Gregor Auble

FWS/OBS-84/16
JULY 1984

A FRAMEWORK FOR ASSESSING THE IMPACTS OF ACIDIC DEPOSITION ON FOREST AND AQUATIC RESOURCES: RESULTS OF A WORKSHOP FOR THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

April 25-29, 1983
Leetown, WV

Fish and Wildlife Service

U.S. Department of the Interior

Gregor Auble

FWS/OBS-84/16
July 1984

A FRAMEWORK FOR ASSESSING THE IMPACTS OF ACIDIC DEPOSITION ON FOREST AND AQUATIC RESOURCES: RESULTS OF A WORKSHOP FOR THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

April 25-29, 1983
Leetown, WV

by

James E. Roelle
Austin K. Andrews
Gregor T. Auble
David B. Hamilton
Richard L. Johnson
James F. Sisler
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2627 Redwing Road
Fort Collins, CO 80526-2899

EPA Interagency Agreement Number
AD-14-F-2A-322

Sponsored by
The Interagency Task Force on Acid Precipitation
722 Jackson Place, N.W.
Washington, DC 20506

Western Energy and Land Use Team
Division of Biological Services
Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

DISCLAIMER

The opinions and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the U.S. Fish and Wildlife Service or the Interagency Task Force on Acid Precipitation, nor does mention of trade names constitute endorsement or recommendation for use by the Federal Government.

This report should be cited as:

Roelle, J. E., A. K. Andrews, G. T. Auble, D. B. Hamilton, R. L. Johnson, and J. F. Sisler. 1984. A framework for assessing the impacts of acidic deposition on forest and aquatic resources: Results of a workshop for the National Acid Precipitation Assessment Program. U.S. Fish Wildl. Serv. FWS/OBS-84/16. 80 pp.

FOREWORD:
PERSPECTIVE OF THE
ACID DEPOSITION ASSESSMENT STAFF

BACKGROUND

Under the Acid Precipitation Act of 1980 (P.L. 96-294), a National Acid Precipitation Assessment Program (NAPAP) has been established. The legislative charge of NAPAP is to perform the necessary research, over a 10-year period, to develop an understanding of the causes, sources, and the physical and economic effects of acid rain and to delineate options for policy. The study is organized under an Interagency Task Force and 10 working task groups. The Assessments and Policy Analysis Task Group (Task Group I) is responsible for performing integrated assessments and developing tools for policy analyses. The Acid Deposition Assessment Staff (ADAS) provides staff support to Task Group I and is responsible for developing plans for and carrying out a series of interim assessments that will lead to a mandated final product in 1989.

NAPAP has planned a program that calls for an interim Assessment of Current Damages (physical and economic) in 1985. Assessments in 1987 and 1989 will incorporate analyses of the benefits (fewer projected damages) of reduced emissions or mitigation alternatives, versus the cost of achieving those benefits.

This document is the report of a planning workshop held in May 1983, 4 months after the organization of ADAS. Its purpose was to define the objectives of the 1985 Assessment and to achieve a common understanding among the participants of the alternative assessment approaches.

The participants included ADAS personnel; key researchers and managers from other task groups who were associated with studies of forests, aquatic systems and fish resources; several resource economists; and the staff of the U.S. Fish and Wildlife Service Western Energy and Land Use Team who were responsible for organizing and conducting the workshop and preparing this report.

PROJECT RESULTS

Valuable results of this project include:

- Conceptual assessment models were formulated and their data needs identified. These are the initial frameworks for assessments in the areas of forest resources, watershed response, and fisheries resources. This work defined some of the methodology development projects needed to implement the frameworks.

- The scope of "current" and future damages was defined. This activity focused the planning for the 1985 Assessment.

- Procedures for economic evaluations of losses to fisheries resources, commercial timber resources, and intrinsic ecosystem values were identified and research activities were planned.

- Understanding of the needs and limitations of each group was furthered by the week-long dialog among researchers, assessors, and economists.

CURRENT STATUS

Now, in late 1984, this report is no longer an accurate record of current plans, but has mainly historical significance. The concepts and the frameworks that were developed have changed as our understanding of the problems' complexities and data availability has increased. No attempt has been made to revise this document to be consistent with current planning. It remains a true record of a critical step in the Acid Deposition Assessment planning process. Still, directions have not changed much in the past year, and the report provides insight into the considerations that started us along our present path.

Robert E. Rosenthal, Project Manager
Acid Deposition Assessment Staff

CONTENTS

	Page
FOREWORD	iii
FIGURES	viii
TABLES	x
ACKNOWLEDGMENTS	xi
INTRODUCTION	1
1985 Assessment Objectives	2
Workshop Objectives	2
Workshop Activities	4
THE 1985 ASSESSMENT: OVERVIEW	8
Components of Damage	8
Valuation of Damage	13
Assessment Framework	20
THE 1985 ASSESSMENT: PROCEDURES	25
Watershed Response	25
Fish Resources	29
Timber Resources	42
Other Ecosystem Attributes	48
LATER ASSESSMENTS	52
Watershed Response	52
Fish Resources	54
Timber Resources	56
Other Ecosystem Attributes	58
DISCUSSION	59
Spatial Scale and Aggregation	59
Uncertainty Issues	62
SUMMARY AND RECOMMENDATIONS	66
The 1985 Assessment	66
Later Assessments	73
Recommendations	75
REFERENCES	80

FIGURES

Number		Page
1	Overall framework for the 1985 damage assessment	3
2	Original workshop conceptualization of components and information flows for the 1985 assessment of damages to fish resources, timber resources, and other ecosystem attributes	5
3	Components of current damage in units of physical resource or utilization	9
4	Decision analysis formulation in units of physical resource or utilization	13
5	Final workshop conceptualization of components and information flows for the 1985 assessment of damages to fish resources, timber resources, and other ecosystem attributes	21
6	Procedure for 1985 current damage assessment of watershed response	27
7	Procedure for 1985 future damage assessment of watershed response: rate of pH change	28
8	Procedure for 1985 future damage assessment of watershed response: steady-state pH based on lumped-parameter model	30
9	Procedure for 1985 future damage assessment of watershed response: steady-state pH based on predictor nomograph ...	31
10	Procedure for 1985 assessment of damage to fish resources	35
11	General form of the relationship between pH and the probability of an aquatic habitat containing a naturally reproducing fish population	36

FIGURES (concluded)

Number		Page
12	Procedure for 1985 assessment of damage to timber resources	44
13	Procedure for post-1985 future damage assessment of watershed response: process models	53
14	Procedure for post-1985 assessment of damage to timber resources utilizing detailed mechanistic models	57
15	Components of current damage in units of physical resource or utilization	67

TABLES

Number		Page
1	Potential fish species of interest and initial estimates of criteria to aid in selection of species to be used in the 1985 assessment	33
2	Current status of information on biota in or associated with the aquatic community that may be useful in a contingent value elicitation	38
3	Status of State fishery data bases and priorities for obtaining additional information	40
4	Estimated ability to produce damage estimates for various regions and States using data currently available	41
5	Use activities and intrinsic values that may be affected by acidic deposition	49
6	Examples of other ecosystem attributes that may be affected by acidic deposition and should be considered for a contingent valuation	50
7	Summary of information on watersheds, fish resources, timber resources, and other ecosystem attributes likely to be available for the 1985 assessment	69

ACKNOWLEDGEMENTS

This report represents an attempt by the authors to synthesize the discussions and conclusions of a workshop designed to outline a framework for assessing the impacts of acidic deposition on forest and aquatic resources. The following individuals participated in the workshop:

Kent Andrews
U.S. Fish and Wildlife Service
Western Energy and Land Use Team
Creekside 1
2627 Redwing Road
Fort Collins, CO 80526-2899
(303) 226-9426/FTS 323-5426

Greg Auble
U.S. Fish and Wildlife Service
Western Energy and Land Use Team
Creekside 1
2627 Redwing Road
Fort Collins, CO 80526-2899
(303) 226-9448/FTS 323-5448

Joan Baker
EPA/NCSU Acid Precipitation Program
North Carolina State University
1509 Varsity Drive
Raleigh, NC 27606
(919) 737-3520

Ann Bartuska
EPA/NCSU Acid Precipitation Program
North Carolina State University
1509 Varsity Drive
Raleigh, NC 27606
(919) 737-3520

David Bennett
Environmental Protection Agency
Acid Deposition Assessment Staff
RD-676, 401 M Street, S.W.
Washington, DC 20460
(202) 382-5600

Richard Bishop
Dept. of Agricultural Economics
University of Wisconsin
Madison, WI 53706
(608) 262-8966

Stan Blacker
Environmental Protection Agency
Office of Research and Development
401 M Street, S.W.
Washington, DC 20460
(202) 383-7676

David Brakke
Institute for Watershed Studies
Western Washington University
Bellingham, WA 98225
(206) 676-3136

Mac Callaway
Battelle, Pacific Northwest Lab.
Bldg. SIGMA-4
P.O. Box 999
Richland, WA 99352
(509) 376-4744/FTS 444-4744

Ted Callender
U.S. Geological Survey
National Center, MS 432
Reston, VA 22092
(703) 860-6951/FTS 928-6951

Robbins Church
Environmental Protection Agency
Corvallis Environmental Res. Lab.
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4350/FTS 420-4350

Bill Currie
Battelle, Pacific Northwest Lab.
Bldg. SIGMA-4
P.O. Box 999
Richland, WA 99352
(509) 376-4355/FTS 444-4355

Terry Haines
U.S. Fish and Wildlife Service
Department of Zoology
University of Maine
Orono, ME 04469
(207) 581-2578

Dave Hamilton
U.S. Fish and Wildlife Service
Western Energy and Land Use Team
Creekside 1
2627 Redwing Road
Fort Collins, CO 80526-2899
(303) 226-9418/FTS 323-5418

Chris Hoogendyk
Terrestrial and Aquatic Ecology Div.
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3744/FTS 666-3744

Josephine Huang
Environmental Protection Agency
Office of Research and Development
RD-680, 401 M Street, S.W.
Washington, DC 20460
(202) 382-5729

Richard Johnson
U.S. Fish and Wildlife Service
Western Energy and Land Use Team
Creekside 1
2627 Redwing Road
Fort Collins, CO 80526-2899
(303) 226-9434/FTS 323-5434

Robert Lackey
Environmental Protection Agency
Corvallis Environmental Res. Lab.
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4806/FTS 420-4806

Thomas Lareau
Environmental Protection Agency
PM-220, 401 M Street, S.W.
Washington, DC 20460
(202) 382-2771

Morris Levin
Environmental Protection Agency
Office of Research and Development
RD-676, 401 M Street, S.W.
Washington, DC 20460
(202) 382-2775

Bob Luxmoore
Environmental Sciences Division
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830
(615) 574-7357/FTS 624-7357

Jim MacLean
Ontario Ministry of Natural Resources
Fisheries Research Section
Box 50, Maple, Ontario,
Canada LOJ 1ED
(416) 832-2761

David Marmorek
Environmental and Social Systems Analysts, Ltd. (ESSA)
678 W. Broadway, Vancouver, B.C.,
Canada V5Z 1G6
(604) 872-0691

Dick Olson
Oak Ridge National Laboratory
P.O. Box X, Bldg. 1505
Oak Ridge, TN 37830
(615) 574-7819/FTS 624-7819

Jim Omernik
Environmental Protection Agency
Corvallis Environmental Res. Lab.
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4613/FTS 420-4613

Jim Perry
Forest Resources
University of Minnesota
St. Paul, MN 55108
(612) 373-0846

Don Peterson
Energy & Resource Consultants, Inc.
P. O. Drawer O
Boulder, CO 80306
(303) 449-5515

Charles Powers
Environmental Protection Agency
Corvallis Environmental Res. Lab.
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4684/FTS 420-4684

Richard Richels
Electric Power Res. Inst.
Environmental Assessment Dept.
P. O. Box 10412
Palo Alto, CA 94303
(415) 855-2602

Butch Roelle
U.S. Fish and Wildlife Service
Western Energy and Land Use Team
Creekside 1
2627 Redwing Road
Fort Collins, CO 80526-2899
(303) 226-9435/FTS 323-5435

Bob Rosenthal
Environmental Protection Agency
Acid Deposition Assessment Staff
RD-676, 401 M Street, S.W.
Washington, DC 20460
(202) 382-5598

Kent Schreiber
U.S. Fish and Wildlife Service
Eastern Energy and Land Use Team
Route 3, Box 44
Kearneysville, WV 25430
(304) 725-2061, ext. 5354/
FTS 925-5354

Dave Shriner
Environmental Sciences Division
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830
(615) 574-7356/FTS 624-7356

Jim Sisler
U.S. Fish and Wildlife Service
Western Energy and Land Use Team
Creekside 1
2627 Redwing Road
Fort Collins, CO 80526-2899
(303) 226-9434/FTS 323-5434

Daniel Violette
Energy & Resource Consultants, Inc.
P.O. Box O
Boulder, CO 80306
(303) 449-5515

Darrell West
Environmental Sciences Division
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830
(615) 574-7367/FTS 624-7367

Raymond Wilhour
Environmental Protection Agency
Corvallis Environmental Res. Lab.
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4634/FTS 420-4634

Ted Williams
Department of Energy
Office of Environmental Analysis
EP-33, Room 4G-024
Forrestal Building
Washington, DC 20585
(202) 252-4770

As facilitators, the authors of this report are indebted to all of these individuals for their contributions to the workshop. In particular, we wish to thank David Bennett and the other members of the Acid Deposition Assessment Staff for giving us the opportunity to facilitate the workshop. In addition, opening presentations on assessment and economic methodologies by David Bennett, Tom Lareau, Dan Violette, Don Peterson, and Richard Bishop were extremely useful and greatly appreciated.

Since the workshop, significant progress has been made in many areas of the framework outlined herein. No attempt is made to document this progress; rather, the report summarizes the framework as it existed at the close of the workshop.

Despite the quality of the contributions by the participants listed above, errors of fact or interpretation may remain. For these, the authors take full responsibility.

INTRODUCTION

The Interagency Task Force on Acid Precipitation was established by the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act of 1980 - P.L. 96-294) with the charge of developing and implementing a National Acid Precipitation Assessment Program (NAPAP) to increase understanding of the causes and effects of acid precipitation. The task force is composed, in part, of ten task groups with responsibilities for various aspects of the National program. Task Group I has responsibility for assessment and policy analysis activities, including: synthesis of information on the composition and distribution of acidic deposition; synthesis of information on current and potential future adverse effects; formulation of alternative emission control and effects mitigation strategies; evaluation of alternative strategies on the basis of cost-effectiveness and cost-benefit; and identification of research that could reduce uncertainties hindering the policy analysis process (Interagency Task Force on Acid Precipitation 1982).

To assist Task Group I in carrying out these activities, the U.S. Environmental Protection Agency and the U.S. Department of Energy formed an Acid Deposition Assessment Staff (ADAS). The ADAS is responsible for managing Task Group I's assessment projects as well as serving as a coordinator between Task Group I and the other task groups. As part of these responsibilities, the ADAS has begun to develop frameworks for a series of assessments to be conducted between 1985 and 1989. The first of these assessments, scheduled for 1985, will concentrate on the description and evaluation of current damages due to acidic deposition and a preliminary analysis of source/receptor uncertainties. Later assessments will refine the analysis of source/receptor relationships and deal with other aspects of the problem, such as evaluation of the consequences of alternative deposition scenarios and analysis of various strategies for emissions control and effects mitigation.

1985 ASSESSMENT OBJECTIVES

The overall structure for the 1985 damage assessment is illustrated in Figure 1. The two right-most boxes represent the principal objectives of the 1985 assessment; that is, to produce, for as many resources in as many areas as possible, estimates of the current physical damages to resources due to acidic deposition and the economic value of those damages. The 1985 assessment will also evaluate the status and current uncertainties associated with source/receptor relationships and discuss the range of policy options and their sensitivity to uncertainty.

WORKSHOP OBJECTIVES

The general purpose of the workshop (held in Leetown, West Virginia, April 25-29, 1983) described in this report was to elaborate, for aquatic and nonagricultural terrestrial resources, that part of Figure 1 represented by the solid boxes and arrows. Particular emphasis was given to the correspondence between the kinds of ecological information required by various economic valuation methods and the kinds of ecological information being developed by the effects research program of the NAPAP. More specifically, the objectives of the workshop were to:

1) develop an expanded dialogue between effects researchers and those (the ADAS, economists, policy analysts) who will use the results of the effects research program for assessment purposes;

2) achieve a common understanding among participants concerning alternative assessment approaches;

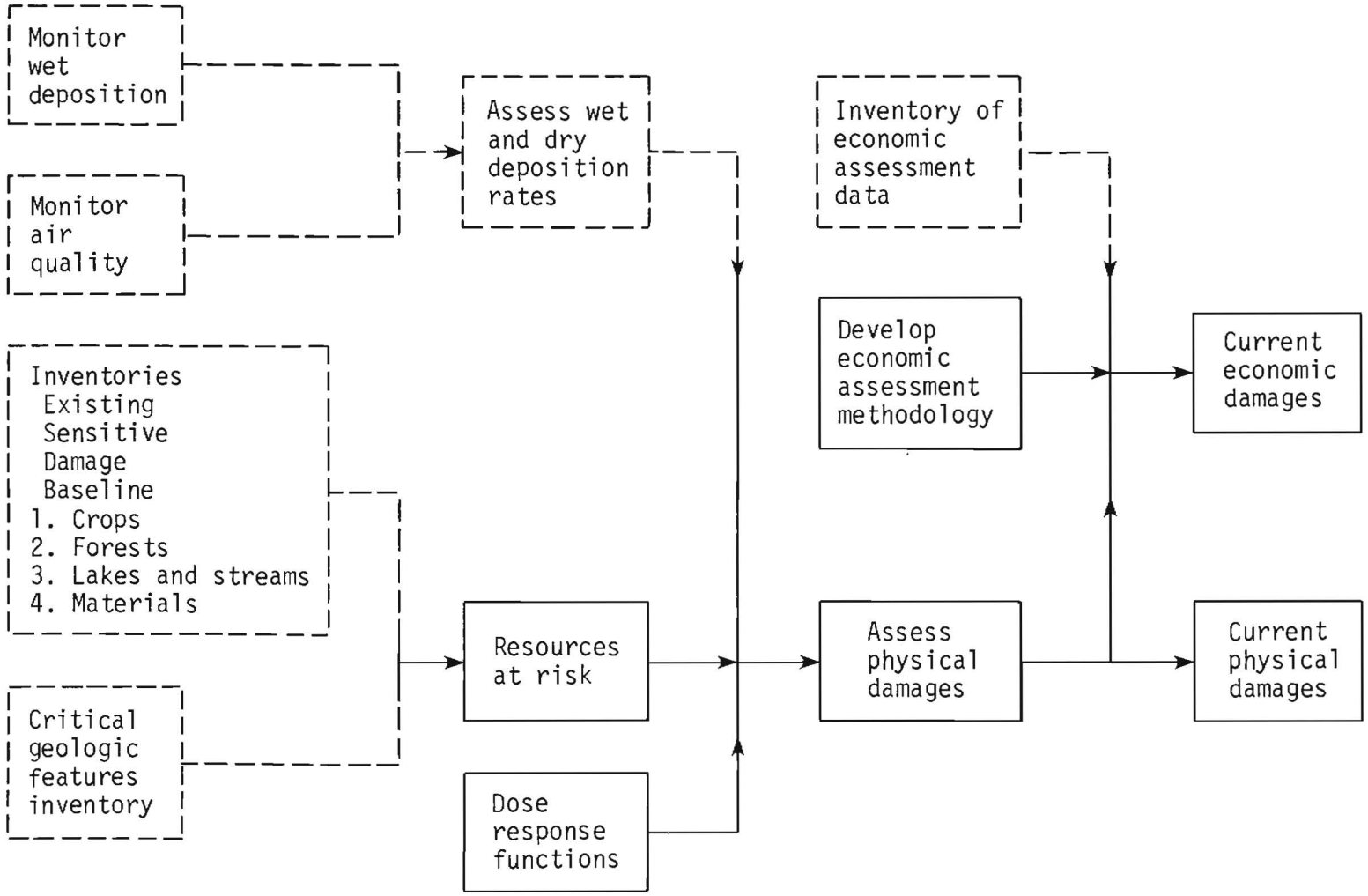

Figure 1. Overall framework for the 1985 damage assessment. Solid boxes and arrows indicate activities and flows of information considered at the workshop.

