Appendixes

Appendix A
Summary of Findings From OTA Workshops on Water Resource Modeling

During the fall of 1979, the Office of Technology Assessment held two series of workshops on water resource modeling. The first series, held on October 24 and 25, addressed issues raised by staff members from 21 Federal agencies. The second series, held on November 28 and 29, brought together 37 representatives of universities and private consulting firms.

The two sets of workshops were identical in organization and operation. During the first day, both sets considered problems in model development and application; on the second day, they considered problems in model management and in the use of model results. Participants in each workshop were divided into four topical discussion groups: 1) surface water flow and supply; 2) surface water quality; 3) ground water; and 4) economic and social factors. Each group, on each day it met, identified a list of problems that emerged during the day's discussion, and then used an idea-writing session to develop solutions to the problems identified.

This appendix synthesizes the results of the two sets of workshops. Because many of the same problems were raised and discussed across topical groups and in both sets of workshops, results will be summarized by problem area. Concerns or suggestions specific to one of the series or to a topical group will be so identified.

Research and Development (R&D)—Specific Areas

Participants in each of the four topical discussion groups identified several specific research needs within their assigned areas. These needs are summarized below.

Surface Water Flow and Supply

Participants identified the following uses as research priorities:

- Online operations of water supply systems. Models need to be developed to aid managers in determining current operating rules on the basis of present and historical flow and demand conditions.
- Prediction of regional low flows and droughts. Models for stochastic analysis of regional hydrology need improvement.

Surface Water Quality

Participants in both workshop series placed high priority on two major research categories: 1) erosion and sedimentation; and 2) the fate and transport of toxicants.

For the first category, Federal participants suggested several specific areas requiring model development:

- Erosion models that predict the outcome of management alternatives, such as deforestation.
  Models that determine the fate of chemicals before they reach the stream system.
- Physically based models for sediment detachment, transport, and channel erosion. Empirically based models are currently being used.
- Sediment transport models linked with ecosystem models.

Participants agreed that improving the current state of knowledge about toxicants is urgently needed before better models can be developed to help in complementing major regulatory programs. Federal participants emphasized the need to improve understanding of:

- transport mechanisms;
- the long-term fate of toxic materials; and
- the effects of toxics on biological organisms and communities.

Federal personnel identified two further categories requiring research: reservoir and river mixing; and nonpoint source pollution. The group considered the first topic a high priority because reservoirs and rivers are receptors of toxics, and because mixing is an important component of sediment transport.

Nonpoint source pollution was considered to be increasingly important, as control of this problem becomes more cost effective than controlling point source pollutants. Specific model needs include:

- nonpoint source models that include toxics as wel] as sediment runoff;
- models to predict reductions in nonpoint source loadings due to various control strategies;
- models that translate nonpoint source loadings into water quality and ecological impacts; and
- models that qualify loadings under event-oriented conditions rather than on an annual basis.

Ground Water

Both series oi workshops advocated R&D of models to analyze flow through aquifers that are difficult to

characterize. The private sector group specifically identified flow through fractured rock as a research need; one Federal participant gave the example of radioactive waste disposal assessment as an application in which ground water flow is a highly important component.

Understanding the transport of chemicals through ground water in order to assess concentrations of contaminants was also identified as a research priority by both workshop groups. Specific suggestions included:

. improving the numerical accuracy of ground water transport models;
. incorporating chemical reaction terms into transport models; and
. researching the capability of aquifers to naturally cleanse themselves of pollutants.

The private sector group unanimously suggested that the Government sponsor research at specific waste disposal sites. Members suggested that this research be part of a national program to deal systematically with production, processing, and disposal of potentially hazardous waste.

Economic and Social

Federal representatives considered interregional microeconomics to be a research priority. Participants disagreed about both the adequacy of economic theory and the availability of data to describe interregional economic effects. Private sector modelers focused on intraregional concerns; specifically, developing methods to analyze the distributional implications of water policies. They pointed out problems of cost and availability for obtaining comparable data on a regional basis, and problems of determining the proper structure of models—e. g., the proper level of geographical aggregation, and assigning relative weights to social, economic, and environmental concerns when characterizing the effects of water resource activities.

