2, some effective plume rise may be included in the values of the stack or release height specified by the user as input to a model. If this approach is adopted, the treatment of plume rise must be determined from the algorithm or formulae by which the effective plume rise is estimated prior to its inclusion as part of the release height. Otherwise, the treatment implemented in the computer program should be determined.

When the "tilted plume" approximation has been used to treat deposition from particulate plumes, this treatment should be included under dry deposition (Table 5.13).

Table 5.4 gives the general treatments of plume behavior, and Table B.5 gives the treatments used by the selected reference models.

5.6 TREATMENT OF HORIZONTAL AND VERTICAL WIND FIELDS

The treatment of the horizontal wind field by the study model may be determined from the following considerations:*

- Whether the horizontal components of the wind velocity may depend on horizontal location.
- If not, whether both wind speed and direction are treated explicitly or whether one or both are not treated explicitly.
- If the horizontal components depend on position, whether the dependence is arbitrary or assumed a priori.
- If arbitrary, whether the components are specified at discrete points or as continuous functions of position.
- Whether both the horizontal components may depend on height above ground.
- If so, whether they are specified at discrete heights or as continuous functions of height.
- If the wind direction is constant with height, whether the wind speed can depend upon height.
- If so, whether the dependence is arbitrary.
- If arbitrary, whether the wind speed is specified at discrete intervals or given as a continuous function of height.

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*Refer to Appendix A.3.2 for a discussion of the possible treatments of the horizontal and vertical wind fields.

Table 5.4. Treatment of Plume Behavior[a]

Method of Treatment
1. Plume rise formulation validated for the specific application of interest.
2. Plume rise formulation validated for applications similar to the one of interest.
3. Fully detailed treatment with plume rise and dispersion treated simultaneously. Limited validation.[b]
4. Two-step treatments. Plume rise is calculated and then dispersion is calculated from a virtual source at an effective stack height.
a. Analytical formulas, depending upon meteorology and stack parameters, used to estimate plume rise:
• Plume rise treated by one of the common formulas: Brigg's 2/3, Holland, CONCAWE, CONCAWE simplified, or ASME.
• Plume rise treated by unvalidated formula satisfying the general guidelines and comparing favorably with common formulas.[c] (See Appendix A.2 and Table A.1 for these guidelines.)
• Plume rise treated by unvalidated formula satisfying some of the general guidelines or comparing unfavorably with common formulas.[c] (See Appendix A.2 and Table A.1 for these guidelines.)
b. Product of plume rise and wind speed assumed constant. User can choose value of constant for each source and use different constants for a small number of meteorological or source parameters, e.g., stability.
c. Product of plume rise and wind speed assumed constant. User can choose value of constant for each source. Constant is independent of other source and meteorological parameters.
d. As in 4 (c), but one value of the constant used for all sources.
e. Single value of plume rise used for all sources. (Could be included in release height.)
5. Not treated explicitly.

[a]Treatments are listed in order of decreasing level of detail.

[b]Not used in most models at this time; used only in special applications.

[c]Special weight should be given to formulas treating plume rise as a function of downwind distance. This consideration is more important for low-level than for elevated releases.

Notes: 1. In addition to comparing the treatments of plume rise, the user should consider whether the models treat downwash or fumigation. Treatment of either or both by a model tends to make that model's treatment of plume behavior better than the treatment by a model that ignores these effects.

2. Where the "tilted plume" approximation has been used for particulate plumes, the user should include this under the treatment of dry deposition. (See Table 5.12.)

- Whether a specified dependence with height of either or both wind speed and direction is assumed a priori.

- If either or both wind speed and direction are constant with height, whether different values are used for different source heights.

- Whether the horizontal components depend on time.

- If so, whether they are specified continuously or at a sequence of elapsed times.

- If specified at a sequence of times, whether they are assumed constant within each interval or interpolated between times.

- Whether the treatment is climatological.

These considerations should guide the user to an identification of the treatment of the horizontal wind field. In addition, the following specific information should be provided on the Evaluation Form-Part C:

- The model classification as determined in Section 4.3.

- A description of the nature of any constraints on the allowable values of the wind speed and direction, e.g., the number of sectors and wind speed classes used in a climatological model.

- A description of the nature of any parameters, either user-specified or built into the model, that govern the dependence of wind speed and direction on position, height above ground, or time, e.g., power law dependence of wind speed on height with exponents dependent on atmospheric stability.

- A description of any dependence of the horizontal wind components on position, height, or time that explicitly or implicitly is assumed a priori by the study model.

- The source of nature of any non-standard meteorological data required in the model determination of the wind field.

- Any additional information relating to the treatment of the horizontal wind field not covered in this discussion.

The treatment of the vertical component of the wind field may be determined in a similar manner from the following considerations:

- Whether the vertical wind field is treated explicitly; whether an implicit treatment is used; or whether the vertical wind field is not considered in the study model formulation.

- If treated explicitly, whether the vertical component depends arbitrarily upon horizontal position and/or height above ground.

- If arbitrarily dependent on position and/or height, whether the vertical component is a continuous function of these variables or whether it is specified at discrete points.

- Whether there is any assumed a priori dependence of the vertical component on position or height above ground.

- Whether the vertical component depends on time.

- If so, whether it is specified continuously or at a sequence of elapsed times.

- If specified at a sequence of times, whether it is assumed constant within each interval or whether its value is interpolated.

Although these questions will enable the user to identify the study model's treatment of vertical wind field, additional information should be provided. This additional information is the same as required above for the horizontal wind field. If the study model uses an implicit treatment of the vertical wind field, the treatment should be described in sufficient detail to make clear the assumptions involved.

Tables 5.5 and 5.6, respectively, give the treatments of the horizontal wind field and the vertical wind field by models in general. Tables B.6 and B.7 give the treatments used by selected reference models.

5.7 TREATMENT OF HORIZONTAL AND VERTICAL DISPERSION

The treatment of both horizontal and vertical dispersion by the study model may represent different modeling approaches.* For example, horizontal dispersion may be described with a semiempirical method and vertical dispersion may be described with a numerical method. On the other hand, the two treatments may be closely related. In either case, separate descriptions of the treatments of these two elements are required on the Evaluation Form-Part C. General treatments of dispersion corresponding to the different types of models identified in the classification procedure outlined in Section 4.3 are given in Table 5.7. Certain information is required to adequately specify the particular treatment used by the study model. Regardless of the model type, the

*Refer to Appendix A.4.2 for a detailed discussion of the treatment of horizontal and vertical dispersion.