3) define information and methods needed to implement each alternative;

4) compare information available, or likely to become available, with information needs; and

5) arrive at a consensus concerning the alternatives most likely to be achievable and credible.

WORKSHOP ACTIVITIES

The workshop was conducted using a modified version of the Adaptive Environmental Assessment (AEA) approach (Holling 1978; Andrews et al. 1982). Briefly, this approach involves breaking a problem of interest down into three to six basic components, identifying the information flows and interactions between those components, dividing workshop participants into smaller groups representing each of the basic components, and constructing a model to produce the information required from each component using the information provided by other components. In a typical AEA workshop, the model constructed in this manner is a computerized, time-dynamic simulation model. Construction of the model is used to synthesize existing information, to identify additional information needs, and to promote among participants a common, holistic understanding of the problem. For a variety of reasons, including scarcity of currently available data and broadness of the problem in a spatial sense, a working simulation model was not the objective of the workshop described in this report. Rather, the workshop focused on identification of information required for the 1985 assessment and development of conceptual models or approaches for producing the necessary information.

The portion of the 1985 assessment (Figure 1) considered at the workshop was conceptualized by the facilitators and ADAS representatives as having five distinct components (Figure 2), each represented by a group of participants. Assessments of damages to crops, materials, and human health are also planned for 1985. However, in order to keep the workshop to a manageable size, these aspects of the 1985 assessment were not considered.

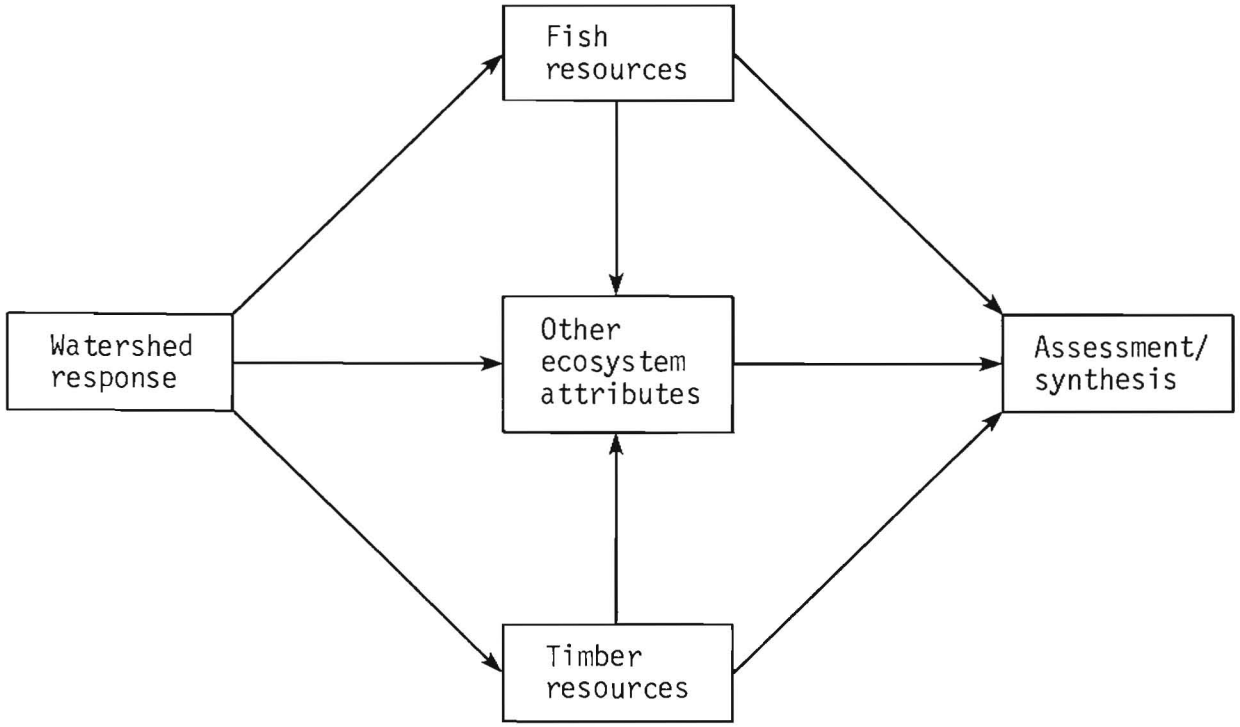

Figure 2. Original workshop conceptualization of components and information flows for the 1985 assessment of damages to fish resources, timber resources, and other ecosystem attributes.

The Assessment/Synthesis group was thought of as having three basic responsibilities: 1) to define the economic methods likely to be used in the valuation of fish resources, timber resources, and other ecosystem attributes over broad spatial scales; 2) to define the ecological information required by these economic methods; and 3) to synthesize the ecological information produced by the other groups and the outputs from the economic models into an internally consistent description of the physical damages to resources and the economic value of those damages.

The Fish Resources group and Timber Resources group were envisioned as having two general responsibilities: 1) to develop methods or approaches for producing the ecological information required by the Assessment/Synthesis group; and 2) to define the information concerning watershed responses needed to apply the approaches developed. For example, it was anticipated that the Assessment/Synthesis group might require an estimate of the number of lakes and streams where fish have been extirpated due to acidic deposition, and that to provide this estimate the Fish Resources group might require information on past, present, and expected future changes in lake and stream pH. Similarly, methods for estimating changes in timber harvest might require information concerning changes in soil fertility due to acidic deposition, which was considered to be a watershed response.

The Other Ecosystem Attributes group was originally conceived as having a similar set of responsibilities for environmental components other than fish and timber: 1) to develop approaches for estimating changes in resources such as wildlife habitat, wildlife populations, forest understory communities, and visual qualities; and 2) to define the information concerning watershed responses needed to apply these approaches. As the workshop progressed, however, it became apparent that separate valuation of changes in each of these components would probably not be possible. As a result, the Other Ecosystem Attributes group shifted its attention to consider methods for estimating the aggregate value of such changes based on a summary description. The Fish Resources group and Timber Resources group, in addition to considering

fish and timber, were requested to provide an indication of other kinds of descriptive information likely to be available for the aquatic and terrestrial systems.

Finally, the Watershed Response group was seen as developing approaches for translating an input of acidic deposition into the kinds of information required by the three resource groups.

The first day of the workshop was devoted to presentations concerning the overall assessment objectives and economic methods likely to be used in the valuation of each type of resource, with particular attention to the kinds of ecological information required to apply the economic methods. During the next three days of the workshop, participants met in smaller groups, each group representing one component in Figure 2, to further discuss and refine information exchanges and to develop approaches for producing the necessary information. An economist met with each of the resource groups to ensure, insofar as possible, correspondence between the ecological information being generated and the needs of the Assessment/Synthesis group. These economists also met occasionally with the Assessment/Synthesis group to report progress and to assist in fitting the information produced by the resource groups into an overall framework for economic valuation. Plenary sessions were held periodically to discuss changes in information requirements as they were identified.

The final day of the workshop was devoted to summary presentations of information needs and approaches developed by each subgroup. The remainder of this report is an attempt by the authors to organize those presentations into a more coherent overall framework and to document additional ideas expressed by participants during the workshop.

THE 1985 ASSESSMENT: OVERVIEW

COMPONENTS OF DAMAGE

The focus of the 1985 assessment will be on "current" damage. A clear definition of current damage is thus a prerequisite to the assessment and was an important topic of discussion at the workshop. General descriptions of three components of current damage were offered for consideration at the beginning of the workshop.

1) Cumulative impact to date (i.e., 1985). The idea of this component was to provide a sense of the magnitude of the damage that has already occurred.

2) Impact occurring this year (i.e., 1985). This component was intended to provide a sense of the rate at which damage is occurring, and thus a sense of the urgency for taking some action.

3) Future impact at current rates of atmospheric deposition. This component was intended to provide a sense of how much additional damage is likely to occur if current deposition continues.

There was considerable discussion at the workshop concerning the relationship of various physical and economic methods of measurement and projection to these three damage components. These discussions were focused through reference to a hypothetical graph of a variable through time (Figure 3). It is assumed that the variable represents some physical resource (e.g., fishable area in a region or pH of a lake) or utilization of a resource (e.g., amount

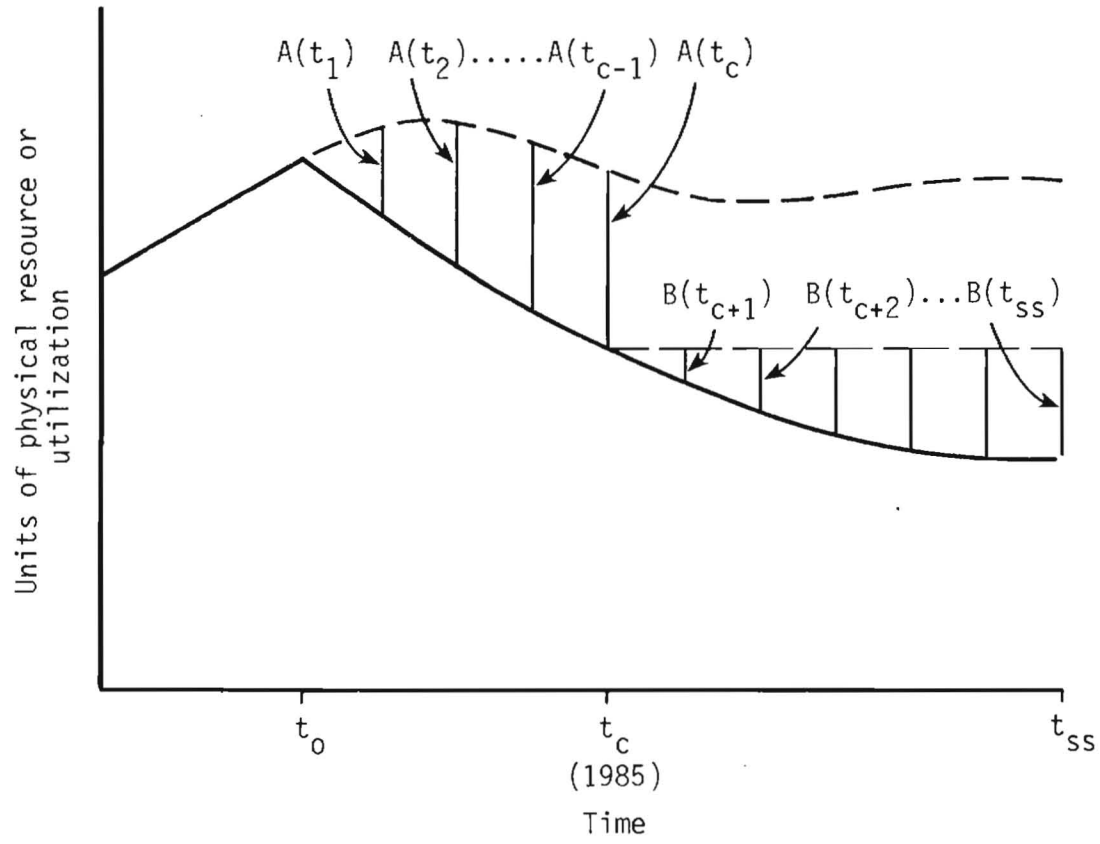

Figure 3. Components of current damage in units of physical resource or utilization.

of recreation provided) that declines as a result of increased acidic deposition. It is further assumed that variation in the variable due to other sources can be separated from the effects due to acidic deposition. This allows a conceptual contrast between a hypothetical trajectory in the absence of acidic deposition (short dash line) and an acidic deposition trajectory (solid line) consisting of response to historical deposition from time t_o to the current time (t_c = 1985) and an estimated future response to continued deposition at current (1985) rates. Note that the hypothetical trajectory in the absence of acidic deposition need not be a horizontal projection of the resource level at time t_o. For example, in the simulation approach that may be used in the assessment of damage to timber harvest (see TIMBER RESOURCES section), the trajectory projected for the absence of acidic deposition would likely be a time-varying probabalistic estimate resulting from the aggregation of many stochastic simulations. On the other hand, practical considerations (e.g., lack of information) may force the assumption of a horizontal projection from time t_o for resources such as fishable area in a region.

In the context of a physical resource, the value $A(t_c)$ in Figure 3 is likely to be the most useful definition of cumulative damage to date. This quantity is the difference between the current state of the physical resource and the hypothetical state of the resource if there had been no acidic deposition (above some nominal baseline value) in the past. In addition to conceptual simplicity, this definition has the virtue that it can be valued using both travel cost and market/dynamic resource approaches (see VALUATION OF DAMAGE section).

Other definitions of cumulative damage to date are of course possible. For example, the sum of $A(t_i)$ from t_1 to t_c would be a meaningful definition for variables involving resource utilization; that is, the total fishing opportunity lost to date is the summation of the opportunity lost each year since the onset of acidic deposition. This definition is equivalent to the area between the two curves in Figure 3 from t_o to t_c. However, obtaining an economic value for this definition would be more difficult and would require not just an estimate of the total area between the curves, but rather an

estimate of the specific sequence of $A(t_i)$ values from t_1 to t_c. Many trajectories could produce the same total area, but would produce different present dollar values as a result of the application of interest rates to points along the trajectory. Given the difficulty of estimating specific historic trajectories from t_1 to t_c, participants felt that the simpler definition of cumulative damage to date [i.e., $A(t_c)$] would probably be the most useful for the 1985 assessment.

The long dash line in Figure 3 is the horizontal projection into the future of the current (t_c = 1985) value of the variable and is useful in defining several other quantities of interest. The values $B(t_i)$ from t_{c+1} to t_{ss} represent the sequence of differences between the current state of the variable and the trajectory projected to result from the continuation of current deposition rates. The first value in this series, $B(t_{c+1})$, is thus an estimate of the additional damage occurring in the current year and is useful in conveying a sense of how rapidly the variable is changing.

The value $B(t_{ss})$ is the difference between the current value of the variable and a new steady-state value (assuming that one exists) occurring at some, perhaps unspecified, time, t_{ss}. For a physical resource (e.g., fishable area) the value $B(t_{ss})$ represents a useful definition of the <u>additional</u> damage that might result from the continuation of current deposition. It is worth noting, however, that the time at which steady state is achieved, t_{ss}, is not provided by a number of approaches that might be used in the 1985 assessment to predict the steady state of the resource.

For variables involving resource utilization (e.g., recreation use), additional damage can be defined as the sum of $B(t_i)$ from t_{c+1} to t_{ss}. This is equivalent to the total area between the horizontal projection of the current value (long dash line) and the expected trajectory with continued deposition at current rates (solid line) from t_c to t_{ss}. Once again, however, knowing the total area is insufficient if the resource is to be valued using economic techniques that involve application of a discount rate to future

conditions. In that case the specific sequence of $B(t_i)$ values must be estimated, because different sequences having the same total area would provide very different discounted present values.

While there was considerable discussion of these points at the workshop, there was general agreement that defining additional future damage as a specific sequence of $B(t_i)$ values would be most useful for the 1985 assessment. Some participants felt that total future damage, which would include an $A(t_i)$ component for each year, would be a more appropriate measure. There was also a consensus that, while annual resolution for the future trajectory would be most desirable, a piecewise-linear approximation from points at 5- to 10-year intervals would probably be acceptable for most economic analyses. It was also noted that a specific sequence of $B(t_i)$ values is not estimable merely from knowledge of the current rate of loss, $B(t_{c+1})$, and the steady-state condition, $B(t_{ss})$. Of course, as a time-trend analysis around the current time becomes more sophisticated and encompasses a larger section of the trajectory, it may come closer to defining the entire trajectory and thus become an empirical, "time-predictive" model.

The components of damage identified in Figure 3 will form the basis of the 1985 current damage assessment. As experts in this area correctly pointed out at the workshop, however, Figure 3 is not necessarily the most relevant formulation in the sense of decision analysis. A decision analysis approach would focus on a comparison among the trajectories resulting from various decision options (Figure 4). This approach differs from that illustrated in Figure 3 in that the various trajectories shown in Figure 4 are all presumed to be achievable alternatives, whereas the horizontal projection of current value (long dash line in Figure 3) may be neither feasible nor desirable. Furthermore, current damage information such as that illustrated in Figure 3 is not in a form to be compared with the costs of reducing damages. Benefit/cost analyses require information like that depicted in Figure 4. Specification of additional future damage as a sequence of $B(t_i)$ values, however, requires the same type of "time-predictive" models that will be needed for later assessments involving comparisons of alternative deposition scenarios.

