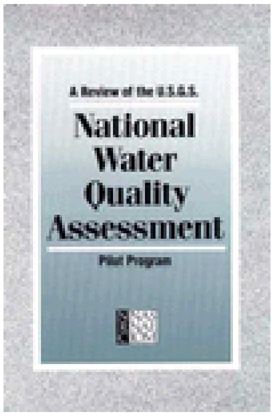

A Review of the USGS National Water Quality Assessment Pilot Program

Committee to Review the USGS National Water Quality Assessment Pilot Program, Water Science and Technology Board, National Research Council

ISBN: 0-309-53713-4, 164 pages, 6 x 9, (1990)

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Water Science and Technology Board
Commission on Geosciences, Environment, and Resources
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1990

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Support for this project was provided by the U.S. Geological Survey under Cooperative Agreement No. 14-08-0001-A0565.

INTERNATIONAL STANDARD BOOK NUMBER 0-309-04292-5
LIBRARY OF CONGRESS CATALOG CARD NUMBER 90-61574

Copies available from
Water Science and Technology Board
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

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S156
Printed in the United States of America

Committee to Review the U.S.G.S. National Water Quality Assessment Pilot Program

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Preface

The mission of the U.S. Geological Survey (USGS) is to provide information that will assist resource managers and policymakers at the federal, state, and local levels in making sound decisions. This information is generated through assessments of the quantity and quality of the nation's natural resources, including minerals, energy resources, and water. In the case of our water resources, the USGS has collected and interpreted data on water quality for more than 100 years. Initial water quality investigations were directed toward the suitability of water for domestic consumption, irrigation, and industrial use. Since these early investigations, the USGS has performed studies directed at a wide array of water quality issues. These studies have ranged from hydrological investigations to interdisciplinary biogeochemical studies. Issues that have been addressed by the USGS include nutrient enrichment of water bodies, dissolved oxygen depletion in rivers, contamination of streambed sediments, acid rain, and contamination of aquifers and rivers by potentially toxic, anthropogenic organic compounds.

Following four years of developing the concepts and approaches for performing an assessment of the quality of the nation's surface waters and ground waters, the USGS was authorized by Congress in 1986 to establish a pilot program to test and refine a National Water Quality Assessment (NAWQA). In 1987, the National Research Council's (NRC) Water Science and Technology Board (WSTB) was requested to undertake a two-year evaluation of the NAWQA Pilot Program and to make recommendations concerning implementation of a full-scale program, including its potential usefulness for establishing and evaluating national policies.

The NRC responded to this request in 1988 by appointing the Committee to Review the USGS National Water Quality Assessment Pilot Program. The committee's task was to consider the program's usefulness to state, local, and private entities for making decisions affecting water resources and its usefulness in advancing the scientific understanding of water quality. The evaluation also considered current expenditures for gathering water quality information by existing programs as well as through NAWQA.

The committee reviewed the extent to which water quality information programs such as NAWQA can be expected to (1) provide a more comprehensive water quality assessment than existing or alternative programs and (2) support more effective and efficient management of our nation's water resources.

During the study period 11 members served on the committee, representing the disciplines of hydrology, geology, chemistry, biology, ecology, statistics, law, hydrogeology, and economics. Additional expertise in sampling methodology, analytical chemistry, contaminant sources, quality assurance/ quality control, and the use and management of various types of environmental data was represented among the committee members.

In carrying out its assignment, the committee developed a constructive and cordial working relationship with the USGS staff involved in the NAWQA Pilot Program. In particular, the committee expresses its sincere appreciation to William Wilber, William Alley, Steven Blanchard, David Rickert, and Patrick Leahy for their cooperation, professional presentations of information covering the concepts and design of NAWQA, and willingness to accept extra challenges which the committee presented to them during the course of the study. A very special thanks is due to Sheila D. David, NRC Senior Staff Officer, for her valuable assistance to the committee, along with her patience and humor, without which our assignment would have been much more difficult. The committee also gratefully acknowledges the resource support provided by Anita Hall, Administrative Secretary.

RICHARD S. ENGELBRECHT, CHAIRMAN
COMMITTEE ON USGS NATIONAL WATER
QUALITY ASSESSMENT PILOT PROGRAM

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Executive Summary

Human health and environmental health are inextricably linked to our nation's water quality. As our population grows and our water resources become intensively developed and stressed, water quality becomes a more important component of our political, economic, social, and environmental decisionmaking. Such decisionmaking cannot proceed without adequate information and understanding.

There has been a general lack of understanding among decisionmakers concerning the importance of water quality monitoring and assessment. Often monitoring and assessment have been included as supporting elements for "action programs" within other budget categories at a low level of effort. However, there has been a gradual realization in Congress and within state and local governments that a well-planned, reliable water quality assessment program needs to be an integral part of any acceptable water resources strategy.

To provide the kind of information needed about the quality of the nation's waters to Congress and the citizens of the nation, in 1984 the U.S. Geological Survey (USGS) proposed a concept for a national water quality assessment. The program was designed to:

1. provide a nationally consistent description of current water quality conditions for a large part of the nation's water resources;
2. define long-term trends (or lack of trends) in water quality; and
3. identify, describe, and explain, to the extent possible, the major factors that affect observed water quality conditions and trends.

This type of information would be obtained on a continuing basis and would be made available to water managers, policy-makers, and the public to provide an improved scientific basis for evaluating the effectiveness of water quality management programs and for predicting the likely effects of changes in land and water management practices. In 1986, Congress authorized the USGS to test and refine concepts for a national water quality assessment program.

In April 1986, based on instructions from the Department of the Interior to test and refine the program, the USGS initiated the National Water Quality Assessment (NAWQA) program, consisting of seven pilot projects: four associated primarily with surface water and three focused on ground water. A National Coordinating Work Group (see Appendix D) was also established for the pilot program; it was made up of members of federal agencies and nonfederal organizations having an involvement or interest in water quality information. A local liaison committee was also created for each individual pilot project and consisted of representatives from key federal, state, and local agencies and private organizations involved in water and land management within the area of each project.

The program is to be executed through a large set of separate investigations of river basins and aquifer systems, referred to as study units. The USGS postulated that by performing NAWQA as an aggregation of many individual study units, the assessment would provide results that would be useful in understanding and managing the water resources of the study unit, and in answering national-scale questions about current conditions, trends, and factors that affect water quality. Further, the program is to focus on conditions that are large scale and persistent in time. Emphasis is to be placed on regional degradation of water quality such as might occur from both nonpoint and point sources of contaminants.

In addition to collecting water quality data, the NAWQA program is designed to take advantage of water quality information compiled by other agencies for various purposes. Thus, one of the first activities within each study unit is to collate and interpret the available data to (1) provide an initial description of water quality conditions, (2) develop hypotheses about major factors influencing water quality, and (3) define data needs.

Because of the emphasis on trends in water quality, the program is to be perennial, recognizing that the emergence of new hydrologic knowledge, improved methods of measurement, and changes in the types of contaminants of concern might require that the program be appropriately modified. The program is to place a high emphasis on repetition of measurements over time and on documentation of the methods of data collection and analysis and of the locations and characteristics of data-collection sites.

COMMITTEE SCOPE OF WORK

In 1987, the Water Science and Technology Board (WSTB) of the National Research Council (NRC) was requested to undertake a 2-year evaluation of the NAWQA Pilot Program and to make recommendations concerning implementation of a full-scale program, including its potential usefulness for establishing and evaluating national policies. The NRC was also asked to consider the program's usefulness to state, local, and private entities for making decisions affecting water resources, and its usefulness in advancing the scientific understanding of water quality.

Implicit throughout this evaluation has been an appraisal of the extent to which water-quality information programs, including the NAWQA program, can be expected to:

1. provide a more comprehensive water-quality assessment than either existing efforts or feasible alternative programs, and
2. support more effective and efficient management of nation's the water resources.

The NRC appointed a committee to review the NAWQA pilot program in 1988. In September 1989, the committee issued an interim report to provide midcourse advice to the USGS on certain NAWQA program components (see Appendix A). During the course of the study, the committee reviewed many documents (see Appendix B); interviewed potential NAWQA users including representatives of state and the federal governments, the Department of Interior's Office of Policy, Budget and Analysis, and the Office of Management and Budget (see Appendix E); and visited and held discussions with USGS pilot project personnel.

The committee's deliberations have resulted in the following general findings, conclusions, and recommendations to the USGS. In his FY 1991 budget, President Bush announced his intention to establish a fully operational NAWQA program. However, a final decision to go to a full-scale program will depend on the outcome of discussions in both houses of Congress. It is the committee's hope that the following recommendations will assist in this endeavor.

GENERAL FINDINGS

National Assessment of Water Quality is Needed

The committee unanimously agrees that there is a genuine need for a long-term, large spatial scale, national assessment of water quality in the United States. It will need to evolve over time as our understanding and data bases increase.

While there is much completed and ongoing research focusing on cause-effect water quality relationships, this research tends to be directed toward smaller-scale understanding. Relatively less is known about the behavior of large systems, such as entire river basins or aquifer systems. For this reason, a national assessment is a particularly timely undertaking.

Such an assessment will face a number of difficulties. It must be of vast scope, it must be highly multidisciplinary, it will need to be well coordinated with the activities of many different organizations, and it will require many experienced, high-quality personnel provided with adequate time and resources. Uniform national analyses or rigorous probabilistic generalizations cannot be expected when a national scope is achieved by assembling a composite of regional or smaller-scale analyses.

Implementing a national water quality assessment using consistent data collection, analysis, and reporting procedures is essential if this nation is to effectively and efficiently maintain, manage, and protect our water resources. Such an assessment must go well beyond mere monitoring and data collection to focus on developing understanding of cause and effect relationships. It should be process-oriented, long-term, highly adaptable, and of large spatial scale.

USGS is Appropriate Agency to Conduct Assessment

As stated in the committee's interim report of September 1989 (see Appendix A), the USGS is ideally suited to provide leadership in an assessment of our nation's waters. The agency's overall mission is to provide information that will assist resource managers and policymakers at the federal, state, and local levels in making sound decisions.

The NAWQA program is directed to an assessment of the freshwater systems of the nation, which comprise the major portion of our water resources. The USGS is well qualified to implement such a program; however, they need to recognize that additional critical elements must be incorporated in the present plan. The USGS has a long history of monitoring freshwater systems (both surface water and ground water), and, more importantly, it has experience in addressing both quantity and quality aspects of water resources problems. Because of its nonregulatory nature, this agency can offer a more objective perspective to both the regional and national assessments. Furthermore, the USGS has an excellent reputation in data collection at the national, state, and local levels and has cooperated well with responsible agencies at these levels.

While acknowledging the suitability of the USGS to perform the task, the committee also recognizes that the Survey has limitations. Relatively few limnological studies have been performed, and only recently have biological investigations been initiated. Of equal or greater importance is that the USGS has experience in surface water quality modeling, an essential element in defining cause and effect relationships.

Another feature of the USGS, which is both a strength and a weakness, is its diffusion of responsibility to its district offices. These offices, which have operated for many years in close coordination with individual states and local governmental bodies, are quite autonomous in how they design and conduct their projects. Local needs and problems have predominated in these investigations, and the committee believes that it will be difficult to refocus some of the study unit teams toward developing a national assessment.

However, in spite of these difficulties, the committee is confident that the USGS will make the necessary adjustments, hire and train new specialists, and develop the additional techniques required to fully accomplish the NAWQA goals.

Integration of Surface Water and Ground Water Study Units has Improved Usefulness of NAWQA

In its interim report, the committee suggested that an integrated approach be used whereby study units would be selected so as to involve a joint investigation of surface and ground waters. As a result, the USGS redefined their concept of study units to include this approach.

The emphasis on integrated study units will result in an improved NAWQA program by enabling it to examine the water quality of an integrated hydrologic system. One of the important aspects of the NAWQA program is an understanding of water quality cause and effect relationships, and the committee believes that this approach will enhance such understanding. It will also allow investigators to ascertain the physics of the system to a greater extent than before and to extrapolate new findings to other parts of the country. The USGS plans to use teams of both surface-and ground-water specialists to develop an understanding of the interrelationships among surface waters, ground waters, and the water quality constituents carried by those waters. To the extent that these reviews are successful, they should enable better planning of new projects as they are initiated.

CONCLUSIONS AND RECOMMENDATIONS

Study Unit Selection

The 60 identified study units (Table 2.1), each involving considerations of both surface water and ground water, represent a variety of hydrologic regions and a broad coverage in terms of geographical area and water withdrawal. Some of the study units are quite large, much larger than any of the seven pilot project study units, but in general, the largest study units are in areas of low population. In selecting the study units, consideration was appropriately given to including those aquifers already being investigated under the USGS Regional Aquifer System Analysis (RASA) program, which emphasizes physical hydrology; this should result in some degree of synergism and aid in delineating cause and effect relationships.

Recommendation

- **To determine whether a large study unit presents any problem with respect to the proposed sampling protocol and data management, it is recommended that in initiating the full-scale NAWQA program, the USGS include two large study units for investigation**.

Lakes and Estuaries

It is in the nation's best interest to monitor, assess, and understand the water quality of its lakes and estuaries and the impacts of lakes on the water quality of other hydrologic systems.

Recommendations

- **The committee believes that an assessment of the long-term trends in the water quality of lakes (including impoundments) and estuaries should be part of any long-term national water quality assessment. At some point, the water quality of lakes should receive the same level of attention in the NAWQA program as that**

of streams and ground water. However, given the present lack of personnel in the USGS with expertise in the biological and chemical modeling of lakes and estuaries, we believe that the NAWQA program should not be expanded at this juncture to include estuaries. In addition, we recommend that initially lakes should be considered but only as they affect downstream surface water quality or downgradient ground water quality.

- **The committee further recommends that the first set of investigations in the NAWQA program include one or more study units in which lakes are likely to be significant contributors to downstream and/or downgradient water quality. Additionally, we recommend that mathematical models be developed at the initial stages of each study unit investigation involving lakes**.

Sampling Approach-Surface Water/Ground Water

Surface water sampling will consist of fixed stations, along with synoptic and selected reach studies. The incorporation of sampling at times of high flow and synoptic sampling are viewed as unique and worthwhile aspects of NAWQA, not included in other water quality monitoring programs.

The strategy for sampling ground waters generally seems adequate. However, in locating sampling wells, special attention must be given to coverage, particularly in the case of a large study unit and where the physical characteristics of a given aquifer may vary with distance.

Recommendation

- **Because each study unit represents a hydrologic system encompassing both surface water and ground water, it is recommended that the sampling strategy be reviewed to ensure that comparable procedures, estimation techniques, and precision levels are employed for proper interpretation. Although the sampling program may not require a major redesign it should include consideration of**:

(1) the distribution and location of sampling sites for surface water and ground water,
(2) quantification of the interaction between surface water and ground water, and
(3) the water quality implications of these interactions.

Rotational Versus Continual Assessment

There are several reasons for adopting a rotational rather than a continual data collection and analysis approach. First, given limited resources, it may be preferable to have cyclical data on a larger number of study units than to have continual monitoring data for a smaller number of study units. Second, the conditions and trends that NAWQA is concerned with develop relatively slowly. Third, the USGS has emphasized that NAWQA is designed to be not only a long-term monitoring program (for which continual data collection and interpretation might be appropriate) but also an assessment of water quality trends.

While NAWQA is intended to assess water quality conditions and trends, it is also designed to develop scientific understanding of the factors that affect those conditions and trends. The emphasis of the NAWQA program is on producing timely interpretative products focused on specific topics of regional and national interest.

Recommendation

- **While the committee agrees with the rationale for the rotational assessment approach, it is recommended that the duration and staging aspects be reevaluated by the USGS and an external scientific advisory committee after the first cycle of 20 study units is completed. The committee recommends that extensions of intensive study be granted only for issues that are truly regional or national in scope. In addition, the committee recommends that the mathematical models for each study unit be selected in the first year of the cycle as part of the planning effort**.

Choice of Chemical Constituents

The committee agrees with the choice of chemical and physical constituents selected for the NAWQA pilot program. The consistent water quality data base across the nation will be a real strength of the program. In addition, the flexibility of NAWQA to add constituents of local or regional interest will facilitate the identification of emerging water quality issues.

Recommendations

- **The EPA's dioxin data, as well as other pertinent water quality data, should be included in the USGS retrospective reports**.

- **A strong coordination role should be created to manage the integration of ecological with chemical and physical data collection**.
- **An external scientific advisory committee should review the constituents that are added at the regional level to determine whether a regional water quality problem is really a national problem**.
- **The USGS should establish a library archive of spectroscopic fingerprints of selected water samples**.

Choice of Biological Constituents

The biological component of NAWQA consists of three parts: assessment of sanitary quality by measuring fecal contamination, analysis of contaminants in tissues, and ecological surveys. Protocols for doing these assessments have been developed, but there has been very limited field testing of the protocols during the pilot studies. The committee has only been able to examine data on fecal contamination.

Fecal contamination will be assessed with the Escherichia coli test. The use of this method will limit the ability of NAWQA teams to relate their data to historical patterns of fetal contamination or to current monitoring efforts because other assessment techniques are more commonly used.

The NAWQA protocol for analysis of organic and inorganic contaminants in biological tissues is well conceived. It will fill a void in existing tissue monitoring programs.

The ecological survey will use a core set of measurements (algal biomass, invertebrate, and fish samples) to document the current status and long-term trends in biological communities. Sampling protocols have been devised, but no examples have been provided as to how these data will be analyzed, even at the study-unit scale. The inclusion of an ecological survey is a valuable addition to NAWQA.

Measurements of rates of biogeochemical processes controlling concentrations of elements in water will not be a routine part of NAWQA. The absence of these measures will reduce the ability of NAWQA to develop mechanistic models and to understand cause and effect relationships.

Recommendations

- **The sanitary quality of water should be determined using both the E. coli test and the standard fecal coliform test**.

- **To provide a measure of temporal variation in sanitary quality, the committee recommends including monthly coliform tests at a limited number of fixed stations in study units where such contamination is a potential problem**.
- **The USGS should adopt protocols for archiving and maintaining tissue samples and should devise protocols to guide site personnel in selecting how many and which samples to archive**.
- **Because the pilot projects have provided few data with which to evaluate the ability of the tissue monitoring and ecological survey efforts to meet the stated objectives, the committee recommends that another external science advisory committee review this component of the program when more data are available**.

Quality Assurance/Quality Control

Federal agencies do not always collect consistent water quality data. For example, the EPA 305b program leaves to each state the definition of water quality issues. The NAWQA program has an advantage over this program because four USGS regions coordinate data collection protocols and methods.

The proposed quality assurance plan of NAWQA is a sound approach for managing the data bases to ensure utility and longevity beyond the first rotation of sites. In the full NAWQA program, periodic data base reviews will need to be continued to ensure completeness and accuracy of data.

The quality assurance program is one of NAWQA's strengths. Consistency of sampling protocols and data collection will aid in analysis and will be essential for timely and meaningful interpretation and synthesis.

Recommendations

- **It is important that the USGS headquarters person in charge of quality assurance be in regular communication with the four regional NAWQA quality assurance personnel to coordinate their activities closely. This will ensure that comparable standards and practices are being used across the full NAWQA network of sites**.
- **In the full-scale NAWQA program, periodic data base reviews will need to be continued to ensure completeness and accuracy of quality assurance and quality control (QA/QC) data**.

The results of all the pilot project audits should be reviewed for recurring areas of concern—particularly with monitoring for low-level organic compounds.

