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Freshwater Imperative - Executive Summary

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EXECUTIVE SUMMARY

FRESH WATER AND SOCIETY

Fresh water is a strategic resource in a rapidly changing world. It is a source of energy, an avenue of transportation, habitat for a myriad of organisms, and essential for life. Fresh water structures the physical landscape, is a central feature of climate, and exerts major influences on economic growth and demographic patterns. Yet, as the human population increases, more and more demands are placed on freshwater ecosystems. Already, sufficient clean water and healthy aquatic habitats have become a rare natural resource. Understanding the abilities and limits of freshwater ecosystems to respond to human-generated pressures has become vital to long-term societal stability. These are problems for basic science; they reflect national and global needs, and they are happening now.

Scientists and managers are increasingly called upon to provide a predictive understanding of freshwater ecological systems, but are unable to respond effectively at a scale commensurate with the issues. There are two primary reasons for this. First, the funding and infrastructure for freshwater sciences have dwindled while United States governmental agencies expend enormous resources on ineffective management activities that have a poor scientific foundation. The Freshwater Imperative seeks to find management strategies that are more efficient and less costly in the long term. To address this, management and science must be balanced and integrated more effectively. Second, the current dependence on short-term studies does not allow the separation of human-caused changes from natural environmental change. As a result, unambiguous criteria for management and policy decisions are generally lacking.

Changes in the distribution, abundance, and quality of water and freshwater resources in this century represent a strategic threat to the quality of human life, the environmental sustainability of the biosphere, and the viability of human cultures. The United States is facing, in a real sense, a freshwater imperative. Will freshwater sciences and management be ready, as professions, to meet this challenge?

WHY FRESHWATER SCIENCES AND MANAGEMENT?

Freshwater sciences and management (i.e., limnology) are dedicated

to understanding inland lakes, reservoirs, rivers, streams, wetlands, and groundwater as ecological systems. Limnology is inherently multidisciplinary, involving all viewpoints that can be brought to bear on understanding the nature of fresh waters (Edmondson 1994). As demands for freshwater resources increase, resource managers and policy makers must ensure that the benefits from water use and the protection of water resources are optimized. The United States spends approximately \$50 billion annually on the protection of aquatic systems; wise use of these funds requires a comprehensive and integrated understanding of those ecosystems (U.S. EPA 1991, National Research Council 1992). This requirement underlies the integrating theme of the Freshwater Imperative (FWI) research agenda: providing a predictive understanding of inland aquatic systems in a changing world.

Recently a number of deficiencies in our national infrastructure supporting freshwater sciences have been identified. These deficiencies include the inability to predict the future vitality of altered environments, to combine environmental and socioeconomic sciences into an integrated ecosystem perspective, and to provide a research and education framework for the nation that allows an effective response to emerging issues. These deficiencies are related to: (1) the fact that less than 20% of the 2.5 billion federal dollars expended on environmental research and development are spent on basic research in ecology (Gramp et al. 1992); and (2) the difficulties of integrating scientific disciplines and coordinating management across agency mandates.

Against this background, the National Science Foundation (NSF), Environmental Protection Agency (EPA), National Atmospheric and Space Administration (NASA), Tennessee Valley Authority (TVA), and National Oceanographic and Atmospheric Administration (NOAA) sponsored a working group of leading aquatic scientists to identify research opportunities and frontiers in freshwater sciences for this decade and beyond. This book summarizes that two-year effort. The following Freshwater Imperative research agenda is framed by science issues with immediate policy relevance, and by fundamental research to help ensure that today's uncertainties do not become tomorrow's problems.

DETERMINANTS OF RESEARCH PRIORITIES

Research priorities need to address the following national issues related to freshwater ecosystems that affect the long-term vitality of

human societies and the Biosphere. (1) Freshwater ecosystems play a central role in balancing socioeconomic values and environmental sustainability; and (2) the scope of water-related environmental issues (i.e. ecological impoverishment, water availability, and human health and quality-of-life) exceeds the capacity of individual disciplines, institutions, or nations to address them.