R&D—Methods

Two major themes emerged from workshop discussions about modeling methods: 1) improving and characterizing predictive capability; and 2) integrating alternative methods and improving their ease of use.

Methods to Measure Uncertainty

Participants in the private sector workshop stated that research on quantifying the uncertainty of predictions is needed. Specifically, they suggested that improved, standardized methods need to be developed and adopted for assessing the total uncertainty in model outputs due to errors in data, sampling, model parameter estimation, and calculation. Knowledge of risks policy makers would most like to avoid would also aid in designing methods for reporting uncertainties.

Federal participants in the area of ground water modeling identified a need to improve parameter estimation and methods for incorporating uncertainty into stochastic models. They suggested: 1) that parameter estimation procedures allow for interaction with the user to permit initial estimations, and to constrain the range of values being generated; and 2) that uncertainty of input and its impact on reliability or confidence in output always be considered during an analysis, to increase the utility and aid in the acceptance of ground water models.

Risk Characterization Methods

The surface water flow and supply group in the private sector placed high priority on two items: developing methods to characterize both long- and short-term risk in water systems, including reservoirs; and conveying the concept of risk to the public. One participant noted that risk is relative, and asserted that modelers should therefore determine the cost of not meeting some requirements when judging risk and its impacts. Another participant argued that this approach would result in guessing with computer models, which he considered less reliable than experienced judgment.

The Federal surface water flow and supply group focused on the relationships between extrapolation techniques and risk characterization. The group identified a need to improve techniques for extrapolating short-term simulation results for long-term implications. These extrapolation techniques are critical for extending the use of available data bases.

Predictive Capability

The surface water quality group from the Federal workshop recognized a need to make ecosystem models predictive at higher trophic levels. Participants stated that development of predictive models appears stalled, even though the techniques are within the state of the art. Recently developed theory has not yet been incorporated into predictive models.

-The same group identified a need to improve predictive capabilities and procedures for dealing with ‘ ‘non-predictive’ events. One participant suggested linking stochastic models with physical models to generate long time-series of simulated ‘ ‘data, which, along with probability analysis, could help improve predictive capabilities, Probabilistic models could also be coupled with or used as complements to parametric and deterministic models.

The surface water quality group was also concerned over the need to improve current capabilities to model transient effects.

Model Integration and Coordination

In the private sector workshops, both the surface water quality and economic/social groups focused on the need to interrelate different types of modeling capacities. Participants in the surface water quality group stated that research should be done on methods to improve compatibility of components of water quality models. The major components of these models—sources of materials, transport to and within receiving waters, and processes occurring within receiving waters—are modeled individually and independently, often at different times and space scales. Research is needed to make the individual components compatible over the longer time and larger space scales needed for effective water quality models.

Private sector economic/social modelers suggested the need for methods to integrate their work with physically based models.

Higher Dimension Models

The need for two- and three-dimensional models for rivers and other water bodies was mentioned by the surface water quality group. One view was that for planning or screening alternatives, one-dimensional models are often, though not always, sufficient. For design purposes, two- or three-dimensional models are frequently important.

Participants suggested developing a research program to determine the type of models needed for different types of problems—relating the dimensionality of the models to different water bodies and pollutants.

Methods To Improve Model Use

Workshop participants suggested several R&D areas that might result in more efficient and productive uses of models. These include:

. using models that address a wider range of ahernatives— this is of primary importance in economic models;

developing more efficient analytical methods to reveal sensitivity relationships to the user; and

developing improved model calibration methods, including automated and user-interactive methods.

Finally, members of the private sector surface water flow and supply group suggested that standard, accepted models for routine tasks be identified and made available. In addition, they advised that standard computer programs be designed that include a set of random numbers already specified for comparative and reporting purposes.

Data

One of the major concerns of both Federal and private participants was that data are not available to develop, calibrate, validate, and apply models. Federal modelers identified the intensive data needs of complex models, the cost of data collection, and the lack of coordination and planning of data gathering as major reasons for the unavailability of data.

Private participants tended to agree that the data-gathering process should be related more directly to the needs of models. Some suggested that modeling should precede and guide data gathering. Federal participants stressed the need for model developers to be more sensitive to the potential data requirements and data costs of their models, and suggested that data collection occur concurrently with model development.