- **The committee would like to see more coordination of the NAWQA program with other agencies, especially in such areas as uniformity of water quality parameters monitored and more consistent sampling and analytical techniques**.
- **After a full NAWQA program is operational, the USGS should determine how much overlap exists between NAWQA and EPA's 305(b) program. Both agencies should have access to the data from these two programs**.

Data Management

For data management (i.e., data documentation, collection, archiving, and retrieval) the pilot studies have used WATSTORE (the USGS National Water Data Storage Retrieval System) and the National Water Information System (NWIS) data bases, which are periodically transferred to EPA's STORET system. A new NWIS-2 is being designed and is targeted for operation in FY 1992. The development of this system is currently under way as part of the upgrading of computer resources for the Water Resources Division of USGS and should be available for the full NAWQA program.

The NAWQA criterion for acceptable storage and documentation is that data records and documentation will be interpretable by a subsequent project team 6 or more years after completion of the initial investigation. The data management plan for the ecological survey is currently being revised.

Sharing information and data files between the USGS and the scientific community would be facilitated if USGS personnel had access to Internet, a collection of local networks (campus, governmental, and industrial) linked by regional networks and attached to a national backbone (NSF Net). The purpose of Internet is to provide high-speed communication to members of the scientific community and to provide access to remote computing resources.

Recommendations

- **The committee endorses the revamping of WATSTORE and encourages the USGS to work quickly to develop and implement their new national water information system**.
- **USGS personnel should have access to the broader scientific community via Internet**.

Analytical Framework

An important feature that appears to be lacking from the overall NAWQA program, particularly the regional pilot studies, is a quantitative and analytical framework that identifies the principal cause and effect relationships. The link between sources, both point and distributed, and the water quality response of a particular system, can be provided by a mathematical model that defines the spatial and temporary distribution of the concentration of relevant water quality constituents.

Mathematical modeling can be used in all phases of water quality assessment, including design of the monitoring program, analysis of data, and evaluation of past and potential management options. Of particular importance is the interactive nature of modeling and data collection. These activities are mutually supportive, and each should evolve throughout the assessment process. This will lead to a better assessment, as well as to an improved understanding of the relevant physical, chemical, and biological processes.

Recommendations

- **In the short term, the USGS should make use of existing models. Because the USGS has relatively little experience with existing surface-water models, it will need to begin immediately to provide or obtain the necessary training. There is also a critical need to determine what data are required by these models, since the current NAWQA design may not include the necessary data. As an example, there is no plan to collect meteorological data, which will be essential for watershed models of water quality. During the first round of intensive monitoring, the leading water-quality models should be applied over a wide range of situations. This would not only enhance the assessment effort but would also provide valuable information on the capabilities of the models. In addition, the committee recommends that a midcourse model evaluation be built into the assessment cycle so that corrections to the models can be made in sufficient time**.
- **Over the long term, the USGS should develop a coherent strategy for water-quality modeling in the context of large-scale assessment, addressing such issues as scale, model complexity, and surface-and ground-water interactions. This should be done (to the fullest extent possible) in cooperation with other federal agencies, particularly with the Environmental Protection Agency**.

Products

The committee is most concerned with the relatively narrow scope of the five retrospective studies that were available for review. While the study-unit teams appear to have been thorough in identifying and acquiring available data, the extent of their investigations was quite limited. In particular, the investigations focused largely on ambient water quality data in streams and aquifers. Data on sources of contamination were not collected and analyzed, in spite of the availability of extensive data bases (e.g., EPA's Permit Compliance System and Industrial Facility Reports).

Because of the timing of the committee's review, no NAWQA reports presenting results at either the study-unit or synthesis level were available for review, with the exception of five retrospective reports.

Recommendations

- **The committee recommends that the concept of a retrospective report be expanded to include data on known sources of water quality constituents, existing studies of water quality processes within the study unit, and previously developed conceptual and mathematical models of the physical, chemical, and biological processes influencing water quality in the study unit**.
- **The committee encourages the USGS to be vigilant and creative in seeking ways to minimize the time required to publish the National Water Quality Assessment findings**.
- **The committee urges the USGS to assure that adequate resources are directed toward reports describing the results of cause and effect analyses**.

NRC Committee-Initiated Case Study

To obtain a sharper focus on how cause and effect analysis would be conducted under the NAWQA program, the committee requested in the summer of 1989 a special study of the effects of changes in wastewater treatment on the downstream water quality of the Illinois River. This request resulted in a USGS open file report (see Appendix B, #59) and three articles on the topic to be published in Water Environment and Technology, the journal of the Water Pollution Control Federation.

NAWQA personnel did a thorough evaluation of quality control problems with the existing data; however, they have not yet done the requested analysis of cause and effect relationships for this test study area. Thus the committee cannot evaluate how cause and effect analysis is to be accomplished under the NAWQA program.

Recommendation

- **The USGS should intensify its cause and effect assessment activities and should provide complete case studies and a coherent national methodology for doing cause and effect assessments. This initial effort should utilize all available data and not be restricted to data generated by the NAWQA monitoring program. The results of this effort should be reviewed by an external advisory group of scientists**.

Implementation, Coordination, and National Synthesis

The activities of NAWQA are focused largely on the study-unit level. A nationally consistent set of analyses will be performed and aggregated to provide assessments at a regional and national scale. The process for synthesizing will employ an array of study teams both inside and outside USGS, e.g., issue-based synthesis teams, national synthesis team, and the National Coordinating Work Group. What is missing is an ongoing, external, scientific advisory committee to review NAWQA's progress.

Current and proposed national water quality monitoring and assessment activities by the federal water agencies contribute a significant and worthwhile component of water resources management activities. However, although interagency cooperative agreements have existed since 1967, no federal interagency master plan has been available to ensure that existing and proposed monitoring activities will provide the basis for a comprehensive national water quality assessment program. Also missing is an effective inter-agency committee among those federal agencies now performing water quality assessments.

Recommendations

Implementation and Coordination

- **The USGS should establish an external scientific advisory committee to provide an ongoing, independent review of the NAWQA program. This committee should consider the recommen**

dations made by this NRC committee and should monitor the progress of NAWQA toward a truly national assessment of water quality.

- **The USGS should establish an interagency council on national water quality assessment to review the activities of the various agencies that gather water quality data and to identify data gaps and duplication. Membership on this council should include representatives of the U.S. Geological Survey, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, Fish and Wildlife Service, Forest Service, Department of Agriculture, the Council on Environmental Quality, and others as appropriate.**
- **During its first two years of activity, this council might consider accomplishing the following tasks:**

1. **Prepare a detailed inventory of current water quality monitoring and assessment activities of the federal agencies. This inventory should be a greatly expanded and improved version of Table 3.1 of this report. This inventory should include accurate estimates on the current expenditures of the agencies for water quality related activities.**
2. **Prepare an action plan of how overall agency programs will perform national water quality assessments by:**

a. **issue, e.g., wastewater treatment, pesticides, nutrients;**
b. **receiving water bodies, i.e., rivers, lakes and impoundments, estuaries, and wetlands;**
c. **beneficial uses, e.g., water supply, recreation, and fish and wildlife protection; and**
d. **type of water quality constituent, i.e., physical, chemical, or biological.**

National Synthesis

- **The committee recommends that the USGS pursue its proposed use of issue-based and national synthesis teams to achieve a national-level synthesis of the information and knowledge at the study-unit scale. These teams should have regular communication with the study-unit teams, and should be given the authority to influence the activities of these teams. In addition, the teams should be led by the most capable and experienced personnel, and they should not restrict their vision only to USGS data and information. A strong review process with broad input should be put in place to assure wise choice of regional and national issues.**
- **The selection of national issues should be made with input from a broad spectrum of interested federal agencies, professional societies, private industry, and academia.**

1

Overview

INTRODUCTION

Realizing that the protection and enhancement of the quality of the nation's surface water and ground water resources had become a priority concern, and that the effective management of these resources requires information on current water quality conditions and trends in their condition, the USGS began to develop a national water quality assessment in 1984. In FY 1986, Congress appropriated funds to initiate the National Water Quality Assessment (NAWQA) pilot program to test and refine the concept and approaches for such an undertaking, and to evaluate the potential use and cost of a fully implemented program.

The overall goals of the NAWQA program are to:

1. provide a nationally consistent description of current water quality conditions for a large part of the nation's water resources;
2. define long-term trends (or lack of trends) in water quality; and
3. identify, describe, and explain, to the extent possible, the major factors that affect observed water quality conditions and trends.

The program is to be executed through a large set of separate investigations of river basins and aquifer systems, referred to as study units. The USGS postulated that by performing NAWQA as an aggregation of many individual study units, the assessment would provide results that would be useful in understanding and managing the water resources of the study unit, and in answering national-scale questions about current conditions, trends, and factors that affect water quality. Further, the program is to focus on conditions that are large scale and persistent in time.

Emphasis is to be placed on regional degradation of water quality such as might occur from both nonpoint and point sources of contaminants.

In addition to collecting water quality data, the NAWQA program is designed to take advantage of water quality information compiled by other agencies for various purposes. Thus, one of the first activities within each study unit is to collate and interpret the available data to (1) provide an initial description of water quality conditions, (2) develop hypotheses about major factors influencing water quality, and (3) define data needs.

Because of the emphasis on trends in water quality, the program is to be perennial, recognizing that the emergence of new hydrologic knowledge, improved methods of measurement, and changes in the types of contaminants of concern might require that the program be appropriately modified. The program is to place a high emphasis on repetition of measurements over time and on documentation of the methods of data collection and analysis and of the locations and characteristics of data-collection sites.

According to the USGS, a full-scale NAWQA program will provide useful information to decisionmakers who set policy, promulgate regulations, establish priorities, or manage water resources. As stated by the USGS, "Information on the status, the trends, and the causes of water quality conditions across the country should be particularly useful to other agencies who are involved in (1) identifying key substances for possible regulation for which research is needed on toxicity, human exposure, and drinking-water treatability; (2) allocating budgetary resources among competing types of water quality problems; (3) determining whether desired goals for water quality improvement are being met; (4) designing monitoring programs in different parts of the country (in terms of the constituents analyzed, sampling locations, sampling frequency, and timing of sampling); (5) targeting regulations for selected water quality constituents to particular geographic regions or hydrologic settings; (6) determining the relative effects on water quality of various types of point and nonpoint sources; (7) identifying aquifers requiring different types and degrees of water quality protection; and, (8) evaluating management practices in terms of their large-scale effects on the water quality of river basins and aquifer systems" (Hirsch, et al., 1988).

Four surface water and three ground water pilot projects, representing a diversity of hydrologic environments and water quality conditions, were selected by the USGS in 1986 to test and refine the assessment concepts of NAWQA. The surface water pilot projects selected included the upper Illinois River basin in Illinois, Wisconsin, and Indiana; the Kentucky River basin in Kentucky; the lower Kansas River basin in Kansas and Nebraska; and the Yakima River basin in Washington. For the three ground water pilot projects, the USGS selected the Carson basin in western Nevada and eastern California, the Central Oklahoma aquifer in Oklahoma, and the Delmarva Peninsula in Delaware, Maryland, and Virginia. A local liaison committee was established for each pilot project (study unit) consisting of representatives from federal, state, and local agencies and private organizations involved in water and land management within the area of the project. The charge to each liaison committee was to assist the USGS by ensuring that the scientific information collected by the pilot project was relevant to local and regional interests. To advise the USGS on the overall pilot project program, a National Coordinating Work Group (see Appendix D) also was created with members representing various federal agencies and nonfederal organizations having an involvement or interest in water quality information.

The committee's assignment to evaluate NAWQA began with a meeting in October 1988. At this meeting, USGS personnel reported that over the prior four years, NAWQA had undergone considerable development, and as a result, a number of refinements and modifications of the basic plan had been incorporated. In fact, the USGS expressed the view that NAWQA would continue to evolve, with certain aspects being further refined and modified, over the next several years. The committee was invited by the USGS to become a part of this evolutionary process by making suggestions for improvement or simply by challenging any of the various elements of NAWQA.

To assist the committee in its assignment, USGS personnel presented a series of briefings covering the details of all the various elements of NAWQA. During the course of its review, the committee also examined many publications and documents provided by the USGS (see Appendix B) and evaluated the potential usefulness of NAWQA in meeting national, state, and local needs for water quality information by interviewing representatives of various government agencies (see Appendix E) and the private sector. Additionally, the committee visited, in small teams, five of the seven sites selected as pilot projects: the Carson basin aquifer, Upper Illinois River basin, Yakima River basin, Kentucky River basin, and Central Oklahoma basin aquifer. Meetings were held with USGS project personnel and the local liaison committee. A committee representative also attended several meetings of the National Coordinating Work Group.

The committee, in its deliberations, reviewed all the elements of NAWQA and as a result, identified areas of concern and made suggestions for change. These concerns and suggestions, along with other comments, both positive and negative, were communicated to USGS by the committee through an interim report dated September 25, 1989 (see Appendix A). A major conclusion of the committee, as expressed in the interim report, was "that a national-scale, long-term water quality assessment is in the best interest of the country."

This final report addresses those elements of NAWQA discussed in the interim report, but in greater detail. It also evaluates other considerations deemed important by the committee in designing and implementing a long-term assessment of the quality of the nation's surface and ground waters which, in turn, will produce useful information for those involved in making decisions regarding the management of the nation's water resources. Unfortunately, because the scheduled 4-year study period for the seven pilot projects had not elapsed at the time of the preparation of this report, the committee did not have access to any final products to review, with the exception of five retrospective reports. This has limited the committee's ability to evaluate the anticipated results and usefulness of NAWQA. Therefore, the committee's findings and recommendations are based on the review of many draft documents, briefings by USGS personnel, and the committee's own experience and knowledge of surface and ground water quality monitoring and assessments.

NEED FOR A NATIONAL ASSESSMENT OF WATER QUALITY

The committee is convinced that there is a genuine need for a long-term, large spatial scale national assessment of water quality in the United States. Human health and environmental health are inextricably linked to our nation's water quality. As our population continues to grow, our water resources are becoming more intensively developed, and more potential contaminants are being produced. Water quality has become an increasingly important component of our political, economic, social, and environmental decisionmaking. Because such decisionmaking affects the quality of each individual's life, as well as public and private expenditures of billions of dollars, it cannot proceed without adequate information and understanding.

Many significant past and future decisions involving water quality are of national or regional scope. This broad scope arises for several reasons. First, hydrologic boundaries do not follow political boundaries. Therefore, water quality issues are often inter jurisdictional. For example, many hydrologic systems, e.g., river basins, lakes, or aquifers, are large and fall within or are adjacent to more than one political unit. These systems are dynamic, flowing systems through which changes propagate over space and time, so that upstream decisions affect downstream users. Second, a number of important water quality problems are widespread throughout the nation. Examples include storm-water runoff quality control and municipal and industrial wastewater treatment. These problems are so widespread that it is often more efficient to make some decisions about them at the national or regional level. Finally, some water quality problems are characterized by long time scales, so that decisions made at one point in time carry impacts far into the future. To the extent that higher levels of government provide continuity over time, these issues may require a national or regional approach.

There are many examples of water quality issues requiring or benefiting from national or regional attention and decisionmaking for one or more of the reasons just discussed. These include evaluating past and guiding future investments in waste-water treatment works; determining the relative contribution of point and nonpoint sources to the loading of contaminants to surface and ground waters; identifying and controlling the water quality impacts of acid deposition, agricultural chemical use (especially pesticides), and toxics; evaluating the effectiveness of federal, state, regional, and local environmental regulations; and controlling eutrophication of inland and coastal water bodies. The future is likely to bring even more issues requiring a large-scale focus, such as determining the value of instream water uses relative to water resources development. This issue has implications for general environmental policy, Indian and non-Indian water rights, and the preservation of threatened and endangered species, among others, and will require attention at many levels of government.

Sound decisionmaking about these and many other water quality issues requires that we identify problem areas before they reach crisis proportions, understand the causes of such problems, and are able to predict adequately the effects of changes in water quality and the impacts of attempts to improve or protect water quality. In other words, we need (1) data quantifying hydrologic, chemical, biological, and other relevant parameters in space and time; (2) information about the past and present states of the system obtained by collating, organizing, and interpreting the available data; and, (3) knowledge about the cause and effect relationships between variables and their evolution over space and time capability. All three are important and build on each other, but ultimately knowledge and understanding, which are essential for predictive capability, must be the goal of any program that supports water quality decisionmaking.

As we define it, then, a water quality "assessment" must do much more than "monitor." In our usage, monitoring is a data-collection activity typically directed toward assuring compliance with a regulation or statute, detecting the presence of known contaminants, or operating control facilities and systems. Assessment, on the other hand, goes well beyond monitoring and data collection to include the analysis, interpretation, and synthesis of data and theory to enhance our understanding of the environment. While data collection activities are necessary, and indeed are one important component of an assessment program, we are convinced that the strongest current need is for a true national assessment, focusing on enhancing knowledge and understanding.

There are several timely examples of the value of such an assessment. One is the issue of pesticides in surface and ground waters. The distribution, mobility, and fate of pesticides in the aquatic environment are controlled by a complex set of physical, geochemical, and biological processes. Mere detection provides no information about sources, pathways, or fate. In addition, detection of a pesticide in one environment typically provides little information about the presence of the same pesticide in another hydrogeochemical environment. For example, aldicarb is often associated with high ground water tables and sandy, mineral soils, where its fate and transport are controlled and its mobility limited by sorption on mineral surfaces and microbiological degradation under fully saturated conditions. However, in the presence of a large unsaturated zone and/ or more organic soils, aldicarb may behave quite differently because of the potential for partitioning into the soil gas and organic solids. Designing management practices to control contamination by this pesticide and then evaluating those practices cannot be accomplished without understanding the mechanisms responsible for its fate and transport.

A second example is the presence of selenium in agricultural drainage waters in such places as the San Joaquin Valley in California. Effective control and management will be possible only after the complex hydrologic interactions between surface and ground waters are understood and the geochemistry of selenium sorption and oxidation-reduction reactions is delineated. An extensive, in-depth study has been required in order to interpret the initial detections of selenium and to develop potential control and management options (Gilliom, et al., 1989).

Two different (and often competing) philosophical approaches can be used to address a complex problem such as a national assessment of water quality. In a purely statistical approach, the collection and analysis of data are based on statistical theory. In other words, variable behavior and the relationships between variables are assumed to be dominated by random uncertainty. In a process-oriented approach, sampling and data analysis are largely driven by deterministic models of the relevant physical processes. It must be stressed that these descriptions represent the extremes of a spectrum of approaches. In practice, it is rare to find an approach that is purely statistical or purely process oriented. Statistical approaches are most effective when they exploit an understanding of relevant physical processes, and statistical methods are essential tools for process modeling in the face of data uncertainty and model simplifications. Nonetheless, it is useful to distinguish between these two basic approaches, since the challenge in any given situation is to find the appropriate mix.

Because the committee is convinced of the need to develop a much greater understanding of our nation's water quality, it has reached the conclusion that a national assessment must take a strong process-oriented approach. While data uncertainty and conceptual simplifications must be properly addressed, the assessment must maintain a strong focus on elucidating cause and effect relationships and developing models that articulate those relationships.

In order to meet the goals of a national water quality assessment, the assessment must also be long term. First, because of the extraordinary complexity of the physical, chemical, and biological processes controlling water quality, any assessment of the state of water quality in the U. S. must evolve over time, probably iteratively, as our understanding and data bases increase. Second, the processes controlling water quality take place over a wide range of time scales. For example, ground water flow rates are very small, and a "snapshot in time," or even several closely spaced snapshots, would provide relatively little information about change. Similarly, the impacts of global climate change on water quality are likely to occur on time scales of decades. On the other hand, mixing processes in moun tain streams are very rapid, so that a single sample, or even a few samples, could easily miss important events. In either case, a static, one-time assessment would have no lasting value, but a long-term assessment would have a better chance of detecting the true water quality and its changes.

