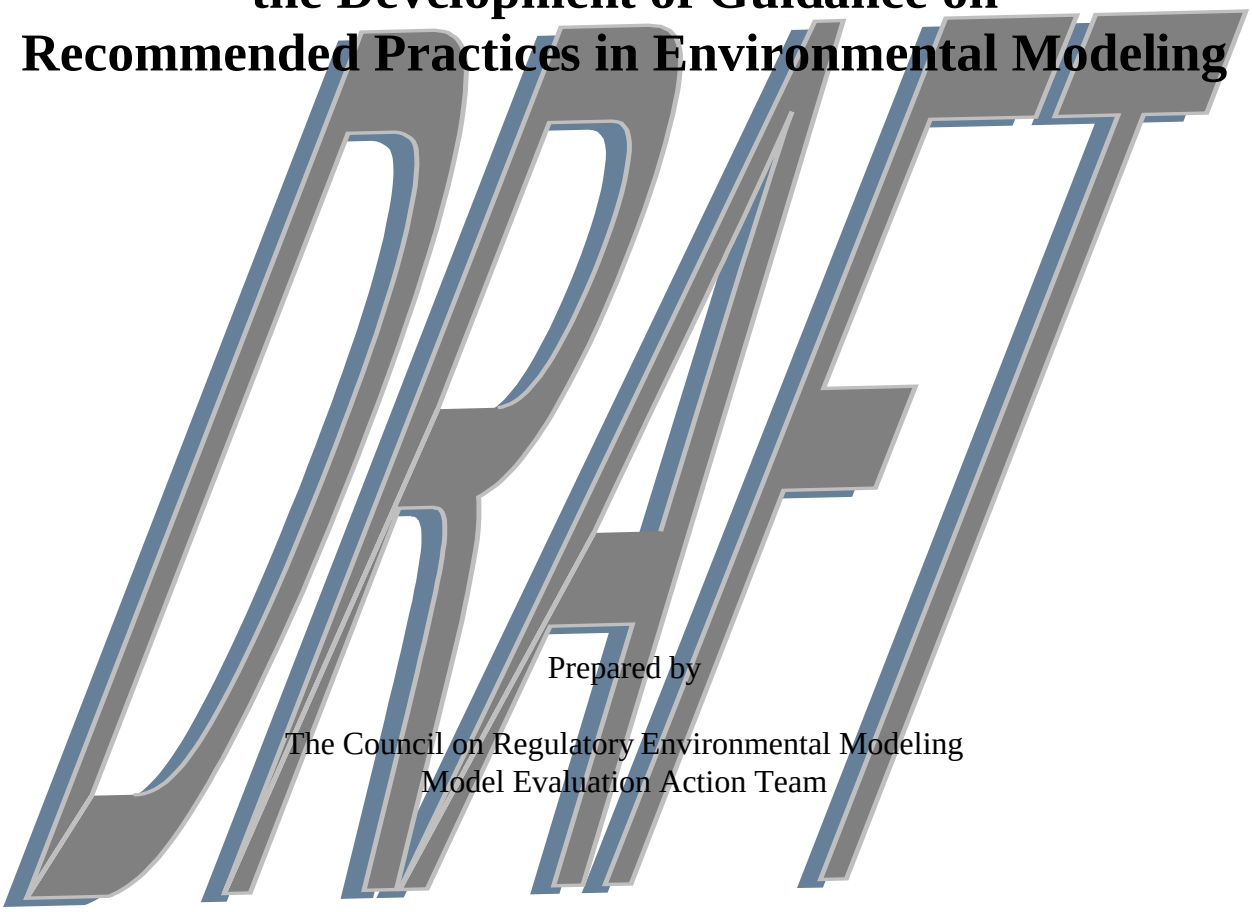
Proposed Agency Strategy for the Development of Guidance on Recommended Practices in Environmental Modeling



Prepared by

The Council on Regulatory Environmental Modeling
Model Evaluation Action Team

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EXECUTIVE SUMMARY

1. What is the purpose of developing guidance for recommended practices in environmental modeling?

Guidance for Recommended Practices in Environmental Modeling (modeling guidance) will encourage Agency-wide consistency in the development, evaluation and application of models that the Agency uses to address environmental problems and support regulatory activities. Modeling guidance can help to minimize apparent inconsistencies in model selection and support EPA's decision-making on models. Users of the models, such as risk assessors, risk managers, and stakeholders need assurance that a model is being used appropriately and within limits throughout EPA, and by other Federal agencies and stakeholders, where applicable.

2. What is the scope of modeling guidance?

Modeling guidance is intended to address regulatory environmental models. *Workshop participants identified three primary categories of regulatory models, based on their purpose: (1) models used for policy analysis, (2) models used for national regulatory decision making, and (3) models used for implementation applications.*

Policy analysis models affect national policy decisions. The results of these models are likely to be analyzed and used to set policy for large, multi-year programs or concepts. Specific examples include models used to develop national policy on acid rain and phosphorous reduction in the Great Lakes. Current and future examples may include models that are used to develop national and international policy on climate change (general circulation models), sustainable development, and fuel oxygenates (reformulated gasoline computer models).

National regulatory decision-making models result in large-scale, national regulatory decisions where the overall policy has already been established. General examples include regulatory programs that require "decision roles," such as when a process is implemented that uses modeling and data analysis as part of the national regulatory decision. Specific examples include the regulation of pesticides where modeling is used to assist in determining the national decision regarding the regulation of that specific pesticide (e.g., LifeLine Model System), or to aid in the establishment of national effluent limitations. The number of stakeholders and parties directly affected by the ultimate results of these models is greater than those for policy analysis models.

Models used for implementation applications include the most widely developed type of model,. These models apply to situations where policies and regulations have already been made. Decisions tend to be local and often lead to design implementations for engineering purposes or a set of actions for local decision-making. The development of these models and the use of their output may be driven by court-ordered schedules and the need for actions. Examples include models used to support the Office of Water Total Maximum Daily Load (TMDL)

program (e.g., QUAL2E; Hydrologic Simulation Program-Fortran, HSPF) and the Superfund program (e.g., AQUATOX, Environmental Fluid Dynamic Code (EFDC) Model). Other examples include most permits (air, water, or cross-media) where the results are often used to demonstrate compliance or establish permit limits. The potential to adjust, update, and improve the modeling after its initial use is more possible with this type of model because permits are often reissued after a period of time and Superfund progress is assessed and plans are reevaluated during various stages of the project.

Models used for policy analysis, national regulatory decision-making, and implementation analysis may include various model types, disciplines, and complexities. The primary determination for the scope of modeling guidance is whether the model is used for "environmental regulatory" purposes. Model types may include atmospheric and indoor air, chemical equilibrium, chemical properties, cost and economic, exposure, leaching and runoff, multi-media, risk assessment, ground and surface water, and toxicokinetic models. It may also include simple and complex models, mathematical and computer-based models, and models utilizing a combination of scientific, economic, socio-economic, or other types of data.

3. How should the guidance be organized?

The Model Evaluation Action Team (Appendix B) developed a document that listed 14 major components, or elements, that affect the development, evaluation and use of environmental models. These 14 modeling elements are essentially an expansion of topics that were discussed in the "White Paper on the Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance." The White Paper reviewed progress in and identified issues associated with developing model use acceptability guidance, through the discussion of current practices and case studies. The original document of 14 elements is entitled "Draft Proposed Elements of a Guidance Document on Model Evaluation (July 6, 2000)," and is presented in Appendix B. This document organized the 14 modeling elements according to the following general categories: Model Suitability, Model Development, Model Uncertainty and Sensitivity Analysis, and Model Calibration, Testing, and Overall Evaluation.

The participants at the EPA Models Evaluation and Peer Review Workshop, which was held November 28-30, 2000, recommended that the 14 modeling elements be framed around concepts that modelers and developers would better appreciate, such as the four types of documentation that often accompany models: Science Formulation Documents, User's Guides, Code Description Documents, and Evaluation Summaries. The Model Evaluation Action Team, in a subsequent discussion, concurred with this approach. The summary report of the EPA Models Evaluation and Peer Review Workshop is presented in Appendix D.