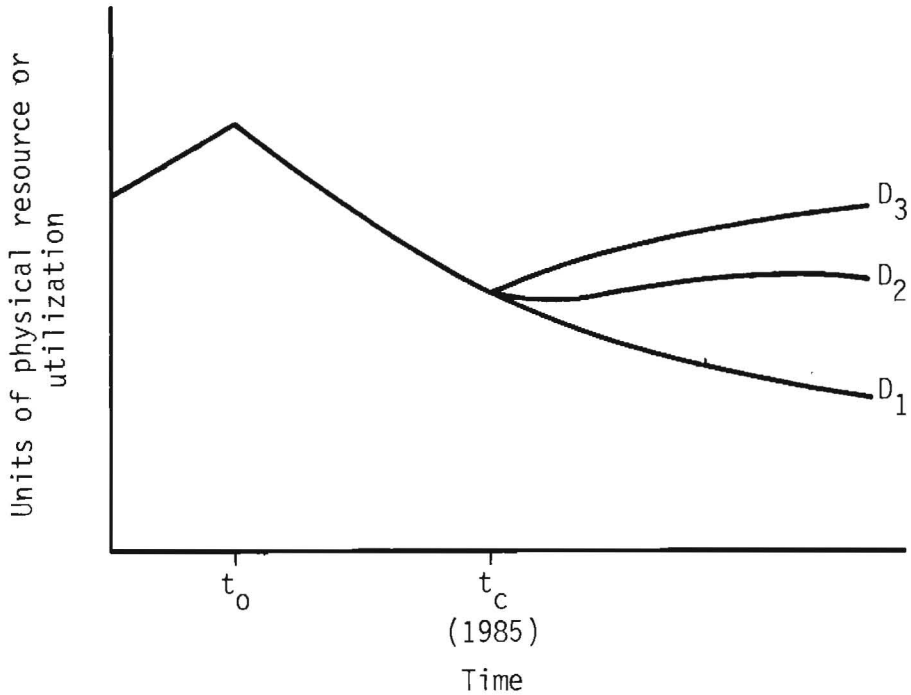

Figure 4. Decision analysis formulation in units of physical resource or utilization. Predictions are made of the trajectories resulting from alternate decision options D_1, D_2, and D_3.

VALUATION OF DAMAGE

The work necessary to judge the most appropriate techniques for converting changes in physical resources and their utilization to monetary units in the 1985 assessment has not been completed. In several cases, proposed approaches represent an extension of techniques into relatively new areas of application in terms of scope and complexity. The economic assessment will thus involve a considerable amount of methods development and pretesting. What can be described at this point is current thinking about the most promising approaches, their most probable information requirements, and some of the questions that will have to be resolved through methodological work and pretesting.

Contingent Value Elicitation

The contingent value approach involves an elicitation, through various survey or bidding-game instruments, of individuals' willingness to pay for a particular condition or state of a physical resource. There are many difficulties with the approach; however, it is basically the only viable way to estimate nonuser or "intrinsic" benefits such as existence or ecosystem integrity. Many participants believed that such nonuser benefits are likely to be significantly larger than benefits deriving from use activities (e.g., sport fishing), and therefore that the methodological development work necessary to implement a contingent value elicitation would be worthwhile.

The overriding consideration in effective utilization of the technique is that the description of the "product" being valued be clear and understandable to the respondents. To the extent that damages could be described at the National level, a Nation-wide survey is thus possible. However, most participants felt that it would be more reasonable to limit application in the 1985 assessment to a region (e.g., New England) or State where the extent of damage due to acidic deposition is better understood.

It was also the consensus at the workshop that a contingent value elicitation would be most effectively applied to a summary description of damages, rather than to individual resource attributes. The resulting value would thus include components associated with specific recreational activities (e.g., sport fishing) as well as nonuser or intrinsic values such as ecosystem integrity. Some of these components would also be estimated separately by different methods (e.g., the travel cost approach applied to sport fishing). It was felt that damage to commercial timber would not be appropriately included in the contingent value elicitation.

To the extent that the damages can be described in a clear and understandable way, the contingent value approach could theoretically be applied to any of the components of damage depicted in Figure 3. Practically, however,

there were serious questions raised at the workshop about applying the technique to monetize the $A(t_c)$ component and about the ability of the technique to value a specific trajectory of future conditions as opposed to a general statement of future conditions such as a new steady state [i.e., $B(t_{ss})$ on Figure 3].

The contingent value elicitation could be structured to provide output in terms of dollars per year. Methodological refinements could also address differences between various types of users and nonusers and residents of the region versus nonresidents. General issues that need to be addressed in the pretesting and development phase include:

1) What is the best "mode" for the instrument (mail survey, telephone, personal interview)?

2) Should information on the uncertainty of various effects be directly incorporated in the elicitation?

3) Should the effects be attributed to acidic deposition or described without reference to cause?

4) What is the appropriate population (national, broad area, specific regional residents) to sample for willingness to pay for damage in a specific region?

5) How stable will the results of an elicitation be over the time period covered by the scope of the assessment with respect to possible shifts in population size and preferences, and how should these possible shifts be addressed in the assessment?

Travel Cost Methods

The travel cost approach estimates a demand curve for recreational use at a site by extrapolating from observed relationships between visitation rates and the "price" of a visit. Visits are priced by calculating out-of-pocket expenses and a cost for travel time.

The underlying assumption is that visitation rates from a general area are inversely related to the "price" of the trip from that area. The model is quantified by developing a regression equation predicting per capita visitation to the site from an area as a function of site characteristics, travel cost from the area, and socioeconomic descriptors of the population in the area. This relationship is then used to generate a demand curve for the site by systematically increasing the travel cost. At each increment of higher travel cost, per capita visitation from the regression equation and the resulting total visitation are calculated for each area of origin and then summed across areas to yield total visitation. The area under this demand curve but above the current price is the site's consumer surplus or the amount that people would be willing to pay in excess of actual expenditures.

A change in site characteristics (such as a decrease in fish populations) is evaluated by constructing a new demand curve using altered values of the appropriate independent variables and comparing the resulting consumer surplus and actual expenditures to the original consumer surplus and actual expenditures. In principle, the method can be applied to any differences in site characteristics that have been incorporated as independent variables in the prediction of visitation rates. The method could thus address the $A(t_c)$, $B(t_{c+1})$, and $B(t_{ss})$ components of damage (Figure 3) if the appropriate sets of site characteristics can be provided.

Several factors complicate the approach. It is very difficult to predict and thus incorporate changes in preferences over time. Thus, the method generally assumes that preferences remain constant and only site characteristics (and perhaps socioeconomic variables and population distributions) change.

Substitution of alternate sites is a major consideration that must be addressed in some fashion. A multisite model can be constructed by including travel cost and site characteristic variables (probably including a measure of congestion) for alternate sites in the regression equation predicting per capita visitation rate at a given site. Actual expenditures, demand curves, and consumer surplus can then be generated for all sites by the system of equations. This approach can become intractable on a regional basis (e.g., 3,000 lake sites). An alternative is to broaden the definition of site to include a number of individual lakes represented by aggregate site-characteristic variables such as total fishable area. Substitution of locations within the "site" is thus handled implicitly by the regression coefficients; substitution among "sites" would require explicit treatment as in a multisite model.

This method was originally developed to evaluate a single site considering the substitution effects of several alternate sites. Application in a regional assessment thus represents a considerable methodological extension. Methods evaluation and pretesting work, which have been recently started, are necessary to define exactly how the travel cost approach could be applied. The consensus at the workshop was that the travel cost approach is the most promising method for valuing damages to sport fishing. It might also be applied to value damage to several other specific activities such as hiking and scenic viewing.

The application that seems most likely at this point would be to value changes in sport fishing activity and demand based on changes in the site characteristics of fishable area (defined as presence or absence of fish) for lakes and fishable length for streams. This information would be needed for each fish species and each lake or stream size class in a series of spatial areas defined by some appropriate characteristic such as alkalinity class (see WATERSHED RESPONSE section). For the 1985 assessment, it is likely that this information will be available only for clear-water systems. In the simplest case, each alkalinity class would be a "site" in the travel cost analysis. Preliminary applications may indicate that additional criteria need to be used to define "sites". Additional criteria might include lake size class or access considerations (such as 1-day trip sites versus 3- to 5-day trip sites

requiring backpacking). The response (in terms of fishable area or length) of these "sites" would be estimated from the information provided by alkalinity region, based on the fractions of each alkalinity region within each of the "sites".

Other ecosystem characteristics used to predict fishing visitation rates to a site would likely include a measure or measures of scenic beauty, congestion, facilities (e.g., docks, lodging), and availability of other activities (e.g., hiking, wildlife viewing, swimming). It is uncertain whether any of these secondary attributes, except congestion, will change predictably as a result of acidic deposition at levels that might alter the demand curve for sport fishing at any site. Regardless, some quantification of their current state will be necessary to express the desirability of alternate sites in order to treat substitution effects.

Application of the travel cost method to activities other than sport fishing (e.g., hiking) will depend on identification of site attributes (e.g., scenic beauty) that predict visitation rates for these activities (which should emerge from preliminary testing) and ability to predict changes in these attributes as a result of acidic deposition (which is uncertain at this point).

The status of information on secondary site attributes, visitation rates, zones of origin for various sites, and travel costs was not well defined at the workshop. Possibly useful sources include various fishing use surveys, visitor statistics at various sites, road maps, census data, and descriptions of secondary site characteristics provided by local resource managers.

The travel cost valuation method cannot be applied to sport fishing where changes in the fisheries resource due to acidic deposition are not quantified. For the 1985 assessment the maximum area of coverage is thus the New York/New England region. In view of the considerable methodological issues that need to be resolved, it might be advisable to concentrate on an even smaller region (such as the Adirondacks or even some subset of the Adirondacks) in order to

fully understand how useful the method might be for later assessments covering broader areas. This would be especially important if results of preliminary applications indicate that many species need to be included, or that alternate measures of the fishery resource (e.g., biomass, productivity, or catch per unit effort) are necessary to obtain acceptable predictions of per capita visitation rates.

There are several alternate methods for valuing changes in sites with respect to specific recreational activities. These include participation models coupled with expenditure estimates and contingent valuation of the activities, activity approaches, and hedonic price approaches. These methods all have drawbacks but might be employed if serious problems are encountered in preliminary work with the travel cost approach.

A final complicating point was raised at the workshop concerning the need to incorporate management actions in the valuation of damage to fisheries. For example, if increased stocking is being employed to offset potential declines in fishable area, the net change in fishable area will not accurately represent damage due to acidic deposition. An estimation of the extent of such management actions and their cost will need to be made in addition to a travel cost valuation.

Market/Dynamic Resource Methods

The simulation approach discussed at the workshop for the estimation of physical damage to timber resources due to acidic deposition (see TIMBER RESOURCES section) suggests that economic valuation may best be accomplished through integration of an economic model with a stand simulator. Harvest schedules are an important part of both stand simulation and economic valuation, and these harvest schedules may change as a result of alterations in growth rate due to acidic deposition. One possible approach for the 1985 assessment is to incorporate a "firm-level" model to determine "optimal harvest" (and associated dollar values) in the FORET stand simulation model. The economic model would be constructed to maximize the present value of a

future stream of income minus costs, and would require information on market structure, harvesting and planting costs, and age-dependent timber prices, in addition to information generated by FORET. Any of the components of damage illustrated in Figure 3 could be evaluated by comparing appropriate sets of simulations. Application of the approach would be limited to areas for which representative FORET simulations can be run.

The utility of such an approach is dependent on a number of factors. First, it must be possible to attribute specific growth rate changes to acidic deposition. Second, the optimal harvest algorithm must be a reasonable approximation of the behavior of an individual firm. This would not be the case, for example, if demand is low relative to supply, or if growth rate changes due to acidic deposition are not sufficiently large to cause individual firms to change their harvest practices. Either of these conditions could quite easily be the case for unmanaged forests that cover much of the Northeastern United States. It is thus possible that the effort required to incorporate a harvest algorithm in the stand simulator would not be warranted if the 1985 assessment focuses on the Northeast.

On the other hand, if the above approach suggests significant damage, more sophisticated market-clearing algorithms could be added to the economic analysis. The more complex analysis would treat shifts in supply resulting from acidic deposition as nonmarginal, consider prices of substitutes, and attempt to treat demand explicitly as a function of exogenous variables such as interest rates and housing starts.

ASSESSMENT FRAMEWORK

The overall framework developed at the workshop for the 1985 assessment of damages to fish resources, timber resources, and other ecosystem attributes is illustrated in Figure 5. Processes of measurement, estimation, or valuation are represented as circles; information products or results are shown as

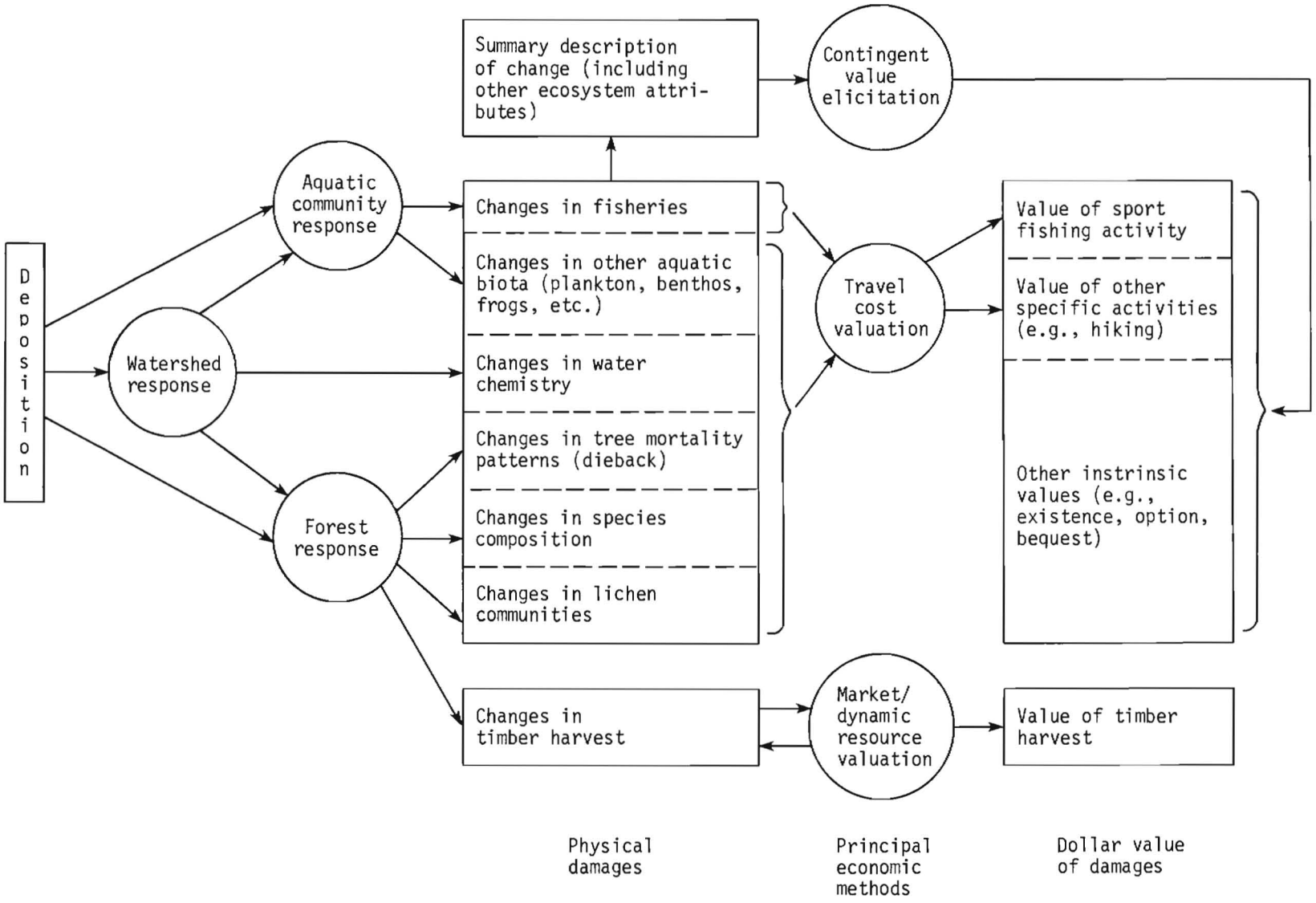

Figure 5. Final workshop conceptualization of components and information flows for the 1985 assessment of damages to fish resources, timber resources, and other ecosystem attributes.

rectangles. Additional detail concerning these processes and information flows can be found in the subsequent section entitled THE 1985 ASSESSMENT: PROCEDURES.

As an example, application of the conceptual framework of Figure 5 to an assessment of damage in the Adirondacks might involve the following activities. A contingent value elicitation would be applied to a summary description of damages to the entire region. This summary would be constructed from physical damage estimates produced for a variety of resources. It would probably include changes in activities such as sport fishing, as well as changes in other aquatic biota, water transparency, tree mortality and species composition, and some other terrestrial species (e.g., lichens). The value of sport fishing would probably also be estimated independently using a travel cost approach; thus, care would need to be taken to avoid double counting in the interpretation of results. Changes in commercial timber harvest, which would be valued by more direct market methods, would not be included in the contingent valuation.

The advisability of broadening the elicitation to encompass other values such as cultural resources and materials was not directly addressed at the workshop. It should be considered, however, because there were strong arguments made at the workshop in favor of basing an elicitation on a single damage summary as opposed to summing results from elicitations dealing only with parts of the damage.

A travel cost valuation would be applied to changes in sport fishing activity resulting from changes in fishing site characteristics. As a first approximation, the analyses would probably be based on changes in fishable area of lakes and fishable length of streams, defined as presence or absence of fish, for as many species as possible. Fishable area and length would be estimated for several size classes of water body within spatial areas defined by existing maps of alkalinity classes. (See WATERSHED RESPONSE section for additional discussion of alkalinity classes.) For the 1985 assessment, such estimates would probably be available only for clear-water systems (< 30

standard color units) and not for organic waters. The "sites" for the travel cost method would be based on this spatial definition (size class and alkalinity class) of homogeneous response units. Estimation of other "site" characteristics (e.g., scenic beauty) would be necessary to treat relative "site" preferences and substitution. Changes in such other characteristics attributable to acidic deposition could also be included in the model if appropriate. However, with the exception of a measure of congestion, the probability that these characteristics will change in clearly understood and significant ways under current deposition rates might be small enough that they could be assumed to remain constant.

Change in fishable area or length (by species, size class, and alkalinity class) would be produced in two ways. Historical and current surveys of the presence or absence of fish would provide one estimate of the damage to date. Another estimate would be obtained through application of pH-based dose-response relationships. Changes in pH would be estimated as a watershed response for each homogeneous unit defined by alkalinity class and size class. These estimates of pH would then be used to predict presence or absence of various fish species. This approach would be dependent on the assumption that field surveys across lakes with different pH values can be used to predict changes in fish populations in other lakes as the pH declines.

The travel cost approach might also be applied to other recreational uses such as hiking. This application is less likely, however, because of the lesser probability that acidic deposition at current rates will cause predictable changes in attributes at a level that would significantly affect visitation rates for activities such as hiking.

Changes in the net value of timber harvest resulting from acidic deposition would be evaluated by aggregating simulations of stand volume and harvest under a variety of conditions (initial species and age distributions, deposition rates, and edaphic factors). Aggregation to the regional level would be accomplished by inventory of the proportion of the total region represented by

a particular set of simulation conditions. The harvest algorithm in the simulation model would most likely be a relatively simple, firm-level, "optimal harvest" calculation designed to maximize the present value of a future stream of income minus costs. The success of this approach would be critically dependent on the ability to discriminate changes in tree growth rates due to acidic deposition.