Both the complexity of water quality processes and the wide range of relevant time scales imply that adaptability is an extremely important characteristic of a successful water quality assessment. As new knowledge is gained, new methods developed, or new contaminants discovered or introduced in the environment, or as an existing condition evolves over time, an assessment program must respond and change. A flexible long-term assessment would make that responsiveness possible.

A national water quality assessment necessarily warrants a large-scale undertaking. Because of the complexity and spatial diversity of water quality issues, a national-level aggregation and integration would be invaluable in maximizing information gained from local experience. Such integration would enhance the ability to generalize from local experience and to adapt knowledge learned from one location to another. Because of complexity and diversity, multiple lines of evidence are often required to develop necessary understanding. A large-scale assessment makes it possible to develop such lines of evidence. Finally, while there is much completed and ongoing research focusing on cause and effect water quality relationships, this research tends to be directed toward smaller-scale (often laboratory-scale) understanding. Relatively less is known about the behavior of large systems, such as entire river basins or aquifer systems. For this reason, a national assessment would be a particularly timely undertaking for scientific reasons alone.

Because of the many advantages of a large-scale, long-term water quality assessment, there is tremendous value in developing consistent, compatible, reliable, and accessible water quality data bases. Unfortunately, there is often relatively little consistency between data sets gathered for local or regional purposes. Consequently, generalization and inference at the national level or across state boundaries or from year to year is very difficult. The USGS study of the effects of changes in municipal wastewater treatment on water quality in the Upper Illinois River Basin provides an excellent example of the difficulties caused by inconsistent data bases (see Appendix B, #57).

To summarize, implementing a national water quality assessment using consistent data collection, analysis, and reporting procedures is essential if we as a nation are to effectively and efficiently maintain, manage, and control our water resources.

Such an assessment must go well beyond mere monitoring and data collection to focus on developing understanding of cause and effect relationships. It should be process oriented, long term, highly adaptable, and of large spatial scale.

While the committee is convinced of the need for a national assessment, this is an enormously difficult challenge because of the immense scale of our nation's waters, the diversity of both the natural hydrologic systems and the human activities that affect those systems, and the complexity of the physical, chemical, and biological processes that govern water quality. There is a vast scope to the types of water bodies of importance, encompassing rivers and streams, estuaries, lakes and reservoirs, and ground water aquifers. These water bodies are combined into hydrologic systems with complex interactions between components. They range in size from small streams to extensive aquifers. Important processes occur on scales ranging from microscopic to global and encompass a broad array of scientific disciplines, including hydrology, geology, chemistry, microbiology, ecology, engineering, and more. Water quality problems range from naturally occurring radon in ground water to the impacts of wastewater discharge on downstream water users.

There are many implications of such a vast scope. First of all, except in a few special cases, uniform national assessments are precluded. Understanding must almost always be developed on regional or smaller scales and a national picture must be assembled as a composite of these smaller-scale assessments. Rigorous probabilistic generalizations at the national scale are possible only for a small subset of relatively simple problems that do not require cause and effect analysis, e.g., number of stream miles with low average dissolved oxygen concentrations. Second, a national assessment must be a multidisciplinary undertaking and a work environment and management structure must be established that fosters interactions between different disciplines. For example, the traditional separateness of surface and ground water hydrologists, as well as of physical and life scientists, must be overcome. Third, there is an existing structure for collecting and interpreting a large amount of water quality data. This effort is highly dispersed across many different public and private organizations and involves data collected for a wide variety of different purposes. Careful coordination is essential to avoid duplication of effort and maximum utilization of resources and existing knowledge, and to ensure consistency. Finally, federal agencies have very little experience implementing a truly national assessment of any particular water quality issue, let alone a national assessment of water quality as a whole.

Therefore, such an assessment cannot proceed quickly and will require adequate resources. Conceptual approaches, models, and other technology will need to be developed as an assessment proceeds. At no point can a national assessment become a routine task. Consequently, the success of a national assessment will be highly dependent on the quality of the people directing and implementing it. Staff must be very capable, well educated, broadly experienced, creative, and motivated.

To conclude, then, the committee is convinced of the need for a national assessment of water quality. However, such an assessment will face a number of difficulties. It will be of vast scope, it will be highly multidisciplinary, it will need to be well coordinated with the activities of many different organizations, and it will require many experienced, high-quality personnel provided with adequate time and resources. Uniform national analyses or rigorous probabilistic generalizations cannot be expected when a national scope is achieved by assembling a composite of regional or smaller-scale analyses.

2

NAWQA Design Evaluation

INTRODUCTION

As discussed in the previous chapter, the scope of a truly national water quality assessment is enormous, both in scale and complexity. Hence, it is essential that the scope of NAWQA be defined judiciously in recognition of the overall budgetary constraints, the organizational strength of the USGS, and the salient characteristics of the physical and cultural systems that define water quality. This chapter contains an evaluation of the design of the NAWQA program components, including integration of the surface water and ground water study units, how study units were selected, the general exclusion of lakes and estuaries from the study plan, the sampling design program, data collection methods, the choice of chemical and biological constituents, quality assurance/ quality control aspects, data management, the analytical framework of the program, and products of the NAWQA program.

Integration of Ground Water and Surface Water Description

The original concept specified 123 separate surface water and ground water study units: 69 surface water and 54 ground water. A major difficulty with the "separate" approach is that it had the potential for missing the important linkages between surface water and ground water systems—linkages that can have profound effects on the water quality of both systems. As the pilot programs proceeded, it became apparent to the committee and to the USGS that the integrated approach was more beneficial. Some of the pilot programs provide good examples of the importance of incorporating surface water and ground water interactions into water quality studies.

For example, in the Delmarva Peninsula pilot project—a ground water investigation—pesticides have caused some contamination of surface water and shallow ground waters. The pilot project used transects of shallow wells installed adjacent to streams to track the infiltration of pesticides from agricultural lands down to the water table and from there into streams. The pilot project in the lower Kansas River basin—a surface water investigation—perhaps best exemplifies the importance of the integrated approach. Along the Kansas River, considerable interchange of water occurs between the river and its alluvial aquifer. During high flows, the river recharges the aquifer; during low flows, base flow from the aquifer contributes an estimated 1 to 4 cubic feet per second of flow per river mile (Fader, 1974). The exchange of water probably has a significant effect on ground water and surface water quality, although the effects were not known at the inception of the study. In the Blue River basin near the Kansas-Nebraska state line, streamflow depletion by wells is about two orders of magnitude greater than that predicted by an analog model in the early 1960s (Alley and Emery, 1986). In the northwestern portion of the study unit (the upper Big Blue River and Little Blue River in Nebraska), the interaction between the streams and the aquifers is great. In dry periods, discharge from the High Plains aquifer sustains these streams. Irrigation return flow from the extensive croplands undoubtedly contributes to the relatively high specific conductance found downstream in the Kansas River; the sulfate ion is a major offender. Similarly, the use of nitrogen fertilizers may contribute to the upward trend in nitrite and nitrate levels in the Big Blue River; a major pathway could be base flow to the river.

Ground water and surface water interaction is also important in some portions of the Central Oklahoma aquifer study unit; this was known prior to the inception of the pilot project. However, the spatial distribution of this interaction was different from that which was previously believed. Prior to the onset of the pilot project, the USGS team thought that most interaction occurred near the major streams, the Canadian and Cimarron Rivers. The pilot project team discovered that the major interaction occurred along two smaller streams, the Deep Fork and Little Rivers, which served as the major ground water sinks instead of the aforementioned larger streams. This surprising result could have important ramifications for water quality, especially for the four streams involved.

Certain other pilot projects might also benefit from an integrated approach. The Yakima River basin pilot project—a surface water investigation—is one such example. Interchange between surface water and ground water is probably important in the upper, forested reaches of the watershed. In the lower portion of the basin, over 400,000 acres are under irrigation. Subsurface irrigation return flow could affect stream water quality, as the potential exists for water quality degradation arising from irrigation (NRC, 1989).

Critique

The original NAWQA plan to keep surface water and ground water study units separate had the potential for missing or minimizing important water quality linkages between these two systems. Therefore, in recognition of the important water quality implications of surface water and ground water interactions and the committee's concern that the original NAWQA concept downplayed these implications, the USGS decided in March 1989 to redefine the study units. Instead of the original 123 separate study units, 60 integrated surface water/ground water study units now exist; selection of these new units will be discussed in another section. The study units are shown in Figure 2.1 and listed in Table 2.1.

Summary

The emphasis on integrated study units will result in an improved program since it will now examine the water quality of an integrated hydrologic system. Flow paths between aquifers and streams will be delineated so that the investigators will be able to quantify the effects of one component (i.e., surface water or ground water) of the system on the water quality of the other component. The integrated approach will also allow the investigators to ascertain the physics of the system to a greater extent than before, thus enabling them to understand the cause and effect relationships, which could be extended to other parts of the country. One of the important aspects of the NAWQA program is an understanding of water quality cause and effect relationships, and the committee believes that the integrated approach will enhance such understanding. The USGS plans to use teams of surface water and ground water specialists to review study unit findings in an effort to develop a basic understanding of the interrelationships among surface waters, ground waters, and the water quality constituents carried by those waters. To the extent that these reviews are successful, they should enable better planning of new projects as they come on-line.

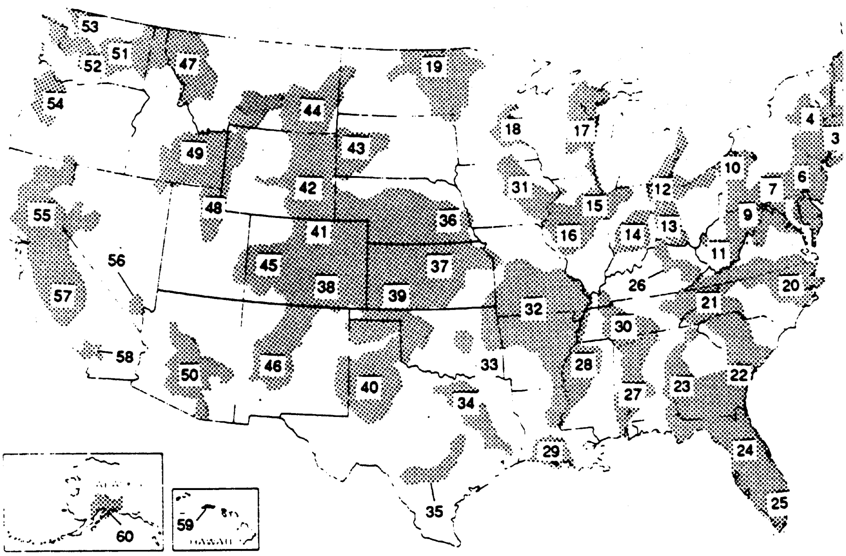

Figure 2.1
Proposed NAWQA study units in the United States. Source: Leahy et al, 1990.

Table 2.1 Proposed Study Units for a Full-Scale National Water Quality Assessment Program

USGS Northeastern Region		USGS Western Region	
1.	New Hampshire-Southern Maine Basins	49.	Upper Snake River Basin
2.	Southeastern New England	50.	Southern Arizona
3.	Connecticut Valley Drainage	51.	Mid-Columbia Basin
4.	Hudson River Basin	52.	Yakima River Basin
5.	Long Island	53.	Puget Sound Drainages
6.	Delaware River Basin	54.	Willamette Basin
7.	Lower Susquehanna River Basin	55.	Sacramento Basin
8.	Delmarva Peninsula	56.	Western Great Basin
9.	Potomac River Basin	57.	San Joaquin-Tulare
10.	Allegheny and Monongahela River Basins	58.	Santa Ana Basin
11.	Kanawha River Basin	59.	Oahu
12.	Lake Erie-Lake Saint Claire Drainage	60.	Cook Inlet Basin
13.	Great and Little Miami River Basins		
14.	White River Basin		
15.	Upper Illinois River Basin		
16.	Lower Illinois River Basin		
17.	Western Lake Michigan Drainage		
18.	Minneapolis-St. Paul Basin		
19.	Red River of the North		
USGS Southeastern Region			
20.	Albemarle-Pamlico Drainage		
21.	Upper Tennessee River Basin		
22.	Santee Basin and Coastal Drainage		
23.	Apalachicola-Chattahoochee Basin		
24.	Georgia-Florida Coastal Plain		
25.	Southern Florida		
26.	Kentucky River Basin		
27.	Mobile River and Tributaries		
28.	Mississippi Delta		
29.	Chicot-Evangeline		
30.	Lower Tennessee River Basin		
USGS Central Region			
31.	Eastern Iowa Basins		
32.	Ozark Plateau		
33.	Central Oklahoma		
34.	Trinity River Basin		
35.	Balcones Fault Zone		
36.	Central Nebraska		
37.	Kansas River Basin		
38.	Upper Arkansas River Basin		
39.	Central High Plains		
40.	Southern High Plains		
41.	South Platte River Basin		
42.	North Platte River Basin		
43.	Cheyenne and Belle Fourche Basins		
44.	Yellowstone Basin		
45.	Upper Colorado Basin		
46.	Rio Grande Valley		
47.	Northern Rockies Intermontane Basins		
48.	Great Salt Lake Basin		

Lakes and Estuaries

Description

In the NAWQA program the term "surface water" is virtually synonymous with "stream." Estuaries will not be considered in the program. Lakes (including impoundments) will only be considered if they significantly affect downstream water quality. However, the extent of this consideration is not clear, nor is the manner in which the significance of individual lakes will be evaluated. The exclusion of lakes has been justified by the USGS on the basis of cost.

Critique

Estuaries and lakes (including impoundments) are critical components of the nation's water resources. Much of the surface water supply of the nation is drawn from lakes (either natural or engineered). Lakes and estuaries support rich and diverse ecosystems, which provide the basis of an extensive seafood industry and abundant recreational opportunities. Lakes also interact with other freshwater components of the hydrologic cycle, in that they act as both sources and sinks of various water quality constituents. Thus they can significantly affect downstream surface water or down-gradient ground water quality. It is clearly in the nation's interest to monitor, assess, and understand the water quality of both lakes and estuaries.

With respect to the major estuaries and lakes in the nation, extensive assessment programs already exist. Notable examples include the Chesapeake Bay, San Francisco Bay, and the Great Lakes. In general, the level of activity in these large systems is much greater than could be supported under the NAWQA program. At best, NAWQA can provide additional information regarding loadings of various water quality constituents. However, NAWQA can and should benefit from the modeling techniques that have been developed during the intensive investigations of these major lake and estuary systems.

In the aggregate, the smaller lakes and estuaries in the nation constitute a very important resource. While the committee believes that this resource deserves attention, it supports the decision of the USGS at this time to exclude estuaries from NAWQA and to consider lakes only insofar as they affect downstream surface water quality and downgradient ground water quality. This support is based on our recognition that the USGS, while traditionally strong in mathematical modeling of estuaries and lakes, has relatively little experience or capability in biological and chemical modeling.

The committee, however, believes strongly that the USGS must include in NAWQA consideration of those lakes that significantly affect downstream or downgradient water quality. This consideration should involve more than just upstream and downstream monitoring of water quality, and should include some degree of mathematical modeling. If developed in the early stages of a study unit, a preliminary model can be used to establish the potential significance of existing lakes, and to guide the monitoring program. Once collected, monitoring data can be used to evaluate the model, and if warranted, to guide its improvement. This in turn may lead to additional monitoring requirements. This iterative use of models is an essential element of a process-oriented assessment, and is discussed further in the Analytical Framework section later in this report.

Summary

The committee believes that an assessment of the long-term trends in the water quality of lakes (including impoundments) and estuaries should be part of any long-term national water quality assessment. At some point, the water quality of lakes should receive the same level of attention in the NAWQA program as that of streams and ground water. However, given the present lack of personnel in the USGS with expertise in the biological and chemical modeling of lakes and estuaries, we believe that the NAWQA program should not be expanded at this juncture to include estuaries. However, we recommend that initially lakes should be considered but only as they affect downstream surface water quality or downgradient ground water quality.

The committee further recommends that the first set of investigations in the NAWQA program include one or more study units in which lakes are likely to be significant contributors to downstream and/or downgradient water quality. This will give the USGS an opportunity to enhance its capabilities with respect to lakes. Additionally, we recommend that mathematical models be developed at the initial stages of each study unit investigation involving lakes.

Selection of Study Units

Introduction

The selection of study units is described in Hirsch et al., 1988, which is the source for much of the discussion in this section. Some changes in the study unit selection process, as described in Hirsch et al., 1988, were dictated by the decision to designate combined surface water-ground water study units; these changes are included in the discussion herein. Since the selection of study units is based largely upon the USGS's hydrologic unit classification system, a brief description of that system, taken from Seaber and others (1986), is warranted.

Description

The USGS divides the United States into 21 major geographic regions and 222 hydrologic subregions. The regions contain either the drainage area of a major river, such as the Missouri region, or the combined drainage area of a series of rivers, such as the Texas-Gulf region, which includes a number of rivers draining into the Gulf of Mexico. Eighteen regions comprise the conterminous United States, with individual regions specified for Alaska, the Hawaiian Islands, and Puerto Rico and other Caribbean areas. A hydrologic subregion includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area. These subregions are further subdivided into 352 accounting units that nest within, or are equivalent to, the subregions. The accounting units are used by the USGS in designing and managing the National Water Data Network.

A set of 200 surface water candidate study units (CSUs) were identified, based primarily on the hydrologic subregions described in Seaber and others (1986). When a given subregion was too large, it was subdivided to form a number of CSUs. In other cases, subregions were combined into a single CSU or a particular accounting unit from one subregion was added to another. In the selection of the surface water CSUs, attempts were made to select ones having similar areas. Modifications were sometimes made to ensure that all sources to a major lake or estuary were contained within the same CSU. An attempt was also made to select CSUs that had relatively homogeneous land use and environmental characteristics. A set of 116 ground water CSUs were also identified. The boundaries of these CSUs were less well defined than those of the surface water CSUs; in some cases, ground water CSU boundaries coincided with those of surface water CSUs.

Each set of CSUs was screened using a modified linear programming model (Fox and Scudder, 1986). The objective function of the linear program minimized the number of study units selected, given certain constraints: (1) the study units account for about 60 percent of the nation's water use, as measured by population served by public water supplies and by total withdrawals excluding thermal and hydropower uses; and (2) each state contains at least one study unit having at least 30 percent of its area within that state. This exercise yielded two maps: one of surface water study units and one of ground water study units. Next, a few study units that were downstream of major river basins (e.g., the Colorado and Ohio rivers) were deleted; the rationale for these deletions was that these basins integrate water quality conditions for many upstream basins (Hirsch et al., 1988). The two sets of study units were then merged and reviewed by all USGS district and regional offices to provide study unit boundaries that accounted for both surface water and ground water boundaries. Some study unit boundaries may be refined once the full-scale program gets under way. Finally, study units were specified for Hawaii and Alaska. The 60 study units encompass about 40 percent of the land area of the conterminous United States and incorporate about 60 to 70 percent of the nation's water use (fresh surface water withdrawals excluding thermal and hydropower uses). It should be noted that in selecting the study units, emphasis was placed on "key river basins" and ground water units that corresponded somewhat to the USGS Regional Aquifer Systems Analysis (RASA) program. Essentially, the purpose of the RASA program is to emphasize the physical hydrogeology of certain regional aquifers. By attempting to coordinate NAWQA study units with RASA efforts, the USGS will take advantage of information already being generated. The RASA program emphasizes the physics of the ground water systems, something that must be understood to undertake a water quality assessment that seeks to identify cause and effect relationships. The coordination of RASA and NAWQA, where possible, will result in an improved NAWQA product.