These issues exist at regional as well as national and global scales. However, research and management are most effective at the regional scale. Consequently, the FWI identifies regional objectives which address: (1) prediction of the effects of regional climate and landscape change on freshwater ecosystems; (2) development of an environmental perspective where biophysical and socioeconomic scientists work cooperatively toward an understanding of regional aquatic problems; and (3) resolution of regional freshwater problems through an understanding of underlying systemic factors.

Each of these regional objectives is closely related to the others. By emphasizing the prediction of change at the regional scale, the FWI seeks to encourage diverse political and institutional cooperation, develop broader environmental perspectives and approaches, and resolve issues at geographic scales relevant to human communities. An integrated regional, socioeconomic-ecological perspective requires institutional and interdisciplinary cooperation at a level seldom achieved in the past but of absolute necessity for the future. The nation's freshwater scientists and managers must assume a leading role in developing a holistic understanding of fundamental factors underlying freshwater problems and issues. Effective managerial solutions to problems concerning freshwater resources will only be achieved with explicit recognition that changes in environmental conditions are directly linked to socioeconomic patterns and processes.

Collectively, these national water issues and regional-scale objectives raise a number of fundamental questions about integrating freshwater research priorities with human needs: (1) How can we predict regional environmental change resulting from alterations in the hydrologic regime? (2) How can we better understand linkages between human activities and the maintenance of viable biotic communities? (3) How should we develop measures which allow reliable evaluation of human influences on freshwater ecosystems over broad spatial and temporal scales? And (4) how can we provide a scientific infrastructure that allows an effective response to emerging issues? (Table E.1). Addressing these integrating questions together with regional objectives (Figure E.1),

and making managerial and policy decisions based on the answers to those questions, is fundamental to sustaining the nation's societies and freshwater ecosystems.

[Table E.1 here]
[Figure E.1 here]

THE FRESHWATER IMPERATIVE (FWI) RESEARCH AGENDA

The regional objectives and integrating questions are the foundation for the FWI research agenda. The agenda focuses on three water issues of fundamental importance to the United States: water availability, aquatic ecosystem integrity, and human health and safety. The research agenda incorporates scientific issues that relate directly to the needs of society, predictive management of freshwater resources, and the ability to meet future needs as unforeseen freshwater issues emerge.

Each of the following priority research areas is integrative and incorporates elements that are scientifically significant and socially relevant; each seeks predictive understanding of freshwater ecosystems and resources at the regional scale for the long-term, and each encourages the development of new paradigms in freshwater science and management.

Scientific Issues

The FWI research agenda supports research on four scientific issues related directly to the needs of human society: restoring and rehabilitating ecosystems, maintaining biodiversity, understanding the effects of modified hydrologic flow patterns, and describing the importance of ecosystem goods and services provided by freshwater ecosystems. Each involves the effects of accelerated, largely anthropogenic, regional environmental change (Table E.2).

[Table E.2 here]

Predictive Management

The FWI research agenda recommends that the wise management of the nation's freshwater ecosystems must be founded on integrative and

accurate measures of human and environmental conditions. The FWI research agenda recognizes the need to provide predictive tools and innovative managerial approaches now and into the future. This research issue is so broad and of such contemporary importance that it has been divided into four subcomponents: disturbance regimes, physical and biological legacies, integrative ecological properties, and model development (Table E.3). The agenda encourages intensified research toward the development of new paradigms of freshwater science and management.

[Table E.3 here]

Solving Future Problems

The FWI research agenda recognizes that interdisciplinary and investigator-initiated basic research programs have been an outstanding and proven investment in the nation's capability for detecting and solving previously unforeseen problems (Table E.4). Scientists conducting basic research, and managers exploring innovative solutions, are of primary importance in coping with the new and inevitable problems associated with freshwater ecosystems that are yet to be identified. The FWI research agenda recommends the development and maintenance of a national scientific infrastructure that can be effective in addressing emerging issues.