THE 1985 ASSESSMENT: PROCEDURES

WATERSHED RESPONSE

Outputs

For the 1985 assessment, information concerning watershed response will be used primarily as input to the evaluation of the impacts of acidic deposition on fish. This information includes distribution of pH, [Al] (aluminum concentration), and [Ca] (calcium concentration) within lake/stream size classes within "regions". Lake size classes were initially defined at the workshop as less than 20 ha, 20-100 ha, 100-200 ha, and greater than 200 ha. Stream size classes were not defined. "Regions" refer to geographical areas within which given deposition levels will be assumed to produce similar watershed responses and thus similar alterations in the alkalinity of surface waters. Changes in pH of surface waters will be estimated from predicted changes in alkalinity. For the 1985 assessment, these "regions," or homogeneous response units, will be defined by the classes (< 50, 50-99, 100-199, 200-399, > 400 μeq/l) of total alkalinity of surface waters mapped regionally by the Corvallis Environmental Research Laboratory of the Environmental Protection Agency (EPA-CERL). Although these "regions" will be defined with respect to alkalinity, the database will allow results to be reaggregated into economically defined areas of interest.

Information on pH, [Al], and [Ca], including the current value, the steady-state value, and either the rate of change or the value every 10 years, will be desirable for the assessment of damages to fish. For the 1985

assessment, current pH values (estimated from alkalinity values) can be provided for the size classes and regions described above. Some current [Al] and [Ca] information may also be available. Methods may be available by 1985 to estimate future steady-state pH and the current rate of pH change. One caution is that some existing methods for predicting steady-state pH are independent of other methods for estimating rate of change. Care is required in the merging of techniques to predict the trajectory to reach steady-state. This trajectory is required for monetization of fisheries impacts. The combined use of these independent estimates is a research need discussed later. Estimates of steady state and rate of change for [Al] will not be available for the 1985 assessment. Some estimates of these parameters may be available for [Ca].

Approach

Damage to date. Estimates of current pH and change to date in lakes/streams by region by size class will be based on the time-trend analysis being developed by Brookhaven National Lab and the regional mapping work by EPA-CERL (Figure 6). The time-trend approach is based on a time series analysis of past trends in water chemistry data in the Acidification Chemistry Information Database (ACID). The models will be used to estimate rates of acidification of freshwaters on a regional basis. Extrapolation of results to larger areas (e.g., the Adirondacks or New England) will likely be based on the EPA-CERL alkalinity maps.

Future damage at current deposition rates. Several approaches will be used to assess future pH changes under current rates of deposition. The rate of pH change will be estimated by projecting the time-trend analysis discussed above into the future (Figure 7). Information on dissolved organic carbon (DOC) and color (both readily measurable surrogates for organic acid concentrations) and alkalinity is currently being developed and may be incorporated to account for differences in acidification due to dissolved organic acids. The time-trend analysis will provide estimates of the rate of pH change but not the steady-state pH.

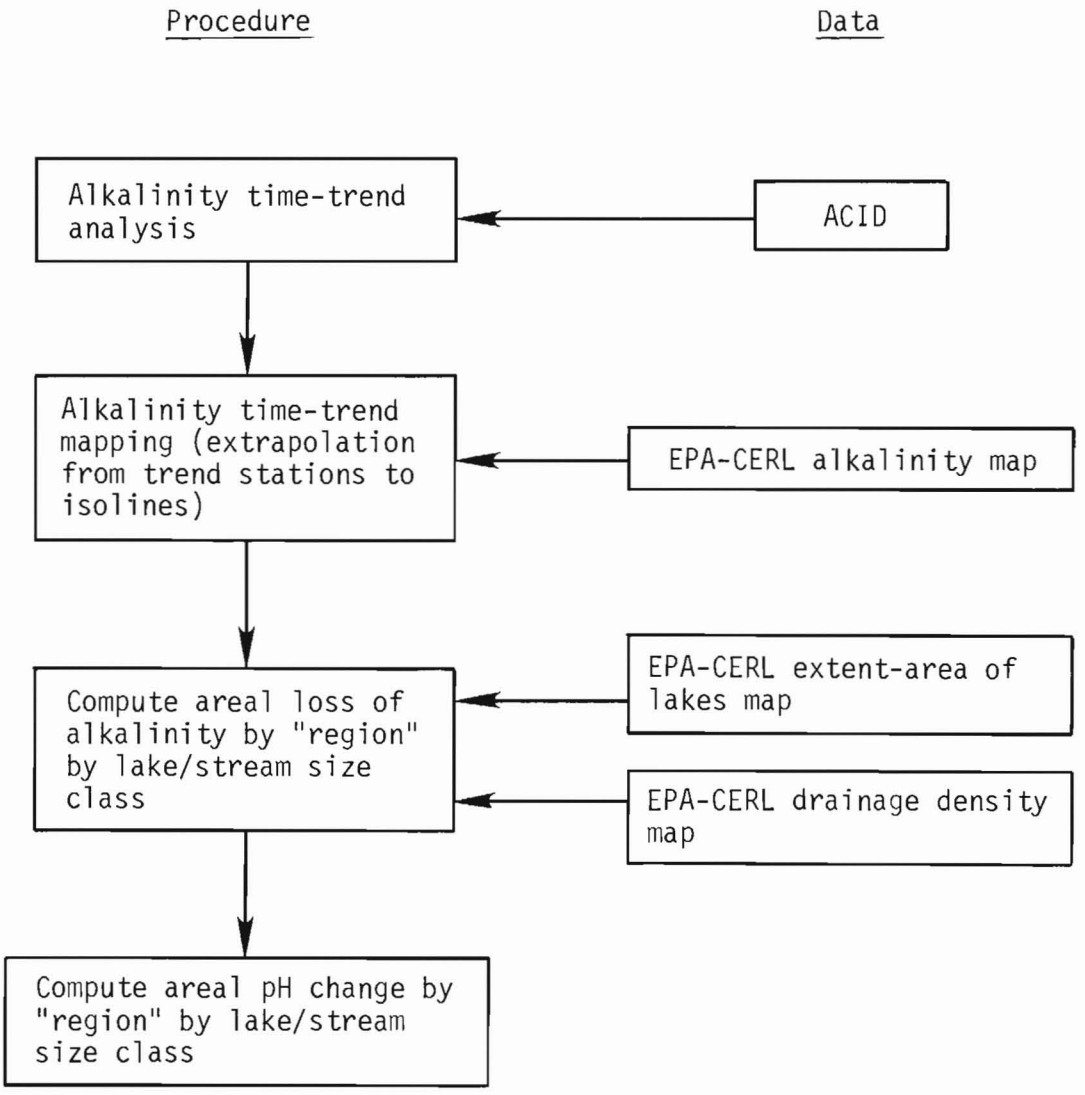

Figure 6. Procedure for 1985 current damage assessment of watershed response.

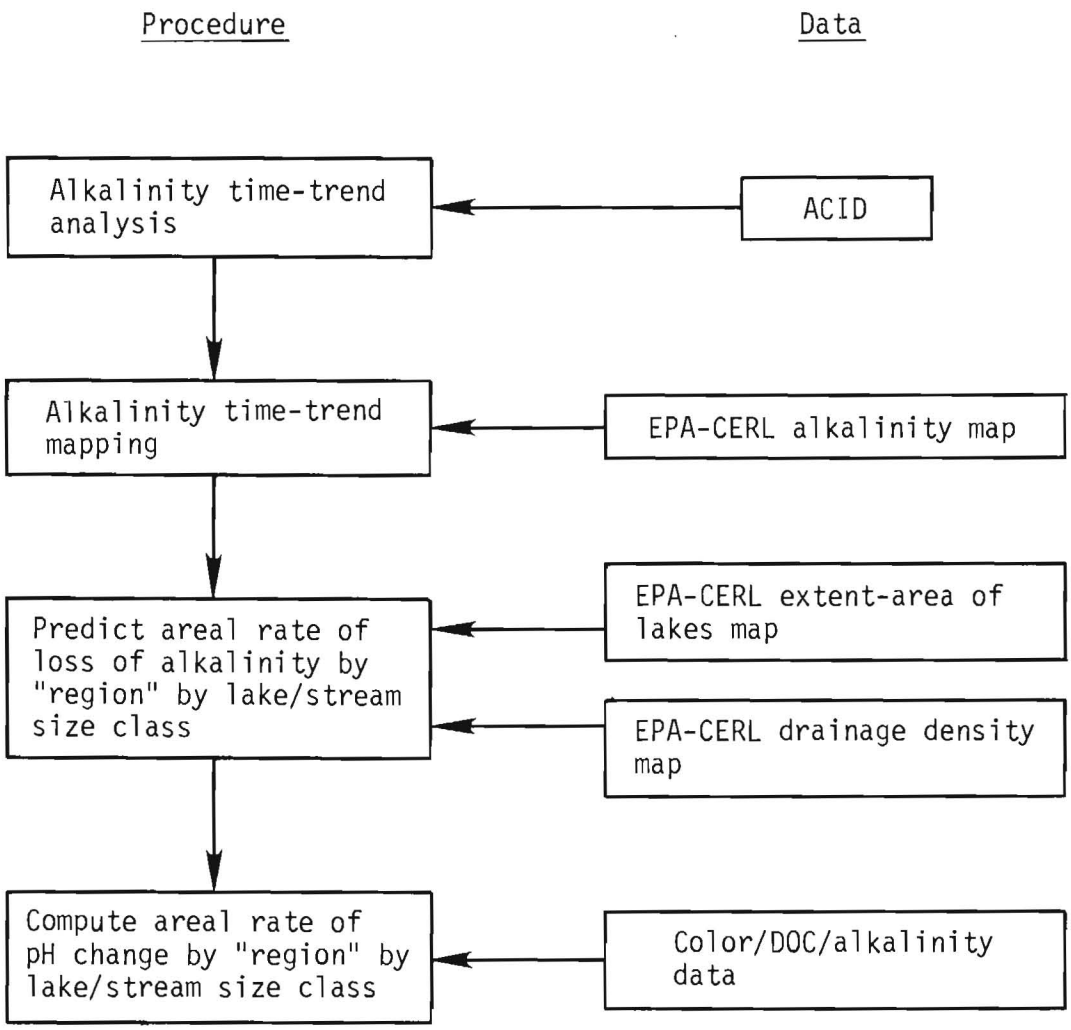

Figure 7. Procedure for 1985 future damage assessment of watershed response: rate of pH change.

The pH at steady state under current deposition will be estimated in two ways. A mass balance or simplified, lumped-parameter model will be used to estimate pH at steady state (Figure 8) and a "predictor nomograph" will be used to estimate steady-state pH classes (Figure 9). Both of these approaches allow estimation of steady-state pH but not the rate of pH change.

For fish resources and associated economic analyses, the steady-state pH and the trajectory to steady state are needed. Unfortunately, the rate of pH change from time-trend analysis cannot simply be extrapolated to the steady-state pH predicted by either the lumped-parameter modeling or the nomograph method to calculate the trajectory to steady state. One of the research needs identified at the workshop was the development of a procedure to integrate rate of change and steady-state pH predictions to estimate the length of time to reach steady state.

Applicability

The methods proposed for the 1985 assessment are generally applicable nation-wide. Data for these methods are available nation-wide but the 1985 analyses will probably focus on the Northeastern United States.

FISH RESOURCES

Outputs

For the 1985 assessment, estimates will be provided of the areal extent of lakes and the lineal extent of streams capable of supporting fish species of interest as a function of pH. These estimates will be made only for clear waters (< 30 standard color units). The questions of whether and how acidic deposition affects fish in colored water communities will not be addressed. Inclusion of colored waters (if necessary) in post-1985 assessments will require (at least) additional field survey data on colored waters and

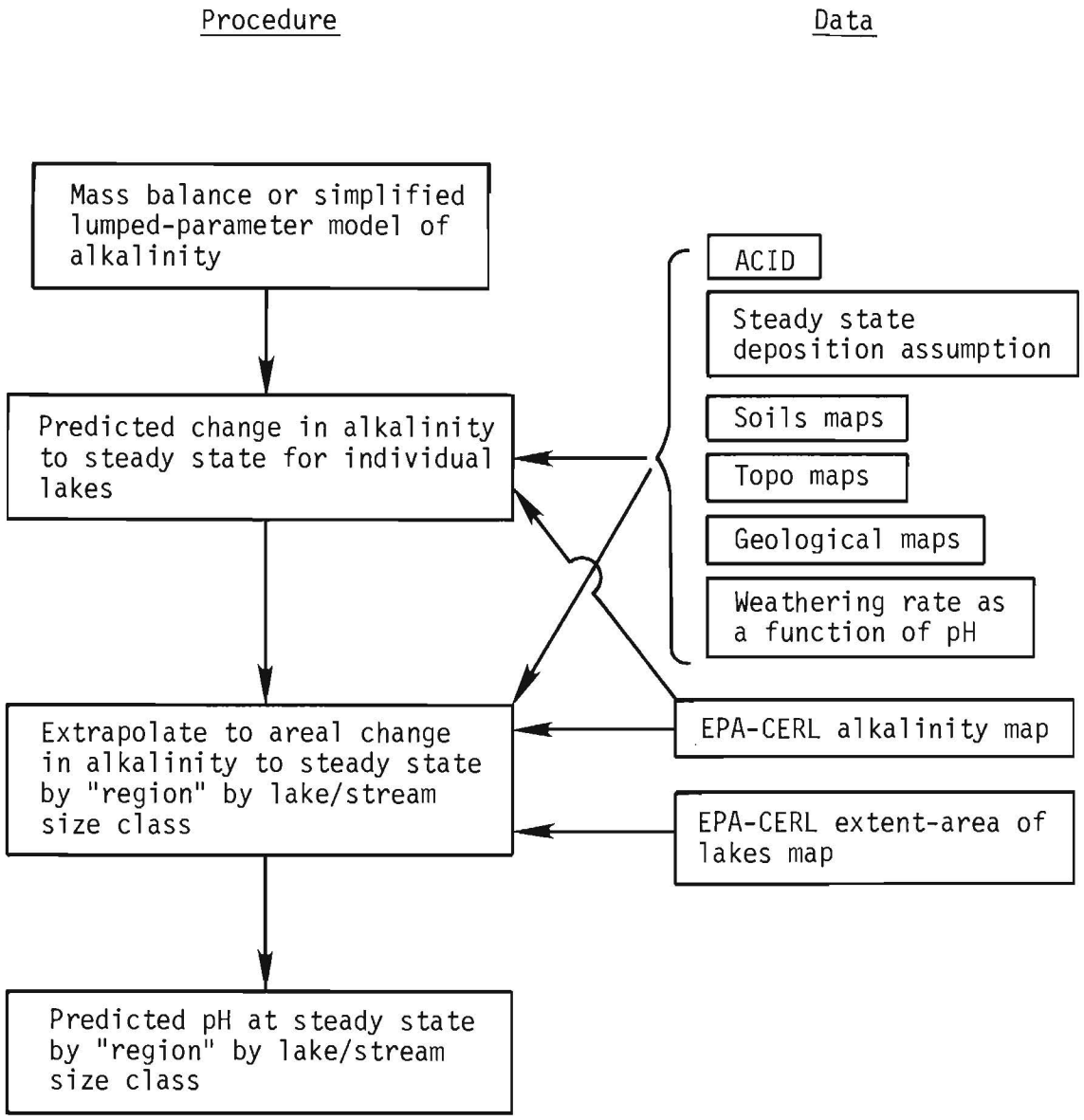

Figure 8. Procedure for 1985 future damage assessment of watershed response: steady-state pH based on lumped-parameter model.

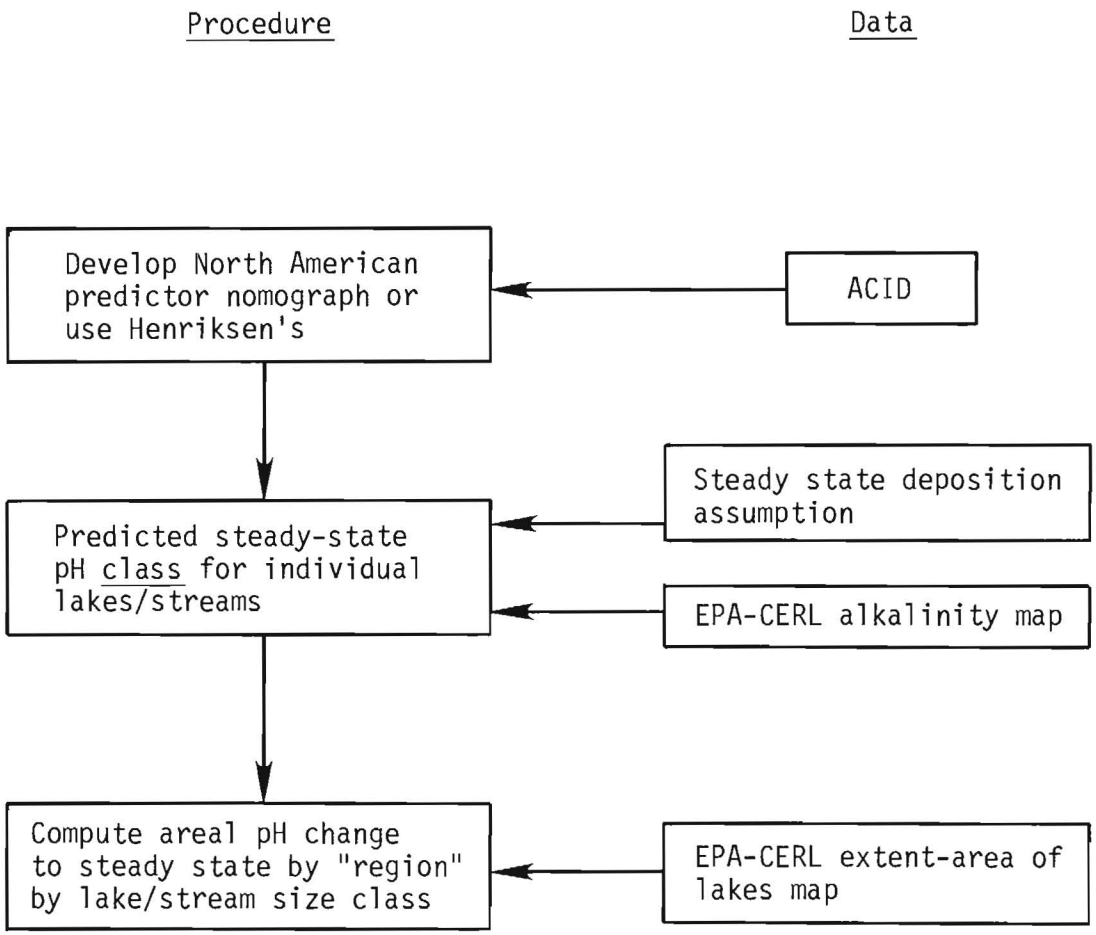

Figure 9. Procedure for 1985 future damage assessment of watershed response: steady-state pH based on predictor nomograph.

additional information on the functional responses of fish in colored waters to changes in pH.