Critique

The geographic coverage of the study units is good, considering that only 40 percent of the continental United States is included.

The variation in size is substantial: the smallest study unit, Long Island (number 5 in Figure 2.1 and Table 2.1), is about 1,300 square miles, and the largest is the Ozark Plateau (number 32), which is over 60,000 square miles. The pilot project study units are relatively small—3,000 to 15,000 square miles. Given the large size of approximately eight study units, the combined ground water-surface water nature of these study units, and the USGS's lack of experience in a large study unit, the committee is concerned that NAWQA objectives may not be met in some of the larger units.

Summary

Study unit selection is generally good; the coverage is broad and represents a variety of hydrologic regions. Coordination of study units with RASA study areas is an approach that should result in some degree of synergism and aid in delineating cause and effect relationships. Some of the study units are quite large, much larger than any of the seven pilot project study units. **To see how well the NAWQA program can accommodate a large study unit, the committee recommends that early in the full-scale NAWQA program, the U.S. Geological Survey select two large study units for investigation**.

SAMPLING DESIGN

Sampling Approach

Introduction

The NAWQA pilot program originally consisted of separate surface-and ground-water study units with separate sampling designs. The committee's evaluation therefore considers the surface-and ground-water sampling designs separately. The full-scale NAWQA will be based on combined surface-and groundwater study units; however, a combined sampling design has not yet been developed. Hence, the committee also points out some issues that need to be considered in designing a sampling program for the combined surface-and ground-water study units.

Ground Water

Description

The major objectives of the ground water investigations (Hirsch et al., 1988) are to (1) describe ground water quality conditions for major hydrogeologic settings; (2) describe the geographic distributions within the study units of selected water quality constituents and problem areas; (3) define long-term trends in ground water quality; and (4) identify, describe, and explain, if possible, the major factors that affect observed current conditions and trends in ground water quality. To attain these objectives, NAWQA projects will conduct three different types of ground water sampling activities: (1) regional, (2) targeted, and (3) long term.

Regional sampling will be conducted throughout each major hydrogeologic setting within a study unit. All of the national target variables for chemistry and physics will be measured in an effort to provide descriptive statistics and to form an initial basis for describing the geographic distribution of water quality variables within the study unit. Sampling will be done in three dimensions and will be designed to be unbiased with respect to particular "problem areas."

Targeted sampling will occur in selected locations for specific groups of water quality constituents; it will focus on "problem areas" but will not be a "plume chasing" exercise. As an example, in the Central Oklahoma aquifer pilot project, targeted sampling variables are (1) naturally occurring trace substances (NOTS) such as arsenic, selenium, chromium, uranium and gross-alpha radioactivity and (2) organics (especially pesticides) beneath central Oklahoma City. Problem areas for targeted sampling will be identified from the regional sampling results, knowledge of the hydrogeologic and land-use factors that contribute to water quality, and consultation with local agencies and individuals involved with ground water quality. Three targeted sampling approaches will be used: (1) search-oriented sampling, (2) statistical hypothesis testing, and (3) local-scale transects (Hirsch et al., 1988).

Local-scale transects will involve high-density sampling of one or more wells per square mile to characterize representative settings that commonly occur throughout large parts of the study unit. These local-scale studies should be useful for examining the interrelationship between surface water and ground water quality. Transects provide very good information about a study unit's physical hydrogeology. The Delmarva Peninsula pilot project has used transects of shallow wells installed adjacent to streams to follow the infiltration of pesticides from agricultural lands down to the shallow aquifer and from there into streams. Local-scale transects have also been used in the Carson basin pilot project.

Search-oriented sampling will involve sampling for constituents within particular settings in which they are most expected. The

NOTS sampling in the Central Oklahoma aquifer study unit is an example. Statistical hypothesis testing will be used to test hypotheses on the regional distribution of contaminants. For example, a program could be designed to test the hypothesis that the ground water quality beneath areas of differing land use varies. Both search-oriented sampling and statistical hypothesis-testing will be used at scales ranging from several hundred square miles to areas approaching the study unit size.

The final sampling activity, long-term sampling, will identify and examine temporal trends in ground water quality. Sampling will be conducted in wells representing ground water of different ages and hydrogeologic settings. The local networks established in the targeted samplings will also be used. Sampling frequencies or target constituents will not be rigid; as the results of the long-term sampling are obtained, certain sampling frequencies may be changed and locations or constituents dropped with the appropriate safeguards so as not to jeopardize long-term analysis. This flexible approach is beneficial in that it will conserve limited resources and concentrate on constituents and locations that will produce meaningful results.

Critique

One of the committee's concerns is whether adequate coverage can be provided, especially in the larger study units. For example, current regional sampling in the three ground water pilot projects calls for an initial batch of 150 to 200 samples for each study unit during the first 2 years. This initial batch will provide the preliminary statistical summary. The three ground water pilot project study units are small, 3,000 to 6,050 square miles. Under the revised plan, study units not only will combine both ground water and surface water but also will be 10 to 20 times larger, as large as 60,000 square miles. It is unclear whether such a small number of samples will be sufficient for the much larger, combined surface-and ground-water study units.

Long-term sampling is beneficial, and the committee is pleased to see its inclusion in the NAWQA program. It is one of the unique aspects of the program. Currently, there is no national systematic examination of the long-term trends (or lack thereof) in ground water quality.

Surface Water

Description

This description of the sampling approach to be used in the surface water component of NAWQA is based on the docu merit describing concepts for a NAWQA program (Hirsch et al., 1988). The major objectives of the surface water investigations are to (1) describe the occurrence and spatial distribution of a broad array of water quality constituents, (2) provide information on the seasonal variation and frequency of occurrence of selected water quality constituents at key locations, (3) estimate loads of selected water-quality constituents at key locations, (4) define long-term trends in the concentrations and/or loads of selected constituents at key locations, and (5) identify, describe, and explain, if possible, the major factors that affect observed conditions and trends in surface water quality. To attain these objectives, NAWQA projects will conduct three different types of surface water sampling: (1) fixed-station sampling, (2) synoptic sampling, and (3) studies of selected reaches.

Fixed-station sampling in the surface waters of each study unit will be conducted in order to describe the seasonal variations and frequency of occurrence of selected water quality constituents, to estimate loads, and to define long-term trends in water quality. Likely fixed-station sampling sites include (1) sites at the mouths of major tributaries or other points that account for a large portion of the total basin runoff; (2) sites up-and downstream from reservoirs or other areas likely to affect water quality; (3) sites on streams with homogeneous land use in the basin; (4) sites near important water uses in the basin (e.g., public water-supply intakes); and (5) existing stations from other programs (e.g., NASQAN). These stations will be sampled monthly during the active phase with an additional 3 to 6 high-flow samples taken annually.

Synoptic surveys will be conducted in each study unit to provide a finer degree of spatial resolution than is attainable with fixed-station samples and to examine the relationship between water quality conditions and land-or waste-management practices. These surveys will consist of measurements on selected parameters taken at many sites during a brief period representative of a particular hydrologic condition. The number and timing of synoptic surveys will vary among study units based on the questions being addressed.

Studies of selected reaches will be conducted to understand the sources, distribution, and fate of particular water quality constituents in greater detail than is available from either the fixed or synoptic sampling. The committee agrees that mathematical modeling will be useful in these studies. The USGS views selected reach studies as likely candidates for funding from the USGS cooperative program.

Critique

Typical water quality sampling programs include fixed-interval sampling at fixed stations. Unique and valuable additions to this in NAWQA include fixed-station sampling at high-flow conditions, synoptic sampling, and selected reach studies. Fixed-station sampling at high-flow conditions will be essential for load and transport calculations. Synoptic sampling will be a valuable tool for examining relations between land use and water quality conditions. The committee is concerned whether the land-use data will be:

- available in a timely manner,
- classified in adequate detail,
- of the proper scale and resolution, and
- updated frequently enough to be useful for documenting cause and effect relationships in long-term trends.

It is clear that NAWQA's ability to ascertain cause and effect relationships lies primarily with the selected reach studies. The committee knows of no selected reach studies funded during the pilot studies. There is also concern that modeling is discussed only in the context of selected reach studies. However, it is this component that is likely to vary most between study units in the amount of financial support provided. Our concerns with respect to modeling and cause and effect analysis in NAWQA are presented in greater detail in the Analytical Framework section of this report.

Combined Surface-and Ground-Water Study Units

The sampling programs described in the previous sections were developed for separate surface water and ground water study units. The study units are now combined, and the USGS needs to reexamine the sampling programs in light of this new organization. The following three issues are among those that should be addressed in this reexamination:

1. Ground water and surface water sampling protocols have been developed independently. With the new emphasis on ground water and surface water interaction, it may be desirable to have some protocols developed in tandem. For example, if models are going to be developed to describe some aspect of this interaction, comparable procedures, estimation techniques, and precision levels may be needed to ensure that sensible and meaningful model interpretations can be drawn.

2. Because the integration of ground water with surface water samples has been a relatively recent design modification, it is still unclear how samples will be allocated between ground and surface water. Surface water systems are visible and, hence, easier to delineate than ground water systems. Ground water flow is inherently three-dimensional and more areally extensive than surface water flow, which dictates that sampling is more difficult and expensive than for surface water flow. Since ground water flows more slowly than surface water, sampling over long periods of time may be required to provide information on water quality changes. Therefore, more ground water samples may be needed to provide the same level of precision provided by the surface water parameter estimation. The determination of the optimum allocation of sample points should be based in part on the level of desired precision in the parameters to be estimated as well as on the amount of inherent variation likely to be encountered in each type of sampling.
3. The need to integrate surface-and ground-water information may influence the choice of sampling location or timing of synoptic sampling.

Summary of Sampling Design

The ground water sampling program will consist of regional, targeted, and long-term sampling. The sampling approach generally seems adequate, although the committee is concerned about the adequacy of regional ground water sampling in the larger study units. The long-term sampling program is a valuable and unique component of NAWQA.

Surface water sampling in NAWQA will consist of fixed-station sampling, synoptic sampling, and selected reach studies. The high-flow samples and synoptic sampling are viewed as another unique and worthwhile aspect of NAWQA that is not part of ongoing water quality programs. Acquisition of adequate land-use data is an essential feature of NAWQA. However, the land-use data must be of adequate detail, available in a timely manner, and updated frequently.

Most importantly, the integration of ground water with surface water will require a new mindset for the USGS operational field teams. In the past, the surface water, ground water, and water quality personnel appear to have operated independently from one another. The new combined approach, which the committee endorses, poses a new challenge to the national headquarters staff to make sure that the degree of communication and integration necessary for a national assessment of surface water, ground water, and water quality actually occurs.

Now that each study unit represents a hydrologic system encompassing both surface water and ground water, the committee recommends that the USGS review the sampling strategy to ensure that comparable procedures and precision levels are used. The review may not require a major redesign of the sampling program, but it should consider three major items:

1. **the distribution and location of sampling sites for surface water and ground water**;
2. **quantification of the interaction between surface water and ground water; and**
3. **the water quality implications of these interactions**.

Rotational Versus Continual Data Collection

Description

As currently planned, NAWQA assessment activities will be conducted on a rotational or cyclical basis (i.e., with high and low activity periods for each study unit), rather than on a continual basis, for data collection and analysis (Hirsch et al., 1988). (See Figure 2.2.) Initially, this rotational structure will consist of five phases:

1. Project planning	1 year
2. Analysis of existing data (retrospective)	1 year
3. Intensive data collection and interpretation	3 years
4. Report completion	1 year
5. Low-level sampling and analysis	4 years

The project planning and retrospective phases actually overlap during the first 2 years of an initial assessment cycle. Some reconnaissance sampling also will occur during these first 2 years. After completion of the initial cycle in a particular study unit, the project planning and retrospective phases would require only one year. Thus, after the initial cycle, subsequent assessment cycles would consist of 4 years of high activity (intensive data collection, data analyses, and report preparation), followed by 4 years of low-level activity.

The program does provide for some flexibility, e.g., some study units may encounter conditions that justify extension of the

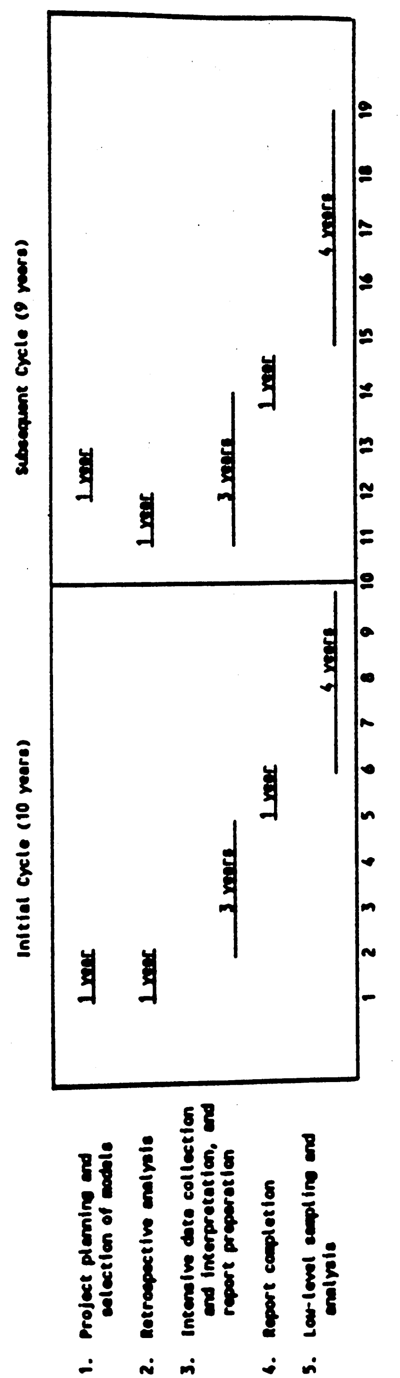

Figure 2.2
NAWQA rotational assessment of study unit.

normal 3-year intensive data collection period. It is also expected that federal or state cooperative programs or local agencies may conduct additional sampling and analysis activities during low-activity periods if circumstances warrant. The 60 study units will be divided into three groups of 20 selected to provide broad geographic coverage and a range of hydrologic conditions. The program will be staged so that only one group of 20 study units is in the intensive data collection and analysis phase at any given time.

Critique

There are several reasons for adopting a rotational, rather than a continual, data collection and analysis approach. First, using a rotational scheme, the USGS is able to cover a larger number of study units for a given staff size and budget. Second, the conditions and trends with which NAWQA is concerned develop relatively slowly. Third, as the USGS has emphasized, NAWQA is not designed to be only a long-term monitoring program (for which continual data collection and interpretation might be appropriate), but also an assessment of water quality trends. While NAWQA is intended to assess water quality conditions and trends, it is also designed to develop a scientific understanding of the factors that affect those conditions and trends. Thus, the emphasis of NAWQA is on producing timely interpretive reports focused on specific topics of regional and national interest.

Summary

While the committee agrees with this rationale for the rotational assessment approach, it recommends that the duration and staging aspects be reevaluated by the USGS and an external scientific advisory committee after completion of the first cycle of 20 study units. The committee recommends that extensions of intensive study be granted only for issues that are truly regional or national in scope. In addition, the committee recommends that the mathematical model for each study unit be selected in the first year of the cycle as part of the planning effort.

Choice of Chemical Constituents

Chemical and Physical Characteristics

Description

One of the key elements of the NAWQA design is the selection of a set of chemical and physical constituents to form the group of target variables on which the program will focus (Appendix B, #22). The chemical and physical data base emphasizes water quality degradation, such as that which occurs from non-point sources of contamination or from many point sources. National target variables consist of a common set of physical measurements, inorganic constituents and organic compounds to be measured by specified analytical methods. Study unit variables will be selected for each study unit by the project team and are a supplement to the national list. This flexibility of adding constituents will meet the needs of local and regional water quality issues.

The NAWQA program has selected a wide range of chemical and physical measurements to monitor in a nationally consistent manner. This broad-based list of water quality constituents will provide the data to assess a number of potentially national water quality issues, such as sedimentation, dissolved oxygen, nutrients (nitrogen and phosphorus), toxic substances, and bacteria levels. Table 2.3 summaries the general classes of compounds that will be measured in each of the various environmental compartments, i.e., ground water, surface water, bed material, tissues, and suspended sediment. The individual constituents to be measured in the surface and ground water samples are listed in Tables 2.4 to 2.6. Table 2.4 indicates those "core" constituents to be measured at all surface water sites, while Table 2.5 indicates the additional constituents to be measured seasonally during the first 12 months of the sampling period. These tables also indicate the "reporting level" for each constituent which is slightly higher than the detection limit of the method. Table 2.6 lists the constituents to be analyzed in ground water and shows the high degree of consistency between surface and ground water samples. The extensive list of pesticides, herbicides, and other volatile compounds to be measured is provided in Appendix C.

In addition to the chemical data described above, consistent records of ancillary information will be recorded on stream flow and basin characteristics, well and aquifer characteristics, and land use and other measures of human activity. Table 2.7 outlines the data to be gathered for wells which are sampled and is an example of the level of detail which will be documented by NAWQA.

The compounds and ancillary information to be monitored as well as the analytical methods to be used in NAWQA were selected by a group of scientists from both inside and outside the USGS. The inorganic and physical constituents were selected primarily on the basis of their effects on human health, ecosystems, and agriculture and on the relevance to water quality issues. Some constituents, such as many of the major ions in ground water, were

Table 2.3 Chemical and Physical Measurements to be Made in Various Environmental Matrices by National Water Quality Assessment Program

	Ground Water	Surface Water	Bed Material	Tissues	Suspended Sediment
Field Measurements (Temp, pH D.O.)	X	X			
Solids, dissolved and suspended		X			
Major ions	X	X			
Nutrients	X	X			
Trace metals	X	X	X	X	X
Organic carbon	X	X	X		
VOC's	X	X			
Semi-volatiles		X*	X	X	
Acid extractables		X*			
Org P pesticides		X*			
PCB's		X*	X	X	X*
Org C1 insecticides	X*	X*	X	X	X*
Carbamates	X	X			
Triazines, Org N pest.	X	X			
Chlorophenoxy herbicides	X	X			
Radionuclides	X	X			

* Only determined in those study units where reconnaissance sampling finds occurrence.