4. What approach should modeling guidance take?

The Model Evaluation Action Team recommended that modeling guidance should provide program offices sufficient flexibility to implement the guidance according to their needs

and requirements. The Action Team considered several approaches for development of modeling guidance and considered pros and cons of each approach. One approach involved a detailed description for each of the 14 modeling elements, including instructions on performing each element. The Action Team was concerned that this approach might be prescriptive and believed that a less detailed approach would provide needed flexibility. A second approach involved developing a document that described the 14 modeling elements in detail without those instructions that could be considered prescriptive. A third approach involved the development of a more general document considering the 14 modeling elements as *principles of good modeling practices*, and providing a set of leading questions that a modeler would answer in developing, evaluating, or using a model.

The workshop participants recommended that EPA avoid developing a strategy that is too specific, long, or burdensome. Participants noted that detailed topics can be addressed in documents other than the strategy. The workshop participants preferred an approach to having modeling guidance that was a "general constitution of principles" rather than a lengthy compendium of methodologies. Given the breadth of model applications in the Agency, the participants favored general modeling guidance over an overly prescriptive document. Many participants cautioned that program offices may not find modeling guidance useful that was long or burdensome. The participants thought the strategy could remain general, while details can be addressed in focused companion documents, white papers, "tool boxes," or guidance.

In a subsequent discussion, the Model Evaluation Action Team recommended that modeling guidance involve the development of a general constitution of principles, to include specific questions that a modeler would answer in developing, applying, or otherwise evaluating a model. The Action Team also recommended that modeling guidance might refer to (or include) examples, or case studies, of models in which the principles were applied. In addition, more detail on particular topics or elements can be provided in focused companion documents on specific topics, such as qualitative uncertainty analysis (from the simplification of governing equations and use of averaged inputs), quantitative uncertainty analysis (error propagation), model calibration, model testing, and model quality assurance.

5. Who should the audience be for modeling guidance?

The workshop participants recommended that modeling guidance apply to models of different rigor (e.g., screening or complex) and to models of different underlying scientific discipline (e.g., toxicology or fate and transport). Modeling guidance should appeal to model developers, computer programmers, and model users, and should contain a glossary of key terms, with definitions that all audiences can appreciate.

All stakeholders involved in the development and use of a regulatory model should be aware of the intended use (the regulatory decision that will be made, based on the model results). This understanding includes the issues that will affect the decision-maker's selection to use or disregard a model, and the ramifications of the ultimate decision. An understanding of these

points will give an important perspective to modelers, data gatherers, and program managers that will allow them to develop an appropriate systematic plan at project initiation.

The primary stakeholders for policy analysis models are representatives of several agencies or offices within EPA. One office or program may dominate the effort, but there is usually significant input from outside sources. Due to the large-scale ramifications and the fact that policy is in the development stage at this point, the users (including decision-makers) are typically interested in obtaining as much information as possible.

The primary stakeholders for national regulatory decision-making models include model developers and users representing Federal agencies, States, non-government organizations, and the regulated community. Because there may be an inherent bias of decision makers toward protection of public policy due to the possibility of litigation, any potential bias should be recognized and be built into the planning for development of these models.

Because models used for implementation applications are the most widely applied type of model, there are more stakeholders and more people with financial or personal interest in the findings of a model.

6. What is the relationship between good modeling practices and the EPA Quality System?

EPA Order 5360.1 A2 covers collection and use of environmental data including information produced from models in the areas of (1) use of a systematic planning approach to develop acceptance or performance criteria; (2) approved Quality Assurance Project Plans (QAPPs), or equivalent documents; and (3) assessment of existing data, when used to support Agency decisions or other secondary purposes, to verify that they are of sufficient quantity and adequate quality for their intended use. Requirements for QAPPs are provided in EPA QA Manual 5360 A1 (May 2000) for EPA personnel and EPA QA/R-5 (EPA Requirements for Quality Assurance Project Plans, EPA 2001), for extramural personnel. Documentation of results from successful implementation of a Modeling Quality Assurance Project Plan would provide supporting quality assurance and peer review planning information as described in modeling element 6 of the "Draft Proposed Elements of a Guidance Document on Model Evaluation (July 6, 2000) (Appendix B).

To assist those conducting modeling projects in meeting these requirements, EPA's Quality Staff is developing Guidance for Quality Assurance Project Plans for Modeling. The scope of the modeling QAPP Guidance document allows for the accommodation of various project types and EPA program requirements. It also allows for the use of a graded approach, in which some efforts may need very detailed and specific planning, testing, and documentation while others may require less.

The purpose of a modeling QAPP is to assure that modeling objectives are met (e.g., model and output assessments), through (1) communication among all stakeholders to ensure

needs are defined at the outset, (2) consideration of model biases, uses, and results, (3) identification of activities that will be used to assess model performance and results, and (4) determination of overall model performance.

Guidance on Recommended Practices in Environmental Modeling can provide additional information on the use of good modeling practices to address the modeling QAPP objectives. However, there is some concern that the two documents may cause confusion within EPA if they convey different philosophies. *It is thus recommended that the Quality Staff and the Models Evaluation Action Team articulate the differences between draft Guidance for Quality Assurance Project Plans for Modeling and draft Guidance for Recommended Practices in Environmental Modeling before the either document is released.*

7. Should a system be established to promote consistency in the selection of modeling elements to perform ?

The workshop participants noted that carrying out all 14 modeling elements would not always be necessary in model development, application, or evaluation of models, and that there was a potential for confusion or inconsistency when determining which modeling elements are most useful. As a result, they considered for further discussion the possibility of the development of a decision tree or matrix to provide guidance on prioritizing the 14 modeling elements. Prioritizing the 14 modeling elements would normally be due to various factors such as appropriateness, necessity, and potential constraints (time, budget). *It is recommended that the Agency consider (1) developing a simple decision tree or system that could be readily consulted for selecting modeling elements to perform, or (2) making some of the modeling elements mandatory in order to avoid inconsistency in model development, applications, and evaluation*

One idea that was briefly discussed by the workshop participants was the concept of developing a three-dimensional matrix, which would include model categories, audience, and model life cycles (screening, short term, long term analysis models). Identifying the appropriate matrix cell(s) would allow users to quickly identify which of the 14 modeling elements to perform, and they could then move to the portion of the guidance that addresses their situation. However, the development of a multi-dimensional, complex matrix may be difficult and somewhat elaborate for effective implementation.

8. How will modeling guidance be implemented?

Each Program Office has case-specific needs for implementing good modeling practices, such as model type, model complexity, how the model will be used, and the decision to make from the model results. Modeling guidance should not be prescriptive; it should be sufficiently flexible to allow for the different needs of EPA Program Offices. Thus, it is recommended that EPA Program Offices be responsible for implementing modeling guidance. Implementation according to program-specific needs could be addressed, for example, by drafting short, program-

specific guidance that reflects or supplements the guiding principles of the national guidance; however, other approaches could be considered. However, it is recommended that each modeling element that is described in modeling guidance should be addressed when developing a new or modified model, or when using an existing model for a new or related application. If the Program Office determines not to perform a modeling element, the reason(s) should be described.

Modeling guidance should be linked to model selection, especially for applications that are different from those the model was originally developed. Modeling guidance should include examples, or case studies, of model development, evaluation, and use for representative model types and complexities, and should take into account the impact of resources that would be needed to implement the guidance.

9. What follow-up activities should be pursued?

The draft outline, presented in Appendix C, should be reviewed and expanded. This activity might be accomplished by either forwarding it to experts for comment, or by convening a workshop for the purpose. Participants can be divided into smaller groups, with each group working on a specific section of the planned document. Once consensus is reached on the content of the outline, then the actual document would be drafted. The development of the actual guidance should also take into account the recommendations of the 1994 Agency Task Force on Environmental Regulatory Modeling (ATFERM) report, as well as other applicable reports that have been developed as part of EPA's modeling policy development activity.