Federal participants also agreed that improved data-collection techniques are needed to facilitate more economical data acquisition. Some participants expressed a need for greater attention to the design of data networks. Private modelers felt that the problem of inadequate data often arises because Congress and governmental agencies are unwilling to conduct data collection and review programs. Participants noted that many model types continue to be developed without adequate data to support them. They felt that certain model types should not be developed without commitments to related data-gathering activities. However, private sector participants noted that if data collection is not funded, regulations will need to be designed to accept qualitative or semiqualitative solutions.

To improve data availability, Federal participants suggested that developers, users, and data gatherers should: 1) share data and identify cooperative data needs; 2) perform sensitivity analyses to identify the most critical data needs; and 3) develop mechanisms to identify and collect long-term data. They also stressed that continual reprogramming of research funds often causes long-term data needs to be neglected.

Existing Data Bases

Federal participants felt that it would be cost effective to spend additional time **analyzing** existing data bases. The surface water flow and supply group suggested that better agency coordination is needed to consolidate existing data bases. The group recommended that data base management specialists be employed to manage agency and interagency data systems.

National Data Bank

The private sector group held extensive discussions on the need for a national data bank. Speaking against the idea, participants stated that data banks in general are not desirable because data collection should be done with specific model formulation in mind. People in the ground water group wanted a standard data base developed for independent model comparisons. Suggestions for groups to manage a data bank included the Environmental Protection Agency (EPA) laboratory at Ada, Okla., or the Holcomb Research Institute, with funding by EPA. Some people in the surface water group wanted a national data base to supply consistent, experimental data for establishing the interrelationships between quantity and quality parameters. In the economic/social group, some members felt that an agency similar to the Census Bureau should be established to obtain reliable and consistent water resource data.

Documentation

Federal and private sector modelers strongly believed that inadequate documentation restricts the wide use of good models and contributes to the misuse of models. Participants agreed that the inadequate allocation of resources for documentation and the lack of incentives to promote good documentation greatly contribute to the problem.

Federal participants suggested the following remedies:

- Assign responsibility for documentation to an organizational unit to ensure that adequate resources are allocated. This unit might also handle technology transfer, users' assistance, etc.
- Provide incentives to modelers to allocate time to documentation efforts.
- Establish minimum guidelines for documentation.

Private sector participants tended to advocate more prescriptive approaches. They asserted that agencies should demand acceptable model documentation of all models developed with public funds. As an added incentive, agencies might withhold a percentage of the project costs until adequate documentation is received. Currently, they complained, Federal agencies such as the Office of Water Research and Technology and the National Science Foundation may end funding before the documentation project is complete.

Federal participants specified two separate components for adequate documentation: 1) a technical document; and 2) a users' document. A separate programmers' document and an executive summary document were suggested by a few participants. In the private sector groups, suggested components for complete documentation of a model included: user's manual; capabilities and limitations (including explicit acknowledgments of the failure to model phenomena that are not well enough understood to be modeled); case studies and examples representing previous successes and failures; references to literature citations and names of people and organizations who have used the model; operation costs; personnel requirements; and a program listing and computer requirements.

Validation/Credibility

Federal participants identified the lack of model validation as one of the most important problems in water resource modeling, and discussed three major factors contributing to the problem.

First, resources are not adequately allocated for model validation because of its high costs. These costs might be reduced if interagency cooperation increased (e. g., cooperative interagency sampling and funding arrangements).

Second, the lack of necessary data for validation requires attention. The cost of data collection, the absence of historic data, and the time necessary to collect validation data are all limiting factors.

The third factor was the absence of guidelines for validation, identified specifically by the surface water flow and supply group. A majority of the group supported guidelines, while recognizing that guidelines would be difficult to establish because of the diversity of model designs and applications. A lead agency might be given responsibility for suggesting appropriate guidelines.

The private sector groups advocated establishing appropriate incentives for validation. Other suggestions from the private sector focused on specific procedures for model validation, requiring sensitivity analyses on all analyses made, and requiring followup investigation where model scenarios have been implemented.

Participants from the private sector also felt that models should be subject to peer review. They suggested that agencies contract for intensive review in key project stages, such as definition, completion of model development, and review of results.