Table 5.5. Treatment of Horizontal Wind Field[a]

Dependence on: Horizontal Location	Height above Ground	Time
1. Arbitrary. Wind speed and direction specified as continuous functions of horizontal position.	1. Arbitrary. Wind speed and direction specified as continuous functions of height .	1. Arbitrary. Wind speed and direction specified as continuous function of time.
2. Arbitrary. Wind speed and direction specified at points of a horizontal grid.	2. Arbitrary. Wind speed and direction specified at heights of a vertical grid.	2. Arbitrary. Wind speed and direction specified at a sequence of elapsed times: a. Values interpolated between times. b. Values constant within each interval.
3. Specific positional dependence built into model, not subject to user modfication beyond the specification of parameter values.	3. Wind direction constant with height. Wind speed an arbitrary continuous function of height.	3. Climatological. Wind speed and direction specified as being within well-defined ranges having known joint frequencies of occurrence.
4. Wind speed and direction independent of position (uniform).	4. Wind direction constant with height. Wind speed dependence on height arbitrary, values specified at heights of a vertical grid.	4. Wind speed and direction constant in time (steady-state).
5. Wind speed independent of position. Wind direction not treated explicity.	5. Specific height dependence built into model, not subject to user modification beyond the specification of parameter values.	5. Not treated explicitly.
6. Wind speed and direction not treated explicitly.	6. Both wind speed and wind direction constant with height (uniform). Values used may depend on source height.	
	7. Both wind speed and wind direction constant with height (uniform). Same values used for all source heights.	
	8. Wind speed and direction not treated explicitly.	

Note: Arbitrary *here means* either that the model will accept any appropriate user-defined wind field which has been independently determined or that the model itself, given appropriate user specification of the problem, will generate the wind field in a manner compatible with mass consistency, the proper boundary conditions for fluid flow, and any assumptions built into the model. No constraints are placed on allowable values.

[a]Treatments arranged in order of decreasing level of detail.

Table 5.6. Treatment of Vertical Wind Field[a]

Dependence on: Horizontal Location	Dependence on: Height above Ground	Dependence on: Time
1. Arbitrary Vertical wind field specified as a continuous function of horizontal position.	1. Arbitrary. Vertical wind field specified as a continuous function of height.	1. Arbitrary. Vertical wind field specified as a continuous function of time.
2. Arbitrary. Vertical wind field specified at points of a horizontal grid.	2. Arbitrary. Vertical wind field specified at heights of a vertical grid.	2. Arbitrary. Vertical wind field specified at a sequence of elapsed times: a. Values interpolated between times. b. Values constant within each interval.
3. Specific explicit positional dependence built into model, not subject to user modification beyond the specification of parameter values.	3. Specific explicit height dependence built into model, not subject to user modification beyond the specification of parameter values	3. Vertical wind field assumed constant in time (steady-state).
4. Vertical wind field treated implicitly. a. Effects of terrain or other factors accounted for by assuming that the center of mass of the pollutant emission follows a prescribed path either with respect to the local topography or as would result from any other factors considered. b. Assumed equal to zero everywhere.	4. Vertical wind field treated implicitly. a. Effects of terrain or other factors accounted for by assuming that the center of mass of the pollutant emission follows a prescribed path either with respect to the local topography or as would result from any other factors considered. b. Assumed equal to zero at all heights.	4. Not treated explicitly. (Effects of vertical wind field not considered in model formulation.)
5. Not treated explicitly. (Effects of vertical wind field not considered in model formulation.)	5. Not treated explicitly. (Effects of vertical wind field not considered in model formulation.)	

Note: Arbitrary here means either that the model will accept any appropriate user-defined wind field which has been independently determined or that the model itself, given appropriate user specification of the problem, will generate the wind field in a manner compatible with mass consistency, the proper boundary conditions for fluid flow, and any assumptions built into the model. No constraints are placed on allowable values.

[a]Treatments arranged in order of decreasing level of detail.

Table 5.7. General Treatments of Dispersion

Model Classification	Method of Treatment[a,b]
1. Numerical/dynamic	
a. Closure models	Numerical solution of equations giving pollutant concentrations and fluxes as well as several meteorological parameters as functions of position and time.
b. Gradient-transfer	Numerical solution of diffusion equation giving pollutant concentrations as a function of position and time. Eddy diffusivities estimated as functions of height, time and/or meteorological variables.
2. Numerical/steady-state Gradient-transfer or "K-theory" models only	As in 1b. except that eddy diffusivities are dependent of time.
3. Semiempirical/dynamic	Dispersion described by an assumed shape function, depending on position and time. Assumed function contains parameters which are adjust to reflect the effects of meteorology and surtace roughness. Examples[a]: a. *Gaussian puff model.* b. Gaussian plume about trajectory. c. Narrow plume approximation (horizontal dispersion only). d. Box model (uniform vertical distribution).
4. Semiempirical/steady-state	Dispersion described by an assumed shape function, a function of position only. Assumed function contains parameters which are adjusted *to reflect the effects of* meteorology and surface roughness. Examples[a]: a. Gaussian plume. b. Narrow plume approximation (horizontal dispersion only). c. Box model (uniform vertical distribution).
5. Climatological	Treatment depends on nature of model used for basic calculations, but normally steady-state. Examples[a]: a. K-theory models (numerical). b. Gaussian models (semiempirical). c. Sector averaging (narrow plume approximation; horizontal dispersion only; semiempirical).

[a]Treatments and examples are listed approximately in order of decreasing level of detail.

[b]Models can be compared on their relative *level of detail* only *after* it has been determined that they use approaches equally applicable to the application of interest.

following information should be provided:

- The model classification as determined in Section 4.3.

- The treatment or parameterization of atmospheric stability used in estimating the values of eddy diffusivities or standard deviations (see Table 5.8). The name (or names) of any parameter or turbulence classification scheme used to specify the stability of the atmosphere or the level of turbulence should be noted. If a classification scheme is used, the number of classes used should be noted. Limits or other constraints to allowable parameter values should be indicated.

- The treatment or parameterization of surface roughness effects used in estimating the values of eddy diffusivities or standard deviations (see Table 5.9). Information similar to that required for the treatment of atmospheric stability should be provided.

- The origin or basis for choosing the specific model parameter values (see Table 5.10). If the specific parameters are widely used or have been published in the scientific literature, it is sufficient to identify them (for example, the Pasquill-Gifford dispersion coefficients for the Gaussian plume model) and provide an appropriate reference; if they are not widely used and not publicly available, the basis for using them should be noted.

- The averaging time for meteorological variables.

This information may be omitted in certain cases in which dispersion is described implicitly, rather than explicitly. This is the case in the narrow plume or sector averaging approximations for horizontal dispersion or in the uniform mixing approximation for vertical dispersion, for example.

Additional information is also required, depending on the treatment classification.

Semiempirical. The functional form assumed for the pollutant distribution should be identified if commonly used (e.g., Gaussian plume, narrow plume approximation, sector averaging, uniform mixing), or described briefly if not widely used, including some indication of its origin. Dependences of model parameters on position, height, time, meteorological, or other variables

Table 5.8. Treatment of Atmospheric Stability[a]

1. Atmospheric stability characterized by the numerical value of a stability parameter (see for example Table A.3) that may take on any value within the range for which the model is designed.