10. What additional issues need to be addressed?

Issue. The proposed strategy may be used as a standard to judge the effectiveness of EPA programs. Program Offices, whose regulations and program implementation are often subject to litigation, are sensitive to the fact that modeling guidance could be considered a standard that EPA must follow. It has thus been suggested that modeling guidance be advisory in nature, perhaps through use of the term 'guidelines' or 'principles' in place of 'guidance.' On the other hand, it has also been suggested that, in situations where enabling legislation or regulation does not define a level of performance, modeling guidance could be equally considered a standard to which stakeholders and the regulated community will also be held, thereby "leveling the playing field."

Issue. Should the proposed strategy cover only EPA-developed and/or applied models? EPA may have little knowledge of environmental models that have been developed by other entities, such as States.

Issue. How will modeling guidance affect models that have already been developed and used? The strategy suggests that EPA Offices should develop documents for models that they are already using. Ideally, the supporting documents that are described in this strategy should

already have been developed for existing models. It is realized, however, that the already developed documents may not reflect the organization of documents or approach that is recommended in this strategy, e.g., Science Formulation Documents, Evaluation Summaries. . How much documentation should be recommended for previous model applications? Should previous model applications be grandfathered?

Issue. The proposed strategy should be strengthened. There is some concern that the modeling strategy as outlined in this document may not be sufficiently strong to ensure national consistency in its implementation. It has been suggested that the strategy be strengthened by linking it more strongly to the elements of systematic planning and to the scientific method, while allowing for flexibility in implementation. However, the strategy includes a recommendation for developing implementing guidance, addressing each modeling element of the guidance, and considering the development of a system to promote consistency in the selection of modeling elements to perform. It is also recommended that the Quality Staff and the Models Evaluation Action Team articulate the differences between draft Guidance for Quality Assurance Project Plans for Modeling and draft Guidance for Recommended Practices in Environmental Modeling before either document is released.

Issue. Program Offices should not be asked to develop implementing guidance. Program Offices may believe that developing implementing guidance is burdensome and unnecessary, particularly since there may be common areas where an EPA-wide approach is appropriate, such as in developing the computer code. However, this recommendation was included in the strategy to encourage and document program-specific approaches to implementing modeling guidance. Implementing guidance does not have to be exhaustive. To streamline the development of implementing guidance, Program Offices could rely on the details of the national guidance by reference, but point out any modifications or clarifications in the implementing guidance.

Issue. Modeling guidance needs to take screening or less comprehensive models into consideration. The outline on Guidance on Recommended Practices in Environmental Modeling (Appendix C) describes a comprehensive approach to incorporating good modeling practices into the Agency's development and use of regulatory environmental models. There is some concern that this approach may be overwhelming for less comprehensive, or screening-type models. Screening models are often used when time or resources are a factor. Common examples of the use of screening level models include risk management decisions for further action, modeling performed under court-ordered deadlines, and situations in which sufficient resources are not available. Thus, data collection and other applicable constraints may determine what type of model one can afford to use. Suggestions for taking screening models into consideration include (1) presenting the trade-offs between uncertainty and confidence level, (2) explaining that uncertainty and variability may not be separable, (3) explaining that there are reducible and non-reducible uncertainties when developing a model, (4) using sensitivity analysis early and often, and (5) using a simple tiered approach for good modeling practices. The approach for less comprehensive toxicity-based models is being considered by a separate EPA group.

Introduction

The Agency develops, evaluates, and applies a wide variety of highly complex environmental models. These models are used to coordinate and/or predict the environmental consequences of a wide range of activities. Frequently, these models become the basis for environmental cleanup, protection, or regulation, and thus serve to provide a basis for resolution of issues that have a cross-Agency impact involving multiple media (e.g., air, water, ground water). In order to ensure the adequacy and consistency in the development, evaluation and application of models, it is recommended that the Agency adopt a set of basic principles that will guide the EPA modeling community in performing analyses that impact various segments of the Agency's programs.

This draft Strategy for the Development of Guidance for Recommended Practices in Environmental Modeling was prepared by the Council on Regulatory Environmental Modeling (CREM) Model Evaluation Action Team at the request of the CREM Council. This draft document provides a proposal for developing broad Agency guidance on good practices in environmental modeling. In developing this draft proposed strategy, the Model Evaluation Action Team identified individual components, or elements, for performing good modeling practices, developed broad guidelines for consideration when modeling guidance is implemented, and held a three-day workshop to discuss the modeling elements that the Model Evaluation Action Team had identified. The results from the workshop were combined with the results from the deliberations of the Model Evaluation Action Team to produce this draft proposed strategy.

Background

A wide variety of models have been used over the years to support environmental decision-making by the Agency. These models often involve environmental characterization, environmental impact, human health and ecological effects, risk assessment, and economic impact models which affect the manner in which the Agency chooses to address a multitude of environmental questions. Over the years, as our understanding of these issues from a scientific perspective has improved, these models have become increasingly complex requiring the involvement of a wide range of scientific disciplines in the development of the models as well as in the interpretation of the results. As a consequence, the Agency and others have become increasingly concerned about consistency, quality, and duplication of effort in model development, selection, and application. As early as 1989, the Science Advisory Board (SAB) expressed its concerns in "Resolution on Use of Mathematical Models by EPA for Regulatory Assessment and Decision Making" (SAB-EEC-89-012). Since that time, the Science Advisory Board (SAB) has continued to recommend that EPA "establish a general model evaluation protocol, provide sufficient resources to test and confirm models with appropriate field and laboratory data, and establish an Agency-wide task group to assess and guide model use by EPA."

In response to these concerns, the Deputy Administrator established the Agency Task Force on Environmental Regulatory Modeling (ATFERM) in 1992. In 1994, the ATFERM published the Report of the Agency Task Force on Environmental Regulatory Modeling - Guidance, Support

Needs, Draft Criteria and Charter (EPA 500-R-94-001). The report contains the following conclusions: (1) the need for training and technical support; (2) the need for model use acceptability criteria; (3) the need for Agency guidance for conducting external peer review of environmental regulatory modeling; and (4) the need for a Committee on Regulatory Environmental Modeling (CREM). To this end, the report included a section entitled Guidance for Conducting External Peer Review of Environmental Regulatory Modeling.

In 1994, the EPA Risk Assessment Forum developed a document entitled Model Validation for Predictive Exposure Assessments, a draft protocol for model validation, which defined a set of procedures for evaluating models for exposure assessments. In 1997, ORD and the Program Offices conducted an Agency-wide conference (Models-2000 Workshop) to facilitate Agency adherence to existing guidance on modeling, to define and implement improvements to the way in which the Agency develops and uses models, and to recommend to the Science Policy Council (SPC) a models implementation and improvement plan for enhancing modeling within the Agency. As a follow-on to the workshop, ten Action Teams and a Steering/Implementation Team (S/IT) were established to develop further action plans for improving the Agency's use of models. Presentations to the SPC, SPC Steering Committee, and consultations with the SAB Environmental Modeling Subcommittee have been made.

In 1998, the SPC commissioned the development of a White Paper on the Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance. The White Paper reviewed progress in and identified issues associated with developing model use acceptability guidance, through the discussion of current practices and case studies.

In February 2000, the Deputy Administrator established the Council on Regulatory Environmental Modeling (CREM) and developed the Framework of guiding principles for its activities. The CREM was established to promote consistency and consensus within the Agency on mathematical modeling issues including modeling guidance, development, and application, and enhance both internal and external communications on modeling activities. The CREM supports and enhances existing modeling activities by Agency Program Offices. The CREM provides the Agency with consistent yet flexible modeling tools to support environmental decision making, in particular as they relate to the development and implementation of programs with cross-Agency implications. Further, the CREM provides EPA staff and the public with a central point for inquiring about EPA's use of modeling.

In May 2000, the CREM initiated several cross-Agency activities that were designed to enhance the Agency's development, use, and selection of regulatory environmental models. One of these activities involved the ultimate development of modeling guidance. The CREM determined that a workshop to facilitate discussion of good modeling practices among participants would constitute a viable starting point for developing modeling guidance. To organize the workshop and develop issue papers for discussion, a cross-Agency Model Evaluation Action Team was formed in June 2000 (Appendix A). Over the next several months, the Action Team (1) reviewed the White Paper on the Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance to identify model evaluation issues; (2) developed a list of components, or elements, that would need to be followed to evaluate a regulatory environmental model; (3)

identified several general principles to support the use of model evaluation guidance; (4) developed an organizational plan for the workshop that covered the identified model evaluation elements; (5) held the workshop; and (6) developed a summary report of the workshop.