For the 1985 assessment, estimates of fish resources will be made for: relatively pristine, preacidification (circa 1930?) conditions to establish a baseline; current conditions; and future conditions. Future predictions will be based on the estimated steady-state pH and the estimated trajectory to steady state (assuming that methods can be developed to provide such an estimate) under current acidic deposition patterns. Estimates of the status of the fish resources will likely be made for spatial units defined by total alkalinity of surface waters, as regionally mapped by EPA-CERL, and for lake and stream size classes within each alkalinity class. Lake size classes were defined at the workshop as < 20 ha, 20-100 ha, 100-200 ha, and > 200 ha. Stream size classes were not defined.

Fish species of interest were tentatively identified at the workshop (Table 1). Final selection will be dependent on the dual criteria of relative economic importance and relative sensitivity to the effects of acidic deposition. Determination of the relative risk to various species through integration of information on expected acidic deposition across alkalinity and size classes may produce a useful pre-1985 assessment product.

In addition to this primary information on fish resources, an attempt will be made to provide information concerning damage to other aquatic resources for use in a contingent value approach. This information is likely to be limited and descriptive in nature.

Approach

Assessment of the current damage to fish resources will require estimation of a baseline condition. Ideally, this baseline should represent the status of the resource prior to the onset of acidic deposition above natural or background levels (circa 1880?). However, historical data on fish resources for establishing such a baseline will not be generally available for periods

Table 1. Potential fish species of interest and initial estimates (H = high, M = medium, L = low) of criteria to aid in selection of species to be used in the 1985 assessment.

Species[a]	Economic importance	Species acid tolerance	Primary lake environment	Environment acid tolerance[b]
Atlantic salmon	H	L	large cold water	H
Brook trout	H	H	small cold water	L
Lake trout	H	L	large cold water	H
Rainbow trout	L	L	small cold water	L
Chain pickerel	L	H	small warm water	M-H
White perch	M	?	small-large shallow warm water	L-H
Yellow perch	M	H	medium-large low elevation warm water	H
Smallmouth bass	H	L	large warm water	H
White sucker	L	M	everywhere	L-H

[a]Common names according to Bailey et al. (1970).

[b]Should be interpreted as resistance to additional acidification.

prior to about 1930. The magnitude of the error that will be introduced by assuming that the true baseline condition can be approximated by the 1930 condition is unknown.

Estimation of the baseline status of fish resources is further complicated by two related issues: the fact that it cannot be assumed that a particular species has had access to all aquatic habitats capable of supporting that species; and the erratic historical stocking activities of the various States. Due to these complications, the workshop consensus was that estimates of the status of fish resources should probably be based on "Potential Fish Habitat." Potential Fish Habitat is defined as any water body capable of supporting a naturally reproducing population of a given species, without regard to whether that species has access (either through stocking or natural movements) to that water body. Physical damages to fish resources will thus be expressed as changes in the amount of Potential Fish Habitat from baseline conditions to current and future conditions.

It is worth noting that this is not the only possible definition of Potential Fish Habitat. Participants pointed out that the definition could be expanded to include those waters capable of sustaining a stocked population. Many lakes are stocked periodically because the habitat is suitable for adult survival, but not for spawning and reproduction. Acidification of these waters would represent a loss of habitat, even though they are not presently capable of supporting a naturally reproducing population.

Use of the concept of Potential Fish Habitat in the 1985 assessment will require that a set of criteria defining habitat requirements be established for each species for which damage is to be estimated (step 1 in the left-hand column of Figure 10). For example, preliminary criteria discussed at the workshop to define potential lentic brook trout habitat in Maine were pH, lake surface area, and either maximum or average lake depth. The nature of these relationships might be similar to that shown in Figure 11, in which the probability of an aquatic habitat supporting a naturally reproducing fish population is depicted as a function of pH. Information for defining these habitat

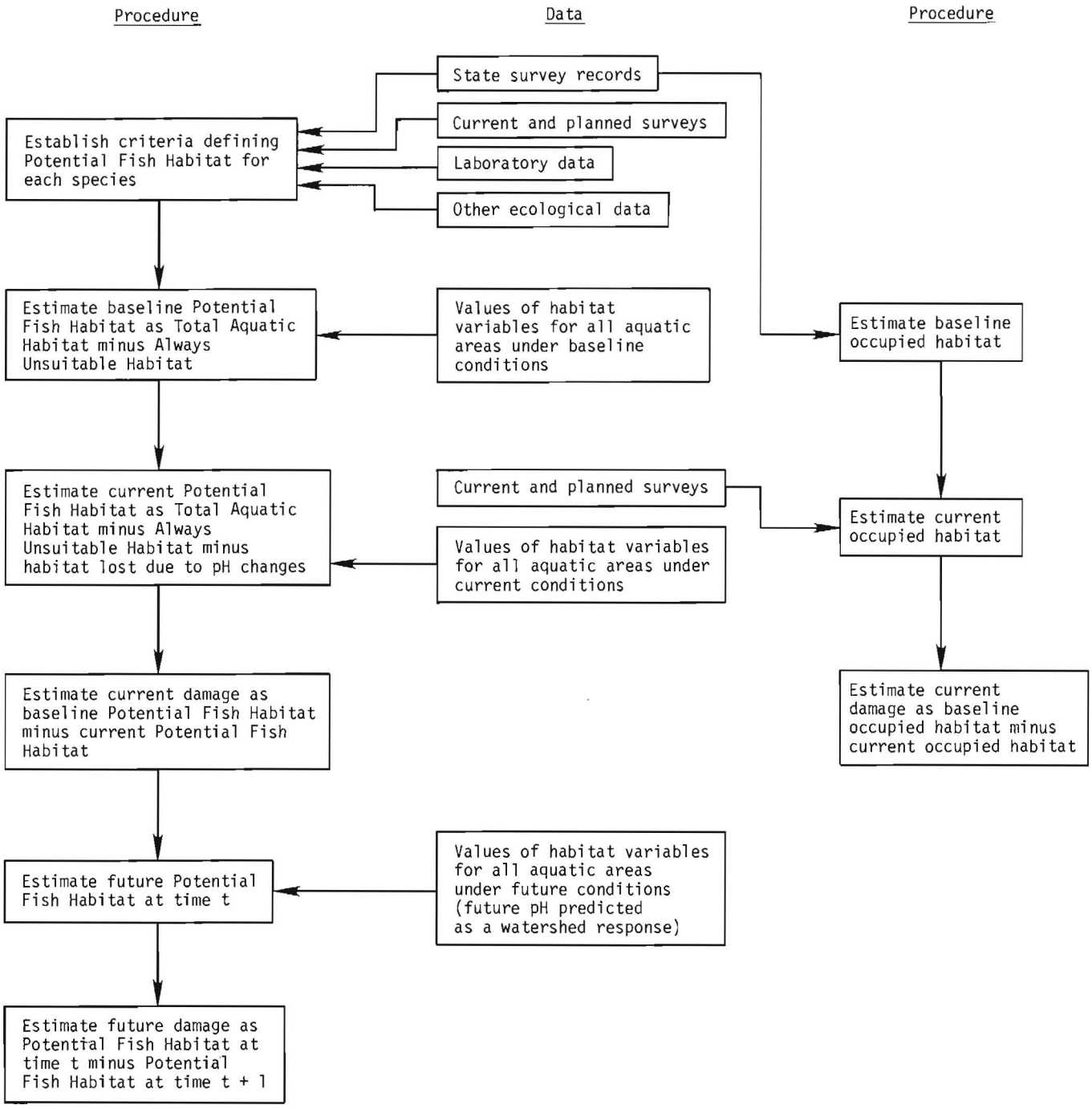

Figure 10. Procedure for 1985 assessment of damage to fish resources.

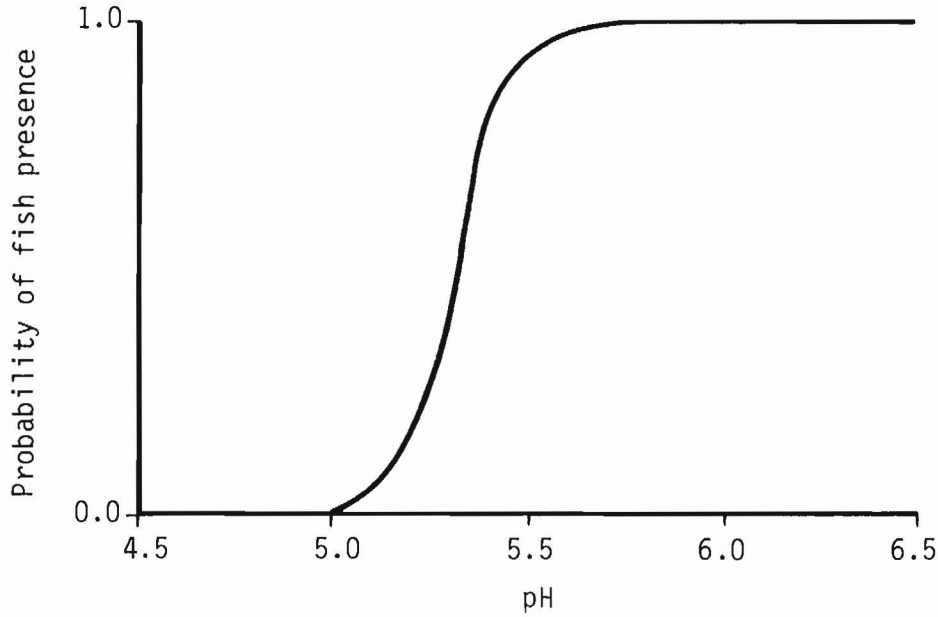

Figure 11. General form of the relationship between pH and the probability of an aquatic habitat containing a naturally reproducing fish population. (The intersection of the curve with the abscissa and the true shape of the curve are defined research needs for each species of interest).

requirements will likely come from a variety of sources, including: past, current, and planned surveys of fish presence/absence and water chemistry; laboratory exposure data; and general ecological knowledge. Examination of current pH and presence/absence of fish in waters known to have supported fish historically might be one of the most useful approaches, because it would eliminate the confounding effects of access.

Once the species criteria set is defined, it will then be necessary to generate values for the habitat variables for all waters under historic or baseline conditions. Given these values, the amount of Potential Fish Habitat present in the baseline condition will be estimated (step 2 in the left-hand column of Figure 10) as the Total Aquatic Habitat minus the Always Unsuitable Habitat (i.e., those waters that never provided suitable habitat for a given

species). Always Unsuitable Habitat will be estimated by applying the species criteria to the values of the habitat variables. Such estimates will likely be made for each size-class of water body within each alkalinity class.

The current (1985) amount of Potential Fish Habitat will be estimated in a similar manner (step 3 in the left-hand column of Figure 10), using the same species criteria sets and estimates of the current values of the habitat variables. Current damage to the fish resource will then be calculated as the difference between the amount of Potential Fish Habitat under baseline conditions and the amount under current conditions (step 4 in the left-hand column of Figure 10).

Future damage estimates (steps 5 and 6 in the left-hand column of Figure 10) at any time, t, will be based on the species criteria sets and estimates of the future values for the habitat variables. Future pH values will be provided as a watershed response. Damage in any interval will then be the difference between the amounts of Potential Fish Habitat at times t and t+1. If future pH values are provided only for the expected steady state, without reference to a specific future trajectory, then it will be necessary to assume a trajectory in order to use this approach.

The principal difficulty with this approach, of course, is that it does not consider the difference between Potential Fish Habitat and that habitat actually occupied by a particular species; that is, the question of access is ignored. There is considerable uncertainty as to whether economic methods such as the travel cost approach can be effectively employed to value a change in Potential Fish Habitat. The magnitude of the difference between potential habitat and occupied habitat is thus an important consideration. It may be possible to obtain an estimate of this difference by comparing the amounts of Potential Fish Habitat calculated for baseline and current conditions with estimates of occupied habitat derived from past and current surveys (right-hand column of Figure 10). A factor derived from this comparison could perhaps also be used to adjust estimates of future Potential Fish Habitat. Such a comparative approach is not without its own problems, of course, since a means

must be found for extrapolating from survey samples to the entire population of water bodies. A strong recommendation resulting from workshop discussions was that future field surveys sample water bodies randomly within spatial strata and that they include both biological and chemical parameters. This will allow maximum use of the survey information in providing: (1) a statistical basis for estimating the difference between potential and occupied habitat; (2) a means for comparing predicted and actual pH within spatial strata; and (3) a means for empirically refining the species criteria sets.

Additional aquatic information available for a contingent valuation of damages to other ecosystem attributes was discussed only briefly at the workshop. This information, which is likely to be qualitative in nature, is summarized in Table 2.

Table 2. Current status of information on biota in or associated with the aquatic community that may be useful in a contingent value elicitation.

Biotic representative	Information status
benthic algal mats	none to limited for different regions
odor-causing acidiphilic algae	none to limited for different regions
lentic and lotic benthos	descriptive
phyto- and zooplankton	descriptive
salamanders	limited surveys, no empirical
frogs	limited surveys, no empirical
waterfowl	good surveys

Applicability

Although selection of the total species list has not been completed for the reasons listed above, it is highly likely that brook trout will be one of the species. Much of the concern over the potential damage from continued acidification of aquatic environments is due to loss of brook trout fisheries in acidified lakes in the Northeastern United States.

Questions of how economic damages to fish will be assessed and integrated will have to be answered in the near future. Under ideal circumstances, the economic methods should be selected before final decisions on spatial resolution and adequacy of existing databases are made; however, these activities will have to progress concurrently given the practical considerations of the time remaining to complete the 1985 assessment. Therefore, it must be assumed that the spatial units resulting from strata based on alkalinity classes and size classes of aquatic habitat within alkalinity classes will provide sufficient resolution to detect different fishery responses to spatially varied acidic deposition.

In addition, it must be assumed that ongoing surveys of State data sources will detect deficiencies soon enough to allow time to fill key information gaps. At the time of the workshop, preliminary evaluation of State databases resulted in an initial set of priorities for supplemental survey projects (Table 3). Based on knowledge of existing databases, planned or ongoing field surveys, and the assumption that the required outputs will not change, it is expected that damage estimates can be provided for the New England region and the State of New York. Estimates for other regions and States are questionable (Table 4).

Table 3. Status of State fishery data bases and priorities for obtaining additional information.

State	Data base status	Priority for obtaining additional information
Maine	Overall fair; good for large lakes, very poor for lakes < 10 acres	High[a]
New Hampshire	Old surveys on large lakes; questionable newer information	High[a]
Vermont	Relatively poor; some ongoing	High for small area in southern Green Mountains, medium for rest of state
New York	Generally excellent	High for Adirondacks and Catskills only[b]
Massachusetts	Unknown	Medium need for good data base
Rhode Island	Good	Low
Connecticut	Unknown, but not at risk	Low
Pennsylvania	Excellent	Low

[a]Small efforts either underway or solicited.

[b]Survey of 1,200 lakes proposed.

Table 4. Estimated ability to produce damage estimates for various regions and States using data currently available.

Geographic area	Ability to produce damage estimate
New England Region	Yes (1985)
New York	Yes (1985)
Midwest Region	Yes (1985) - probably no damage but good fisheries data base
Pennsylvania	Maybe (1987)
Virginia	Maybe (1987)
Southern Blue Ridge Province	?
Rocky Mountain Region	No
Far West Region	
Sierras	No
Cascades	No
Florida	? - most likely not affected by acid deposition

In conclusion, the ability to meet the requirements for a 1985 assessment of damages to fish resources is dependent on immediate resolution of which species will be included in the assessment and what other characteristics of aquatic communities will be used for the economic damage assessment.

TIMBER RESOURCES

Outputs

As conceptualized at the workshop, an assessment of damages due to acidic deposition will require two kinds of information about forest resources: (1) quantitative estimates of changes in the economic value of the commercial timber harvest; and (2) descriptions of changes in forest characteristics that can be used in a contingent value elicitation.

Estimation of the value of the commercial timber harvest with and without acidic deposition will require the integration of ecological and economic models. The precise form of the ecological data required will depend on which economic models are selected and their points of interface with ecological models. The concensus of workshop participants, however, was that any economic model would require changes in species-specific growth rates as a result of acidic deposition. The remainder of this section assumes that changes in growth rate are the primary ecological data required and discusses the integration of these data with economic models to produce the ultimately desired output, changes in economic value.

A contingent value elicitation will also require descriptions of changes in other forest characteristics attributable to acidic deposition. Examples of these characteristics discussed at the workshop include changes in tree species composition, changes in understory and lichen communities, the extent of forest dieback, effects on rare and endangered species, and changes in fall coloration patterns.

Approach

The general approach to the valuation of commercial timber resources as discussed at the workshop is illustrated in Figure 12. The approach involves four components: (1) determination of species-specific growth rate changes; (2) incorporation of those changes into simulations of representative stands; (3) aggregation of stand simulations to a regional level; and (4) integration of economic models with the stand simulator and aggregation to the regional level.

Growth rate changes. Species-specific growth rates are being examined by the Forest Responses to Anthropogenic Stress (FORAST) project, which involves collection and analysis of increment cores from older trees (50+ years) of 34 species in approximately 88 stands in the Eastern and Midwestern United States. Additional data on soil chemistry, stand biomass, and stem density are also being collected for each stand. These data, along with meteorological information, have the potential to allow isolation of growth rate variations attributable to climate, soils, and stand competition. Residual variability will then be examined for relationships with a variety of indicators of past and present air pollution stress, including gaseous pollutants (primarily ozone) and acidic deposition.

Results from the FORAST program are not yet available and therefore represent one of the greatest uncertainties in the approach to the valuation of forest resources. Of particular concern is whether or not the sparse data base on past and present air pollution stress is sufficient to allow separation of growth rate changes due to acidic deposition from those due to other types of air pollution. If the FORAST program is unsuccessful in demonstrating growth rate changes, an assessment of damages to forest productivity in 1985 will not be possible. To cover this contingency in terms of future assessments, it might be useful to establish a program for screening seedlings and saplings. Such a program would yield relative sensitivities of species in the short term and perhaps growth rate changes per unit of deposition as a long-term product.