Table 2.4 Field measurements and constituents, to be determined in all surface-water samples collected from fixed stations as part of the pilot National Water-Quality Assessment Program

Compound	WATSTORE code	Reporting level
FIELD MEASUREMENTS		
ALKALINITY (mg/L as CaCO3)	00410	—
DISSOLVED OXYGEN		
PH (standard units)	00400	—
SPECIFIC CONDUCTANCE (umho/cm at 25)	00095	—
TEMPERATURE (degrees Celsius)	00010	—
MAJOR CONSTITUENTS		
CALCIUM, DIS. (mg/L as Ca)	00915	.02
MAGNESIUM, DIS. (mg/L as Mg)	00925	.01
SODIUM, DIS. (mg/L as Na)	00930	.20
POTASSIUM, DIS. (mg/L as K)	00935	.10
CHLORIDE, DIS. (mg/L as C1)	00940	.10
SOLIDS, R.O.E. AT 180'C (mg/L)	70300	1.00
SULFATE, DIS. (mg/L as SO4)	00945	.20
NUTRIENTS		
NITROGEN, DIS., NH4 + ORG (mg/L as N)	00623	.20
NITROGEN., NH4 + ORG (mg/L as N)	00625	.20
NITROGEN, DIS., NH4 (mg/l as N)	00608	.01
NITROGEN, DIS., NO2 + NO3 (mg/L as P)	00631	.10
PHOSPHORUS, DIS., ORTHO (mg/L as P)	00671	.01
PHOSPHORUS, TOT., (mg/L as p)	00665	.01
TRACE ELEMENTS		
ARSENIC, DIS. (ug/L AS As)	01000	1.0
ARSENIC, SUS., TOT. (ug/g as As)*		1.0
CADMIUM, DIS. (ug/L as Cd)	01025	0.1
CADMIUM, SUS., TOT. (ug/g as Cd)* CADMIUM		0.2
CHROMIUM, DIS. (ug/L as Cr)	01030	0.5
CHROMIUM, SUS., TOT. (ug/g as Cr)* CHROMIUM		1.0
COPPER, DIS. (ug/L as Cu)	01040	0.5
COPPER, SUS., TOT. (ug/g as Cu)* COPPER		0.7
LEAD, DIS. (ug/l as Pb)	01049	0.5
LEAD, SUS., TOT. (ug/g as Pb)* LEAD		7.0
MERCURY, DIS. (ug/L as Hg)	71890	0.1
MERCURY, SUS., TOT. (ug/g as Hg)**		1.0

Compound	WATSTORE code	Reporting level
SEDIMENT		
SUSPENDED SEDIMENT (ug/L)	80154	
PERCENT FINER THAN 0.062 mm	70331	
ORGANIC CARBON		
CARBON, ORG., DIS. (ug/L as C)	00681	0.1
CARBON, ORG., SUS. (ug/L as C)	00689	0.1

* Suspended, Total = Total digestion being made on the suspended sediment.
** Mercury, SUS, TOT = Digestion with HNO_3 and Na, Cr_2, 0_7. Source: Wilber, W., personal communication to M. Conditt of Procter and Gamble, 1990.

Table 2.5 Field measurements and constituents, to be determined seasonally at fixed stations during the first 12 months of operation as part of the National Water-Quality Assessment Program

Compound	WATSTORE code	Reporting level
FIELD MEASUREMENTS		
ACIDITY (mg/L as H)	71825	———
MAJOR CONSTITUENTS		
BROMIDE, DIS. (mg/L as Br)	71870	0.01
FLUORIDE, DIS. (mg/L as F)	00950	0.10
MAJOR METALS AND THACE ELEMENTS		
ALUMINUM, DIS. (ug/L as Al)	01106	10-20
ALUMINUM, SUS., TOT. (ug/g as Al)*		20.00
ANTIMONY, DIS. (ug/L as Sb)	01095	1.00
ANTIMONY, SUS., TOT. (ug/g as Sb)*		1.00
BARIUM, DIS. (ug/L as Ba)	01005	2.00
BARIUM, SUS., TOT. (ug/g as Ba)*		1.00
BERYLLIUM, DIS. (ug/L as Be)	01010	.50
BERYLLIUM, SUS., TOT. (ug/g as Be)*		.70
BORON, DIS. (ug/L as B)	01020	1.00
BORON, SUS., TOT. (ug/g as B)*		2.00
MOLYBDENUM, DIS. (ug/L as Mo)	01060	10.00
MOLYBDENUM, SUS., (ug/g as Mo)*		2.00
NICKEL, DIS. (ug/l as Ni)	01065	5-10
NICKEL, SUS., TOT. (ug/g as Ni)*		0.70
SELENIUM, DIS. (ug/L as Se)	01145	1.00
SELENIUM, SUS., TOT. (ug/g as Se)*		5.00
SILVER, DIS. (ug/L as Ag)	01075	2-10
SILVER, SUS., TOT. (ug/g as Ag)*		0.20
VANADIUM, DIS. (ug/L as V)	01085	6.00
VANADIUM, SUS., TOT. (ug/g as V)*		1.00
ZINC, DIS. (ug/L as Zn)	01090	3.00
ZINC, SUS., TOT. (ug/g as Zn)*		0.01
IRON, DIS. (ug/L as Fe)	01046	10.00
IRON, SUS., TOT. (ug/g as Fe)*		3.00
MANGANESE, DIS. (ug/L as Mn)	01056	1.00
MANGANESE, SUS., TOT. (ug/g as Mn)*		0.70
OTHER		
GYANIDE, DIS. (mg/L as CN)	00723	0.01
GROSS alpha RAD, DIS. (mg/L as U, natural)	80030	0.40
GROSS ALPHA as U natural		
FILTRATION, laboratory	———	0.40
GROSS beta HAD, DIS. (pGi/L as SR-90/ Y-90 natural)	0050	0.40

Compound	WATSTORE code	Reporting level
GROSS BETA pCi/L as Cs-137		
GROSS alpha RAD, SUS. (mg/g as U, natural)	80040	0.40
GROSS beta RAD, SUS. (pCi/g as SR-90/ Y-90 natural)	80060	0.40
RADON-222 (50 pCi/L)		

* Suspended, Total = Total digestion being made on the suspended sediments.
Source: Wilber, W. personal communication to M. Conditt, Procter and Gamble, 1990.

Table 2.6 Water-quality constituents to be included in sample analysis for all three ground water pilot projects, National Water-Quality Assessment Program

Constituent(s)	Laboratory code (LC) or schedule number (SH)
Properties and major constituents	
pH	LC0068
Specific conductance	LC0069
Alkalinity	LC0070
Calcium	SH1043
Magnesium	SH1043
Potassium	LC0054
Sodium	SH1043
Chloride	LC1213
Fluoride	SH1043
Sulfate	LC1200
Silica,	SH1043
Nutrients	
Ammonia	LC0301
Nitrite	LC0160
Nitrite and nitrate	LC0228
Kjeldahl nitrogen (ammonia plus organic nitrogen)	LC0268
Orthophosphate phosphorus	LC0162
Major metals and trace elements	
Antimony	LC0077
Arsenic	LC0112
Barium	SH1043
Beryllium	SH1043
Boron	SH1043
Cadmium	SH1043
Chromium	SH1043
Cobalt	SH1043
Copper	SH1043
Iron	SH1043
Lead	SH1043
Lithium	SH1043
Manganese	SH1043
Mercury	LC0225
Molybdenum	SH1043
Nickel	SH1043
Selenium	LC0087
Silver	SH1043
Strontium	SH1043
Vanadium	SH1043
Zinc	SH1043

Constituent(s)	Laboratory code (LC) or schedule number (SH)
Radionuclides	
Gross alpha	SH0456 or SH0458[2]
Gross beta	SH0456 or SH0458[2]
Radon-222	LC1369
Tritium[1]	LC0624 or LC1043[3]
Organic compounds	
Dissolved organic carbon	LC0113
Volatile organic compounds	SH1380
Carbamate insecticides	SH1359
Chlorophenoxy-acid herbicides	SH0079
Nitrogen-containing pesticides (largely triazine herbicides)	SH1389
Stable isotope ratios	
Deuterium/protium[1]	LC0300
Oxygen-18/oxygen-16[1]	LC0489

[1] Samples should be collected and stored at project office for possible analysis later.
[2] Use SH046 if estimated concentration of dissolved solids is less than 250 mg/L and SH0458
[3] Appropriate laboratory method depends on use of date (Robert Michel, U.S. Geological Survey, written communication, 1988).
Source: Wilber, W. personal communication to M. Conditt, Procter and Gamble, 1990.

Table 2.7 Site characteristics for sampled wells in the National Water Quality Assessment Program

Unique site identification number
Type of site (well, drain, and others)
Data reliability
Project identification number
District, state, and county codes
Latitude and longitude of site
Altitude of land surface
Topographic setting
Use of site (observation well, withdrawal well, and so forth)
Primary use of water
Aquifer name code
Aquifer type code (unconfined, confined, mixed)
Depth of well
Water level
Depth to top and bottom of each open interval
Depth to top and bottom of each geohydrologic unit
Rated pump capacity
Type of lift
Date of well construction
Method of construction
Type of finch
Type of surface seal
Casing material
Sampling method
Primary reason for well selection (with or without regard to known or suspected local problem areas)
Occurrence of various land uses and local features such as gas stations and septic tanks within a 100 ft and 1/4 mi radius of the sampling well
Predominant land use within 100 ft radius of the sampling well
Predominant land use within 1/4 mi radius of the sampling well
Percent of total area within a 1/4 mi radius of the well that consists of predominant land use
Known occurrences of major changes in land use near the well within the last decade
Local agricultural practices

Source: Hirsch et al., 1988.

selected to provide information on the geochemical environment associated with each sample. The list of organic constituents was selected by examining several broad-spectrum methods that were capable of detecting several target compounds at once and by reviewing the EPA priority pollutant list as well as the Safe Drinking Water Act. A comparison was made of the list of chemical constituents measured in NAWQA with those measured in EPA, the National Oceanic and Atmospheric Administration (NOAA), and the Fish and Wildlife Service programs (Tables 3.2 and 3.3, Appendix C), and attention was given to complementing the other programs rather than duplicating their analyses. In general, the suites of synthetic organic compounds to be measured in surface water will be different than those for ground water. Also, reconnaissance level sampling will be done to determine whether a particular group of organic compounds needs to be measured more extensively. Importantly, as knowledge and technology in trace organic analysis improves with time, the list of organic targets may be modified.

Critique

The NAWQA program has selected a broad-based list of physical and chemical constituents, which will allow a number of potential water quality issues to be addressed. The list of constituents is thorough and well thought out. A group of scientists from both inside and outside the USGS studied and selected the constituents and methods while considering the efforts of other environmental agencies and striving to complement the other programs (Rickert, personal communication, 1989). NAWQA has properly selected hydrophilic compounds to measure in the water samples and selected hydrophobic compounds to measure in tissues based upon their octanol/water partition coefficients.

One decision by NAWQA program personnel was to not add dioxin and furans (Table 3.3, Appendix C) to the NAWQA list of constituents because of the prohibitive cost and the small number of labs that perform analysis. The committee agrees that this is a wise choice since the EPA already gathers extensive dioxin data; however, the EPA's dioxin data should be included in NAWQA's retrospective reports.

The committee urges a strong coordination between biologists and chemists at the study unit level role so that the choice of sites for ecological sampling should be well coordinated with sites chosen for physical and chemical monitoring in NAWQA. Analysis of the same toxic trace metals and organics in water and tissue samples will help correlate exposure to bioaccumulation. Also, in the determination of pesticides in fish, the same constituent should be measured in both water and sediment to get a distribution of the pesticide into the various environmental compartments.

If a regional study issue is believed to be a national issue, then a USGS oversight committee should determine whether it is appropriate to pursue that issue on a national scale. This flexibility will also enable the NAWQA program to detect emerging water quality issues rather than focus on the classical or current water quality constituents.

In order to evaluate those emerging water quality problems, the USGS should consider a library archive of spectroscopic data, such as ultraviolet (UV), infrared (IR), nuclear magnetic resonance (NMR), or gas chromatograph/mass spectrometer (GC/MS) scans, from sample extracts so that years from now, when a new chemical issue emerges, the fingerprints will provide some clue as to the background levels or magnitude of the problem. We cannot know today what the water quality issues of the year 2000 are going to be; thus archived spectroscopic information would be very useful.

A real strength of NAWQA lies in the nationally consistent data gathered from sensitive, consistent analytical methods. This will allow water quality data to be compared across the United States for many years. This consistency is the key to making long-term assessments.

Summary

The committee agrees with the choice of chemical and physical constituents selected for the NAWQA pilot program. The consistent water quality data base across the nation will be a real strength of the program. Also, the flexibility of NAWQA to add constituents of local or regional interest will facilitate the identification of emerging water quality issues.

Therefore, the committee recommends the following:

- **The EPA's dioxin data, as well as other pertinent water quality data, should be included in the USGS retrospective reports**.
- **A strong coordination role should be created to manage the integration of ecological data with chemical and physical data collection**.
- **An oversight committee should review the constituents that are added at the regional level to determine if a regional water quality problem is really a national problem**.
- **The USGS should consider establishing a library archive of spectroscopic fingerprints of all water samples**.

Choice of Biological Constituents

Description

To accomplish the stated goals of NAWQA, it will be essential to combine the results of physical, chemical, and biological studies. Biological studies in NAWQA will attempt to meet the following goals:

1. Determine the occurrence and distribution of fecal contamination through synoptic surveys for focal indicator bacteria.
2. Determine the occurrence (and bioavailability) of potentially toxic trace elements and synthetic organic compounds through animal and plant tissue analysis.
3. Assess the relations between physical and chemical characteristics of streams and functional or structural aspects of the biological community through ecological surveys.
4. Define and quantify biological processes that affect physical and chemical aspects of water quality (Appendix B, #29).

Fecal contamination will be assessed in NAWQA with analyses of available information and by measuring concentrations of Escherichia coli (E. coli) during each of the 3 years of the active phase as part of annual synoptic surveys. The objectives of these surveys are to describe the occurrence and distribution of E. coli within surface waters of the study unit and to relate them to patterns of land use and waste management practices. The techniques for doing this have been described in a protocol (Appendix B, #30) and used in surface water pilot projects. The synoptic survey conducted during the pilot phase of the Yakima project (Appendix B, #69) provides an example of the results of such a survey.

Sampling for contaminants in tissues in NAWQA will be done in three phases: reconnaissance, synoptic, and nonintensive. During the first phase, samples from relatively few sites will be tested for a large number of contaminants. In the second phase (intensive sampling phase) samples from more sites will be tested for a limited set of contaminants. The tissue analysis protocol (Appendix B, #31) sets out a decision tree to be utilized in determining which species to sample at a site. This will result in a suite of target species for the national survey. The introduced and widely distributed Asiatic clam, Corbicula fluminca, will be the target species where it is present. Other mollusc species will be second choice, then fish species, aquatic insects, and last, submersed macrophytes.

The objective of the ecological survey in NAWQA is to document the current status and long-term trends in biological communities and to provide background ecological information to complement other NAWQA measurements. The protocol (Appendix B, #33) proposes a core set of a few measurements using similar approaches in all study units at sites similarly selected. Stage I sampling will be done in year I of the active phase and will include reconnaissance sampling of 30 to 50 sites with qualitative sampling of benthic invertebrates. Stage II sampling will be done at about 15 sites during years 2 and 3 with sampling for fish abundance and diversity once per year. In addition to the sites used for synoptic sampling in other parts of NAWQA, sites used in the ecological survey will also include low (first through third) order sites selected in pairs so that one member represents a reference site, and the second is representative of a particular type of land use. Quantitative description of habitats (e.g. descriptions of riparian vegetation, bank and substrate characteristics, photo documentation) will be assessed at each site.

Critique

Fecal Contamination

The presence of fecal contamination in surface and ground water has routinely been estimated using either the total or, more commonly in the recent past, the fecal coliform test (American Public Health Association, 1989). Thus the vast majority of historical sanitary data is reported as total or fecal coliform. However, the NAWQA program proposes to assess the sanitary quality of surface water by testing specifically for the presence of the bacterium E. coli. This bacterium is associated with the feces of warm blooded animals, including humans, and makes up an important subset of coliforms which are measured in the fecal coliform test.

This method has been chosen by NAWQA because the EPA has found a better statistical correlation between suspected gastrointestinal diseases among swimmers and the E. coli test results than with the number of fecal coliforms found in the nonmarine bathing waters tested (Dufour, 1984). On this basis, the use of this test for the NAWQA program is justified.

Because historical data as well as data currently being collected by other agencies are reported in terms of total or fecal coliforms, there is concern that the use of the E. Coli test alone will provide information which cannot be compared to prior bacteriological water quality analyses. If such comparisons are warranted then it will be necessary to perform the more traditional fetal coliform tests as well as the E. Coli test.

The protocol developed for the detection of fecal contamination (Appendix B, #30) provides a clear description of the techniques to be used. If all projects follow that protocol, the data should be comparable within the program. For synoptic surveys to be of maximum value, fetal contamination should be assessed at the same time as synoptic sampling for nutrients and dissolved oxygen.

The frequency of monitoring for fetal contamination should be such that (1) statistical variations in the collected data can be considered in evaluating differences between stations, (2) at critical sites where fetal contamination and human exposure vary seasonally, such variation can be evaluated, and (3) the impact of changes in wastewater discharge practices (such as a change in chlorination practices) can be assessed. Clearly only one sample per year per station will be of limited value in addressing these issues. Monthly sampling at selected fixed stations in addition to that done during synoptic surveys is recommended.

To date NAWQA has collected data concerning fetal contamination in only one study unit during one synoptic survey (Appendix B, #69). **Therefore, it is too early for the committee to evaluate the ability of the program to provide regional or national assessments or to evaluate long-term trends**.

Tissue Analyses

Biological tissues provide the best information about the availability of contaminants to the biota, provide a time-averaged assessment of contaminants, and increase the probability of detecting trace contaminants because of higher concentrations in tissues (Appendix B, #29 and 31). The protocol describing how tissue analysis will be used in NAWQA (Appendix B, #31) provides an excellent summary of existing tissue monitoring, a clear rationale for choice of contaminants to be analyzed, a decision tree to use in selecting target species, and a detailed protocol for sampling tissue removal and sample preservation. A fully implemented NAWQA could fill an existing void in tissue monitoring programs because of the broad coverage of freshwaters, consistency in target species sampled, and its ability to relate contaminants in tissue samples to other physical, chemical, and biological data at the site.

Field testing of this protocol in the Yakima and Illinois River pilot projects began only recently (summer 1989). Samples located were sent to laboratories under contract to the U.S. Fish and Wildlife Service (USFWS), which is also responsible for quality control. Since the results of this work will not be available until summer 1990, the committee cannot evaluate this component of the effort, although it seems to be a wise decision to use the USFWS labs so that the data will be compatible and complementary to those being collected as part of the National Contaminant Biomonitoring Program (NCBP).

The U.S. Geological Survey has also begun discussions with the National Institute of Standards and Technology (NIST) regarding long-term cryogenic storage of tissue samples. The archiving of carefully selected samples is a critical component of any long-term monitoring program. It is impossible to determine what substances will be contaminant problems in the future, and hence it is essential that considerable attention be paid to archiving samples that will be useful for future analyses. The USGS should adopt protocols for procedures to use for archiving samples and maintaining the archives. Equally important is devising protocols to guide study units in selecting how many and which samples are to be archived. Archiving samples is costly; hence researchers at sampling sites must be judicious in their choices of samples to archive. Samples should be archived from currently contaminated as well as reference sites. It may be wise to make the number of samples to be stored a function of the variability observed at the site rather than simply archiving a fixed percentage at all sites.

Based on a careful assessment of the literature (Appendix B, #32), the USGS has decided not to include toxicity testing as a routine part of NAWQA. Toxicity testing is not appropriate for a long-term monitoring program at this time because:

- tests results are procedure and species dependent,
- experimental systems do not adequately duplicate the complexity or variability of natural systems, and
- tests are often not adequately sensitive.

Ecological Surveys

The inclusion of an ecological survey in NAWQA is an important addition to the more traditional physical and chemical measures of water quality. The biota provide an integrated picture of water quality because they are exposed to the range of stresses at a site and may respond to a short-term change in water quality (e.g., a spill) that would be missed by the routine sampling effort. In addition, sensitivity to different stresses varies across taxonomic groups. Hence, an assessment of the biotic community offers a level of interpretation not available with only physical or chemical measures of water quality. Furthermore, much of the public concern over water quality stems from a desire for the protection of public health and aquatic life, and it is valuable to include these aspects in a water quality monitoring program.