Modeling Elements

In preparing for the EPA Models Evaluation and Peer Review Workshop, the Models Evaluation Action Team developed a document entitled "Draft Proposed Elements of a Guidance Document on Model Evaluation (July 6, 2000)." See Appendix B. These modeling elements were an expansion of topics in from the White Paper on the Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance, and the Action Team believed they constituted the individual components of good modeling practices.

The 14 modeling elements identified in the document entitled "Draft Proposed Elements of a Guidance Document on Model Evaluation (July 6, 2000)" were divided into four general categories, and included the following:

Model Suitability

- Model uses
- Model output
- Model performance
- Model usability
- Model users guide
- QA/QC documentation

Model Development

- Model theory
- Model algorithms
- Model computer code

Model Uncertainty and Sensitivity Analysis

- Error propagation analyses
- Sensitivity analyses

Model Calibration, Testing, and Overall Evaluation

- Model calibration
- Model testing
- Overall model performance

Recommendations for Developing and Implementing Modeling Guidance

In preparing for the EPA Models Evaluation and Peer Review Workshop, the Models Evaluation Action Team discussed issues associated with performing the 14 modeling elements, and provided recommendations for the successful implementation of modeling guidance. These recommendations include:

- Each EPA Program Office should be responsible for implementing modeling guidance. Each Program Office has case-specific needs for implementing good modeling practices, such as model type, how the model will be used, and the decision to make from the model results.

- The strategy for developing the guidance and the guidance itself should reflect the case-specific nature of good practices in modeling, taking into account models of varying complexities.

- The guidance should address the 14 modeling elements of the four evaluation categories covered in the Models Evaluation and Peer Review Workshop.

- Program Offices should address all 14 modeling elements when developing a new or modified model, or when using an existing model for a new or related application. If the Program Office determines not to perform a modeling element, its reason(s) should be described.

- For each of the 14 modeling elements, the guidance should include descriptions of the goals - that is, what is to be gained from doing a particular activity, with some specificity.

- The guidance should not be prescriptive.

- The guidance should specify the minimum attributes of a good model and include minimum modeling elements to be performed.

- The guidance should be linked to model selection, especially for applications that are different from those for which the model was originally developed.

- The guidance should include descriptions of modeling methodologies, including standard practices.

- The guidance should include examples, or case studies, of model development, evaluation, and use for representative model types and complexities (e.g., multi-media models *vs* screening level models).

- The guidance should take into account the impact of resources that would be needed to implement the guidance.

EPA Models Evaluation and Peer Review Workshop

To discuss the feasibility of incorporating the 14 modeling elements (described in the document entitled "Draft Proposed Elements of a Guidance Document on Model Evaluation (July 6, 2000)") into modeling guidance, the Agency held a three-day Models Evaluation and Peer Review Workshop on November 28-30, 2000. Nearly 100 participants, including EPA scientists and representatives from other Federal agencies, States, industry, and consultants attended the workshop, which consisted of presentations by guest speakers, open discussions among the participants, demonstrations of online software applications, poster sessions, and four breakout groups that addressed specific topics. The workshop participants discussed the 14 modeling elements and provided recommendations for developing the modeling guidance. A summary of the workshop is provided in Appendix C. The following key recommendations emerged from the workshop discussions:

Finding 1: Modeling guidance should be sensitive to the fact that regulatory environmental models span a broad range of applications. Consequently, the guidance should be sufficiently general to apply to models of different rigor (e.g., screening or complex), intended users (e.g., used only by EPA scientists or throughout the regulated community), application (e.g., policy analysis or national regulatory decision making), and underlying scientific discipline (e.g., toxicology or fate and transport). The guidance also should appeal to model developers, computer programmers, and model users.

Finding 2: The guidance should follow a "general constitution of principles" rather than a lengthy compendium of methodologies and information. Given the breadth of model applications in the Agency, the workshop participants favored general guidance over an overly detailed and potentially prescriptive document. Many participants cautioned that modelers and developers might not adopt the modeling elements if the document is too long or burdensome. While modeling guidance could remain general, detailed topics can be addressed in companion documents, white papers, "tool boxes," or guidance.

Finding 3: Workshop participants were concerned that the 14 modeling elements may be overwhelming to modelers and developers. One suggestion was to structure the model evaluation strategy around, and integrate the 14 modeling elements into, the four types of documentation that typically accompany models: Science Formulation Documents, User's Guides, Code Description Documents, and Evaluation Summaries. (NOTE: A Quality Assurance document can potentially be added as well, which could include peer review, a model development plan, a model application protocol, and a model support plan.)

Finding 4: The guidance should clearly define all important terms and use consistent terminology throughout. There is a need for a glossary of terms, given that some

words (e.g., dispersion) have different meaning across different scientific disciplines and others (e.g., testing) are interpreted differently by modelers and developers. For instance, modelers generally consider "testing" to mean model validation, while developers consider it to mean code verification. Participants thought EPA's strategy should, at a minimum, provide comprehensive definitions of define the following terms: calibration, deterministic, model, model code, model theory, stochastic, uncertainty, validation, verification, and testing.

Finding 5: Workshop participants suggested some revisions to the document entitled "Draft Proposed Elements of a Guidance Document on Model Evaluation (July 6, 2000)" (Attachment B). Refer to Sections 3 through 6 of the EPA Models Evaluation and Peer Review Workshop Summary Report (Attachment D) for detailed accounts of these suggestions.

Finding 6: Workshop participants in two breakout groups repeatedly grappled with the term uncertainty, and exactly how modelers should (or even can) characterize it. Many doubted that modelers could quantify many types of uncertainty (e.g., uncertainty in theories, uncertainty in translating theories to mathematical representations, and uncertainties in translating these representations into code). Given that modelers often overlook uncertainty analysis altogether, several participants recommended that EPA carefully consider how to address this issue in the guidance. One suggestion was to refer to the Risk Characterization Handbook (EPA 100-B-00-002) on addressing uncertainty in risk characterization for insights on uncertainty analysis.

Finding 7: Noting that EPA has made several attempts to adopt general modeling principles for more than 20 years, some participants thought the success of the CREM depends largely on the Agency's current dedication and commitment not only to developing guidance on good modeling practices, but ensuring that it is systematically implemented. In short, many participants thought EPA needed a greater institutional commitment to model development, implementation, and evaluation.

Finding 8: Many participants thought ongoing discussions and workshops were necessary to ensure that the CREM activities are consistent with its audience's expectations. Soliciting inputs from all affected EPA Offices and the entire spectrum of environmental regulatory modelers was advised. Several participants advocated collaborative efforts with non-Agency modelers at universities, research centers, industry, and other federal agencies.

Proposal for Guidance on Recommended Practices in Environmental Modeling

The workshop participants were enthusiastic about an opportunity to meet with EPA modelers from all media offices. As a result of the recommendations from the workshop, an outline for a document was created that would reflect the major findings from the Models

Evaluation and Peer Review Workshop. The new document would be entitled "Guidance on Recommended Practices in Environmental Modeling" (Appendix C).

As suggested by the outline, the document would be organized according to modeling documents familiar to modelers: Science Formulation Document, User's Guide, Code Description Document, and Evaluation Summary (Workshop Finding 3). We believe the recommendation to provide a "general constitution of principles" can best be addressed by developing a series of leading questions to be answered by someone who is documenting either a new or existing regulatory environmental model (Workshop Finding 2). This format was considered sufficiently general with enough specifics to (1) span a broad range of applications, (2) apply to models of different rigor, intended users, application, and underlying scientific discipline, and (3) appeal to model developers, computer programmers, and model users (Workshop Finding 1). A section for a glossary of modeling terms would be added (Workshop Finding 4), and a relaxation of uncertainty in some sections was incorporated (Workshop Finding 6).