2. Atmospheric stability divided into discrete classes within which no variation is recognized.

    a. Many classes, including time of day or other parameters.

    b. Many classes, <u>not</u> including other factors, or Few classes, but including additional factors.

    c. Few classes, no additional factors included.

3. Atmospheric stability not explicitly treated.

[a]Treatments given in order of decreasing level of detail.

Table 5.9. Treatment of Surface Roughness[a]

1. Surface roughness characterized by the numerical value of a roughness parameter (such as the roughness length) which can take on any value within some appropriate range.

2. Surface roughness characterized in terms of discrete classes or types of surface.

    a. Many classes.

    b. Few classes.

3. Surface roughness not treated explicitly.

[a]Treatments given in order of decreasing level of detail.

Table 5.10. Possible Bases for Estimating Dispersion Parameter Values[a]

Model Type	Parameters	Bases for Evaluation
Numerical	Horizontal or vertical eddy diffusivity	1. Diffusivity values determined from special meteorological data acquired for the specific application of interest.
		2. Diffusivity values estimated from routinely measured meteorological quantities using either theoretical or empirical formulae.
		3. Diffusivity values assumed known; specified within model.
Semiempirical[b]	Parameters depend on model formulation (in Gaussian plume case, horizontal and vertical standard deviations).	1. Standard deviations determined from special meteorological data acquired for the application of interest.
		2. Standard deviations specified within model, values based on prior field studies; correction factors based on user-supplied information applied to correct for different meteorological or surface conditions.
		3. Same as No. 2 but without correction factors.
		4. Standard deviations estimated within model from analytic solutions to the advection-diffusion equation (necessarily involving simplified meteorology) and user-supplied information.
		5. Simple theoretical estimates of standard deviations used, specified within model.

[a]Bases in approximate order of decreasing applicability.

[b]Descriptions of bases written in terms of a Gaussian model.

should be indicated if not adequately described under the general information above.

Numerical. The dependence of the eddy diffusivity on position, height, time, meteorological, or other variables should be indicated, in addition to the basis for the values or for the specific parameterization that is used by the study model (see Table 5.11). The general name or type of numerical method used to solve the diffusion equation should be mentioned, although comparison based on the details of the numerical techniques is beyond the scope of this methodology.

Steady-State. The averaging time, or the period of time over which a steady-state condition is assumed to hold, should be indicated.

Sequential or Climatological. No specific additional information is required if the study model has been classified as sequential or climatological.

Dynamic. The time dependence should be described to a sufficient extent to indicate its general nature. For example, a model that has been classified dynamic because it involves the determination of a trajectory, but in which the time dependence of the pollutant concentration is not explicit, should be distinguished from a model in which it is. In cases involving explicit time dependence, the method of describing the temporal variation, either continuously or in a sequence of time steps, should be indicated along with the size of the time step used.

Finally, any additional information relevant to the treatment of dispersion that may affect the evaluation or clarify the operation of the study model should be given. This information may include:

- Different modes of operation under different meteorological circumstances,
- Different treatments for different source geometries, and
- Any additional or different assumptions made in the formulation of the study model not covered in the discussion in this workbook.

Table 5.7 gives the general treatments of dispersion. Tables 5.8 and 5.9, respectively, give the treatments of atmospheric stability and surface roughness used in estimating the values of the dispersion parameters (the

Table 5.11. Spatial and/or Temporal Dependence of Eddy Diffusivities[a]

Dependence of Horizontal or Vertical Eddy Diffusivity on		
Horizontal Location	Height above Ground	Time
1. Arbitrary. Diffusivity specified as a continuous function of horizontal position.	1. Arbitrary. Diffusivity specified as a continuous function of height.	1. Arbitrary. Diffusivity specified as a continuous function of time.
2. Arbitrary. Diffusivity specified at points on a horizontal grid.	2. Arbitrary. Diffusivity specified at heights of a vertical grid.	2. Arbitrary. Diffusivity specified at a sequence of elapsed times: a. Values interpolated between times. b. Values constant within each interval.
3. Specific positional dependence built into model, not subject to user modification beyond specification of parameter values.	3. Specific dependence on height built into model, not subject to user modification beyond specification of parameter values.	3. Diffusivity constant in time (steady-state).
4. Diffusivity independent of position: horizontal uniformity assumed.	4. Diffusivity independent of height: vertical uniformity assumed.	

Note: Arbitrary here means that the model will accept any appropriate user-defined eddy diffusivity dependence on horizontal and vertical position and time or that the model itself, given appropriate user-supplied input, will estimate this dependence. No constraints are placed on the allowed values.

[a]Treatments arranged in order of decreasing level of detail.

eddy diffusivities or standard deviations). Table 5.10 gives possible bases for comparing different choices of dispersion parameter values. Table 5.11 gives possible treatments of the spatial and temporal dependence of eddy diffusivities. Treatments of horizontal and vertical dispersion by selected reference models are given in Tables B.8 and B.9.

5.8 TREATMENT OF CHEMISTRY AND REACTION MECHANISM

The treatment of chemistry and reaction mechanism used by the study model may be determined from the following considerations (expert advice may be required in some cases):

- Whether all relevant reactions and chemical species are handled.
- Whether similar compounds are treated together in one or more classes (lumping approximation) or whether only some of the relevant compounds are treated.
- Whether the equilibrium approximation is applied to the system of reactions.
- Whether all reactions are truly first-order (linear).
- Whether the appearance and disappearance of pollutants of interest are approximated by one or more first-order processes.

In addition to these considerations, the user must also determine:

- Whether any adjustment is made for the effects of incomplete turbulent mixing.

Finally, the following additional information should also be provided:

- A two-or three-word description of the general chemical system being treated (e.g., photochemical smog system).
- The number of distinct chemical reactions considered.
- The number and an explicit list of the chemical species, real or "lumped," treated in the mechanism.
- If the lumping approximation is used, a list of those species treated in the mechanism that are representative compounds for the classes being used.

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*Refer to Appendix A.5.2 for a discussion of the possible treatments of chemistry and reaction mechanism.

- If the steady-state approximation is used, a list of those species to which it is applied.

- A description, including the extent of any user input, of any spatial or temporal variation attributed to any chemical reaction rate constant.

- A description of any optional modes of operation, such as user-specification of an arbitrary reaction mechanism.

Table 5.12 gives the general treatments of chemistry and reaction mechanism. The treatments used by selected reference models are given in Table B.10.

5.9 TREATMENT OF PHYSICAL REMOVAL PROCESSES

Two physical removal processes are considered in this workbook: dry deposition and precipitation scavenging. The guidelines in this section enable the user to identify the treatment of each used by the study model.*

Dry Deposition

The treatment of dry deposition may be determined from the following considerations:

- Whether both the effect on the vertical concentration profile and the effect of pollutant removal are treated.

- If so, whether the deposition velocity is assumed constant and/or independent of position.

- Whether only the effect of pollutant removal is treated. (Effective source-strength treatment.)

- If so, how the effective source strength is determined.

  - Integration of mass removal rate proportional to ground level concentration, or

  - Assumed exponential decay.