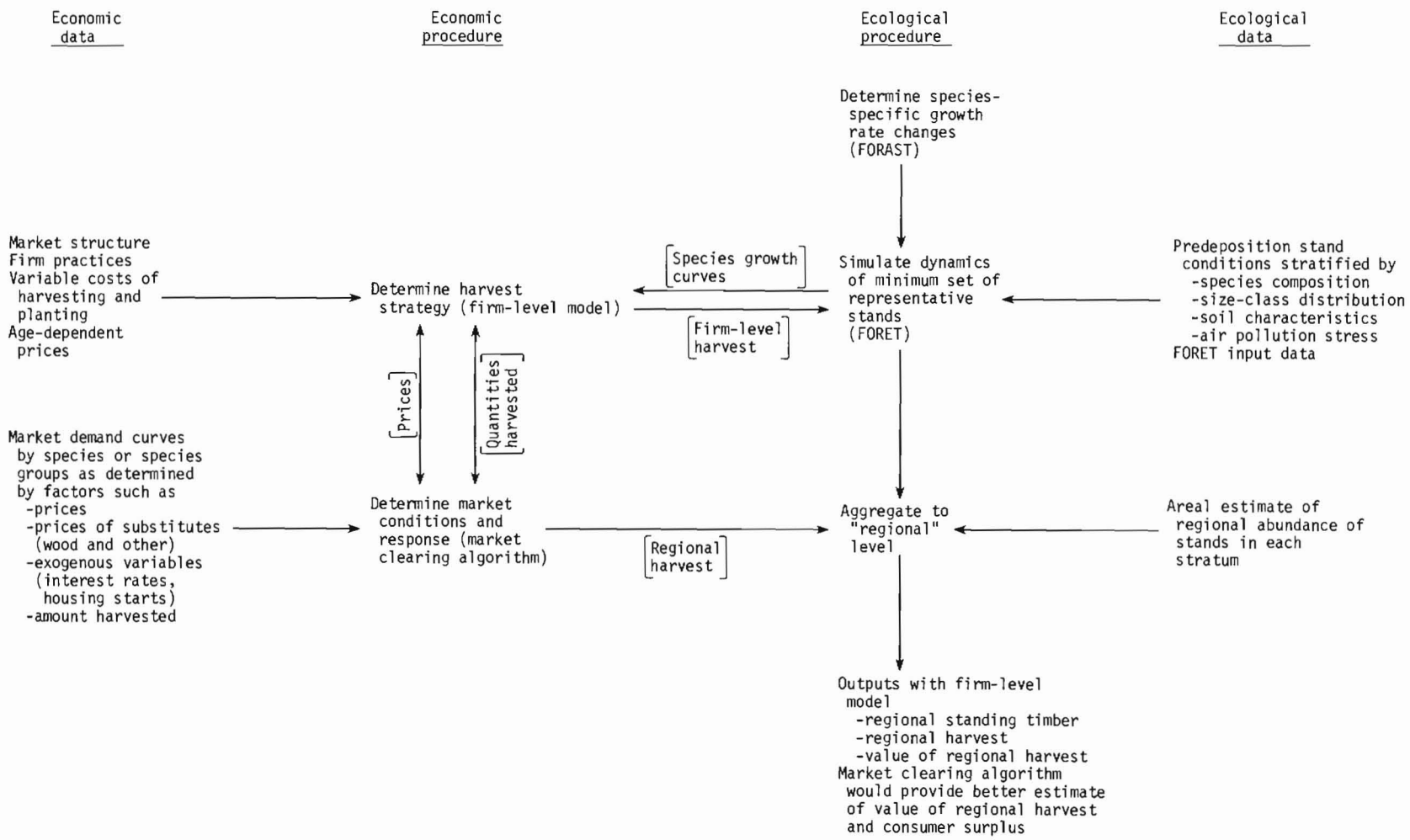

Figure 12. Procedure for 1985 assessment of damage to timber resources.

Stand simulations. Assuming that growth rate changes can be documented, the next step in the approach involves simulations of representative stands both with and without the changes in growth rate, probably using the simulator called FORET. This step will require definition of a minimum set of homogeneous response units based on species composition, size-class distribution, soil characteristics, and levels of air pollution stress, including acidic deposition. Multiple simulations with stochastic variation of input parameters will probably be run to establish a range of output values. A fairly extensive data set will be required as input to the FORET model, but it is likely that most of the necessary data are presently available either in the Continuous Forest Inventory of the U.S. Forest Service or in sets of information previously assembled for use with FORET.

Regional aggregation. Aggregation to the regional level will require estimates of the area occupied by each of the stand types simulated with the FORET model. These data will likely have to come from the U.S. Forest Service Continuous Forest Inventory and forest type maps. An effort to ensure that these data are available in a usable form should be initiated very soon. The exact nature of the regions used will depend on the precise formulation of the economic data and models, but will probably not be smaller than States. Extrapolation to the regional level represents another area of considerable uncertainty in the approach outlined. The sites being sampled in the FORAST program may not include a sufficient range of conditions to allow adequate definition of a minimum set of homogeneous response units.

Integration of economic models. In order to calculate the dollar value of timber harvest according to the approach outlined in Figure 12, economics models will need to be integrated at the level of the individual firm (i.e., an individual timber producer), and perhaps at the market level as well.

The firm-level model is necessary in order to determine a harvest strategy for the stand simulator. The simplest approach would be to assume that each individual firm follows an optimal strategy defined such that harvest occurs when there is no net gain in value by allowing the timber to grow for another

year; that is, harvest occurs when the increase in timber value due to growth for an additional year is offset by the opportunity cost of leaving capital invested in the standing timber. Such an approach would require a minimum amount of information concerning market structure, firm practices, variable costs of harvesting and planting, species-specific growth rates, and age-dependent timber prices for each species, and should be fairly easy to implement for the 1985 assessment.

The basic assumptions of this simple model are that: (1) the real, net prices of the marketable resources do not change over time; (2) harvest by an individual firm does not affect the market price; and (3) per unit costs of harvesting and planting are independent of quantity (i.e., returns are independent of scale). In order to use such a model in the manner described in Figure 12, it must also be assumed that growth rate reductions due to acidic deposition are not sufficient to cause prices to change, and that individual firms tend to follow a harvest strategy similar to that incorporated in the model.

Workshop participants, although not intimately familiar with the economics of the forest industry in the Eastern United States, felt that some of these assumptions were questionable. There was particular concern that present demand is substantially less than the potential supply, which would mean that the optimal harvest strategy outlined above does not describe the actual behavior of individual firms. If this is true, it may be necessary to incorporate a more complicated market clearing algorithm.

The market clearing algorithm would incorporate calculations of demand for a species or group of species as a function of factors such as price, prices of substitutes, and exogenous variables, including interest rates, number of housing starts, and prices of goods in the product chain. Harvest at the level of the individual firm would then be determined on the basis of market price and quantity demanded.

Incorporation of such an algorithm would provide a better estimate of regional value of the timber harvest, plus an estimate of consumer surplus. A careful evaluation of the availability of specific models for the Eastern forest industry, adequacy of data to operate those models, and the associated costs and benefits of using alternative models should be made before proceeding.

Applicability

The approach outlined in Figure 12 should be applicable in principle to any area where growth rate changes can be documented, where an appropriate stand simulator is available, and where appropriate economic data and models exist. Practically, for the 1985 assessment, this probably means that the approach can be applied only to unmanaged mixed hardwood and softwood stands in the area covered by the FORAST program. Comparable data on growth rate changes (assuming that the FORAST program can indeed document such changes) will not be available for managed pine plantations in the Southeast or for other areas of the United States.

Application of the approach outlined both with and without changes in growth rates due to acidic deposition will provide estimates of both the $A(t_i)$ and $B(t_i)$ components of damage (Figure 3), as well as an estimate of the current rate at which damage is occurring $B(t_{c+1})$. It will not, however, provide an estimate of steady-state conditions at present levels of deposition $[B(t_{ss})]$, because long term changes in soil fertility and mobilization of toxic metals are not considered. In the context of economic valuation this may not be a particularly serious drawback. Any reasonable discount rate will likely imply a shorter time horizon than would be required to reach new soil equilibria. In terms of physical damage, however, long-term changes in soil characteristics may be among the greatest concerns.

OTHER ECOSYSTEM ATTRIBUTES

Outputs

The Other Ecosystem Attributes group was charged with developing approaches for estimating damages to resources other than fish and timber; e.g., wildlife habitats, wildlife populations, and visual qualities. Early in the workshop it became apparent that valuation of damage to these resources individually would probably not be possible. As a result, the group focused its attention on an approach for estimating the aggregate value of such damages based on a summary description. Such a description, which would be synthesized from inputs provided from a number of resource areas, would represent the primary output concerning other ecosystem attributes.

Approach

The values derived from ecosystems can be generally grouped into two categories (Table 5): use activities such as fishing and hiking; and intrinsic or nonuse values such as ecosystem diversity and richness. Nonuse values can be further characterized as deriving from at least three perspectives:

1. Option value--the value to an individual of maintaining the option of enjoying resource benefits in the future;

2. Existence value--the value to an individual from just knowing that resources exist; and

3. Bequest value--the value to an individual of providing resource attributes for future generations.

Table 5. Use activities and intrinsic values that may be affected by acidic deposition.

Use activities	Intrinsic values
Fishing	Ecosystem diversity and richness
Timber harvest	Existence of natural systems
Hunting	Existence of wilderness sytems
Canoeing	Existence of rare and endangered species
Swimming	Water clarity
Hiking	
Wilderness camping	
Touring	
Viewing	

Participants perceived that none of the intrinsic values and only two of the use values shown in Table 5 were being considered initially in the groups dealing with timber and fish resources. Furthermore, many participants believed that the value of damages to intrinsic characteristics such as ecosystem diversity and richness may be large relative to damages to fish and timber. For this reason it was thought to be very important that an attempt be made to value these other damages.

Use activities can often be valued using market behavior techniques such as the travel cost approach, as well as market simulation techniques such as contingent valuation. Intrinsic or nonuser values are not reflected in the marketplace and can only be estimated through contingent value methods. The contingent value approach involves elicitation of individuals' willingness to pay for some desired state of a resource. Participants felt that this would likely be best accomplished through a summary description of damages to a variety of resource attributes such as those shown in Table 6. Those attempting to perform the contingent valuation would need to work closely with scientists in order to construct an accurate description of damages. This

Table 6. Examples of other ecosystem attributes that may be affected by acidic deposition and should be considered for a contingent valuation.

Watershed	Aquatic	Terrestrial
Water clarity	Naturally reproducing populations Rare or endangered species Habitat loss Ducks, loons, and other waterbirds Salamanders, frogs, and other wildlife Water odor Benthic algae Frog eggs, insects, leaches, etc.	Naturally reproducing populations Rare or endangerd species Habitat loss Mortality and dieback Species mix Fall color patterns Forest understory and lichens Visibility characteristics of air

description would then have to be converted into a series of questions for use in the contingent valuation. The questions would have to be sufficiently explicit to provide a clear perception of change, while avoiding creation of biases through unfair or leading connotations. Participants felt that the summary description might well include damages to fish and fishing opportunity, but probably should not include damages to commercial timber. Care would thus need to be taken in the interpretation of results to avoid double counting of damages to fishing estimated by a travel cost approach.

Participants pointed out that use of the contingent value approach in this manner would represent a considerable extension of the methodology and would require developmental work that might or might not be successful (see section on VALUATION OF DAMAGE). Many believed, however, that a summary description of damages would be useful, even if the economic valuation cannot be accomplished, so that these damages are not ignored in the political decisionmaking framework.

Applicability

In theory, the contingent value approach to determining the value of other resource attributes would be applicable in any area where damages due to acidic deposition can be adequately described. It was the consensus of participants, however, that, with the exception of changes in fish populations, current physical damages due to acidic deposition are not likely to be extensive enough that significant changes could be described in a questionnaire. Some participants felt that, pending resolution of methodological problems, a contingent valuation of current damage to fish resources should be attempted in order to determine the value of those damages to both users and nonusers. (The value of current damages to users would also be estimated using the travel cost approach). There was strong agreement that a contingent valuation of future damages, perhaps expressed as a range with strong qualifiers for uncertainty, should be attempted.

LATER ASSESSMENTS

As presently conceived, later assessments will attempt to improve on the 1985 assessment by: 1) considering additional resources over broader geographic areas; 2) attributing damages more explicitly to SO_x and NO_x components of deposition, as well as to local versus remote sources; 3) incorporating estimates of the effects of alternative future deposition scenarios and better estimates of rates of damage; and 4) estimating the utility of various emissions control and effects mitigation strategies in reducing damages. The probability of achieving these results would be enhanced by the following activities.

WATERSHED RESPONSE

For assessments after 1985, new methods will be developed to predict steady-state values and time dynamics of pH, [Al], and [Ca] changes for lake/stream size classes within homogeneous response units. Although these methods will be generally applicable nation-wide, the extensive databases required will probably be developed for only a few sites in the region bounded by the southern Appalachians and New England. The methods described previously for the 1985 assessment will be used as checks on these new methods.

Methods for predicting steady-state values and time dynamics of pH, [Al], and [Ca] involve simulation modeling of aquatic chemistry changes resulting from future scenarios of acidic deposition (Figure 13). The models differ in their level of complexity and the extent of the database required.

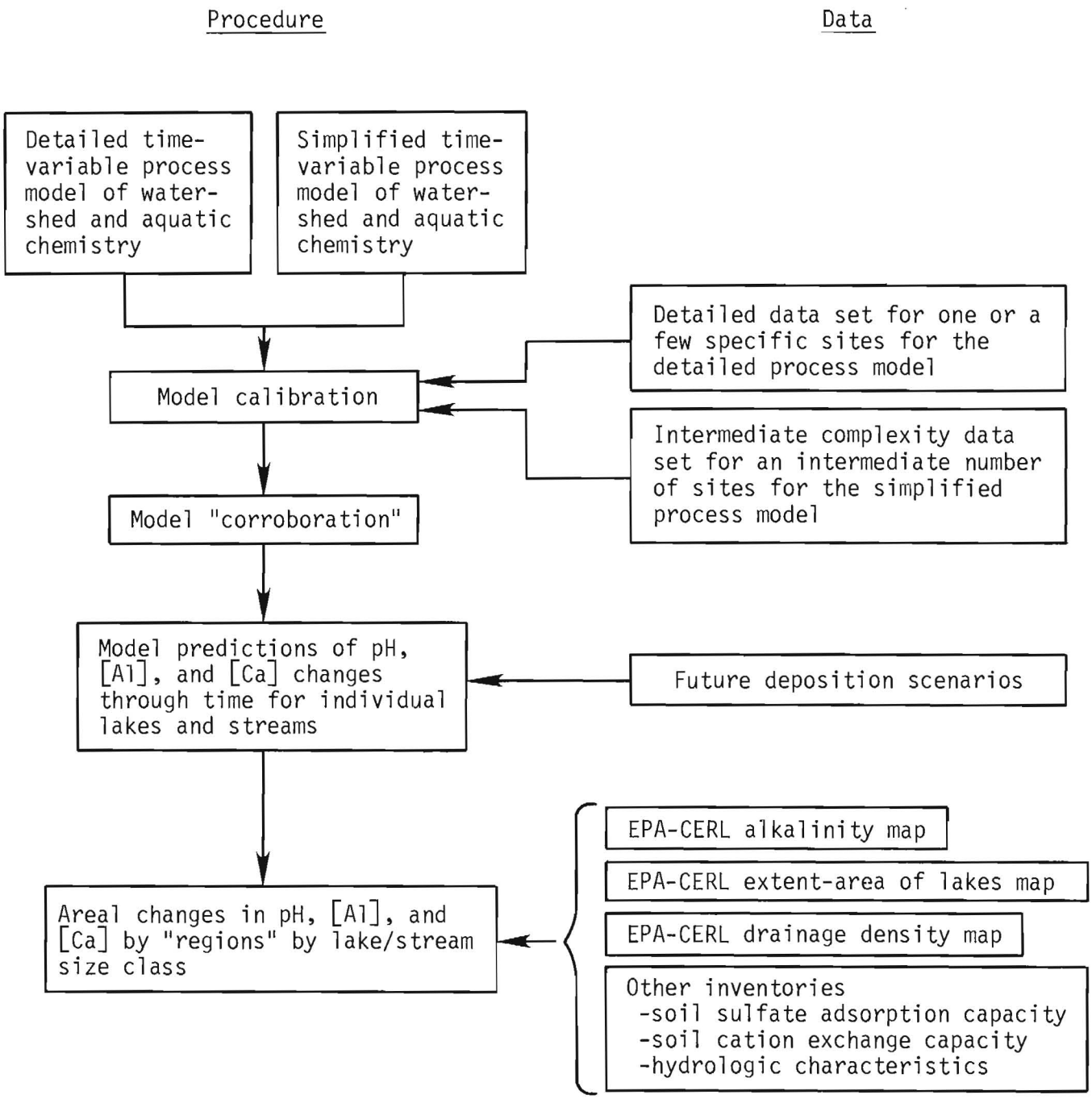

Figure 13. Procedure for post-1985 future damage assessment of watershed response: process models.

The homogeneous response units defined by alkalinity classes for the 1985 assessment may not account for all the variability in the response of waterbodies to acidic deposition. For assessments after 1985, additional properties should be used to further define homogeneous response units, including soil sulfate adsorption capacity, soil cation exchange capacity, watershed hydrologic characteristics, and organic acid influenced lakes. Maps or databases containing this information are not generally available for the region bounded by the southern Appalachians and New England. Surveys to provide this information must be initiated soon if results are to be available for the 1987 assessment.

FISH RESOURCES

The post-1985 assessments will differ from the 1985 assessment in three ways: (1) more extensive use of mathematical models to make damage predictions; (2) inclusion of more water quality parameters in the dose response functions; and (3) generation and evaluation of mitigation alternatives.

More extensive use of mathematical models to predict current and future damages is largely dependent on two elements (terms) used in the damage prediction method (Figure 10). First, and more critical, is the development of reliable procedures to predict water quality parameters in the future (see discussion in WATERSHED RESPONSE section). If both the shape of the function and the length of time it takes to reach steady state are predicted, then annual or 10-year increments of loss can be generated. Use of an annual time step for calculating losses is inherently more difficult from the biological point of view because it requires much more detailed knowledge of how the fish populations will respond to relatively small changes in pH. It would seem inadvisable to deal with detailed species life-stage population dynamics in the 1985 assessment considering both the desirability of consistency with the water quality (pH) predictions and the fact that such an approach would require inclusion of a large number of assumptions (about fish life-stage responses) having unknown uncertainties. Selection of a longer time step (e.g., 10

years) means that fish response may be dealt with at a coarser level. For example, loss of reproduction, for which some empirical information exists, might be used to estimate presence or absence of fish after 10 years without accounting for annual population variations. Using the empirical information it may then be possible to estimate the magnitude of the uncertainty associated with the less detailed assumptions needed when using a longer time step. Second, and less important (assuming that the proposed method of estimating Potential Fish Habitat is valid), is empirical refinement of the species criteria sets. Once again, these dose-response relationships depend on the assumption that fish presence or absence across lakes with varying pH can be used to predict the response of fish in a given lake as the pH changes. If both of these activities are successful, then credible damage predictions can be made.