Technology Transfer and Training

The majority of participants in the Federal workshop considered improving technology transfer to be a top priority; private sector participants agreed that appropriate technology transfer and Federal agency policies on technology transfer do not currently exist.

While most Federal participants believed that responsibility for technology transfer lies with the model developer, they also recognized that agencies need to provide adequate resources for technology transfer programs. They suggested that proper allocation of re-

sources might be expedited if responsibility for technology transfer were given to a lead agency. Modelers from the private sector suggested that for agencies currently without technology transfer mechanisms, either in-house development or outside contracting would be appropriate.

Private sector participants tended to focus on training in specific disciplines and related model use as an important component of technology transfer. Participants mentioned the federally supported university training grant programs in environmental pollution and environmental health (now discontinued)—a comparable training program in water resources is needed today. They felt that funding universities to transfer new developments to the agencies should continue.

Participants from Federal agencies made a number of suggestions regarding particular methods of accomplishing technology transfer. Most agreed that the most important mechanism is one-to-one interaction between the user and the developer. For example, developers might be temporarily assigned to a user's organization to assist the user, and in addition, provide feedback for the developer. Using a central technical support staff to help solve operational problems was also suggested.

Workshops that give participants "hands on" interaction with models, and seminars, were considered good transfer techniques, especially if the developer is directly involved. Workshops and seminars designed for different levels of users (e. g., managers, technical specialists, modelers, and laymen) were also deemed necessary.

Generally, Federal participants believed that agencies need to develop incentives for developers to invest time in technology transfer activities. Many acknowledged that current agency career evaluation systems discourage modelers from providing adequate technology transfer.

Model Maintenance

Both Federal and private workshop participants strongly believed that adequate model maintenance is essential for effective model use. Private sector participants specified that Federal funding should be provided to support model maintenance and updating, but differed in their views on appropriate institutional arrangements to provide such support. Proposals included:

- designating a lead agency to track and disseminate Federal model information and revisions;
- requiring the sponsoring agency itself to maintain and update the model; and
- having the agency provide funds to the developer (or other outside group) to maintain and update models.

Federal participants proposed several specific methods to improve model maintenance:

- establish minimum guidelines and standards for model maintenance;
- prepare a written plan for long-term maintenance and assurance of adequate resources to undertake such maintenance. Year-by-year requests are inappropriate;
- assign responsibility for model maintenance to an organizational unit and assure that appropriate resources are available to carry out this goal. This group might also be responsible for model documentation, user assistance, and technology transfer; and
- establish an interagency clearinghouse to conduct a periodic survey of models, and to update and/or revise model components as needed.

Clearinghouse

Perhaps the most controversial of the subjects addressed at the workshop series was the concept of a clearinghouse for information on available models. Most participants in the private sector agreed on the utility of some form of a model clearinghouse; Federal modelers in the surface water quality and surface water flow and supply groups classified the concept as one of their 15 priority categories. The latter groups stated that a clearinghouse or inventory is needed to aid technology transfer and to serve as an information source for effective planning for future model development.

In the Federal workshop, the clearinghouse concept was conceived as having various possible levels of operation. At the simplest level, a periodic inventory might be established—e. g., a central catalog of models by subject area, listing available models, the agencies that use the model, and a contact person or agency. While such an inventory might be adequate, it would likely be difficult to administer.

A fully established clearinghouse could offer several extra services. The participants felt that responsibility for the clearinghouse should be assigned to either an interagency group or a particular agency. The clearinghouse could assist future model development by acting as a focal point for the questions of both developers and users. It could help to isolate needs for cooperative studies and determine areas of duplication.

Some Federal participants felt that technical literature, conferences, and professional meetings could adequately serve the same function. Other participants strongly believed that these mechanisms were not sufficient, partly because some operational agencies seldom publish their modeling efforts. Additional skepticism was

84-583 O - 82 - 12

expressed about the cost effectiveness of the clearinghouse approach.

Private sector modelers who opposed the idea asserted that it might cause centralization, resulting in red tape, regulation and ineffective action; and siphon limited funding that could be better spent elsewhere.