- Whether the deposition velocity is a function of meteorological variables.

- Whether the tilted plume approximation is used to treat gravitational settling.

Additional information relating to assumed deposition velocity values or assumed dependences on meteorological or other parameters should be

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*Refer to Appendix A.6.2 and A.6.3 for discussions of possible treatments of dry deposition and precipitation scavenging.

Table 5.12. Treatment of Chemistry and Reaction Mechanism[a]

1. Complete mechanism used:

   a. System of truly first-order reactions - exact treatment possible independent of dispersion.

   b. More general system of reactions -

      - Includes all known relevant reactions except those definitely known to be insignificant and

      - Treats all chemical species explicitly.

2. Simplified mechanism used, incorporating the steady-state approximation for highly reactive intermediates but not the lumping approximation for similar species.

3. Simplified mechanism used, involving the lumping of similar chemical species into classes and/or treatment of only some of the relevant compounds but not the steady-state approximation.

4. Simplified mechanism used, involving both steady-state and either the lumping approximation and/or the treatment of only some of the relevant compounds.

5. Equilibrium approximation used, with or without the lumping approximation.

6. Approximates the disappearance and/or appearance of a pollutant of interest and/or the appearance of its reaction products as first-order reactions and uses exact treatment for the first-order (exponential) processes.

7. Not treated explicitly.

[a]Treatments given in order of decreasing level of detail.

included in the description on the Evaluation Form-Part C.

Precipitation Scavenging

The treatment of precipitation scavenging may be determined from the following considerations:

- Whether the study model allows the washout coefficient to be an arbitrary function of time.
- Whether the washout coefficient is obtained from a user-supplied time-dependent rainfall rate.
- Whether the washout coefficient is assumed to be constant over the period during which precipitation occurs.
- Whether each occurrence of rainfall is assumed to remove the same fraction of pollutant.
- Whether the user may specify the frequency of rainfall.

As before, additional information relating to any model assumptions such as washout coefficient values, rainfall frequencies, etc. should be provided. Precipitation scavenging should be assumed to occur only during precipitation. If a study model always applies an exponential decay factor, that treatment should not be considered as a treatment of precipitation scavenging.

Table 5.13 gives the general treatments of these two removal processes and Table B.11 gives the treatments of physical removal processes by selected reference models.

5.10 TREATMENT OF BACKGROUND, BOUNDARY AND INITIAL CONDITIONS

There are five aspects of the element to be considered:

- Background,
- Upper boundary condition at the mixing height,
- Lower boundary condition at the earth's surface,
- Boundary condition at the vertical sides of the region of interest, and
- Initial conditions in the region of interest.

The treatments of each of these aspects depends upon the classification of the

Table 5.13. Treatment of Physical Removal Processes[a]

Dry Deposition	Precipitation Scavenging
1. Both pollutant removal and effect on vertical concentration profile treated by imposition of appropriate boundary condition at ground surface.	1. Integrated exponential decay with time-dependent rainout or washout coefficient appropriate for specific variation in cloud density or rainfall rate.
a. Deposition velocity a function of position (and time for dynamic models), surface roughness, and atmospheric stability.	2. Exponential decay with constant rainout or washout coefficient.
b. Deposition velocity a constant.	Removal process operates only for the fraction of time during which it rains; rainfall frequency input by user.
2. Pollutant removal simulated by time or downwind-distance dependent factor (effective source-strength treatment). Effect on vertical concentration profile not treated explicitly.	3. Each occurence of precipitation scavenging assumed to reduce pollutant concentration by a constant factor.
a. Factor determined by:	
• Ground level pollutant concentration and/or	4. As in No. 2 but rainfall frequency fixed internally and not subject to user specification.
• Dependence of deposition velocity on time, position, surface roughness, atmospheric stability.	5. Not treated explicitly.
b. Factor equal to simple exponential decay term.	
3. Tilted plume approximation (gravitational settling of large particulate matter only).	
4. Not treated explicitly.	

[a]*Treatments given in order of decreasing level of detail.*

study model as numerical/dynamic, numerical/steady-state, semiempirical/dynamic, or semiempirical/steady-state.* The treatment used by a climatological model depends upon the treatment employed by the model used to do the basic dispersion calculations. Sequential steady-state treatments may account for variations by using different values for each time interval involved and hence provide more detail than treatments that treat only a single steady-state.

Background

Numerical models treat upwind pollutant levels in terms of the boundary condition at the upwind vertical side; hence background does not need to be considered for them.

For semiempirical/dynamic models the user must determine whether spatial and temporal variations in background are treated:

- Whether the background is time-dependent or constant.
- Whether the background can change arbitrarily from receptor to receptor, or whether it must be uniform across the region of interest.

For semiempirical/steady-state models, only the second consideration need be made, because there can be no time dependence.

Upper Boundary Condition

The upper boundary condition refers to the way in which dispersion is treated at the mixing height. The user should focus on the variations in mixing height which can be accommodated by the model and whether the top of the mixing layer is treated as an absolute or partial barrier to pollutants.

For numerical/dynamic models, the user should determine:

- Whether pollutants dispersing upward are allowed to be only partially reflected at the mixing height, or whether perfect reflection is specified.
- Whether pollutants can be entrained into the region of interest from above as the mixing height increases.
- Whether the mixing height can vary with location.

*Refer to Appendix A.7.2 for a detailed discussion of treatments of background, boundary and initial conditions.

For a numerical/steady-state model only the first three considerations apply.

For semiempirical/dynamic models, the user must determine:

- Whether the mixing height can be a function of time.
- Which method of treatment is used:
  - Perfect reflection simulated by multiple image sources and evaluation of the resulting infinite sum, or
  - Perfect reflection with interpolation used between the region where the mixing height has no effect and the region of uniform mixing.
- Whether a functional form has been chosen that implicity assumes the mixing height is large enough so as not to affect pollutant concentrations.
- Whether an implicit treatment has been used.

Implicit treatments simulate the effect of the mixing height by limiting the appropriate parameters of the semiempirical dispersion function. For example, the vertical dispersion coefficient in a Gaussian plume formulation may be limited to simulate the limited upward spread of a plume.

Only the last three considerations apply to a semiempirical/steady-state model.

Lower Boundary Condition

The lower boundary condition refers to the way in which dispersion is treated at the earth's surface.

For a numerical/dynamic model the following considerations should be made:

- Whether partial reflection treated, or whether perfect reflection must be used.
- If partial reflection is treated, a numerical model will generally do so in terms of a dry deposition velocity. In this case the user must determine:
  - Whether the dry deposition velocity can vary with location within the region of interest.
  - Whether the dry deposition velocity can vary with time.

For numerical/steady-state models, the consideration of time dependence is irrelevant.

The considerations (and treatments) are the same for both semiempirical/dynamic and semiempirical/steady-state models. The user should consider:

- Whether partial reflection is treated, or whether only perfect reflection is treated.
- If only perfect reflection is treated:
  - Whether multiple image sources or a single image source is used.
  - Whether the infinite sum giving the concentration estimate is evaluated or whether interpolation is used between the region where the mixing height has no effect and the region of uniform mixing.