The draft outline, presented in Appendix C, should be reviewed and expanded. This might be accomplished by either forwarding it to experts for comment, or by convening a workshop for the purpose. Once consensus is reached on the content of the outline, then the actual document would be drafted.

APPENDIX A

MODEL EVALUATION ACTION TEAM AND WORKSHOP CO-CHAIRS

Model Evaluation Action Team

Tom Barnwell, ORD
Tim Barry, OP
Tom Brennan, OPPT
Steven Chang, OSWER
Mary Clark, OAR
Mimi Dannel, OW
David Ford, University of Washington, Seattle
Howard Fribush, OSP
John Irwin, OAR
Linda Kirkland, OEI
Henry Nelson, OSP
Annett Nold, OEI
Jim Rowe, OSP
Mary White, Region 5
Larry Zaragoza, OSWER

Model Evaluation Workshop Co-Chairs

Linda Kirkland, OEI
Lee Mulkey, ORD
John Irwin, OAR
David Ford, University of Washington, Seattle
Tom Barnwell, ORD
Mimi Dannel, OW
Ken Schere, ORD
Joe Williams, ORD
Ray Whittemore, National Council for Air and Stream Improvement

APPENDIX B

ELEMENTS FOR EVALUATING REGULATORY ENVIRONMENTAL MODELS

Draft Presentation Groups for the September 2000 Workshop on Developing Guidance on Model Evaluation (July 6, 2000)

Presentation Group A: Evaluation of Potential Model Suitability

1) Defining current and/or intended uses of the model.

(a) Identifying the regulatory activities the model is intended to support

(b) Identifying how the model is to be used in supporting the regulatory activities identified in 1(a).

2) Evaluating model output with respect to current and/or intended model uses.

(a) Identifying the minimum and optimum model output necessary to support the current and/or intended uses of the model

(b) Comparing model output to the minimum and optimum model output necessary to support the current and/or intended uses of the model

3) Evaluating model performance with respect to intended model uses.

(a) Estimating the maximum acceptable (allowable) uncertainties in model output for the current and/or intended uses of the model

(b) Determining whether the differences between modeling estimates and the results of monitoring/field studies (or alternatively other measures of model uncertainties such as those obtained by error propagation analyses) are within the allowable uncertainties

4) Evaluating model usability (excluding the user's guide discussed in #5).

(a) Evaluating operating system, hardware, and software requirements with respect to current and/or anticipated resources available for current and/or anticipated model use(s)

(b) Evaluating model complexity and input requirements with respect to needed model output (as described in item #1)

(c) Evaluating the adequacy of the model's operating mode/interface (i.e., batch vs. interactive) with respect to the model's complexity and needed input

(d)Evaluating the adequacy of the model's internal tools and/or links to external tools (databases, GIS, Monte Carlo, pre-processors, post-processor/data analysis, graphical)

The following two elements can be excluded from the presentations or as an option, included briefly in presentation group A:

5) Evaluating the model user's guide

(a) Model abstract/description

(b) Designation of minimal/optimal operating system, hardware, and software requirements

(c) Diagrams showing interaction of model components and model structure; equations, equation solution methodologies, and related simplifying assumptions

(d) Presentation of equations, equation solution methodologies, and related simplifying assumptions

(e) Input and output variable documentation including definitions, units, temporal/spatial dimensions, temporal/spatial resolution options, ranges, and format
(f) Guidance on selecting and/or estimating values and/or distributions for input variables (including guidance on calibration and selecting default values and/or distributions)
(g) Mathematical guidance with respect to setting initial and/or boundary conditions (e.g., specified fluxes, gradients, heads, and/or concentrations), selecting computational time steps, and selecting the number and size of computational segments
(h) Guidance on the analysis and interpretation of output
(i) Example input/output files
(j) Description of error propagation analyses, sensitivity analysis, calibration and model testing methodologies and results

6) Evaluating the documentation of QA/QC activities and results with respect to the current and/or intended uses of the model.

(a) Documentation of the development of the initial model and any subsequent versions
(b) Documentation of model uncertainties, assumptions, and simplifications
(c) Documentation of peer review
(d) Documentation of error propagation uncertainty analyses and results
(e) Documentation of sensitivity analyses and results
(f) Documentation of model calibration activities and results
(g) Documentation of model testing activities and results

Presentation Group B: Uncertainty in Developing Models

7) Evaluating the uncertainty associated with the theory upon which the model is based.

(a) Describing the theory upon which the model is based and alternate theories (if any)
(b) Uncertainties associated with a given theory including those associated with a failure to adequately account for one or more important processes and attempting to apply it outside its range of applicability
(c) Comparing uncertainties associated with alternate theories

8) Evaluating the uncertainty associated with the translation of theory into mathematical representations.

(a) Uncertainties associated with simplifying ordinary and/or partial differential equations for purposes of obtaining analytical and/or simpler numerical solutions
(b) Uncertainties related to the numerical dispersion associated with some numerical solutions
(c) Uncertainties associated with simplifying and/or idealizing initial and/or boundary conditions
(d) Uncertainties associated with setting computational time steps and computational segments
(e) Uncertainties associated with the failure to provide one or more sensitive input parameters with adequate dimensions to account for temporal and/or spatial variability in the values of the variables

(f) Uncertainties associated with applying a model outside its range of applicability
(g) Uncertainties associated with the use of deterministic models such as the failure to adequately reflect natural variability
(h) Uncertainties associated with probabilistic modeling such as those due to failure to adequately account for correlations between input variables and those associated with the tails of distributions in cases where the distributions are fit only to more centrally located data.

9) Guidance on evaluating the uncertainty associated with the transcription into computer code.

(a) Verification of code for model algorithms
(b) Uncertainty associated with interfacing between the component modules or sub-models of a model
(c) Software code stress performance tests (NIST Special Publication 500-234)

Presentation Group C: Uncertainty and Sensitivity Analysis

10) Guidance on performing error propagation uncertainty analyses

(a) Defining error propagation analyses and describing how the results are used
(b) Common methods for performing propagation of error uncertainty analyses (e.g., total differential based, Monte Carlo based)
(c) Comparing and selecting methods for estimating error propagation
(e) Evaluating error propagation analyses with respect to the methods used and the extent to which they have been performed
(f) Examples

11) Guidance on performing sensitivity analysis

(a) Defining sensitivity analyses and describing how the results are used
(b) Common methods for performing sensitivity analyses (e.g, one variable at a time sensitivity ratios, derivative based sensitivity indices, Monte Carlo/regression methods, decomposition of variance methods such as FAST and Sobel indices)
(c) Comparing and selecting methods for performing sensitivity analyses
(d) Evaluating the adequacy of sensitivity analyses with respect to the methods used and the extent to which they have been performed
(e) Examples

Presentation Group D: Model Calibration, Testing, and Overall Evaluation

12) Guidance on model calibration

(a) Defining model calibrations and how they are used.
(b) Determining whether model calibrations are needed.
(c) Selecting model input variables for calibration based upon sensitivity analyses and upon anticipated directions and magnitudes of change that are scientifically defensible

(d) Common methods for performing model calibrations
(e) Comparing and selecting methods for performing model calibrations
(f) Evaluating the adequacy of model calibrations with respect to the method(s) used and the extent to which necessary ones have been performed
(g) Examples