Coordination

Participants in both sets of workshops concurred on the lack of coordination of resources and information for model development among Government agencies. Private sector participants, while dismissing the issue of duplication as a minor problem, proposed better regional and interagency cooperation to improve coordination. Federal modelers noted the lack of mechanisms to promote interagency efforts, and the absence of incentives or precedents for agencies to work together.

Federal participants suggested a number of mechanisms for improving interagency coordination:

- a national clearinghouse and periodically published information directory to provide users with information about the quality, availability, and characteristics of models;
- an interagency model development review committee. This responsibility might be assigned to an existing committee. Some participants felt that the committee should have only an advisory role, fearing infringement on agency and scientific freedom; and
- a centralized source of expertise to advise on interagency data base creation.

Questions arose as to the practical value of some of the suggested mechanisms in view of the diversity of agency needs. Coordinating efforts through interagency meetings were considered to be too broadly philosophical to aid with actual development. However, participants recognized the importance of avoiding new model development when an existing model can be modified to serve the same purpose.

Educating Managers and Decisionmakers

The need to educate management and decisionmakers to the capabilities, assumptions, and limitations of models was stressed by participants in both workshop series. Private participants emphasized the importance of demonstrating to managers/decisionmakers that models are simply tools that provide information and insight, rather than solutions. Federal modelers were concerned about the loss of credibility suffered by models as a result of poor user understanding. They noted that users' lack of understanding of key concepts leads to model misuse and distrust of good models. User understanding was considered especially important for economic models, because they cannot be easily validated. In this case, it would be very important for the user to understand model construction in order to have confidence in the model.

Workshop participants felt that managers/decisionmakers must be provided with the following information:

- the underlying conceptual basis of models (rather than detailed mathematics);
- a taxonomy of resource models matched to a corresponding taxonomy of resource problems;
- the relative uncertainty of different models' results; and
- alternative ways to use models to solve " real-world' problems.

Responsive Model Selection and Development

Federal and private sector modelers concurred in considering the selection and development of inappropriate models a major problem, and in the need for modelers to pay greatest attention to policymakers' needs and objectives in selecting/developing appropriate models. One participant estimated that 75 percent of all models are created without a suitable set of specifications defined by the problems toward which they are directed. Federal participants further emphasized the need for users to understand their own needs and the limitations and assumptions of the models they consider.

Users often want quantitative answers to specific management questions and issues. However, according to Federal participants, the users may be unsure of what information is necessary or may perceive that models have greater capabilities than they actually do. In general, good documentation can help users understand model capabilities. The participants suggested several specific mechanisms to help users gain a better understanding of what models exist and how these models can be used to solve specific problems:

- Summary documents listing models available in each agency. These documents would briefly describe operational and developmental models and their assumptions, capabilities, limitations, appropriateness for specific applications, and the developers' names and phone numbers. These documents could stress the specific questions that available models can address.
- Seminars for users in each agency on state-of-the-art modeling efforts.

A final recommendation from private sector modelers was that repeated interaction between modelers and pol-

icymakers is necessary to respond to new objectives and problems suggested by model results. Federal participants suggested a number of specific mechanisms for accomplishing these interactions. To develop general-purpose models, the participants recommended using modern group management techniques to solicit the needs of potential users. For more specific models, improved communication between users and developers was considered necessary. Several participants suggested predevelopment working sessions to help modelers determine users' needs and help the users understand what models can provide.

Legal and Regulatory Problems

Problems mentioned by conference participants from the private sector in this category ranged from legal liabilities associated with the use of models to interjurisdictional disputes over model use. Participants suggested that agency contracts be more specific concerning the legal liability of the model developer.

Conflict among Federal, State, and local decisions based on the use of different models was also considered. Communication and cooperation among agencies, including joint model development, was suggested to alleviate these problems. However, participants also noted that different and conflicting laws, delegations of authority, and organizational interpretation of laws and models contribute to interjurisdictional disputes.

Participants from the private sector emphasized that regulations should not require specific methods. Many thought that models used in regulatory applications should stress objectives, not specific methods. Others thought that models used in regulatory applications should be required to undergo peer review and validation. Another suggestion *was to* establish a continuously reviewed listing of models appropriate for certain regulatory applications.