It is clear that the ecological survey portion of the program is still in the methods development phase. Preliminary field sampling (Appendix B, #55) has provided some useful insights on using fish as indicators of water quality. However, there are no data with which to judge the appropriateness of methods proposed for invertebrates, algae, or habitat documentation. In the material reviewed by the committee, there has been no discussion of how the biological data collected will be incorporated into a national or even regional synthesis. Despite considerable recent progress, the biological component of NAWQA lags behind other aspects. Effort has been put into designing appropriate sampling protocols, and it is now time to provide examples of how these data are to be interpreted to provide a regional and national synthesis. Future NAWQA review committees will need to consider how well this sampling program meets the described objectives. This committee did not have the data necessary to make this assessment.

Biological Processes Affecting Water Quality

Measurements of the rates of biogeochemical processes (e.g., nitrification and denitrification) controlling concentrations of elements in water will not be a routine part of NAWQA (Appendix B, #29). They may be included as a part of selected reach studies if the problem warrants their inclusion. The decision not to include these measurements is a consequence of fiscal constraints and lack of agreement among scientists as to the best techniques to use. The absence of these measures will limit the ability to develop mechanistic models of transformations at NAWQA study sites and will limit the ability of the NAWQA program to understand some of the aspects of cause and effect relationships. The extent to which modeling and understanding will be limited will depend on local conditions and could be anticipated by the early application of models in the study unit.

Summary

Fecal contamination will be assessed using the E. coli test. **Because the use of this method will limit the ability of NAWQA teams to relate their data either to historical patterns or to concurrent measurements made by other agencies, the committee recommends that parallel standard tests for the presence of fecal coliform also be made. To provide a measure of temporal variation in**

fecal contamination, the committee recommends including monthly E. coli and fecal coliform tests at a limited number of fixed-station sites in study units where fecal contamination is a potential problem. The procedures for analysis of contaminants in tissues appear adequate to provide an assessment of tissue contamination that fills a void in existing tissue monitoring programs.

The committee recommends that USGS adopt protocols for archiving and maintaining tissue samples, and that they devise protocols to guide site personnel in selecting how many and which samples to archive. The ecological survey will use a core set of measurements (e.g., algal biomass, invertebrate and fish abundance and diversity, and habitat characterization) to document the current status and long-term trends in biological communities. The inclusion of an ecological survey is a valuable addition to NAWQA. **Because there are few data from the pilot projects with which to evaluate the ability of the tissue monitoring and ecological survey efforts to meet the stated objectives, the committee recommends that another scientific advisory group review this component of the program when more data are available**.

Quality Assurance/Quality Control

Description

The NAWQA's quality assurance (QA) program consists of a matrix of record keeping, methods and prototype validation, and standardized field and laboratory activities which will be consistent across the NAWQA network (Mattraw et al., 1989). The QA program requires that:

1. data collection activities follow USGS approved methods,
2. data analysis and interpretation procedures are documented and capable of being verified, and
3. reports are technically and editorially sound and consistent with USGS policies.

Quality assurance will employ the following:

1. field blanks to deal with contamination,
2. field spikes to deal with degradation of sample constituents,
3. multiple samples at the same time and location to deal with sampling precision,

4. splits of collected samples sent for lab analyses to account for lab precision, and
5. standard samples sent as unknown samples to lab to account for lab accuracy.

In terms of personnel, one full-time person will be responsible for QA on the headquarters staff, and one person per regional GNAW team will be assigned to oversee QA on all the projects within that region (D. Ricer, personal communication 1989). Most of the laboratory analyses for the NAWQA pilot program have been provided by the National Water Quality Laboratory (NWQL). The Branch of Quality Assurance (BQA) has two responsibilities:

1. developing, implementing, monitoring, and updating a water resources division-wide QA program that addresses sample collection, field measurements, laboratory analysis, and data management; and
2. providing technical administrative guidance to field, laboratory, and data base QA programs.

The BQA had responsibility for providing an unbiased, external review of the QA program associated with the pilot NAWQA program. As of this writing (2/90—confirmed with W. Wilber via telephone conversation), a decision has not yet been made to use either a government owned, contractor operated (GOCO) or an in-house operation for lab analyses. Several of the USGS personnel would like to retain the in-house operation. Based on an economic analysis (W. Wilber and W. Alley, personal communication 1989), it would be less expensive to use in-house lab analyses because a GOCO operation would require an additional 5 percent of current laboratory support.

The pilot projects underwent periodic review to ensure that the quality of the data, interpretations, and reports met the standard of the USGS. Periodic reviews provided an objective assessment of the effectiveness of project work activities, procedures, and documentation. These reviews were conducted by a review team consisting of members from the regions, headquarters, BQA, National Research Program (NRP), and other districts. Each team prepared a report summarizing their findings from the review. The reviews were thorough and followed the quality assurance checklist for surface-water projects or the checklist for ground water projects.

Each major element of the study unit plan was examined for adherence to the QA/QC procedures. The data were examined for completeness and conformance to information management guidelines. Laboratory QA samples were checked against NAWQA minimum standards and for proper review and (if needed) action.

Critique

The USGS appears to be committed to a sound practice of quality assurance and quality control. The QA program assures that technically sound procedures will be used in the NAWQA program.

The reviews demonstrated that the proposed QA/QC program is working in the study units. The review process provided a complete examination of the QA/QC program in the study unit. It identified deficiencies and actions to correct them. In addition, the reviews identified areas where additional national guidance should be considered to aid the study units. The following were items mentioned in more than one study unit review:

1. concerns with aspects of low-level trace organic analyses;
2. the need for national archival guidelines; and
3. more guidance on how to evaluate the QA laboratory samples. The site review program is an effective process for assuring the integrity of the NAWQA quality assurance program.

Summary

The proposed QA plan is a sound approach for managing the NAWQA data bases to ensure utility and longevity beyond the first rotation of sites. In the full NAWQA program, periodic data base reviews will need to be continued to ensure completeness and accuracy of data. **The results of all the pilot project audits should be reviewed for recurring areas of concern—particularly with monitoring for low-level organic compounds.** The committee believes that the QA program is a strong component of the NAWQA program. For the program's stated purposes it is desirable to have one agency, preferably a nonregulatory agency, responsible for a program of this scale. Consistency of sampling protocols and data collection will aid in analysis and be essential for timely and meaningful interpretation and synthesis. **It is important that the headquarters person in charge of QA be in regular communication with the four regional NAWQA QA personnel to coordinate their activities closely, thereby ensuring that comparable standards and practices are being employed across the full NAWQA network of sites.**

There is a lack of consistency in terms of water quality data collected by federal agencies. In the EPA 305(b) program, each state defines its water quality issues (USEPA, 1989). **The committee would like to see more coordination of the NAWQA program with other agencies, especially in such areas as uniformity of water quality parameters monitored and more consistent sampling and analytical techniques**. The NAWQA program has the advantage over EPA's 305(b) program owing to its coordinated effort among the four USGS regions in terms of data collection protocols and methods. While local issues are important, the committee believes that the national synthesis planned in NAWQA will be a contribution. **In time, after a full NAWQA has been operational, it would be desirable for the USGS to determine how much overlap exists between the two programs, NAWQA and 305(b) to avoid costly duplication of effort. At the very least, both agencies should have access to the data from both programs**.

Data Management

Description

For data management (i.e., data documentation, collection, archiving, and retrieval), the pilot studies have used the USGS National Water Data Storage Retrieval System (WATSTORE) and the National Water Information System (NWIS) data bases, which are periodically transferred to EPA's STORET system. For the full NAWQA program, a new system, NWIS-2, is being designed and is targeted for operation in FY 1992. The development of this system is currently under way as part of the upgrading of computer resources for the Water Resources Division of the USGS.

Critique

WATSTORE is on a 15-year-old Amdahl Computer, which uses outdated computer technology from the 1960s and 70s (W. Wilber, personal communication 1989). People unfamiliar with WATSTORE have great difficulty using the system. As part of the computer upgrade mentioned above, the USGS is developing specifications for a new water quality information system. Eventually, NWIS-2 will replace WATSTORE (W. Wilber, personal communication 1989). Currently, state data bases are on Prime computers that are uploaded to the national WATSTORE system and are periodically transferred to EPA's STORET system. It is not clear whether the new system will handle the Geographical Information System (GIS) data any differently from what was done in the pilot studies. The committee endorses the revamping of WATSTORE and encourages the USGS to work quickly to develop and implement NWIS-2.

The NAWQA criterion for acceptable storage and documentation is to ensure that the data records and documentation will be useful to a succeeding project team 6 or more years after completion of the initial investigative phase (i.e., beyond the first cycle of activity). In addition to the sanitary water quality data, the ecological survey is documenting the current status of the biological community (fish and invertebrate distribution data and tissue sampling for bioaccumulation) at each NAWQA site to provide a basis of the spatial variation and assess long-term changes in the biological community. The data management plan for the Ecological Survey is currently being revised.

Sharing information and data files with the USGS within the scientific community is not easy because very few of the USGS personnel are connected to the Internet, a collection of local networks (campus, governmental, and industrial) linked together by regional networks and attached to a national backbone (NSF Net). The purpose of the Internet is to provide high-speed communication among members of the scientific community and to provide access to remote computing resources. Linking the USGS scientists to the scientific community via Internet would facilitate greater collaboration and coordination.

Summary

The committee believes it would be much easier to communicate with the USGS if their personnel and their computers had access to the Internet system. This would facilitate better coordination with universities and other research facilities and agencies. The committee endorses the revamping of WATSTORE and encourages the USGS to work quickly to develop and implement their new national water information system.

ANALYTICAL FRAMEWORK

Description

For reasons discussed in Chapter 1, the committee firmly believes that a national assessment of our nation's waters must take a strong process-oriented approach. Such an approach improves basic understanding of the physical, chemical, and biological processes that contribute to water quality and is essential to intelligent water-resource management. The committee further believes that the basic design of NAWQA is strongly process-oriented, and that the USGS is well suited to execute such a design.

Much of the NAWQA design reflects an emphasis on hydrological processes. Study units are based on hydrological boundaries. Monitoring locations will be determined based on understanding of the relevant flow system. Synoptic surface water surveys provide opportunities to sample distinct hydrological events. Reach studies and local-scale transects enable detailed analysis of important subsystems. The integration of surface water and ground water studies provides sorely needed opportunities to understand the important interactions between surface and ground waters.

The USGS is ideally suited to conduct a process-oriented assessment of our nation's waters. The overall mission of the USGS is to provide information that will assist resource managers and policy-makers at the federal, state, and local levels in making sound decisions. This information is generated through assessments of the quantity and quality of the nation's natural resources, including minerals, energy resources, and water. In the case of water resources, the USGS has collected and interpreted data on water quantity and quality for more than 100 years. While many of these investigations have been relatively small in scale, a significant number have been comparable to a NAWQA study unit. A notable example is the ongoing study of selenium in the San Joaquin Valley in California (Gilliom, et al., 1989.) The committee reviewed the activities of the USGS in this study and was favorably impressed with the scientific understanding that has resulted. Furthermore, it is clear to the committee that without such understanding, management strategies in the region would be poorly grounded.

The strength of the USGS in conducting a process-oriented assessment of our nation's waters lies in the fact that it has well-trained, personnel representing a variety of disciplines dispersed throughout the nation. This means that a particular study-unit investigation will not be starting from scratch, since it will have access to personnel who understand the local and regional hydrology. Given the enormous variation of the hydrologic processes through the nation, such expertise is critical.

Therefore, the committee believes that the NAWQA design has a strong process orientation, and that the USGS is well suited to execute the design. However, in the course of evaluating the NAWQA program, the committee also concluded that the ability of NAWQA to elucidate hydrologic processes should be strengthened by a greater reliance on mathematical modeling. This issue is discussed in the subsequent sections.

Critique

An important feature that appears to be lacking from the overall NAWQA program, particularly the regional pilot studies, is the quantitative and analytical framework that identifies the principal cause and effect relationships. While this issue has been qualitatively addressed in NAWQA documents and in comments by USGS personnel, its quantitative definition, which is essential for decisionmaking, appears to be inadequate at this stage. The link between sources, both point and distributed, and the water quality response of a particular system, can be provided by a mathematical model that defines the spatial and temporal distribution of the concentration of relevant water quality constituents. The formulation of such a model should be an integral part of the individual studies. Although it has been stated or suggested that some kind of modeling would follow the data collection, there remains a reasonable question that this task may not be effectively realized. More importantly, the structuring of a quantitative model should be incorporated in the early phase of each project, to whatever degree is possible given the nature of the problem and available data.

The use of models can serve many purposes in NAWQA. First, a model provides a tool for organizing what is known about a given system, at the scale of interest. Consequently, a model also serves to reveal gaps in knowledge. A model can be used to predict what should be the critical factors affecting water quality (e.g., point versus nonpoint sources). This information can be used in designing the sampling strategy. Once data have been collected, they in turn can be used to refine the model. A model provides a way to account explicitly for meteorologic and hydrologic variations. This makes it much easier to resolve water quality impacts caused by other factors, such as human activities. It also makes it possible to extrapolate for conditions other than those observed during the sampling period. A model can be used to simulate water quality for different scenarios of human activity. Such a capability is essential for evaluating hypothetical management options and is also useful in evaluating the impact of past management practices.

Thus, water quality modeling can be used in all phases of water quality assessment, including design of the monitoring program, analysis of data, and evaluation of past and potential management options. Of particular importance is the interactive nature of modeling and data collection. These activities are mutually supportive, and each should evolve throughout the assessment process. This will lead to a better assessment, as well as to an improved understanding of the relevant physical, chemical, and biological processes.

Just as we recognize the necessity for using models in NAWQA, we also realize that the state-of-the-art in water quality modeling may have to be improved if models are to be used effectively in support of NAWQA. While a number of excellent surface water quality models are widely used for management purposes, most notably those supported by EPA, the applicability of these models to large spatial scale water quality assessment is unclear. Existing surface water models were designed to be used at relatively small scales and are most commonly applied to evaluate compliance with standards under hypothetical flow conditions (such as the 7-day, 10-year low flow). In comparison, NAWQA study-unit investigations will be conducted at enormous scales and will involve a very large suite of water quality constituents over a wide range of flow conditions. With respect to ground water, the USGS has played a leading role in developing models of both flow and quality. Of particular importance is the large-scale flow modeling that was undertaken by the USGS in the RASA program. These models should provide a framework for ground water modeling in many of the NAWQA study units (and in fact, have been used this way to some extent in the pilot studies). What remains, of course, is the incorporation of water quality into these models. A more difficult challenge is the integration of surface water and ground water modeling.

Given the lack of appropriate existing models in some cases, the USGS's inexperience in most cases, and the considerable difficulty of the task, some models will prove inadequate or infeasible. Therefore, a midcourse model evaluation should be built into the assessment cycle so that corrections can be made in sufficient time.

Summary

Water quality modeling should be an essential component of NAWQA. **In the short term, the USGS should make use of existing models**. Because the USGS has relatively little experience with existing surface water quality models, it **will need to begin immediately to provide or obtain the necessary training**. There is also a critical need to determine the data required by these models, since the current NAWQA design may not include collection of necessary data. (For example, there is no plan to collect meteorological data, which will be essential for watershed models of water quality.) **During the first round of intensive monitoring, the leading water quality models should be applied over a wide range of situations. This would not only enhance the assessment effort, but would also provide valuable information on the capabilities of the models. A midcourse model evaluation should be built into the assessment cycle so that corrections can be made in sufficient time**.

Over the long term, the USGS should be developing a coherent strategy for water quality modeling in the context of a large spatial scale assessment, addressing such issues as scale, model complexity, and surface and ground water interactions. To the fullest extent possible, this should be done in cooperation with other federal agencies, particularly the Environmental Protection Agency.

PRODUCTS

Description

The goals of NAWQA are to "describe the status and trends in the quality of the nation's surface and ground water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources" (Appendix B, #36) in order to "provide an improved scientific basis for evaluating the effectiveness of water quality management programs and for predicting the likely effects of contemplated changes in land and water management practices" (Appendix B, #38). Essential to achieving this goal of improving the evaluation and prediction of the consequences of management practices is the dissemination of the results of NAWQA to the appropriate audiences.

The USGS has proposed three broad classes of report topics to be prepared under NAWQA (Appendix B, #38):

1. statistical descriptions of water quality conditions and changes over time,
2. information on the geographic distribution of contaminants across the United States, and
3. information on key factors that affect water quality.

It is the committee's understanding that this information will be provided in USGS water-supply papers, open-file reports, water resources investigations reports, yearbook articles, and other publications, as well as in scholarly journal articles. For example, each pilot project has been assigned a Water-Supply Paper number. The "A" chapter of each will be a project summary, the "B" chapter will be a retrospective report (see below), and later chapters will be specific to each study unit (Appendix B, #37). Presentation methods in these reports will include tables, graphs, maps, and supporting text. Raw data will be available via a single, consistent computer data base. Similar products are to be prepared for both the study-unit investigations and the issue-based and national synthesis team studies.

Unfortunately, because of the timing of the committee's review, no NAWQA reports presenting results at either the study-unit or synthesis level were available for review, with the exception of retrospective reports for 5 of the pilot projects (Appendix B, #62, 70, 79, 83, 89). Therefore, our evaluation of NAWQA products is necessarily broad and general for the most part. The retrospective reports available for review focus on compiling available existing data from federal, state, and local agencies, evaluating the suitability of these data for NAWQA study unit activities, and presenting a preliminary spatial analysis of water quality conditions in the study unit via mapping, summary statistics, and descriptive text. They also contain background material of the study unit, its natural and cultural features, and its hydrologic systems.

Critique

The retrospective reports available for review have been prepared and designed well, and should serve the purpose for which they were intended. During their visits to the pilot projects, committee members were frequently told that the compilation of all available data into one documented source and data base was by itself a significant contribution to local decisionmaking. The reports do exhibit some unevenness in the quality of their analyses, with some study-unit teams apparently being more capable and creative than others in extracting and presenting useful information from the available data.

After examining the more general aspects of the planned products of NAWQA, the committee first noted that the maps and reports at the USGS are in general highly respected among the potential users of NAWQA. Potential users interviewed by the committee were practically unanimous in that opinion. In fact, some local and state users made the point that data and information provided by the USGS will be far more helpful to them in their water quality management responsibilities than data and information acquired by the users themselves because local and state governmental authorities have such high regard for the integrity of the USGS.

One concern brought to the attention of the committee during its evaluation is the timeliness of USGS reporting. A number of potential users expressed frustration at the time required for publication of USGS reports, especially those containing data. The committee commends the USGS for its decision to publish the Water-Supply Papers for the pilot projects initially as open-file reports in order to accelerate the availability of this information. However, the committee would like to encourage the USGS to be vigilant and creative in seeking out ways to minimize the time required to publish NAWQA findings.

In considering the three broad classes of report topics envisioned by the USGS for NAWQA, the committee noted that the first two classes will be of greatest interest in support of policy formulation and resource allocation at fairly high levels of decisionmaking, while the third class will be of greatest interest to water quality management decisionmaking at the implementation level. It was also noted that the first two classes of reports will in many ways be the easiest to produce. The committee urges the USGS to strike an appropriate balance and assure that adequate resources are directed toward reports describing the results of cause and effect analyses, even if those are more difficult to produce. Many of the potential users of NAWQA with whom the committee spoke, especially on the local and state levels, emphasized the value they would place on reports bettering their understanding of processes.