13) Guidance on performing model testing

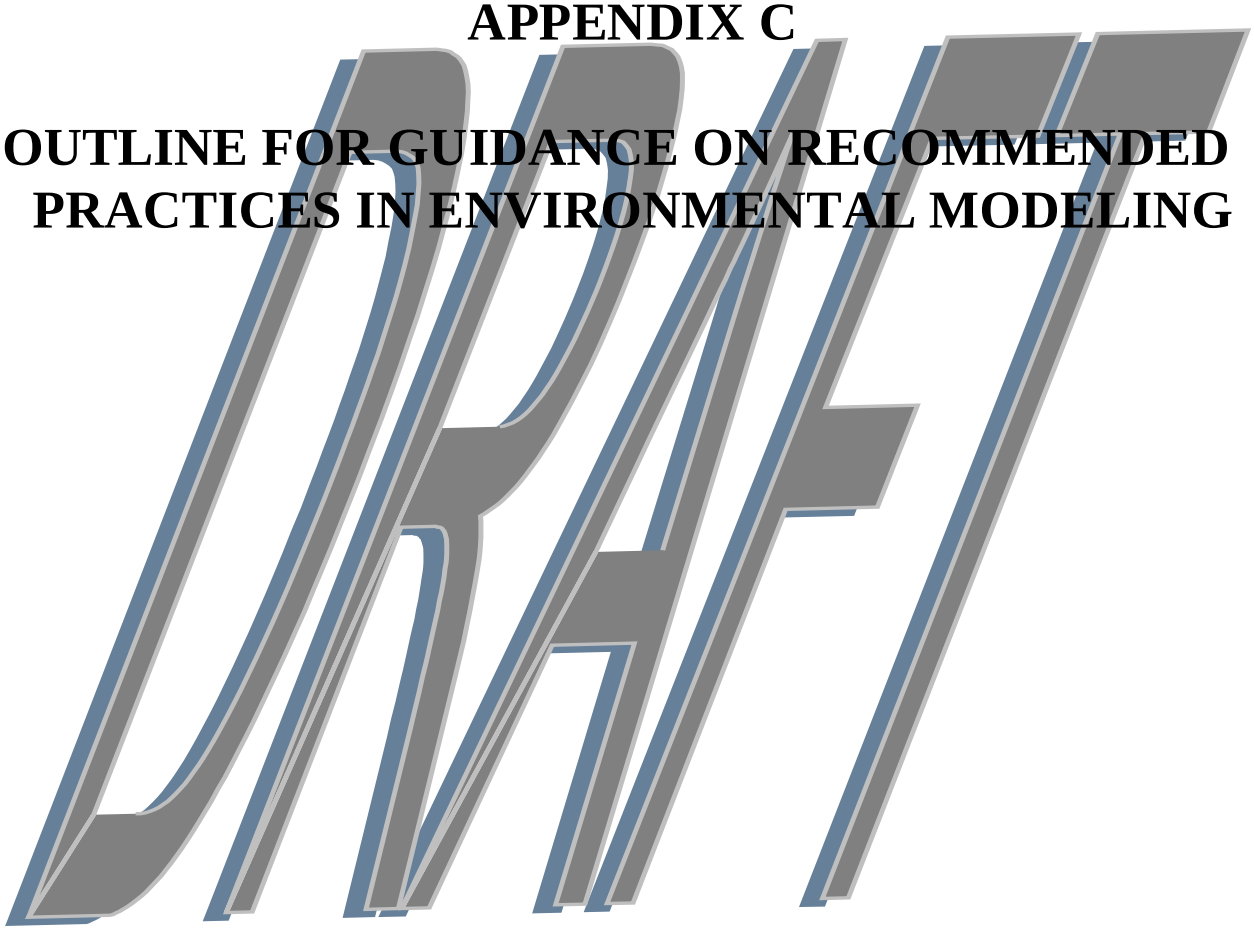
(a) Defining model testing and how the results are used
(b) Generating model testing surfaces based upon a comprehensive range of modeling scenarios associated with the current and/or anticipated model use(s).
(c) Selecting model output variables in performing model tests
(d) Common methods for testing models (statistical methods for comparing model estimates to the results of monitoring and/or field studies)(e.g., model predicted versus measured regression analyses, ANOVA based analyses)
(e) Comparing and selecting methods for model testing
(f) Evaluating the adequacy of model testing with respect to the method(s) used and the extent to which the model testing surfaces have been covered
(g) Examples

14) Guidance on performing overall, integrated model evaluations

(a) Weighing/integrating all of the above elements of model evaluation
(b) Identifying the most essential elements of model evaluation.
(c) The use of model evaluation in model selection

APPENDIX C

OUTLINE FOR GUIDANCE ON RECOMMENDED PRACTICES IN ENVIRONMENTAL MODELING



GUIDANCE ON RECOMMENDED PRACTICES IN ENVIRONMENTAL MODELING

Cover Memo - The message would be that the author expects this guidance to be considered by all EPA program offices. That program offices are responsible for tailoring the general principles provided, to be relevant and applicable to their needs.

Preface - What process (**History)** was followed in developing this document? What offices within EPA were directly involved? Who is ultimately responsible for the care and upkeep of this document, to insure that it remains current?

Glossary of Terms

Related Guidance Documents of Interest

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I. INTRODUCTION

A. Why is this document being provided? Use of mathematical modeling for the characterization of pollutant impacts in various media is commonplace within EPA. There is a need to promote the use of 'good modeling practices' to improve the use and evaluation of regulatory environmental models by the Agency.

B. What is the intended level of detail for this document? This document is intended to provide a constitution of principles (through a series of leading questions) that if followed, will promote good modeling practices. EPA is attempting to provide sufficient flexibility, such that EPA Program Offices can interpret the application of these principles to assure that modeling will meet their program's specific goals and needs.

C. For existing models, is there a basic set of questions that should be addressed? Regardless of whether an existing model is or is not being used for a situation for which the model was explicitly designed, good modeling practices suggest there are several major questions to address:

1. Has the model's science been peer reviewed?
2. Is the model applicable for the intended purpose on a theoretical basis?
3. Are the data bases which are necessary to perform the modeling available and adequate?
4. Are there adequate laboratory measured and/or field monitoring data for comparison to model outputs for the purpose of model testing?
5. Have appropriate performance evaluations shown the model's performance is acceptable for the intended purpose?
6. Has a protocol on modeling methods and procedures to be followed been established ?

7. When should the model be updated and discarded?

D. When new models are developed, what additional basic questions arise?

1. Can the development of new models be defended or justified? There are two basic cases for which new models are developed:

a) To provide a model for which there is no existing suitable model, which raises the question: What is so unique about the case to be addressed, that makes existing models inappropriate?

b) To provide a better model (improved performance), in which case there must be one or more existing models for this application, which raises the question: Why is the existing performance inadequate, and what has happened to suggest improvement is possible?

2. In either case, the one new question that should be addressed is: Has a development plan been established (that when completed) will provide all the relevant information needed?

3. How will modeling guidance apply to models that were originally developed long ago but have been periodically enhanced? Should the guidance provide a scaled-down version of the essential modeling elements to be addressed for upgraded models, or should modeling guidance be as stringent as for new models?

4. How should the model not be applied?

References: Model Validation for Predictive Exposure Assessments. USEPA ORD. Athens, GA. 1994.

Report of the Agency Task Force on Environmental Regulatory Modeling (ATFERM). EPA 500-R-94-001. March 1994.

White Paper on the Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance. USEPA. May 1999. Appendix B.

II. GOOD PRACTICES IN DOCUMENTATION

To answer the above questions requires access to credible information. Depending on the complexity of the model, the documentation needs may be easily summarized in one small report, or may span a series of comprehensive technical volumes.

A. The basic areas for technical documentation are:

1 Documentation of the model's science. This includes a description of governing equations, initial and boundary conditions, numerical methods, numerical tests performed, and coding development and verification followed. Typically this can be accomplished in a single Model Formulation Document.

2. Documentation of performance evaluations, sensitivity analyses, and numerical limitations and uncertainties. This includes assessments of model uncertainty, error propagation, calibration, and testing. Typically this can be accomplished in a single Model Evaluation Document.

3 Documentation of the model's data requirements, output, and options. This includes guidance on use of options. Typically this can be accomplished in a single Model User's Guide.

B. The basic areas for quality assurance documentation are:

1. Documentation of peer reviews. See: http://intranet.epa.gov/allncea1/peerindx.htm

2. Model application protocols. How often is this model going to be applied, and by how many different people? What level of expertise will these model users have? Depending on the frequency a model will be applied, and the number of users, protocols could be defined in agency guidance, or developed for each application. Model protocols typically involve a compromise between what ideally one might like to see done, and what can reasonably be expected. Hence, model protocols involve a blend of science and agency policy. For complex or recurrent model applications, program offices might consider drafting specific guidance to define procedures to be followed and data bases to be employed.