Current planning provides for inclusion of free aluminum [Al] and calcium [Ca] in the prediction of the fish presence (or absence) dose-response function depicted in Figure 11. This assumes both that the amounts of Al and Ca present can be predicted and that research needed to integrate these elements into the dose-response function will be completed. As mentioned earlier, even greater uncertainty exists concerning how to deal with colored waters.

The primary mitigation alternatives currently being considered for evaluation are: (1) reduction in acidic deposition; (2) fish stocking to maintain fish populations where reproduction has failed but adults can survive; and (3) liming of the affected waters to counter continued acidification and/or rehabilitate acidified waters. The first two alternatives can be evaluated using the approach described in the earlier sections concerning FISH RESOURCES. However, dealing with the effects of liming on the predicted response of fish communities will require development of an additional set of models and investigation of differences in response of fish communities in limed waters. If fish communities do respond differently, then additional research will be required to reformulate the dose-response functions.

TIMBER RESOURCES

To the extent possible, later assessments of timber resources should attempt to improve on the 1985 effort in two areas. First, assuming that the FORAST approach is able to demonstrate changes in growth rates due to acidic deposition, coverage should be expanded to include other important resources, such as the pine plantations of the Southeast and the commercially important species of the Western United States. Second, an attempt should be made to evaluate the potential effects of long-term changes in soil chemistry (e.g., fertility, mobilization of metals) that may affect tree growth.

Evaluation of the importance of long-term changes in soil fertility will likely require the use of more detailed mechanistic models that consider plant physiology, soil hydrology, and soil chemistry (Figure 14). One candidate is the Unified Transport Model (UTM) currently in use at Oak Ridge National Laboratory. Although this model does not presently contain hypotheses describing the impacts of acidic deposition on soil chemistry, the model framework is probably amenable to the necessary modifications. Close interaction between model development activities and the design of experimental programs would contribute to more relevant research and to a more credible model. It is also worth noting that such models will be very similar if not identical to the detailed watershed models needed to predict changes in surface water chemistry.

The ultimate goal of using such a mechanistic model would be to develop more refined estimates of growth rate changes under a variety of deposition scenarios. Data presently being collected by the FORAST program could be used to corroborate the growth rate changes predicted by the more detailed model. However, because mechanistic models require extensive data sets, it is likely that some degree of simplification, perhaps through regression analysis performed on the output of the detailed model, would be necessary before the results would be useful for assessment purposes.

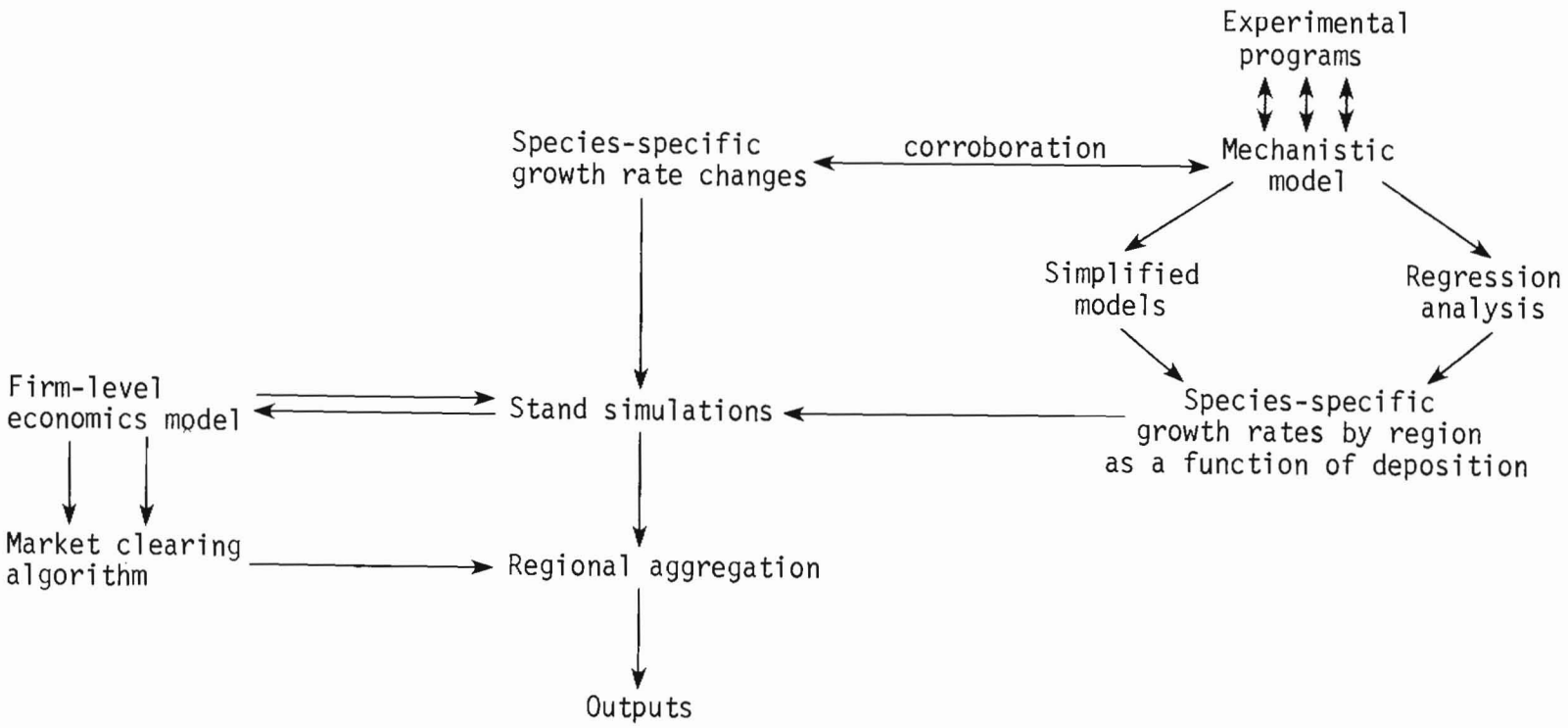

Figure 14. Procedure for post-1985 assessment of damage to timber resources utilizing detailed mechanistic models.

OTHER ECOSYSTEM ATTRIBUTES

The contingent value method described for the 1985 assessment could also be used for later assessments. Experience gained in the 1985 assessment would probably contribute greatly to later efforts. Future applications would also be improved to the extent that expectations of damage at various deposition levels could be described with greater certainty.

DISCUSSION

SPATIAL SCALE AND AGGREGATION

There was considerable concern voiced at the workshop with regard to definition of spatial analysis units and methods for aggregating those units to larger areas for regional damage descriptions and economic analyses. Some participants seemed to feel that there was a need to define spatial units in the same way for all resources and to define a single region to which the 1985 assessment would be applicable.

The first of these concerns, whether or not spatial subunits should be identical for all resources, should be considered in the context of how to define an area of homogeneous response. For example, can all lakes in a county or State be expected to respond in the same way to a given level of deposition? In all probability the answer is no. Response of an individual lake is likely to vary as a function of factors such as soil characteristics and size of the surrounding watershed, and depth and volume of the lake. Similarly, can all forests in a county or State be expected to respond in the same way to a given level of deposition? Again, probably not, because forest response is likely to depend on a variety of factors such as soil type, species composition, and stand density.

From this point of view, the question becomes one of establishing, given current information, those characteristics that can most likely be used to identify areas where responses to a given deposition level will be similar. Because it is unlikely that these characteristics will be the same for all

resources, it is also unlikely that a single set of spatial subunits will be adequate for all resources. The concern should therefore be how best to define homogeneous response units for each resource, rather than a single set of subunits appropriate for all resources.

However, definition of such characteristics is not the only criterion of interest when there is a need to aggregate information from the spatial subunits to represent larger areas. When aggregation is necessary, care must be taken to insure that the quantity of resource in each smaller unit can be assigned to one and only one of the larger units. That is, if the larger analysis area is the State of New York, and the smaller unit is a 10-ha stand of maple-beech forest, it must be possible to determine how many hectares of maple-beech forest exist in New York in order for the aggregation to be successful. The general feeling at the workshop was that the response units being chosen for each resource were sufficiently small that aggregation to any scale suitable for economic analysis would be possible.

The second concern (i.e., whether or not all resources should be considered only in a single, common region for the 1985 assessment) is perhaps less significant. There is reasonable agreement that the 1985 assessment should incorporate as much information on damages as possible. To the extent that different resources have been studied in different areas and are affected in different ways by deposition, this implies different overall analysis areas. What is important, however, is to ensure that the spatial limits of the analysis are well specified in each case so that problems of double-counting and omission are avoided.

Homogeneous response units for the watershed, water chemistry, and fisheries analyses will probably be defined by lake size classes (< 20 ha, 20-100 ha, 100-200 ha, and > 200 ha) within surface water alkalinity classes (based on regional alkalinity maps by EPA-CERL). The alkalinity classes seem to be the best indicators <u>currently</u> <u>available</u> for integrating the response to acidification of a number of potentially important watershed factors and

processes. Lake size classes are important because of potential differences in acidification rates and presence and density of fish populations. Stream size classes are thought to be important for the same reasons but the appropriate size classification scheme has not yet been determined.

The homogeneous response units based on watershed response may not be consistent with analysis units required for the various economic valuation techniques. The regional characterizations of pH change are based on extrapolations from individual sampling stations, which have spatial location stored as part of the database. Therefore, regional results can probably be disaggregated back to individual lakes or smaller geographical areas, then reaggregated into units appropriate for economic analysis (e.g., political boundaries, or zones of travel from major metropolitan areas).

Homogeneous response units for the valuation of commercial timber will likely be representative stands defined on the basis of species composition, size class distribution, soil characteristics, deposition level, and perhaps other factors, such as moisture and light regimes. The degree of detail used in defining such units will, in large part, depend on the amount of detail available in existing inventories. It was considered highly likely that the inventories would contain sufficiently detailed information to allow aggregation to any level suitable for economic evaluation (i.e., the State level or larger).

The basic spatial unit identified at the workshop for a contingent valuation of other resource attributes was a region such as the Northeastern United States. However, two important issues remain unresolved. The first pertains to the domain of the sample. Should the elicitation instrument be distributed only to individuals residing in the area for which the damage is described, or to individuals in some larger area because they may have use or nonuse (existence) values associated with the damaged area? A pretest of the contingent value approach is essential for resolving this question. The second unresolved issue concerns methods for aggregating to, say, a National

assessment. If an integrated assessment is required at the National level, it may not be appropriate simply to sum the results of individual regional analyses. There is some reason to suspect that a given individual may respond differently to two separate inquiries about damages to two areas than he would to a single inquiry about combined damages in the two areas. A valuation of damages at the National level may therefore require a single elicitation which describes damages throughout the Nation.

UNCERTAINTY ISSUES

The consensus of the workshop was that there would be large uncertainties associated with estimates and projections of physical and economic measures of damage due to acidic deposition. Responsible input to decisions must contain an explicit treatment of these uncertainties. Characterization of uncertainty and the extent to which that uncertainty might be reduced by additional data collection serves an additional function in the 1985 assessment in guiding the emphasis on various areas for later assessments. Many parts of the 1985 assessment discussed at the workshop involve methodological extensions or developments. This introduces another level of uncertainty in the assessment framework itself. Estimation of some damages (e.g., fish) is dependent on estimation of other damages (e.g., pH changes) in the framework. There is uncertainty at this point about whether sufficiently precise methods in earlier stages will be refined in time to allow application of methods involved in later stages. This is especially apparent in the relationship of the FORAST analysis to FORET simulations in the assessment of timber damages.

Several types of uncertainty were identified in the estimation and prediction of damage:

1. <u>Underlying stochastic properties</u> such as future precipitation events not amenable to reduction by increased data collection;

2. Measurement error such as uncertainty in current fish populations that is amenable to reduction by more intensive sampling. This would include both error in state variables and parameter estimates in a predictive model;

3. Model selection including the possibility that models selected are fundamentally inappropriate or contain poor assumptions.

There was a strong feeling expressed at the workshop that uncertainty associated with model selection could be large and might dominate other more easily specified sources of uncertainty. A particularly difficult type of model selection error in a regional or National assessment stems from the definition of homogeneous response units and their subsequent aggregation. This problem is common to many of the resource damage calculations. There is considerable uncertainty as to how many FORET simulations are necessary to represent adequately the range of site conditions in the Northeast or how many alkalinity or lake size classes are necessary to represent the variance in pH and fish population responses. Subsequent aggregation will include as error all the variance in response within what have been assumed or defined to be homogeneous response units. Approaches based on subjective elicitation seemed the only reasonable way to represent uncertainty associated with some aspects of model selection.

The workshop did not achieve a clear resolution or even a full discussion of uncertainty issues. Rather, the focus was on how various parts of a deterministic assessment would fit together. The following section briefly describes the major areas of uncertainty identified by each of the resource subgroups. A possible approach to an integrated representation of uncertainty is to cast later assessments in a Bayesian decision analysis framework (e.g., Keeney 1982). This option was not fully discussed at the workshop and pertains more to a conceptualization of the assessment as a choice among decision options (Figure 4) than as a current damage evaluation (Figure 3). Nonetheless, it could be included in the 1985 assessment as a way of summarizing estimates of uncertainty for the decision option of current deposition rates.

Furthermore, if estimates of potential reductions in uncertainty from additional work could be obtained, such an approach could guide the allocation of effort for later assessments. To be effective in this regard it would need to be implemented before that effort is irreversibly committed. This approach would be heavily dependent on Bayesian subjective elicitations and might be severely constrained by the ability to formulate clear decision options and decision criteria or an objective function.

Major Areas of Uncertainty

Watershed response. The primary uncertainty in the watershed response analyses concerns the extrapolation of alkalinity changes from individual trend stations or simple modeling of individual lakes to regional areas. An assumption that will probably be made for the 1985 assessment is that all water bodies in a lake size/surface water alkalinity class will react the same to current deposition. However, it is possible that differences in factors such as watershed soil characteristics, type of lake (e.g., seepage versus drainage), and water color may cause lakes in the same size/alkalinity class to react differently. The potential variability of response within the homogeneous response units chosen for the 1985 assessment is the major source of uncertainty associated with the regional extrapolation. In as much as estimates of fish losses are based on the regional characterization of pH change, this uncertainty will be propagated through the fisheries analysis.

Fish resources. The major uncertainties in the fish resources calculations concern estimation of the baseline status of the resource and the functional response to pH change. Error will be introduced in the estimation of baseline status through the set of assumptions (for each species) that define potential adequate habitat. Errors will be introduced in the functional response to pH change by not including additional effects of inorganic monomeric aluminum.

Other questions related to these major uncertainties concern: (1) the relative importance of excluding colored waters from the assessment;

(2) whether or not the empirical relationships between current pH and fish presence (which will be developed during the course of the assessment) truly represent the future response of fish in other lakes to changing pH; and (3) the relative importance of other fish and organisms to the species selected for the assessment (i.e., have the correct indicator species been selected).

Timber resources. The primary area of uncertainty in the calculations of damage to timber resources concerns the degree to which the FORAST analysis will be able to identify growth rate changes and more specifically to separate those changes attributable to acidic deposition from those attributable to other factors such as gaseous pollutants. Uncertainty in this measurement will propogate through the FORET simulations and economic analysis. If significant changes in growth rate due to acidic deposition cannot be identified in the FORAST analysis, an assessment of the economic value of damage to commercial timber will not be possible in 1985.

Other ecosystem attributes. Results of a contingent value elicitation based on a summary damage description will be sensitive to the survey design in a number of ways. These unresolved methodological questions could thus introduce considerable error in the final dollar valuation.

A particularly difficult methodological question is whether estimates of the scientific uncertainty concerning the likelihood of various effects should be directly incorporated in a contingent value elicitation. The prevailing opinion at the workshop was that the summary description should include estimates of uncertainty allowing some discrimination between highly certain effects and other possible effects. This may make the description too complex to be readily understood, however. This issue can only be effectively resolved through careful pretesting of the contingent value elicitation instrument.

SUMMARY AND RECOMMENDATIONS

THE 1985 ASSESSMENT

Components of Damage

A considerable amount of progress was made at the workshop toward consensus on a precise set of definitions of the components of current damage. These definitions are depicted in a preceding section as Figure 3, which is repeated here as Figure 15. There are two fundamentally different and independent components of relevant current damage. The $A(t_c)$ component is the difference between the current state of the system and the hypothetical current state of the system if there had been no history of acidic deposition (Figure 15). The $B(t_i)$ component involves knowledge of the future trajectory of the system under current deposition rates. The $B(t_i)$ component is the sequence of differences between the current state and the projected trajectory of future states under current deposition rates. This component of damage contains a tremendous amount of information and will not be possible to address for all resources in the 1985 assessment. Two especially important types of information contained in the $B(t_i)$ definition are the current rate of change, depicted as $B(t_{c+1})$, and an estimate of the difference between the current state and the steady (no further change) state, depicted as $B(t_{ss})$ (Figure 15). These parts of the B damage component can be estimated in some cases without projecting the entire sequence of values under current deposition rates.

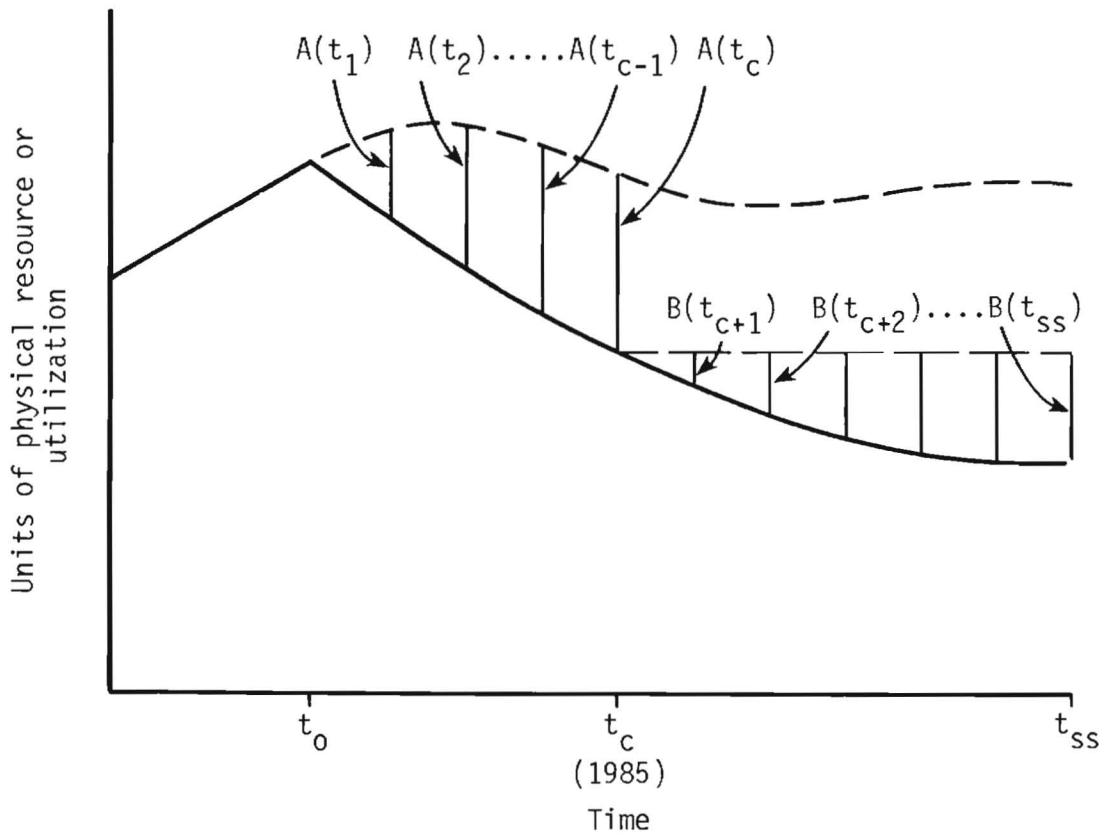

Figure 15. Components of current damage in units of physical resource or utilization.