[Table E.4 here]

LINKING RESEARCH, MANAGEMENT AND POLICY

Proactive and continuous interaction between freshwater research and government agencies with various management mandates is vital to developing and implementing a progressive national water policy. Moreover, research must effectively interact with management and policy-making processes over short timeframes, and in terms understood by the nation's citizens. The FWI research agenda encourages an adaptive management approach (Lee 1993), recognizing that the urgency and scale of freshwater issues require that many management and policy decisions need to be made now. Given the inherent uncertainties, large-scale restoration and management projects are best viewed as experiments with mechanisms for regular assessment and adaptive change to produce

an ever-improving product. In order to do this, managers and policy makers must invest in research, and scientists must be cognizant of the information needs of managers and policy makers. Three themes are of high priority: (1) evaluation of "best management practices;" (2) application of ecological engineering techniques; and (3) monitoring and assessment (Table E.5). The FWI proposes a model, based on the reorganization of Department of the Interior research personnel in the National Biological Survey (NBS), to uniquely link research, management, and policy as it affects freshwater resources.

[Table E.5 here]

IMPLEMENTATION REQUIREMENTS

Implementation of the FWI priority research areas and their integration with management and policy involves changes in institutions as well as improvements in infrastructure. Actions recommended in this report demand administrative leadership to insure that an adequate base of information and expertise is available to resolve regional and national issues. The centerpiece of the implementation strategy is a coordinated, interagency initiative with private-sector partnerships which draws on the expertise of agency scientists and managers, academic researchers, and private-sector groups. The FWI does not duplicate successful ongoing activities. Rather, it provides a framework for coordination across agencies and between federal and non-federal partners. It emphasizes connections between scientists and decision-makers, as well as issue-focused research.

Implementation of the FWI research program is expected to cost approximately \$200M/year. This is less than 1% of what the United States spends annually on procurement regulation and remedial protection of its waters. It is the considered opinion of the FWI Committee and the professional societies supporting the FWI (Appendix 3) that the FWI research agenda is timely, balanced, and relevant, and that the costs are thoroughly justified and appropriate.

Many agencies are moving toward an ecosystem management approach. The FWI supports this movement and encourages the incorporation of an integrated watershed management perspective into programs. Key elements of this approach are a science-management-policy partnership, increased resources for extramural research, and freshwater

scientific advisory panels for agency directors. The estimated \$200M/year cost would provide more effective water management including anticipating and resolving critical environmental problems.

Institutional support for the FWI can be provided by:

Enhancing existing programs of government agencies with water resource responsibilities to support innovative research and technology development and transfer. Key elements are provision of adequate equipment and technical capabilities for the field and laboratory settings, and standardization of protocols (\$60M/year).

Establishing regional institutions to provide interdisciplinary research integrating human sciences and natural sciences, and bringing together managers from government, academia, and the private sector (\$60M/year).

Initiating an integrated National Science Foundation program to promote effective multidisciplinary research on a scale commensurate with contemporary issues in limnology (\$10M/year).

The anticipated immediate benefits from enhanced institutional support for freshwater science include: strengthening the research, education, and technology needed to respond effectively to critical issues; ensuring that issues are evaluated at scales commensurate with the problems; and developing multidisciplinary approaches to increasingly complex problems. The anticipated benefits to the nation include: increased health and safety of U.S. citizens; less waste and more efficient use of the nation's resources; greater responsiveness of management to societal needs; a greater ability to respond to future threats; and increased environmental security.

The physical and intellectual infrastructure for the FWI can be enhanced through:

Establishing a freshwater biodiversity center to provide factual data on freshwater biodiversity, develop sensitive biotic indices on environmental change, and enhance predictability and accuracy in monitoring programs (\$15M/year).

Establishing an array of long-term and altered research sites with specific fresh water emphases (\$20M/year).

Strengthening education and communication to provide innovative and broad-based training above and beyond traditional efforts for students and professionals in the freshwater disciplines. This includes support for continuing education and "re-tooling" for mid-career scientists and managers, workshops on newly evolving technologies and concepts, and cooperative public and private sector training grants (\$15M/year).

The anticipated benefits to the nation from an enhanced physical and intellectual infrastructure include: factual data and innovative approaches to biodiversity issues, an ability to address linkages between human and environmental sustainability, and a continued high-level of literacy about freshwater ecosystems and their management.

The FWI research agenda and its implementation should become an integral part of the regulation and rehabilitation of the nation's freshwaters.

The FWI is designed to be the foundation for a national effort to find a productive and healthy balance between human needs and environmental requirements.