3. Model support plan. Who will answer user's questions? How will errors be documented? How will corrective actions be defined, tested and implemented? How will modeling data be updated? What software stress performance tests recommended (NIST Special Publication 500-234)? How will the model and computer code be maintained? When will the model be discarded?

III. MODEL FORMULATION

There are a variety of instances, when one finds it necessary to be able to provide a summary of the model's science, not the least of which is for the science peer review panel members.

A. Model Theory. Model theory includes the principles and assumptions of the model, and the algorithms that reflect the model's principles and assumptions.

1. What are the founding principles and assumptions of the model?
2. How does the chosen theory (basis) satisfy the intended model uses?
3. If there are alternative theories, why were they discarded?
4. What are the known assumptions and limitations of the chosen theory?

B. Model Theory to Numerical Code

1. What numerical approximations are employed in conversion of the theory into governing equations and a mathematical algorithm?
2. What numerical simplifications were made?
3. What (if any) auxiliary models were introduced (such as using a particular frequency distribution, a least-squares fit, steady-state assumptions, boundary conditions, etc.)?
4. Can we provide quantified estimates of the numerical approximations and simplifications made?
5. Has the model computer code been verified to ensure that it correctly represents the mathematical algorithms?

References: Systems Development Life Cycle Methodology (SDLCM). Statement of Policy, Standards, and Guidelines. USEPA ORD Center for Exposure Assessment Modeling (CEAM). Athens, GA.

FORTRAN Code Review/Evaluation, Procedures and Standards. USEPA ORD Center for Exposure Assessment Modeling (CEAM). Athens, GA.

IV. MODEL EVALUATION

Model evaluation involves a statistical comparison of model-estimated values with field (measured) data to assess model uncertainty and performance. Other components of model testing, such as comparing model-estimated and monitored rates of change with respect to independent forcing variables (such as source emissions and loadings), are beneficial but historically have infrequently been performed. Due to the limited supply of evaluation data sets, there are severe practical limits in assessing model performance. Consequently, statistical evaluations with field data may often be accompanied by science peer reviews, sensitivity assessments, and uncertainty assessments for determining whether a model can be applied for the anticipated purposes.

There are a variety of procedures and analyses used to assess model uncertainty and performance. The specific procedures and data processing used is always specific to the model, and specific to the manner in which the model's estimates are to be used. At this writing, we will only provide a few leading questions for consideration. Program offices will have to assess how they wish these questions to be addressed and the guidance they wish to provide.

Sensitivity and error propagation analyses are closely related, but they are not the same. Error propagation involves predicting the uncertainty in the output based upon the uncertainties in the input variables. Sensitivity analyses involves determining the contributions to the output by each of the inputs, thereby identifying those input parameters that most affect the output.

A. Were sensitivity and error propagation analyses conducted, and what are the results? Sensitivity analyses range from an investigation of the model's response to step changes in one or more input parameters; to comprehensive Monte-Carlo uncertainty analyses. They can provide information on: 1) which model inputs must be most carefully determined, 2) where a modeling system's uncertainty can most effectively be reduced. They also can provide estimates of the error bounds to be associated with the modeling results. Have considerations been given to that fact that input variables may be correlated, and if so, how has this been addressed?

B. Were comparisons made with field data, and what are the results? Comparisons with field data provide estimates of the precision and bias to be associated with the modeling results.

1. In some modeling situations, field data comparisons are routinely performed each time a model is applied, in order to define one or more site-specific parameters. This usually is referred to as model calibration. In the course of determining these site-specific parameters, the precision and bias of the model is estimated. Was the model calibrated, and what are the results? Are there any caveats in model calibration that should be taken into account?

2. In other modeling situations, field data comparisons are only possible for a few experiments, especially conducted for the purpose. For these situations, the comparisons with field data are used to estimate the anticipated precision and accuracy of the model's performance (since it will not be possible to collect field data for assessing the model's performance in every application). This usually is referred to as model performance evaluation (see ASTM D6589-00). How does the model perform over the range of conditions for which the model was intended? Are there any caveats in model performance evaluation that should be taken into account?

C. Can we provide an overall summary of the model's anticipated performance, its limitations, where we might expect it is appropriate for use? The process of summarizing the overall performance of a model over the range of conditions experienced within a field experiment typically involves answering the following questions: (1) Which of the models being assessed has on average the smallest combined bias and scatter in comparisons with observations, and (2) Are the differences seen in the comparisons with the other models statistically significant in light of the uncertainties in the observations? Since models are approximations, and field data for comparisons are often limited, the results from sensitivity and uncertainty analyses, and science peer reviews must be also considered in judging a model's anticipated performance, limits in usage, most critical requirements for successful application, etc.

References: Policy for Use of Probabilistic Analysis in Risk Assessment at the U.S. Environmental Protection Agency. http://www.epa.gov/ncea/mcpolicy.htm

Guiding Principles for Monte Carlo Analysis. USEPA ORD. EPA/630/R-97/001. March 1997. http://www.epa.gov/ncea/monteabs.htm

Risk Assessment Guidance for Superfund Volume 3 Part A: Process for Conducting Probabilistic Risk Assessment (RAGS 3A) (DRAFT). http://www.epa.gov/oerrpage/superfund/programs/risk/rags3adt/index.htm

Exposure Factors Handbook. USEPA ORD. EPA/600C-99/001. February 1999. http://www.epa.gov/ordntrnt/ORD/WebPubs/exposure/index.html

Guideline on Air Quality Models. http://www.epa.gov/scram001/t26.htm#guide http://www.epa.gov/scram001/guidance/guide/appw.htm

Statistical Evaluation of Air Dispersion Models. ASTM. 2000.

V. MODEL USER'S GUIDE

The model user's guide should address all critical assumptions inherent in the model. If the model is intended to be used only once, do you really need a user's guide? Experience suggest that models rarely get used only once, and nor only by one user. It is considered good practice to at least document the answers to a few common questions.

A. What are the current or intended uses? This usually is defined from a regulatory perspective (i.e., in terms of specific program applications), and includes identifying how the model is to be used in supporting the regulatory activities. You can also briefly describe the types of envisioned situations and the phenomenon that the model is intended to represent. Since a model may have many uses, even for different EPA program offices, it usually is not feasible to define in the Model User's Guide, the specific protocols to be followed for each application or situation. Model application protocols are best defined separately from the model user's guide.

B. Who are the anticipated users? What experience and education is expected? Is special training required (recommended)?

C. What are the known model limitations? (Note, this is meant to provide a general overview of the model's strengths and limitations. This is not meant to repeat detailed evaluation results. User's guide should focus on the pragmatic steps needed to run the software, and detailed discussions of theory and evaluation results can be referred to if this information is readily available elsewhere.)

1. Evaluation data is never sufficiently comprehensive to cover all known or intended applications, hence it is important to summarize any known restrictions in the model's use, or at least provide a contact where such information can be obtained.

2. Models only simulate a portion of the variations seen in the natural system. Can we describe the expected variations that will be seen when modeling results are compared with observations (i.e., the 'unexplained natural variations')? This information is helpful when people are considering use of the model for purposes other than foreseen in its development.

D. What are the needed data bases, computer requirements, software needs? (Consider using schematic diagrams, to illustrate the various relationships, sequence of execution steps, etc.)

E. If the model has options, what are they, and when might one think about using them?

F. What inputs (or parameter settings) are to be specified by the user, and what guidance can be offered to assist the user in defining these inputs or settings? Were the inputs developed from site-specific databases, from recommended literature values, or from other sources?

G. What information is generated by the model? What is the model's time and spatial resolution (grid average, point average, 1-hr average, etc.)?

H. Consider providing a simplistic example input and output for each executable, so that the user can confirm the software is performing, and so the user can better understand the input and output to the modeling system.

Reference: Handbook for Preparing User's Guides for Air Quality Models. Environmental Sciences Research Laboratory. RTP, NC. EPA-600/8-83-018. May 1983.