Coverage

Table 7 provides a summary of information on watersheds, fish resources, timber resources, and other ecosystem attributes that should be available for the 1985 assessment. The following sections on individual resources elaborate on the information in Table 7.

Watershed response. Changes in surface water alkalinity will be determined by time trend analysis for water quality stations in the ACID data base. These stations are distributed throughout the United States, with some geographic areas more intensively sampled than others. The analysis of alkalinity trends and the extrapolation from trend stations to regional areas (e.g., based on alkalinity classes) will be more robust in these more intensely sampled areas.

Changes in pH will be estimated from alkalinity trends. Techniques are currently available for making these estimates for low color lakes and streams and are being developed (but may not be available by 1985) for high color water bodies. Independent methods exist to estimate the current rate of pH change and future steady-state pH under current deposition. However, the current rate of change cannot simply be extrapolated to the steady-state pH to determine the time to reach that value. Estimates of [Al] (aluminum concentration) changes will not be available for the 1985 assessment. Estimates of changes in [Ca] (calcium concentration) may be available.

Changes in water chemistry will not be economically valued in the 1985 assessment in a direct way. Rather, water chemistry changes will be used to predict effects on fish habitat, which will in turn be used as input to an economic analysis.

Table 7. Summary of information on watersheds, fish resources, timber resources, and other ecosystem attributes likely to be available for 1985 assessment. $A(t_c)$, $B(t_{c+1})$, $B(t_{ss})$, and $B(t_i)$ are defined in Figure 15.

Resource category	Damage	Geographic area	Physical damage: Qualitative description only	Physical damage: Quantitative estimate $A(t_c)$	Physical damage: Quantitative estimate $B(t_{c+1})$	Physical damage: Quantitative estimate $B(t_{ss})$	Physical damage: Quantitative estimate $B(t_i)$	Economic value $A(t_c)$	Economic value $B(t_{c+1})$	Economic value $B(t_{ss})$	Economic value $B(t_i)$
Watershed response	Alkalinity changes in lakes and streams.	Entire U.S., given constraints of ACID database.		X	X	X					
	pH changes in low color lakes and streams (techniques under development for high color lakes and streams).	Entire U.S., given constraints of ACID database.		X	X	X					
Fish and other aquatic resources	Changes in area of lakes and length of streams supporting selected fish species.	Northeastern U.S.		X	X	X					
	Changes in dollar value of fishing activity.	Northeastern U.S.						X	X	X	
	Impacts on benthos, plankton, salamanders, frogs, and waterfowl.	Specific research sites.	X								

Table 7. (concluded)

Resource category	Damage	Geographic area	Physical damage: Qualitative description only	Physical damage: Quantitative estimate $A(t_c)$	Physical damage: Quantitative estimate $B(t_{c+1})$	Physical damage: Quantitative estimate $B(t_{ss})$	Physical damage: Quantitative estimate $B(t_i)$	Economic value $A(t_c)$	Economic value $B(t_{c+1})$	Economic value $B(t_{ss})$	Economic value $B(t_i)$
Timber and other forest resources	Changes in growth rates for 34 species included in FORAST program.	Portion of Eastern and Northeastern U.S. covered by FORAST program.		X							
	Changes in standing timber and harvest in unmanaged mixed hardwood and softwood stands.	Portions of Eastern and Northeastern U.S. covered by FORAST program.		X	X		X				
	Changes in dollar value of harvest from unmanaged mixed hardwood and softwood stands.	Portions of Eastern and Northeastern U.S. covered by FORAST program.						X	X		X
	Changes in species composition of unmanaged mixed hardwood and softwood stands.	Portions of Eastern and Northeastern U.S. covered by FORAST program.	X								
	Impacts on lichen communities	Specific research sites.	X								
	Extent of forest dieback.	Eastern and Northeastern U.S.	X								
	Rare and endangered species distributions relative to deposition.	Entire U.S.	X								
Other ecosystem attributes	Summary description of damages listed above, exclusive of commercial timber damages (perhaps will also be extended to include descriptions of damages to materials).	Northeastern U.S.						?		X	

Fish resources. Physical damage estimates will be made for the Northeastern United States in the form of change in area of lakes and length of streams supporting fish populations. Which fish species can be included in the 1985 assessment is still open to question. It should be possible to estimate physical damage at present compared to preacidification levels [$A(t_c)$], the amount of damage for the current year [$B(t_{c+1})$], and the amount of damage between current conditions and future steady-state conditions at current deposition rates [($B(t_{ss})$].

The travel cost method for valuing the changes in fish habitat should yield dollar estimates for all three physical damage components. The increment of loss from preacidification conditions to the present [$A(t_c)$] will require information on current travel costs and assumptions about past distributions of the fishery resource and fishing effort. The economic value of fishery losses in the current year [$B(t_{c+1})$] can be estimated without additional assumptions. The dollar value of losses between current conditions and future steady-state conditions [$B(t_{ss})$] can be estimated only by assuming a value for the time required to reach steady state.

It should also be possible for the 1985 assessment to provide descriptive information concerning the impacts of acidic deposition on benthos, plankton, salamanders, frogs, and waterfowl, at least for specific research sites. Such descriptions will probably be sufficient for use in a contingent value elicitation.

Timber resources. The FORAST program is attempting to document, for 34 Eastern tree species, changes in growth rates over the last 50+ years not attributable to variations in soils, climate, and competition. Residual variability will be examined for relationships with various components of air pollution stress, including acidic deposition. To the extent that these investigators are successful, the changes in growth rates due to acidic deposition will constitute a useful description of physical damage.

Additional information on physical damage will likely be obtained by incorporating growth rate changes in a stand simulator. By defining a set of representative, predeposition stands and simulating their behavior through 1985, both with and without acidic deposition, it should be possible to obtain estimates of the loss to date [$A(t_c)$] and current annual loss [$B(t_{c+1})$] of standing timber and harvest. Estimates of the areal extent of each of the stand types will also be necessary in order to sum these effects for large spatial regions. Continuation of these simulations into the future assuming constant deposition at current levels should also provide an estimate of the expected future damage [$B(t_i)$]. Estimates of the total damage at some new steady state [$B(t_{ss})$] will not be possible, however, because long-term changes in soil conditions are not accounted for in the approach described.

Valuation of the changes in harvest in dollar terms will require integration of an economics model for determining harvest strategies with the stand simulator. The complexity of the economics component required may vary considerably depending on current market structure and firm practices. Workshop participants were not sufficiently familiar with either the forest industry or currently available economic models to determine how complex the economic model will need to be. Assuming, however, that such a model can be integrated with the stand simulator, estimates of the dollar value of the $A(t_c)$, $B(t_{c+1})$, and $B(t_i)$ components of damage should be possible.

In addition to the above information, it should also be possible to provide descriptions of changes in species composition, changes in lichen communities, the extent of forest dieback, and distributions of rare and endangered species with respect to deposition level for use in a contingent value elicitation.

Other ecosystem attributes. The task of the group dealing with Other Ecosystem Attributes evolved during the course of the workshop and, as a result, the group spent the majority of its time discussing application of a contingent value elicitation. As currently envisioned, the task of this group

would be to develop, in cooperation with scientists from each of the other resource groups, clear descriptions of damages due to acidic deposition. These descriptions would then be used to elicit information concerning individuals' willingness to pay either to rectify existing damages or to avoid future damages. It is not at all clear at the present time that current damages to resources other than fish are sufficiently large and/or that those damages can be sufficiently well described to warrant an attempt to value them [the $A(t_c)$ component in Table 7]. Such an attempt may be justified, however, simply to estimate the nonuse values associated with current damage to the fishery resource. It is also likely that such an approach could be used to estimate willingness to pay to avoid a scenario of future damage. Table 7 shows this as an estimate of the $B(t_{ss})$ component of damage. It should be noted, however, that the estimate will actually pertain to the state of resources at some relatively non-specific time in the future (e.g., 30-40 years) and that individual resources might or might not have reached a new equilibrium by that time.

LATER ASSESSMENTS

Watershed Response

The primary improvements that need to be made in the watershed response analyses for post-1985 assessments include: (1) better definition of homogeneous chemical response units; (2) development of techniques to estimate the time dynamics of pH change including pH change in high color lakes and streams; and (3) development of techniques to estimate changes in [Al] and [Ca] associated with predicted pH changes. Better definition of response units will probably require surveys of soil sulfate adsorption capacity, soil cation exchange capacity, watershed hydrologic characteristics, and organic acid influenced lakes (high color). Output from these surveys would likely be maps similar to the regional surface water alkalinity maps done by EPA-CERL. This information may also be useful in better estimating the effects of acidic deposition on forests. These surveys will have to be started very soon if

results are to be used in the 1987 assessment. Time-variable process models of watershed and aquatic chemistry are being developed or are planned to provide time dynamics of pH change, including high color water bodies, and concomittant [Al] and [Ca] changes. These models will not necessarily be useful in evaluating chemical mitigation options such as liming. Because these models will be data intensive and therefore used for only a small number of lakes, techniques used in the 1985 assessment will also be used in conjunction with these models to provide regional characterizations of watershed response.

Fish Resources

Assuming that the required outputs do not change from the 1985 assessment, refinements that will have the greatest effect on the quality of the post-1985 assessments center on inclusion of inorganic monomeric [Al] and [Ca], a better understanding of the response of the selected species to all water quality parameters, and a refined definition of the criteria sets for describing potential habitat for the assessment species. Questions of the adequacy of the spatial units as currently defined cannot be addressed until attempts have been made to use them in predicting physical and economic damage to the resource. The same is true concerning the adequacy of the database that will be generated to describe the current status of the aquatic resources. The need for inclusion of other geographic areas of the U.S. cannot be assessed until some estimate of the relative susceptibility (risk) of these areas has been made.

Timber Resources

To the extent that the approach outlined is successful for the 1985 assessment, it should also be applicable for later assessments. The primary information needs for later assessments will probably include: (1) changes in growth rates for commercially valuable species in other areas of the U.S. (e.g., the Southeast and Northwest); (2) stand simulators applicable to those areas and species; and (3) economic models applicable to those areas and

species. In addition, careful consideration should be given to the possibility of utilizing more detailed mechanistic models to evaluate the potential for long-term changes in soil fertility due to acidic deposition.

Other Ecosystem Attributes

The approach described for other ecosystem attributes should be applicable to future assessments, but will hopefully be refined based on experience gained in the 1985 assessment. In addition, the approach may be more useful for future assessments if the scientific uncertainties associated with various alternative deposition scenarios can be reduced.

RECOMMENDATIONS

Watershed Response

- A simplified procedure should be developed to estimate the length of time to reach steady-state pH (assuming current deposition) from the independent estimates of rate of pH change and steady-state pH discussed for the 1985 assessment. If initiated soon, results of this procedure development might be available for the 1985 assessment, but there were no specific ideas at the workshop as to what such a procedure might entail.

- A relationship should be developed to relate [Al], [DOC] (dissolved organic carbon concentrations), alkalinity, and pH so that [Al] changes associated with acidification can be estimated in both low and high color lakes. This will not be available for the 1985 assessment.

- Homogeneous chemical response units should be better defined. The surveys required to better define these homogeneous chemical response units (intensive water quality surveys, soil sulfate adsorption

capacity, cation exchange capacity, watershed hydrologic characteristics, and organic acid influenced lakes) should be initiated immediately if results are to be available for the 1987 assessment.

Fish Resources

- For the 1985 assessment recommended actions are:

  - formulate a preliminary risk assessment for species present in waters stratified by lake (stream) size class and alkalinity class;

  - estimate the relative economic importance of the species present within the assessment area;

  - use the risk assessment and relative economic importance (above) to make a final selection of the species to be included in the assessment;

  - specify (develop) criteria sets for defining "potential habitat" for the selected species;

  - construct and implement the experimental design to establish the current status of the fish resources and the empirical relationship between species presence and pH (NOTE - biological and chemical surveys should be integrated); and

  - conduct data sampling exercises structured to estimate error associated with use of species criteria sets to estimate "potential habitat".

- For post-1985 assessments, recommendations based on anticipated needs are:

  - initiate a research to define the functional relationship between pH, [Al], and [Ca] for the selected species;

  - initiate a project to ascertain the validity of the empirical relationship between pH and probability of fish presence; and

  - attempt to determine the relative importance of other fish and organisms to the selected species (may require reformulation of the predictive models).

Timber Resources

- The effects program should be augmented to provide data on young trees in order to:

  - enable an assessment in 1985 of species at risk if the FORAST program is unable to quantify growth rate changes; and

  - provide additional information on age-specific damage sensitivity.

- An analysis of the sensitivity of FORET simulations to species growth rate changes such as might be generated by the FORAST program should be performed immediately.

- If the above analysis indicates that differences in harvest and stand dynamics may be significant, identification and implementation of appropriate economic models should proceed quickly in order to ensure availability for the 1985 assessment.

- An effort should be initiated very soon to identify available forest inventory information and verify that such information:

  - is sufficient to define a set of stand types that could be expected to respond homogeneously to a given level of acidic deposition;

  - is sufficient to estimate the quantity of resource represented by each of the stand types; and

  - results in a sufficiently small set of stand types such that simulation of the dynamics of each is feasible.

- If a mechanistic model of soil chemistry, soil hydrology, and plant physiology is to be useful for later assessments, planning for its incorporation in the assessment design should be initiated soon.

General

- Form an advisory committee of scientists and economists for each study valuing the different effects areas. The committee should operate at the stages of:

  - methods development;

  - pretesting; and

  - application.

- Prepare a summary of the overall spatial focus (units of homogeneous response) and aggregation strategy including contributions to uncertainty.

- Identify projects to be used for analysis of uncertainty characteristics by the American Statistical Association in Summer, 1983.

- Evaluate the extent to which uncertainty estimates (including subjective elicitation data) in the 1985 assessment can be refined or supplemented in order to provide clearer probability statements about the alternatives in the 1985 assessment and better estimates of the relative potential of future work to reduce uncertainty.

- Immediately review the rationale for selection of species or areas being given concentrated study.

REFERENCES

Andrews, A. K., G. T. Auble, R. A. Ellison, D. B. Hamilton, J. E. Roelle, D. R. Marmorek, and O. L. Loucks. 1982. Impacts of acid precipitation on watershed ecosystems: an application of the Adaptive Environmental Assessment Process. Pages 393-400 in W. J. Mitsch, R. W. Bosserman, and J. M. Klopatek, eds. Energy and ecological modeling. Elsevier Science, New York.

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, R. C. Robins, and W. B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. 6, Third Edition. Washington, DC. 150 p.

Holling, C. S., ed. 1978. Adaptive environmental assessment and management. John Wiley and Sons, New York. 377 p.

Interagency Task Force on Acid Precipitation. 1982. National acid precipitation assessment plan. Interagency Task Force on Acid Precipitation, Washington, DC. 92 p.

Keeney, R. L. 1982. Decision analysis: an overview. Operations Research 30:803-838.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-84/16	2.	3. Recipient's Accession No.
4. Title and Subtitle A framework for assessing the impacts of acidic deposition on forest and aquatic resources: Results of a workshop for the National Acid Precipitation Assessment Program.			5. Report Date July 1984 6.
7. Author(s) James E. Roelle, Austin K. Andrews, Gregor T. Auble, David B. Hamilton, Richard J. Johnson and James F. Sisler.			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Western Energy and Land Use Team Fish and Wildlife Service Division of Biological Service U.S. Dept. of the Interior Creekside One Building 2627 Redwing Road Fort Collins, Colorado 80526-2899			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address Western Energy and Land Use Team Office of Biological Services Fish and Wildlife Service U.S Dept. of the Interior Washington, D.C. 20240			13. Type of Report & Period Covered 14.

15. Supplementary Notes

Workshop held in Leetown, WV, April 25-29, 1983. Sponsored by the Interagency Task Force on Acid Precipitation.

16. Abstract (Limit: 200 words)

The National Acid Precipitation Assessment Program has planned a series of assessments to analyze the costs and benefits of various approaches to deal with the impacts of acidic deposition. The first of these assessments, to be completed in 1985, will focus on the extent of current damages (both physical and economic) due to acidic deposition. This report describes the results of a planning workshop, held in April 1983, whose purpose was to define the objectives of the 1985 assessment with respect to forest and aquatic resources, and to achieve a common understanding among participants of alternative assessment approaches. Participants included assessment and policy analysis staff, key researchers and managers, and several resource economists. The workshop was facilitated by members of the Western Energy and Land Use Team, U.S. Fish and Wildlife Service.

Workshop activities focused on three principal topics. First, alternative definitions of current damage and their implications for various assessment methodologies were examined. Second, these discussions were used as the basis for developing conceptual models of damages to fishery resources, timber resources, and intrinsic ecosystem values. Data requirements of the conceptual models were used to identify and plan additional research activities. Finally, procedures for economic evaluation of damages to these resources were discussed and several projects needed to further develop assessment methodologies were identified. The Week-long dialog among researchers, assessors, and economists resulted not only in a useful assessment framework, but also in a better understanding of the needs and limitations of each group.

17. Document Analysis a. Descriptors

Acidification
Meetings
Pollution
Natural Resources

b. Identifiers/Open-Ended Terms

National Acid Precipitation Assessment Program
Acid Rain
Aquatic Resources
Forest Resources

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release Unlimited	Unclassified	80
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

☆U.S. GOVERNMENT PRINTING OFFICE: 1984-781-021/9489