The committee is most concerned, however, with the relatively narrow scope of the retrospective studies. While the study-unit teams appear to have been thorough in identifying and acquiring available data, the extent of their investigations was quite limited. In particular, the investigations focused almost exclusively on ambient water quality data in streams and aquifers. Data on <u>sources</u> of contamination were not collected and analyzed, in spite of the availability of extensive data bases (e.g., EPA's Permit Compliance System and Industrial Facility Reports). In addition, the retrospective reports make no attempt to identify and assess available <u>studies</u> of water quality processes in the study units or available water quality <u>models</u> that have been developed for all portions of the study units. If the goal of NAWQA is indeed to improve our understanding of water quality processes on the study-unit, regional, and national scales, it is imperative that information on sources and previous investigations of processes be included within the concept of a retrospective report.

Summary

The committee recommends that the concept of a retrospective report be expanded to include data on known sources of water quality constituents, existing studies of water quality processes within the study unit, and previously developed conceptual and mathematical models of the physical, chemical, and biological processes influencing water quality in the study unit.

The committee encourages the USGS to be vigilant and creative in seeking ways to minimize the time required to publish the findings from the National Water Quality Assessment program. In addition, the committee urges the USGS to ensure that adequate resources are directed toward reports describing the results of cause and effect analyses, even if those are more difficult to produce.

Committee-Initiated Case Study

Description

In order to obtain a sharper focus on how a cause and effect analysis would be conducted under the NAWQA program, the committee recommended that the USGS conduct a special study of the effect of changes in wastewater treatment on trends in the downstream water quality of the Illinois River. Wastewater treatment was selected as the problem area owing to the large federal investment in these facilities. The Illinois River Basin was selected as the study area because it is relatively simple from a hydrologic point of view and an extensive long-term data base already exists.

As a result of this request, NAWQA personnel conducted a detailed inventory of past and present wastewater treatment data in this area. Their study focused on the availability and suitability of municipal wastewater treatment information. Their results, indicating several areas where significant improvements are needed, are being featured in a series of three articles in Water Environment and Technology, the journal of the water Pollution Control Federation (Appendix B, #46) and in a USGS Open File Report (Appendix B, #57).

Critique

Although the NAWQA personnel did a very thorough evaluation of quality control problems with the existing data, they have not yet completed the originally requested analysis of cause and effect relationships for this test study area. Thus the committee cannot evaluate how cause-and effect analysis is to be accomplished under the NAWQA program. While it is understandable that the USGS is more comfortable monitoring since it is their traditional forte, NAWQA needs to be a first-class assessment activity if it is to serve its intended purpose.

Summary

The USGS should immediately intensify its cause and effect assessment activities and provide complete case studies and a coherent national methodology for doing cause and effect assessments. This initial effort should utilize all available data and not be restricted to data generated by the NAWQA monitoring program. The results of this effort should be reviewed by an external science advisory committee.

3

Implementation, Coordination, and National Synthesis

CURRENT STATUS OF NATIONAL WATER QUALITY ASSESSMENT AND MONITORING PROGRAMS

At the request of the committee, W. G. Wilber of the USGS prepared a summary of national water quality assessment activities of the federal agencies (Appendix B, #18). A description of the present and proposed programs is presented here and in Table 3.1. Except for NAWQA, the current USGS national monitoring and assessment activities are the National Stream Quality Accounting Network (NASQAN), the Hydrologic Benchmark Program, and the National Trends Network. The total annual budget for these three programs is $6.8 million. NAWQA, if fully funded, will have an annual budget of $60 million. The primary focus of the present and proposed USGS assessments is rivers and ground water. NAWQA will be more comprehensive than any other national assessment in the media sampled with planned sampling of the water column, sediments, and fish and wildlife tissues.

At present, EPA has the largest water quality assessment program through its $27 million per year National Water Quality Inventory as required by Section 305(b) of the Clean Water Act. This assessment covers rivers, lakes, and ground water. The National Pesticides Survey and the Bioaccumulation Study are one-time activities. If EPA's proposed Environmental Monitoring and Assessment Program (EMAP) is funded, then EPA will have an additional $60 million per year national assessment capability. EMAP will evaluate a wide variety of receiving waters, forests, wetlands, and agroecosystems. The NOAA National Status and Trends Program is the major assessment of water quality conditions in near coastal waters. This $5.0 million per year program includes analysis of fish and mollusc tissues.

Table 3.1 National Water Quality Assessment Activities of Federal Agencies

Agency	U.S. Environmental Protection Agency			
Title	National Water Quality Inventory (305(b))	Environmental Monitoring and Assessment Program	National Pesticides Survey	Bioaccumulation Study
Acronym/abbrev.		EMAP		
Primary Goats	Assess progress on fishable/swimmable goats of Clean Water Act	Assess overall risks to natural ecosystems	Estimate percentage of municipal water supplies contaminated by pesticides	Define distribution & hearth effects of contaminated fish
Resources assessed				
Rivers	X	X		X
Lakes	X	X		X
Ground water	X	X		
Estuaries				
Wetlands		X		
Forests		X		
Agroecosystems		X		
Near-coastal marine		X	X	X
Atmosphere		X		
Spatial scales				
State	X			
Regional		X	X	X
National	X	X	X	X

Agency	U.S. Environmental Protection Agency			
Temporal scales				
Multi-year	X		X	X
Decadal		X		
Duration				
One time				
Continuous	X	X		
Media sampled				
Water	X	To be determined	X	
Suspended sediment				
Streambed material				
Mollusc tissue				X
Fish tissue				
Duck wings				
Starlings				
Budget				
One time			$11.0 million	$1 million
Continuous	$27 million	$60 million*		

Agency	U.S. Geological Survey			
Title	National Water Quality Assessment Program	National Stream Water Quality Accounting Network	Hydrologic Benchmark Network	National Trends Network
Acronym/abbrev.	NAWQA	NASQAN		NTN
Primary Goals	Status & trends Cause-effect relations	Long-term trends	Hydrology of undisturbed watersheds	Status & trends of precipitation quality
Resources assessed				
Rivers	X	X	X	
Lakes				
Ground water	X			
Estuaries				
Wetlands				
Forests				
Agroecosystems				
Near-coasta marine				X
Atmosphere				
Spatial scales				
State				
Regional	X	X		X
National	X	X	X	X

Agency	U.S. Geological Survey			
Temporal scales				
Multi-year	X			
Decadal	X	X	X	X
Duration				
One time				
Continuous	X	X	X	X
Media sampled				
Water	X	X	X	
Suspended sediment	X			
Streambed material	X			
Mollusc tissue	X			
Fish tissue	X			
Duck wings				
Starlings				
Budget				
One time				
Continuous	$60 million*	$3.6 million	$8 million	$3.0 million

Agency	U.S. Fish & Wildlife Service	National Oceanic & Atmospheric Administration
Title	National Contaminant Biomonitoring Program	National Status & Trends Program
Acronym/abbrev.	NCBP NS&T Program	
Primary Goals	Status & trends of contaminant levels in fish and wildlife	Status & trends of concentrations and potentially toxic effects
Resources assessed		
Rivers	X	
Lakes		
Ground water		
Estuaries		
Wetlands		
Forests		
Agroecosystems		
Near-coastel marine		
Atmosphere		
Spatial scales		
State		
Regional	X	X
National	X	X

Agency	U.S. Fish & Wildlife Service	National Oceanic & Atmospheric Administration
Temporal scales		
Multi-year		
Decadal	X	X
Duration		
One time		
Continuous	X	X
Media sampled		
Water		
Suspended sediment	X	X
Streambed material		
Mollusc tissue		X
Fish tissue	X	X
Duck wings	X	
Starlings	X	
Budget		
One time		
Continuous	$.3 million	$5.0 million

Note: * = Annual budget if fully implemented.

Source: Wilber, W. personal communication to S. David of the Water Science and Technology Board, August 22, 1989.

The National Contaminant Biomonitoring Program (NCBP) of the Fish and Wildlife Service evaluates the status and trends of contaminant levels in fish and wildlife. Its budget is $0.3 million per year.

Summaries of these national water quality assessment programs are presented below. Most of this information was received from W. Wilber of the USGS (Appendix B, #18).

National Stream Quality Accounting Network

The U.S. Geological Survey established the National Stream Quality Accounting Network (NASQAN) in 1973. The current goals of NASQAN are to:

1. identify national water quality trends and, to the extent possible, relate these trends to upstream land and water use; and
2. account for constituent transport between major river basins and into estuaries and the Great Lakes.

The NASQAN network is made up of 411 active and 26 inactive data collection sites. The majority of the NASQAN sites are located on major rivers at the downstream end of the hydrologic accounting units. More than 50 measurements are made at fixed sampling intervals at each site. These measurements include field parameters such as discharge, water temperature, and pH; selected nutrients; major ions; trace elements; and fecal indicator bacteria. Samples are collected bimonthly at 58 percent of the sites and quarterly at 42 percent of the sites. These data are stored in the USGS WATSTORE data base with biennial transfers to the EPA's STORET data base. The 1989 funding for NASQAN was $3.6 million.

Hydrologic Benchmark Network

The U.S. Geological Survey's Hydrologic Benchmark Network was established in 1964 to do the following:

1. document natural changes in hydrologic characteristics,
2. provide a better understanding of the hydrologic structure of natural basins, and
3. provide a comparative basis for studying the effects of man on the hydrologic environment.

The network consists of 58 stations located in watersheds across the country that have been minimally affected by humans. Most of the network stations are sampled for water quality, and more than 50 physical and chemical measurements are made at fixed sampling intervals. Field measurements include discharge, water temperature, pH, and alkalinity. Water samples are analyzed for concentrations of selected nutrients, major ions, trace elements, and fetal indicator bacteria. Samples are collected quarterly at 73 percent of the stations, bimonthly at 23 percent of the stations, and monthly at 4 percent of the stations. These data are stored in WATSTORE with biennial transfers to STORET. This program was funded at $800,000 in fiscal year 1989.

National Trends Network

The U.S. Geological Survey, as lead agency for the Task Group on Atmospheric Deposition and Air Quality Monitoring of the National Acid Precipitation Assessment Program, manages the National Trends Network (NTN). A variety of federal, state, and local agencies operate the 150 rural monitoring stations. The goals of this network are to:

1. provide regional-scale information on the spatial variation in the chemistry of precipitation (rain and snow) in the United States, and
2. detect long-term trends in precipitation chemistry.

Wet deposition samples are collected weekly. Funding for fiscal year 1989 was $3.0 million.

National Water-Quality Inventory

In accordance with Section 305(b) of the Clean Water Act of 1972 and its 1986 amendments, the EPA must submit a water quality assessment report to Congress every two years. This report consists of a set of state reports prepared by the states and an overview prepared by EPA. The goals for the 1990 cycle (U.S. Environmental Protection Agency, 1989) are as follows:

1. Increase the coverage of the nation's waters. In 1986, only one-fifth of the nation's river miles and one-third of its lake shoreline miles were assessed by the states. In addition to increasing this coverage, additional emphasis will be given to assessing water quality in estuaries, coastal areas, and wetlands.

2. Improve data quality and utility to support the shift in emphasis from technology-based to water-quality-based approaches. A computerized data system called the Waterbody System (WBS) has been developed for this purpose and is already in use in several states.
3. Continue Clean Water Act reporting as follows:

Under Sections 304(1) and 303(d), identify all waters threatened or impaired with toxic pollution control problems.

Under Section 314, identify the trophic states of lakes that are impaired and lakes with acidity problems.

Under Section 319, identify waters that cannot reasonably be expected to attain or maintain water quality standards owing to nonpoint pollution.

Primary sources of information for the state reports include long-term monitoring records, short-term intensive surveys, and professional judgments of state agency personnel. Funding for this program was approximately $27 million in fiscal year 1989.

Environmental Monitoring and Assessment Program

The U.S. Environmental Protection Agency is developing concepts for an Environmental Monitoring and Assessment Program (EMAP) to assess the overall risks to natural ecological systems from multiple pollutants and stresses. The proposed goals of EMAP are to:

1. characterize ecological resources at risk,
2. quantify baseline conditions and trends and their status, and
3. identify probable causes by examining corresponding patterns and trends in pollutant exposure and other stressors.

Ecosystems to be assessed by EMAP include the atmosphere, forests, agroecosystems, lakes and streams, wetlands, near-coastal marine systems, and estuaries. A variety of indicators and environmental measurements would be taken during 5- to 7-year index periods to define current conditions. Annual sampling would be done at selected sites to define trends. If fully funded, EMAP would have an annual budget of $60 million.

National Pesticide Survey

The U.S. Environmental Protection Agency began the National Pesticide Survey of ground water used for drinking water purposes in 1988. The goals of this one-time survey are to:

1. provide estimates of pesticide contamination in community and domestic drinking water wells in the United States due to selected pesticides, and
2. examine relationships of pesticide contamination to patterns of pesticide use and ground water vulnerability.

About 750 private domestic wells and 600 community wells are being sampled over a two-year period. Field work is scheduled for completion in early 1990 with a report expected by December 1990. Total estimated funding for this two-year survey is $11 million.

Bioaccumulation Study

The National Bioaccumulation Study of EPA began in 1986 as an outgrowth of the National Dioxin Study. The objectives of this one-time screening study are to determine the extent to which water pollutants are bioaccumulating in fish and to identify correlations with sources of the contamination. Potential effects on human health from exposure through consumption of contaminated fish are also being evaluated. The total cost for this one-time survey was about $1 million.

National Contaminant Biomonitoring Program

The National Contaminant Biomonitoring Program (NCBP) of the U.S. Fish and Wildlife Service began in 1967 as the National Pesticide Monitoring Program, a cooperative effort with the USGS, Food and Drug Administration, and Federal Water Pollution Control Administration. The primary goals of this program are to:

1. describe contaminant levels in freshwater fish and wildlife, and
2. define long-term trends in contaminant levels in fish and wildlife.

The 1989 funding for this program was approximately $300,000.

National Status and Trends Program

The National Oceanic and Atmospheric Administration began the National Status and Trends (NS&T) program in 1984 to determine the current status of and to detect any long-term trends that are occurring related to toxic contamination in the coastal and estuarine waters of the United States. Under this program, concentrations and effects of potentially toxic chemicals in bivalve molluscs, bottom-feeding fish, and sediments are measured. The NS&T Program has two monitoring components: the Benthic Surveillance Project and the Mussel Watch Project.

The NS&T data, stored on a NOAA data base, are available through NOAA's National Oceanographic Data Center. The funding for this program was $5.0 million in 1989.

ANCILLARY DATA BASES FOR NATIONAL WATER QUALITY ASSESSMENTS

Hirsch et al., 1988, summarize ancillary data bases that could be used by the NAWQA program (see Table 3.2). These data bases contain information on source characteristics and related demographic data in addition to other water quality data.

Since 1983, the USGS has prepared an annual National Water Summary. The themes differ from year to year. For example, the 1984 summary dealt with hydrologic events, selected water quality trends, and ground water resources; the 1985 summary described hydrologic events and surface water resources; and the 1986 summary dealt with hydrologic events and ground water quality. These national summaries are done in cooperation with other federal agencies and feature the results of numerous studies by USGS personnel. They provide an excellent overview of the resources and issues at the state and national levels.

In addition, the U.S. Department of Agriculture (USDA) is planning major initiatives in the area of water quality with a program to collect, analyze, and disseminate data describing agricultural chemical use and its relation to water quality. Specifically, the Economic Research Service, in cooperation with the National Agricultural Statistics Service (NASS), will expand farm-level data collection to include pesticide use on major field crops (every three years) and on fruits and vegetables, livestock, and specialty crops (every five years). Also, socioeconomic, geographical, and related data will be gathered in order to provide the basis for determining the benefits and costs of alternative actions by USDA, EPA, and other agencies.

Table 3.2 Data Bases Containing Ancillary Data to be Used in the National Water Quality Assessment Program

Data Base		Reference
Acid Deposition System	Information on the chemistry of wet atmospheric deposition collected at about 400 sites in North America.	Olsen and Slavich, 1986.
National Uranium	Information on the concentrations of of trace elements for nearly one million samples in water and sediments from the 48 conterminous states and Alaska, identified by 1" × 2" quadrangle.	Averett, 1984.
Natural Resources Inventory	Estimates of sheet and rill erosion for about 800,000 sample plots, aggregated by country and identified according to land use, including cropland, pastureland, rangeland, and forest land.	U.S. Department Commerce, 1984a.
Resources for the Future, Environmental Data Inventory	Estimates of biochemical-oxygen demand, nutrient, and metal loads discharge to U.S. streams and lakes from about 32,000 industrial and municipal waste treatment facilities and from runoff from major land types, including urban, cropland, pastureland, rangeland, and forest land.	Gianessi and Peskin, 1984; Gianessi and others, 1986
Resources for the Future, Pesticide Usage Inventory	Inventory of 184 pesticides used in the United States, identified by crop type and by country.	Gianessi and Puffer, 1986.
U.S. Census of Agriculture	Census of farm operators, including county-based estimates of crop, forest, pasture, and range acreage, agricultural chemical and fertilizer use, and inventories and sales of livestock and poultry.	U.S. Department of Commerce, 1984b.

Data Base	Description	Reference
U.S. Census of Agriculture	Population in the United States summarized for about 400,000 block groups and enumeration districts; identified by latitude and longitude.	U.S. Census Bureau, 1983.
U.S. Coal Production	Surface and underground coal production by county.	Mining Information Services, 1983.
U.S. Environmental Protection Agency Industrial Facility Discharge File	Estimated discharge from about 54,000 industrial and municipal facilities having EPA permits; identified by permit number in the National Pollution Discharge Elimination (NPDES) and by river-reach number.	Philip Taylor, U.S. Environmental Protection Agency, commun., 1988.
U.S. Environmental Protection Agency Needs Survey	Estimates of flow and concentrations of biochemical-oxygen demand in the effluent discharged from about 30,000 publicly owned sewage treatment plants identified by NPDES permit number and river-reach number.	U.S. Environmental Protection Agency, 1982b.
U.S. Environmental Protection Agency River-Reach File	Numeric listing of about 67,000 stream reaches arranged systematically to provide hydrologic linkages among major U.S. rivers.	Dewald and others, 1987.

Data Base	Description	Reference
U.S. Environmental Protection Agency STOrage and RETrieval System (STORET)	A computerized data base containing geographic and other descriptive data for water-quality data-collection sites; data related to the physical characteristics and chemical constituents of water, fish tissue, and sediment; information on municipal waste sources and disposal systems; data on pollution-caused fish kills; and daily streamflow data.	U.S. Environmental Protection Agency, 1982a.
U.S. Fish and Wildlife Service National Contamination Biomonitoring Program	Formerly referred to as the National Pesticide Monitoring Program, the program was established to monitor temporal and geographic trends in organochlorine chemical and elemental contaminants in the nation's freshwater fish.	May and McKinney, 1981; Lowe and others, 1985.

Source: Hirsch et al., 1988.

NATIONAL ASSESSMENTS AS A COMPONENT OF ENVIRONMENTAL MONITORING PROGRAMS

Table 3.3 summarizes the estimated expenditures for environmental monitoring by federal and nonfederal organizations. The cost of environmental monitoring by federal agencies was estimated to be about $500 million in 1989. This estimate includes all types of monitoring (e.g., compliance, status, and trends) and activities related to monitoring such as program design, data collection and processing, data management, analysis, interpretation, and synthesis. A like amount of money is estimated to be spent by nonfederal agencies for a total estimated annual expenditure of about $1 billion per year.