VI. QUALITY ASSURANCE DOCUMENTS

(NOTE: Not sure how best to structure this section of the report. As described earlier, there appears to be four quality assurance documents (although there may be others).) Quality Assurance documents could include the following:

1. Peer Review Documentation. When was a science peer review conducted, what were the findings, and corrective actions taken (if any)? Peer review of regulatory environmental models, including methods of performing peer review, is discussed in the Report of the Agency Task

Force on Environmental Regulatory Modeling (EPA 500-R-94-001) and the Science Policy Council Peer Review Handbook (EPA 100-B-000-001).

2. Model Development Plan. Who developed this model, and for what purpose?
3. Model Application Protocol. Is there a standard protocol that one should follow?
4. Model Support Plan. How will the model live forever? How will the model be maintained? Model maintenance can include the provision of (1) open source, public domain access, (2) user support groups in a list-serve environment, (3) internet-based distribution of the model's computer code, preprocessors and post processors, (4) limited user support, and (5) maintenance and updating of the model's computer code as part of a clearinghouse.

These four 'documents' seem to be stand alone items, and they may be composed of multiple sub-items. Furthermore, there may be additional quality assurance documents in existence that already describe 2 - 4 listed above. When and if this section is expanded, its content and format should be re-evaluated..

References:

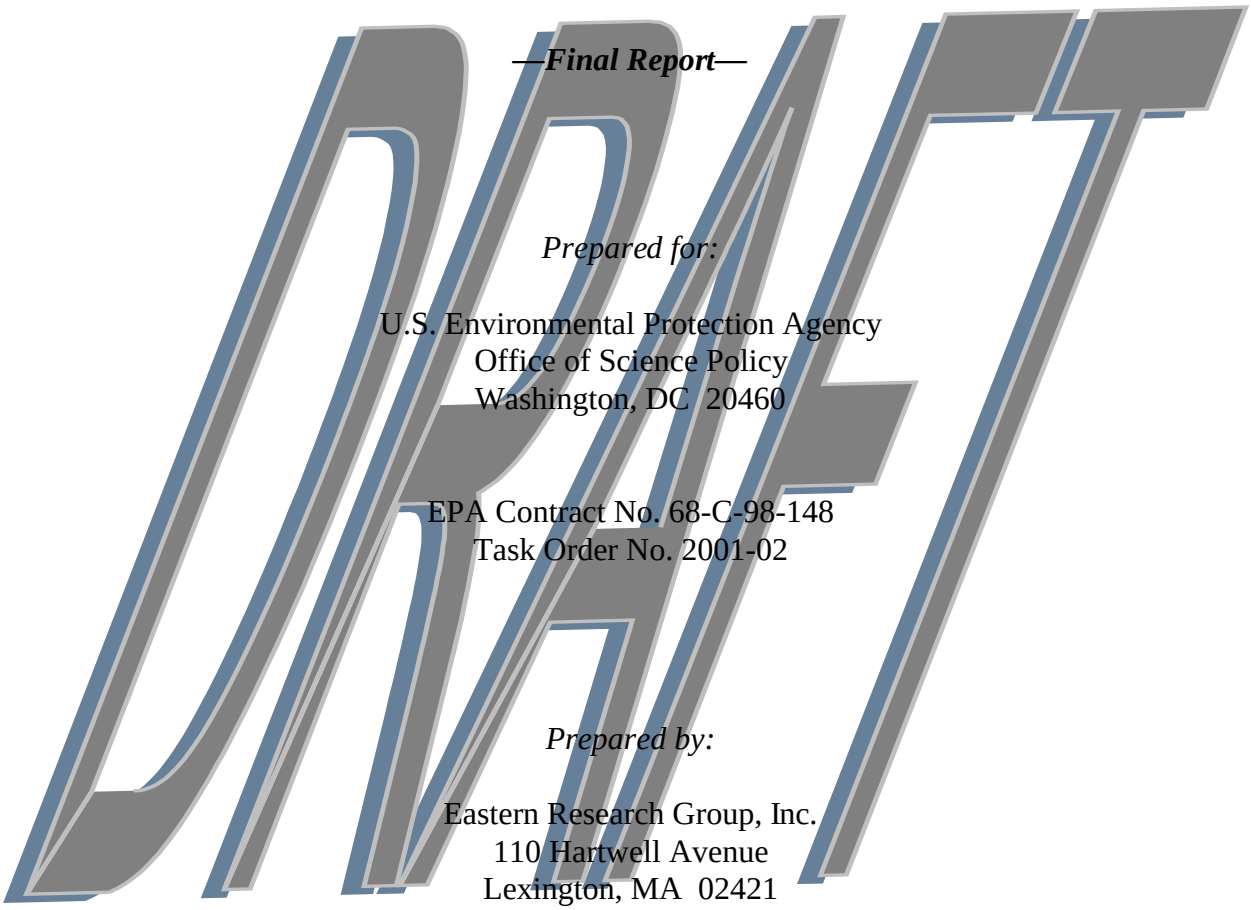
EPA Guidance for Model Development & Application. Quality Assurance Project Plans. EPA QA/G-5m. Washington, D.C. 2001

Report of the Agency Task Force on Environmental Regulatory Modeling (ATFERM). EPA 500-R-94-001. March 1994.

APPENDIX D

EPA MODEL EVALUATION AND PEER REVIEW WORKSHOP SUMMARY REPORT

REPORT ON THE "U.S. EPA MODELS EVALUATION AND PEER REVIEW WORKSHOP"



—Final Report—

Prepared for:

U.S. Environmental Protection Agency
Office of Science Policy
Washington, DC 20460

EPA Contract No. 68-C-98-148
Task Order No. 2001-02

Prepared by:

Eastern Research Group, Inc.
110 Hartwell Avenue
Lexington, MA 02421

March 30, 2001

NOTE

This report was prepared by Eastern Research Group, Inc. (ERG), an EPA contractor, as a general record of discussion for the "U.S. EPA Models Evaluation and Peer Review Workshop." This report captures the main points of scheduled presentations and highlights discussions among the participants. This report does not contain a verbatim transcript of all issues discussed during the workshop. Additionally, the report does not embellish, interpret, or enlarge upon matters that were incomplete or unclear. Except as specifically noted, no statements in this report represent analyses by or positions of ERG.

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LIST OF ABBREVIATIONS

ATFERM	Agency Task Force on Environmental Regulatory Modeling
CREM	Council on Regulatory Environmental Modeling
EIMS	Environmental Information Management System
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
MIMS	Multimedia Integrated Modeling System
SAB	Science Advisory Board
TMDL	total maximum daily load

EXECUTIVE SUMMARY

In November, 2000, the U.S. Environmental Protection Agency (EPA) held a 3-day workshop titled, "U.S. EPA Models Evaluation and Peer Review Workshop" (November 28, 2000 through November 30, 2000). Nearly 100 participants, mostly EPA scientists, attended the workshop, which consisted of presentations by guest speakers, open discussions among the nearly 100 participants, demonstrations of online software applications, poster sessions, and four breakout groups that addressed specific topics. The following key recommendations emerged from the workshop discussions:

- EPA's model evaluation strategy needs to be sensitive to the fact that environmental regulatory models span an extremely broad range of applications.
- The model evaluation strategy should espouse a "general constitution of principles" rather than be a lengthy compendium of requirements. EPA should avoid developing a strategy that is too specific, long, or burdensome. Participants noted that detailed topics can be addressed in documents other than the strategy.
- Participants suggested that EPA avoid drafting a strategy that is framed entirely around the 14 proposed model evaluation elements. An alternate suggestion was to frame the strategy around concepts more familiar to modelers and developers, such as the types of model documentation they typically write (i.e., Science Formulation Documents, User's Guides, Code Description Documents, and Evaluation Summaries).
- The modeling evaluation strategy should have a glossary of key terms, with definitions that all audiences can appreciate. Many participants grappled with the term "uncertainties" and exactly how different types of uncertainties can be quantified.
- Participants offered several recommendations for how EPA can adopt a greater institutional commitment to model development, implementation, and evaluation.

Readers interested in a more detailed account of these and other main findings should refer to Section 2.0, and readers interested in detailed accounts of the discussions that led up to these findings should refer to Sections 3.0 through 6.0.