Note also that some semiempirical models use only a single image source to treat perfect reflection at the earth's surface. In this case, no multiple reflections can occur and the upper boundary is implicitly assumed to have no effect on pollutant concentrations. If partial reflection is treated by a semiempirical model, the functional form used is normally a solution to the diffusion equation appropriate to the partial reflection boundary condition.

Vertical Sides

For a numerical/dynamic model, the following considerations should enable the user to determine the model's treatment of the boundary conditions at the vertical sides. The considerations are almost the same for numerical/steady-state models, except that time dependence need not be considered. The user should determine:

- Whether the flux into the region can vary from point to point.
- Whether the flux can differ at different elevations.
- Whether the flux can vary with time, or whether it must be constant.

The user should recall that numerical models treat background pollutant concentrations as a boundary condition at the vertical sides.

Semiempirical models treat this boundary condition at the vertical sides as background. Hence, this condition need not be considered for such models.

Initial Conditions

Initial conditions need only be considered for dynamic models. For both numerical/dynamic and semiempirical/dynamic models, the user should determine:

- Whether the initial concentrations can vary from point to point, or whether they must be uniform throughout the region.

In making this determination, both the dependence on horizontal location and elevation should be considered.

After taking these considerations into account, the user should be able to determine the study model's treatment of each relevant aspect of background, boundary and initial conditions.

Any additional information which would clarify the study model's treatment of a particular element should also be included with the description of the treatment on the Evaluation Form-Part C. Examples of such information include:

- How background levels are determined at different locations or times. For example, whether they are user-specified at each time interval or are interpolated between one initial value and one final value.
- How mixing height is determined and upon what parameters it depends.
- The parameters limited and the limiting values or the method used in an implicit treatment of an upper or lower boundary condition should be noted.
- How the flux through the vertical sides of the region of interest is determined for different locations and times.
- Any additional assumptions made in the study model's treatment that are not covered by this workbook.

General treatments of background, boundary and initial conditions are given in Table 5.14 and the treatments used by selected reference models are given in Table B.12.

5.11 TREATMENT OF TEMPORAL CORRELATIONS

In dealing with temporal correlations, the quantities of primary interest are emissions, meteorological variables, removal processes, background, and the various boundary conditions.*

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*Detailed discussions of treatments of temporal correlations can be found in Appendix A.8.2.

Table 5.14. Treatment of Background, Boundary and Initial Conditions[a]

a. Background

Type of Model	Method of Treatment[a]
Numerical/ dynamic	(Treated as a boundary condition at vertical boundaries.)
Numerical/ steady-state[c]	(Treated as a boundary condition at vertical boundaries.)
Semiempirical/ dynamic	1. Time-dependent level added to calculated concentrations; value can change at each receptor. 2. As in No. 1, but value is uniform throughout region of interest at all times. 3. Single uniform, constant level added to calculated concentrations. 4. No treated explicitly.
Semiempirical/ steady-state[c]	1. Background level can vary with location within region. 2. Single uniform level for entire region added to calculated concentrations. 3. Not treated explicitly.
Climatological	Level of detail depends upon treatment employed by model used to do basic dispersion calculations.

b. Upper Boundary Condition (at Mixing Height)

Type of Model	Method of Treatment[a]
Numerical/ dynamic	1. Treats both partial reflection and entrainment of pollutants from above mixing layer.[b] Mixing height depends upon location and time. 2. Treats either partial reflection or entrainment, but not both. 3. Treats only perfect reflection. Mixing height depends upon location and time. 4. Treats only perfect reflection. Mixing height is a constant and uniform over region of interest.

Table 5.14 (Contd.)

b. Upper Boundary Condition (at Mixing Height)	
Type of Model	Method of Treatment[a]
Numerical/ steady-state[c]	1. Treats both partial reflection and entrainment of pollutants from above mixing layer.[b] Mixing height depends upon location only.
	2. Treats either partial reflection or entrainment.
	3. Treats only perfect reflection. Mixing height depends upon location only.
	4. Treats only perfect reflection. Mixing height uniform over region of interest.
Semiempirical/ dynamic	1. Uses perfect reflection boundary condition. Mixing height is a function of time. Uses method of multiple images and evaluates infinite sum.
	2. Same as No. 1, but with constant mixing height.
	3. Uses perfect reflection with interpolation between region where mixing height has no effect and region of uniform mixing.
	4. Functional form implicitly assumes mixing height large enough to have no effect.
	5. Implicit treatment limits appropriate parameters, such as vertical dispersion coefficient.
Semiempirical/ steady-state[c]	1. Uses perfect reflection with constant mixing height. Uses method of multiple images and evaluates infinite sum.
	2. Uses perfect reflection with interpolation between region where mixing height has no effect and region of uniform mixing.
	3. Functional form implicitly assumes mixing height large enough to have no effect.
	4. Implicit treatment limits appropriate parameters, such as vertical dispersion coefficient.
Climatological	Level of detail depends upon treatment employed by model used to do basic dispersion calculations.

Table 5.14 (Contd.)

c. Lower Boundary Condition (at Earth's Surface)

Type of Model	Method of Treatment[a]
Numerical/ dynamic	1. Allows for partial reflection in terms of a dry deposition velocity, which can depend on location and time. 2. Treats partial reflection using constant dry deposition velocity. 3. Treats perfect reflection only.
Numerical/ steady-state[c]	1. Allows for partial reflection in terms of a dry deposition velocity, which can depend on location. 2. Treats partial reflection using constant dry deposition velocity. 3. Treats perfect reflection only.
Semiempirical/ dynamic	1. Assumed form of vertical concentration profile based on solution to diffusion equation which includes boundary condition describing partial reflection. 2. Treats only perfect reflection by method of multiple images; evaluates infinite sum. 3. Treats only perfect reflection; uses single image source treatment and interpolates between region where mixing height has no effect and region of uniform mixing. 4. Treats only perfect reflection; uses single image source treatment with an implicit treatment of upper boundary condition (hence no multiple reflections).
Semiempirical/ steady-state	1. Assumed form of vertical concentration profile based on solution to diffusion equation which includes boundary condition describing partial reflection. 2. Treats only perfect reflection by method of multipe images; evaluates infinite sum. 3. Treats only perfect reflection; uses single image source treatment and interpolates between region where mixing height has no effect and region of uniform mixing. 4. Treats only perfect reflection; uses single image source treatment with an implicit treatment of upper boundary condition (hence no multiple reflections).
Climatological	Level of detail depends upon treatment employed by model used to do basic dispersion calculations.

Table 5.14 (Contd.)

d. Vertical Sides

Type of Model	Method of Treatment[a]
Numerical/ dynamic	1. Treats flux into region as function of location (including elevation) and time.
	2. a. Treats flux into region as function of horizontal location (no elevation dependence) and time, or
	b. Treats flux as a function of either location (including elevation) or time, but not both.
	3. Treats flux as a function of horizontal location only (no elevation or time dependence).
	4. Treats flux as a constant.
	5. Not treated explicitly; assumes horizontal uniformity.
Numerical/ steady-state[c]	1. Treats flux into region as function of location (including elevation).
	2. Treats flux as a function of horizontal location only.
	3. Treats flux as a constant.
	4. Not treated explicitly; assumes horizontal uniformity.
Semiempirical/ dynamic	(Treated as background.)
Semiempirical/ steady-state	(Treated as background.)
Climatological	Level of detail depends upon treatment employed by model used to do basic dispersion calculations.

Table 5.14 (Contd.)

e. Initial Conditions

Type of Model	Method of Treatment[a]
Numerical/ dynamic	1. Treated as a function of position (including elevation). 2. Specified as uniform, independent of position.
Numerical/ steady-state	Not applicable.
Semiempirical/ dynamic	1. Treated as a function of position (including elevation). 2. Treated as uniform, independent of position.
Semiempirical/ steady-state	Not applicable.
Climatological	Level of detail depends upon treatment employed by model used to do basic dispersion calculations.

[a] Treatments are listed in order of decreasing level of detail within each type of model.

[b] Fumigation may also be treated by numerical models through an appropriate choice of the upper boundary condition during the time of the fumigation.

[c] Sequential steady-state treatments can account for variations in parameters like background and mixing height by assigning a different value to each of the time intervals involved. Models providing this capability give more detailed treatments of this element than those which do not.

If the study model is dynamic or sequential, the temporal correlations between these various quantities are usually accounted for automatically; in other cases, the degree or correlation between the various time-dependent quantities must be assessed by the user. For both sequential and non-sequential treatments the user must determine:

- The degree of temporal resolution available to describe the temporal variations. The degree may be different for different parameters.
- Whether these quantities are correlated to a high degree. In other words, whether a concentration estimate for a particular time is made on the basis of values of the varying parameters that are appropriate to that particular time.

These considerations should enable the user to determine the study model's treatment of temporal correlations.

In addition, when comparing treatments by two different models, the user should consider:

- Whether the magnitude of the variations in the specific application of interest are sufficiently large to require detailed correlation.
- Whether the quantities correlated by the model are important to the specific application.

For example, if emission rates are truly constant, it is unnecessary to correlate them with changes in meteorology. Or, it may be more important to correlate two highly critical quantities than to correlate four quantities of lesser importance to the application of interest.

When describing the treatment on Evaluation Form-Part C, the user should list:

- The quantities correlated,
- The degree of temporal resolution; for example, day-night differences or hourly differences in emission rates,
- The method used to accomplish the correlations; for example, via a stability wind rose or by hourly values input by the user,
- Any scheme used to correlate variables; for example, adjusting input mixing height by stability class,
- Any correlations particularly important in the application of interest, and

Any correlations that are unimportant because certain variables are constant in the particular application of interest.

General treatments of temporal correlations are given in Table 5.15 and treatments by selected reference models are given in Table B.13.

Table 5.15. Treatment of Temporal Correlations[a]

Method of Treatment[b]
1. Sequential treatments (correlations automatic).[c]
a. High degree of temporal resolution (usually one hour) of all quantities.
b. High degree of temporal resolution of time-dependent quantities most important to the application.
c. Either low degree of temporal resolution or failure to correlate some important quantities.
2. Non-sequential treatments with limited correlation.
a. High degree of temporal resolution and correlation of time-dependent quantities important to application.
b. Either low degree of temporal resolution or failure to correlate some important quantities.
3. Correlations not treated explicitly.

[a]The quantities of interest here are those used to determine emissions, meteorology, removal processes, background, and boundary conditions.

[b]Treatments are listed in order of decreasing level of detail.

[c]Found in dynamic and sequential models.

6 COMPARATIVE EVALUATION

6.1 INTRODUCTION

This section provides detailed guidance on comparing two simulation models. The comparison is made after the importance rating of each element has been reviewed and the treatment of each element has been determined. The comparative evaluation is technical in nature and consists of two steps described in Sections 6.2.1 and 6.2.2, respectively. In the first step, the models are compared on an element-by-element basis; in the second, these individual comparisons and the importance ratings are combined into the technical evaluation.

6.2 TECHNICAL COMPARISON

Before initially attempting to compare the treatments of an element by two models, it is strongly recommended that the user be familiar with the technical material presented in the appropriate section of Appendix A. Experienced users may have a lesser need for such reference material.

6.2.1 Comparing Treatments of Individual Elements

The study model's treatment of a particular element should be rated as BETTER than, COMPARABLE to, or WORSE that the reference model's treatment. This rating depends on the relative level of detail with which the two models treat the element and the need for a detailed treatment. If the study model's treatment is significantly more detailed than that used by the reference model and considerable detail is needed in the application, the study model's treatment is rated BETTER. If both treatments are essentially the same, the study model is rated COMPARABLE. Finally, if the study model incorporates substantially less of the detail needed in the application, it is rated WORSE. Guidance on determining the relative level of detail is available from three sources:

- The general tables in Section 5,
- The discussions in Appendix A, and
- The degree of flexibility the user has in defining input to the model.

The tables in Section 5 list various treatments of each element in order of decreasing level of detail. These tables are the basic tools to be used in determining the relative level of detail used in a given treatment. Some elements have been further subdivided into several aspects, each of which must be considered in making the comparison for those elements.

When there is only a single aspect, the user should locate the treatment used by the study model and the treatment used by the reference model on the appropriate table in Section 5. Tables B.2–B.13 in Appendix B give the treatments used by selected reference models. Since not all possible treatments are listed in the tables, the user may need to infer at what level a given treatment would be located if it were explicitly included in the table. On the basis of the relative level at which the two treatments occur, the user should decide upon a comparative rating of the study model with respect to the reference model. Judgment must be exercised at this stage; a treatment occurring at a slightly higher level in the table than another is not necessarily a BETTER treatment. COMPARABLE should be interpreted as meaning "near" or "approximately the same" and should not be interpreted as meaning exact equality. A significant or substantial difference makes the comparative rating BETTER or WORSE.

When the relative level of detail of two treatments is determined, the relevance of that detail to the particular situation should also be considered. The tables of treatments in Section 6 are general in nature and may indicate a difference in the level of detail that is irrelevant in the application of interest. For example, assume that the application involves level terrain, that the study model accounts for physical stack height, and that the reference model accounts for both the topographic elevation of the source as well as the physical stack height. In this case, the study model would not be rated as WORSE than the reference model, since elevation corrections are not required in the specific situation being modeled.

The situation becomes more complicated for those elements for which several aspects are discussed. The comparison is made for each aspect separately and the results combined to give a comparative rating for the element as a whole. The user should be guided by two things:

- The likely importance of the various aspects in the particular situation to be simulated, and
- The expected sensitivity of model estimates to changes in each aspect separately.

The actual situation can be examined to determine which aspects might require more detailed treatment. These would then weigh more heavily in the evaluation of the element as a whole. Treatments of aspects to which the concentration estimates are most sensitive would weigh more heavily than treatments of aspects to which the estimates are least sensitive. A qualitative judgement on these matters is being sought; quantitative information is not required. It may become necessary to consult an expert if questions regarding sensitivity arise.

In difficult situations, the discussions in Appendix A may help resolve the problem.

Specific guidance for all possible situations is clearly not feasible, but the general principles discussed above should enable the user to compare the treatments in most situations. If this guidance does not allow the user to reach a decision, an expert should be consulted.

One final point needs to be made regarding the comparative rating of treatments. For elements like dispersion for which the model itself must be classified, the user must consider the appropriateness of the type of model to the application at hand. Many factors could go into determing whether a particular type of model is appropriate and no specific guidance can be given. The user must make a decision based on specific needs of the problem. For example, the tables for dispersion in Section 5 list numerical/dynamic treatments above the semiempirical/steady-state treatments. However, as discussed in Appendix A, if certain conditions are satisfied, a semiempirical/steady-state treatment may be just as good as a numerical/dynamic treatment. In fact, if a high degree of spatial resolution is required, the semiempirical approach may be more applicable. Thus, the user would be warned that a highly detailed approach may be inapplicable given the user's specific needs. This example illustrates the need for the user to be familiar with the material in Appendix A.

6.2.2 Overall Technical Comparison

This section describes the procedure for synthesizing the comparisons of the individual elements into the TECHNICAL EVALUATION.

When there have been no designations of CRITICAL elements, the user should proceed as follows:

1. Examine the distribution of the treatments of the HIGH-rated elements among the categories BETTER, COMPARABLE, and WORSE. Based on the type of distribution and the guidance below, formulate a tentative evaluation.

2. Based on the distribution and number of the MEDIUM-rated elements, determine the need to modify the tentative rating assigned in step 1. Modify as required.

3. The modified rating obtained in Step 2 will normally be the TECHNICAL EVALUATION. In ambiguous situations, the LOW-rated elements may need to be considered.

If the user is unable to complete the TECHNICAL EVALUATION given the following guidelines, an expert should be consulted.

It is also strongly suggested that the user document the reasons for the decisions made, particularly in ambiguous cases.

6.2.2.1 Comparison Based on HIGH-Rated Elements (Step 1)

In step 1, only the high-rated elements are considered. The user should take the following points into consideration:

- The relative numbers of treatments in each category (the distribution),
- The specific application elements in each category,
- The relative importance of these elements in the application of interest,
- Factors unique to the application of interest, and
- Possible ambiguous ratings in parentheses.

Five types of distributions can arise. Each is described below along with the manner in which the other considerations affect the evaluation. It is not always necessary for the user to identify the particular distribution as long as the application of the general ideas is understood.

Case 1 - All Treatments of High-Rated Elements in Same Category (BETTER, COMPARABLE, WORSE)

In this case, the comparison is obvious. For example, if there are three highly important elements and the treatment of each by the study model is rated better, BETTER is the unambiguous entry in the "Comparative Rating" column.

Case - 2 Equal Numbers of Treatments in Each Category

With equal numbers of treatments in each category, the user cannot simply assume that one better treatment balances out one worse treatment. Rather, the user should identify those elements whose treatments are being considered in the three categories. The importance of these elements to the specific situation to be modeled should then be reassessed and any factors unique to that situation should be considered. This process should not be interpreted as a reassignment of the importance ratings but rather as a means to "fine tune" the HIGH ratings in order to resolve an otherwise ambiguous situation. Although all these elements are of generally high importance in the application, the HIGH category itself covers a rather broad range and some of these elements may be more important than others. If such a determination can be made, a basis may exist for making a comparison other then COMPARABLE.

Other information may be gained by looking at any ambiguous element-by-element comparisons. For example, if one of the COMPARABLE ratings is ambiguous and is indicated as perhaps belonging in the BETTER category, the judgement would lean toward BETTER as the Comparative Rating. This judgment is made only after the relative importances of the elements rated as better and worse have been considered.

Case 3 - A Large Number of Treatments in One Category and a Smaller Number in the Other Two

The considerations here are similar to those described above. The comparative rating is that category with the largest number of elements. The confidence in this rating increases as the relative number of treatments in this category increases. For example, a rating of COMPARABLE based on three comparable treatments and two worse ones is much more tenuous than a COMPARABLE rating based on four comparable treatments and one worse one. Some additional insight may also be gained by examining any ambiguous ratings. Since these ratings are second guesses, their major use should be in cases where they tend to remove ambiguity from the situation, that is, if they support the initial comparison. In any case, no final assignment of the Comparative Rating should be made until the elements whose treatments are listed in each column are identified and their relative importance reevaluated. It may be possible, for instance, for a single WORSE treatment of a highly rated element to justify a Comparative Rating of WORSE even if the treatments of several other high-rated elements are COMPARABLE.

Case 4 - Large Numbers of Treatments in COMPARABLE and One Other Category and a Small Number in the Third

The same considerations apply here as enumerated in Case 3. Here, however, any change in rating from the category with the largest number of treatments would generally be to that associated with the next larger number of elements.

Case 5 - A Large Number of Treatments in the BETTER and WORSE Categories and a Small Number in COMPARABLE

This type of distribution should be considered anomalous and the user should review the individual comparisons and importance ratings before proceeding. If the anomaly cannot be resolved, an expert should be consulted for aid in the comparison.

6.2.2.2. Comparison Based on MEDIUM- and LOW-RATED ELEMENTS (Steps 2 and 3)

In step 2, the MEDIUM-rated elements are considered and the user must decide whether or not to change the Comparative Evaluation reached at the end of step 1. Keeping in mind that the MEDIUM-rated elements are by definition less important individually than the HIGH-rated elements, the user should consider the following:

- The same considerations as involved in step 1, and
- The relative numbers of HIGH- and MEDIUM-rated elements.

The consideration of the distribution of the MEDIUM-rated elements and factors unique to the application follow lines parallel to those discussed in Section 6.2.2.1. If the distribution of high and medium elements are similar, no change is made in the rating. If the distributions are different, the desirability of a change becomes stronger as the relative number of medium elements increases. When the numbers of high and medium elements are considered, the user must think about which elements are involved and their relative importance in the specific situation of interest. For example, consider the two cases outlined in Table 6.1. In case A, the user would be much more likely to change the initial Comparative Rating from BETTER to COMPARABLE than in case B, because of the relatively larger number of MEDIUM-rated elements in case A.

Table 6.1. Effect of Numbers of Elements on Ratings

Case	Importance Rating	Better	Comparable	Worse	Comparative Rating
A	HIGH	1	1	0	BETTER
	MEDIUM	0	6	0	COMPARABLE
B	HIGH	3	1	0	BETTER
	MEDIUM	0	4	0	BETTER

In most cases, step 3 simply involves writing down the Comparative Rating reached at the end of step 2 as the TECHNICAL EVALUATION. The LOW-rated elements are usually not considered. In cases in which the user considers that a contemplated change based on the MEDIUM-rated elements is ambiguous, it may be necessary to look at the LOW-rated elements in an attempt to resolve the ambiguity. The rules for the comparison are essentially the same as in step 2, except that in this case the user is examining the distribution, number of elements, and importance to the application to see if the indicated direction of change is the same as that being contemplated. If it is, the ambiguity may be removed. If not, the change should probably not be made. If problems still remain, an expert should be consulted.

At this point, the TECHNICAL EVALUATION is complete.

6.2.2.3 Comparison with a CRITICAL Element

If a CRITICAL element has been designated, the procedure is almost the same, except that the initial rating is based upon consideration of that element alone. Possible subsequent modifications are then based first upon consideration of the treatments of the HIGH-rated elements and then upon those of the MEDIUM-rated elements. However, if a critical element is treated worse, the user may consider making this single comparison the basis of the entire TECHNICAL EVALUATION. For comparable and better treatments of the critical element, the entire procedure should be applied. Since there will generally be only a single critical element and several HIGH-rated elements, the user must decide how many high elements would be required to override an initial Comparative Rating based on the critical element alone. Again, the user must reach a qualitative judgment based on the considerations discussed above and must not base an entire comparison on a single critical element.

7 ROLLBACK/STATISTICAL MODELS

7.1 GENERAL

The emphasis in this workbook is on the comparison of simulation models. By definition, these models simulate mathematically the effects of physical and chemical processes that affect air quality. Furthermore, the relevant phenomena are considered and described in terms of fundamental physical principles of general applicability. As a result, a simulation model has the property of being transferable from one location to another as long as the limitations imposed by assumptions made in the basic formulation of the model are not violated. Air quality data taken within the region of interest is not required except to fix boundary and/or initial conditions.

Models which do not satisfy these criteria may be encountered by the user. This section provides general guidelines for their evaluation and comparison. Such models are termed rollback/statistical models throughout this workbook and are characterized by one or both of the following properties:

- Only a very few of the factors relating to emissions, meteorological, transformation, and removal processes are explicitly considered in the formulation of the model.
- Locally measured air quality data is required in order to determine empirically the values of various coefficients or parameters in the model.

Included in this classification is the simple rollback model and various extensions of it. The simple rollback model assumes a linear relation between total pollutant emissions within some region and pollutant concentrations within that region. It does not explicitly consider the spatial distribution of emissions, the location of the receptors of interest, nor any meteorological factors.

Also included in the rollback/statistical category are those models that require the use of actual atmospheric monitoring data, including both air quality and meteorological variables, for the empirical adjustment of model parameters. The relationship between air quality and selected meteorological parameters is determined empirically in these models, commonly through the use of regression or other statistical techniques.

7.2 ADVANTAGES AND DISADVANTAGES

The major technical advantage enjoyed by statistical models is the close relationship between concentration estimates and values actually measured under more or less similar circumstances. The effects of all those factors that determine atmospheric pollutant concentrations are implicitly accounted for in the air quality data used to develop and optimize the model. The same may be said about rollback, since an air quality measurement is used to estimate the ratio of emissions to atmospheric concentrations. Due to the nature of the procedures used in developing a statistical model, information is often available regarding the statistical significance of the variables that are taken into account and the magnitude of the statistical error made by the model; no such information is available for rollback. Other advantages of rollback/statistical models, such as their low development cost and low resource requirements, are primarily pragmatic in nature.

The major disadvantage of rollback/statistical models also arises from their dependence on air quality data. A statistical model is not, in general, applicable under conditions that are outside the range of conditions included within the data used in its development and optimization. The range of conditions commonly includes variations in meteorological variables, but for practical reasons very little variation in the spatial distribution of emissions can be investigated. Consequently, statistical models are not generally suited for applications that involve the consideration of significant changes in the distribution of emissions and, as a result, are not transferable without re-evaluation of their specific empirical parameters or coefficients. Rollback considers only one set of conditions, specifically that set of meteorological conditions and emission rates which existed over that period of time in which the air quality measurement used in the model was made. Therefore, it is also unsuited for the consideration of changes in the emission distribution.

The applicability of rollback/statistical models is more limited than that of a simulation model for other reasons as well. For example, only rather general concentration estimates may be obtained. The dependence of pollutant concentrations on position cannot normally be predicted, nor can individual source contributions at any given position of interest.

If a model that falls into the rollback/statistical category is to be evaluated, the user should consider the applicability of the particular model to the application of interest, keeping in mind the generally limited applicability of such models. Statistical models are often formulated for a very specific purpose. If that purpose coincides with the requirements of the user, and if the range of conditions of interest to the user are included within those used to develop the model, the model is applicable and may give better results than a simulation model. Otherwise, the model may not be appropriate.

7.3 COMPARISON OF ROLLBACK/STATISTICAL MODELS

The only basis that may exist for the comparison of a given statistical model with a given simulation model is the observed performance of each in previous practical applications. In general, the philosophies and goals of these two approaches to estimating atmospheric pollutant levels are sufficiently different as to preclude any systematic, objective, a priori technical comparison. If, however, estimates of the errors made by the simulation model in applications similar to the one of interest are available, they may be compared directly with the expected error for the statistical model, thereby allowing a comparative evaluation to be made. Unfortunately, even this basis does not exist for rollback, since the emission-concentration relationship is an assumed one, rather than one obtained using accepted statistical procedures.

It may be possible in some cases to make a comparison of a rollback/statistical model with a simulation model by determining the approximations that must be made to reduce the working equations to a linear relation with constant coefficients between the pollutant concentration and the total emission rate. The degree of validity of the necessary approximations in the situation to be modeled is a measure of the degree of comparability of the simulation model and the rollback/statistical model. If this approach is adopted, the Evaluation Form provides a convenient format for recording the necessary information. Furthermore, if the element-by-element comparisons are interpreted as a measure of the validity of the relevant approximations in going from the simulation model treatment to the rollback or statistical model treatment, the information can be summarized easily on Part D of the form. The technical comparison can in this case be made following the same guidelines as are used for the comparison of two simulation models as described in the other sections of this workbook.

It may not always be possible to make a comparison in this manner. A statistical model may still be evaluated on its past performance. However, since rollback is: (1) not really based upon consideration of the application elements discussed in this workbook; (2) not obtained by statistical analysis of appropriate air quality data; and (3) as yet unverified, no basis exists for objectively evaluating the performance of a rollback model.

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16. ABSTRACT

The workbook describes a technique for the qualitative comparison of modeling approaches on technical grounds. The methodology is based upon an applications approach. The results of the model comparison depend upon the application for which the model is to be used as well as upon the model characteristics. In each application of the technique, the model of interest is compared with a reference model. Any model may be specified as the reference model, as long as it is compatible with the application of interest.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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