The National Water Quality Assessment program is estimated to have an annual budget of approximately $60 million, or 6 percent of the total annual expenditure for monitoring activities. Many of the monitoring data being collected outside of NAWQA are useful for regional and national assessments. Thus it is vital that a significant component of the NAWQA activity be committed to

Table 3.3 Estimated Costs of Environmental Monitoring by Federal Agencies

Agency	Budget	% for Monitoring	Millions of dollars per year
Agriculture			
Soil Conservation Service[1]	387	10	38.7
Forest Service			23.2
Administration & Resource cons.	34.8	25	
Forest environment research	31	25	
Range management	27	25	
Commerce			63.9
NOAA-Coastal % estuarine assessments	6.9	100	
National Marine Fisheries Service	49	100	
Other (e.g., weather, coast watch)[2]	8	100	
Defense			68
Corps of Engineers[3]	18	100	
Other[4]	50	100	
Energy[5]			25
Environmental Protection Agency[6]			237.4
Ambient	92.9	100	
Methods	27.5	100	
Planning/management	19	100	
Quality assurance/quality control	14.6	100	
Source	74.7	100	
Auto. data processing	8.7	100	
Interior (FY 1989)			44.4
National Water Quality Asses. Program	7	100	
National Stream Quality Accounting Net	3.6	100	

utilizing this large amount of data available from secondary sources. Also, NAWQA should attempt to use information from ongoing studies by other groups with a view toward using these results as part of the national assessments.

Table 3.3 Estimated Costs of Environmental Monitoring by Federal Agencies

Agency	Budget	% for Monitoring	Millions of dollars per year
Hydrologic Benchmark Network	0.8	100	
National Trench Network	3	100	
Other environmental monitoring activities in USGS[7]	100	30	
Total			500.6

NOTE:

[1] Estimate is based on FY 89 budget for conservation operations. Expenditures include surveys of soil and inventory and monitoring of natural resource trends.

[2] No direct estimate available.

[3] A significant part of this funding is for the dredging program.

[4] No direct estimate available. Known large monitoring activities to support hazardous waste remediation activities.

[5] No direct estimate available. Known large monitoring activities at national labs for hazardous materials and ecological activities.

[6] This estimate is based upon data for 1987. The total is the sum of monitoring expenditures in the programs: Water (23.0%), Air (29.0%), Solid Waste (23.5%), Research and Development (22.6%), and Pesticides (1.9%).

[7] Estimate needs to be checked.

Source: Holland, F. (Versar, Inc., Columbia, Maryland) personal communication 1990 to K. Thornton and R. Kutz, U.S. Environmental Protection Agency.

INTERAGENCY COOPERATION

Description

Information on interagency cooperation on water quality data monitoring activities was provided by Bill Wilber of the USGS at the request of the committee (W. G. Wilber private communication to J. P. Heaney, February 6, 1990).

The Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use were formed in 1967 to coordinate the data acquisition activities of federal agencies. The responsibility for these committees was delegated by Office of Management and Budget Circular A-67 to the Depart merit of the Interior, which placed the responsibility with the USGS. The Interagency Advisory Committee on Water Data has representatives from 34 federal agencies, and the Advisory Committee on Water Data for Public Use consists of 27 members representing state and local agencies, technical societies, universities, and private enterprises.

With regard to NAWQA coordination at the national level, a National Coordinating Work Group was established in the pilot program to advise the USGS on national aspects of the NAWQA program. The work group, which has met every six months since November 1986, functions under the auspices of the long-standing Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use. The work group is chaired by the chief hydrologist and currently consists of nine federal members, seven nonfederal members, and representatives from each of the pilot project liaison committees. Organizations represented include the American Water Resources Association, the Association of American State Geologists, the Association of State and Interstate Water Pollution Control Administrators, the Chemical Manufacturers Association, the Interstate Conference on Water Policy, the National Association of Conservation Districts, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the EPA, the U.S. Fish and Wildlife Service, the U.S. Forest Service, NOAA, the Soil Conservation Service, and the Council on Environmental Quality.

Two new subcommittees focusing on water quality will be formed within the existing subcommittee structure. These committees will focus on the overall problem of national water quality assessments, including, but not limited to, the NAWQA program.

In addition to the above subcommittees, EPA and the USGS have an Interagency Committee for Program Coordination. This Memorandum of Understanding, signed November 26, 1985, includes explicit mention of the NAWQA program. Other inter-agency committees exist with NOAA, Office of Surface Mining, Bureau of Reclamation, Forest Service, and Soil Conservation Service. The USGS and the Fish and Wildlife Service have a draft Memorandum of Agreement (see Appendix G) that outlines the terms and conditions under which these two agencies will operate with a fully implemented NAWQA program.

Current national assessment activities related to water quality are being conducted by EPA, USGS, NOAA, and the Fish and Wildlife Service. The total expenditures for these programs, including the NAWQA pilot program, are about $46 million per year. Full-scale NAWQA and EMAP programs will greatly expand these national assessment activities with each of these programs esti mated to cost $60 million per year. The total annual investment in environmental monitoring in the United States is about $1 billion per year. The federal agencies have long-standing agreements to cooperate on water quality monitoring activities. They appear to be aware of the activities and programs of their sister agencies.

Critique

Current and proposed national water quality monitoring and assessment activities by the federal water agencies constitute a significant and worthwhile component of water resources management activities. However, in spite of the fact that interagency cooperative agreements have existed at least since 1967, no master plan has been available to ensure that existing and proposed monitoring activities will provide the basis for a comprehensive national water quality assessment program, even with NAWQA and EMAP. Such a plan is essential in order to evaluate whether federal funds are being wisely allocated among the suites of problems, e.g., bacteriological contamination, pesticides, and nutrients; receiving environments, e.g., rivers, lakes and impoundments, ground water, and wetlands; constituents (physical, chemical, and/or biological); and beneficial uses, e.g., water supply, recreation, and fish and wildlife protection.

The local liaison committees and the National Coordinating Work Group are the current means of outside input into NAWQA. Each of these groups serves an important function of technology transfer and information sharing, but they do not have any apparent authority to decide the direction of NAWQA. They can influence NAWQA by participating in the selection of the national issues to be addressed by the issue-based teams. Since no issue teams have yet been formed, the committee has been unable to evaluate this process. A new, independent, and unbiased scientific advisory committee should be considered for outside review of NAWQA's progress.

Summary

Cooperation among those agencies performing water quality assessments is essential to providing a thorough, detailed assessment of the nation's water. NAWQA alone cannot assess all of the nation's water quality. For example, lakes and estuaries are not a part of NAWQA. Other agencies have water quality data on these water bodies that should be integrated with the USGS data to provide the national water quality assessment that decisionmakers need. **In order to combine and synthesize the water quality data from those agencies, an interagency council is recommended to serve this important function. Membership on this council should comprise representatives of USGS, EPA, NOAA, the Fish and Wildlife Service, the Forest Service, USDA, and the Council on Environmental Quality. During its first two years of activity, this council might consider accomplishing the following tasks**:

1. **Prepare a detailed inventory of current water quality monitoring and assessment activities of the federal agencies. This inventory should be a greatly expanded and improved version of Table 3.1 of this report. This inventory should include accurate estimates on the current expenditures of the agencies for water quality related activities**.
2. **Prepare an action plan of how overall agency programs will perform national water quality assessments by**:

   a. **issue, e.g., wastewater treatment, pesticides, nutrients**;
   b. **receiving water bodies, i.e., rivers, lakes and impoundments, estuaries, and wetlands**;
   c. **beneficial uses, e.g., water supply, recreation, and fish and wildlife protection; and**
   d. **type of water quality constituent, i.e., physical, chemical, or biological**.

This master plan should also indicate which agencies will perform which tasks.

To ensure the success of NAWQA to provide a truly national assessment of water quality, the following internal and external committees are envisioned.

USA	NAWQA	
Interagency	External	Internal (USGS)
Interagency council on national water quality assessment*	Liaison Committees	Study-Unit Teams (60)
	Nat'l Coord. Work Grp	Issue-Based Teams
	Scientific Advisory Committee*	National Synthesis Team

* Indicates a new committee proposed by the WSTB

NATIONAL SYNTHESIS

Description

NAWQA is intended to characterize water quality and detect trends, and therefore incorporates both fixed and synoptic sampling. But more importantly, it is designed to improve our understanding of physical, chemical, and biological processes and causal relationships. This is to be accomplished by focusing on the study-unit scale, by including intensive sampling at relatively small scales, and by using both deterministic and statistical models. The advantage of this approach is its emphasis on process understanding. However, because it is not based on an overarching statistical design, it will not lead to rigorous probabilistic generalizations at the national scale. Instead, national conclusions will be based on aggregating "findings from comparative studies conducted in a wide range of hydrologic settings nationwide" (Hirsch et al., 1988).

Each study-unit team in carrying out its portion of NAWQA will implement a nationally consistent set of analyses and protocols such that data can be aggregated and compared. It is the committee's understanding that two approaches will then be used within the USGS to synthesize these data into information that is useful at the regional and/or national scale.

The first approach to national synthesis will be "issue-based" teams to focus on critical regional and national water quality issues. Issues under consideration at the time of this report include (1) factors influencing the distribution and fate of pesticides in surface and ground waters; (2) nutrient and suspended sediment impacts on streams, lakes, and impoundments; and (3) volatile organic compounds (VOCs) in ground water and urban surface waters (W. Wilber, personal communication, April 11, 1990). During the first NAWQA cycle, four such issues will be addressed, each by separate teams of four to five individuals. Each team will operate for an average of six years, during which a series of reports will be published. For example, preliminary plans call for three reports from the issue-based team investigating factors influencing the distribution and fate of pesticides in surface and ground waters: (1) an initial report summarizing current knowledge; (2) a summary of reconnaissance level efforts to improve understanding based on the pilot studies, the initial 20 study units, and other USGS programs; and (3) a report on detailed case studies in some study units focusing on factors related to the management of pesticides (W. Wilber, personal communication, April 11, 1990). The initiation of each team will be staggered at yearly intervals, starting in 1993. This will make it possible for at least some of the topics to be based on early findings of the study-unit investigations. Selection of topics will also be based on results of other water quality assessment programs and on the advice of the National Coordinating Work Group and other technical advisory committees.

The second approach to national synthesis will use a "national synthesis" team of five individuals to compile information and key findings from the study units, the issue-based teams, and other USGS programs to prepare a general overview of national water quality conditions and trends. This team will function continuously over the ten-year cycle and will prepare two or three reports.

In addition to the above mentioned internal issue and national synthesis teams, the USGS plans to obtain input on national and regional synthesis from outside sources such as other federal agencies, professional societies, and academia. The current methods of soliciting outside advice and guidance are through the local liaison committees, the National Coordinating Work Group, and other informal contacts.

Critique

One of the strengths of NAWQA is the study-unit concept, which focuses activity at the scale dictated by hydrological processes. The challenge of NAWQA is to use the information and understanding obtained at the study-unit scale to make generalizations at the regional scale, and then to aggregate the regional findings to inform decisionmaking at the national scale. The issue-based and national synthesis teams have the potential to perform this critical integrating role. Because these teams were not in place during the pilot program, the committee was unable to evaluate their actual performance. However, the committee does offer some comments on the prerequisites for successful synthesis.

The success of the national synthesis will depend on the following:

- The choice of critical topics. Because only a few national issues will be explored during each NAWQA cycle, it is critical that these issues be chosen wisely and with broad input. Once a topic has been chosen, several years will be needed for the series of synthesis reports to be completed. Hence, the choice of issues must anticipate the key questions facing decisionmakers.
- The capabilities of the personnel. It is essential that each issue-based and national synthesis team be led by an experienced

individual who is familiar with both the scientific and management issues of the particular problem, since the goal of each team is to synthesize scientific information and understanding into products that are useful to decisionmakers.

- The extent of communication with the study units. It is obvious that the synthesis teams must be well aware of the activities of the study units. Close communication is essential.
- The ability to influence the activities of the study units. If effective regional and national synthesis is to be achieved, the synthesis teams must have the ability to influence the design of the individual study-unit activities. Otherwise, the study units will likely be dominated by local interests and concerns. Based on observations of the pilot studies, there will be strong resistance to outside influence on study-unit activities. The most effective way to overcome this resistance is to have strong group leaders who can develop a good rapport with the individual study unit teams.
- The extent of interaction and coordination with organizations outside USGS. As with all of NAWQA, the USGS must not rely solely on its own data and expertise in achieving national synthesis. It is imperative that the issue-based and national synthesis teams make a significant effort to identify relevant data and information from all available sources in preparing reports on regional and national issues.

Summary

The committee recommends that the USGS pursue its proposed use of issue-based and national synthesis teams to achieve a national-level synthesis of the information and knowledge developed at the study-unit scale. These teams should be in regular communication with the study-unit teams, should be given the authority to influence the activities of the study-unit teams, should be led by the most capable and experienced personnel, and should not restrict their vision only to USGS data and information. A strong review process should be put in place to assure wise choice of regional and national issues with broad input.

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Appendix A

Interim Report

NATIONAL RESEARCH COUNCIL
WATER SCIENCE AND TECHNOLOGY BOARD
2101 Constitution Avenue Washington. D C. 20418

(202) 334-3422
fax (202) 3342 620

September 25, 1989

Dr. Dallas C. Peck
Director,
U.S. Geological Survey The National Center Reston,
Virginia 22092

Dear Dr. Peck: We are pleased to transmit ten copies of an interim report by the Committee to Review the USGS National Water Quality Assessment (NAWQA) pilot program. As you know, the committee was requested to review the technical aspects of the program, as currently being developed by USGS, and to consider ways of improving it. The committee was also requested to review the program's potential usefulness for establishing and evaluating national policies and activities concerning water quality. The committee is scheduled to provide a final report on its review of the NAWQA pilot program by April 1990. This report is submitted to provide the USGS with a summary of the committee's evaluations to date. In general, on the basis of our review the committee is convinced that a national-scale, long-term water quality assessment is in the best interest of the country. Additionally, we believe that the USGS is well qualified to implement the proposed NAWQA program because it is a nonregulatory agency and because of its ability to undertake the long-term commitment necessary for such a program to be successful. The USGS has an excellent reputation in performing its water quality data collection programs at the national, state, and local levels. This attribute will be important when it comes to cooperation with other federal, state, and local agencies. Thus, the committee recommends that the NAWQA program continue to be developed by the USGS. Special attention should be given to resolving the question of performing the necessary biological monitoring, such as cooperating with the academic community and other appropriate government agencies. The committee sincerely appreciates the constructive working relationship that has developed with the USGS in its review of the NAWQA pilot program. The committee members look forward to continuing their work and issuing a final review document in 1990.

Sincerely,

Richard S. Engelbrecht,
Chairman
Committee to Review the USGS National Water Quality Assessment Pilot Program

cc: P. Cohen, Chief Hydrologist

The National Research council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations. The Water Secure and Technology Board is responsible to the National Research Council through the Commission on Engineering and Technical Systems and the Commission on Geosciences, Environment, and Resources.

September 25, 1989

REVIEW OF THE USGS NATIONAL WATER QUALITY ASSESSMENT PILOT PROGRAM INTERIM REPORT OF THE NATIONAL RESEARCH COUNCIL

In 1987 the U.S. Geological Survey (USGS) requested that the National Research Council's (NRC) Water Science and Technology Board assemble a committee to review its National Water Quality Assessment (NAWQA) pilot program. The committee was appointed by the NRC in 1988 and has met four times. In addition, various committee members have made site visits to five of seven pilot study areas to discuss the program with local officials and researchers as well as with USGS personnel directly involved in the sampling and data collection program. The committee is scheduled to provide a final report on its review of the NAWQA program by April 1990. This interim report is submitted by the committee to provide the USGS with a summary of its evaluation to date and mid-course advice. In this interim report, the committee has focused on an overall review of the general concept of a national water quality assessment program—its usefulness to the nation, and whether or not it should be carried out by an agency such as the USGS. Only in this context has the committee had occasion to address the question of implementation. Thus, a more detailed analysis of the technical aspects of NAWQA, such as the frequency of the sampling program, or the chemical constituents to be measured, has yet to be performed by the committee.

The committee was asked to review the technical aspects of NAWQA and to consider ways of improving the program, as designed by the USGS. It was also requested to review the program's potential usefulness for establishing and evaluating national policies. Additionally, the committee has considered the program's usefulness to state, interstate, local, and private entities for making decisions affecting water resources and advancing the scientific understanding of water quality.

As stated in USGS Circular 1021, "Concepts for a National Water-Quality Assessment Program," the goals of the NAWQA program are as follows:

1. Provide a nationally consistent description of current water quality conditions for a large part of the nation's water resources;

2. Define long-term trends (or lack of trends) in water quality; and
3. Identify, describe, and explain, as possible, the major factors that affect observed water quality conditions and trends. The information should be obtained on a continuing basis and made available in a timely manner to water managers, policy-makers, and the public. Such continual, timely information should provide an improved scientific basis for evaluating the effectiveness of water quality management programs and for predicting the likely effects of contemplated changes in land use and water management practices.

To address the potential usefulness of a full-scale NAWQA program, the committee members (in small teams) visited five of the seven pilot site study areas, including the Carson River Basin, Upper Illinois River Basin, Yakima River Basin, Kentucky River Basin, and Central Oklahoma Aquifer. Through these site visits, the committee gained insight into the NAWQA program from the state and local users of the data being generated and collated by the USGS. All the visiting teams agreed that the pilot projects were valuable studies for their respective regions. The committee also reviewed sample reports or products of the type that would be published as a result of NAWQA.

Since other water quality monitoring efforts are ongoing or planned within the state and federal governments, the committee interviewed representatives of the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the U.S. Forest Service, the U.S. Fish and Wildlife Service, the Maryland Department of the Environment, the Association of State-Interstate Water Pollution Control Agencies, the Soil Conservation Service, the National Oceanic and Atmospheric Administration, and the Interstate Conference on Water Policy to obtain their views concerning the usefulness of the NAWQA program to national, state, and local needs for water quality information. Representatives of the Department of Interior's Budget Office and the Office of Management and Budget also participated in several meetings.

On the basis of the information provided by the representatives of these organizations, it was clear that the USGS enjoys an excellent reputation among potential NAWQA users at all levels—national, state, and local. Several state agencies even indicated that any water quality data provided by the USGS would have greater credibility than data collected by their own agencies.

The USGS obviously has a proven track record of providing reliable and useful information through its water programs such as the National Stream-Quality Accounting Network, the Regional Aquifer-System Analysis program, and the Hydrologic Benchmark program. There was a general consensus among those associated with state and local agencies having responsibility for water quality that the information to be provided by NAWQA would be extremely valuable; in fact, in a few instances it was reported that the information available through the pilot studies had already proven useful.

In addition, it was pointed out, and the committee agrees, that there are certain inherent advantages to having a non-regulatory agency collect, analyze, and interpret NAWQA-type data; e.g., it may be unrealistic to expect a regulatory agency such as EPA to objectively evaluate the effectiveness of its own water regulatory programs and expenditures. Most of the agency representatives did not see any serious duplication between NAWQA and other water quality data gathering efforts but cautioned that care should be exercised to avoid any such situation. In this sense, the committee agrees with the agency representatives that there should be as much cooperation and coordination among the different water quality monitoring programs as possible and appropriate. One identified area of potential cooperation among agencies was biomonitoring, i.e., the collection of biological data.

Some of the agency representatives expressed doubt as to whether NAWQA, as currently designed, will be able to elucidate cause-effect relationships to the degree necessary to effectively predict future water quality problems. However, there was a general consensus that the USGS has the ability to undertake the long-term commitment necessary for a NAWQA-type program to be successful. The data and information generated by the NAWQA program should be able to be made available to state and local agencies and to private industry in a timely and cost-effective way.

NEED FOR A LONG-TERM WATER QUALITY ASSESSMENT

The committee believes there is a genuine need for a longterm, large-scale national assessment of water quality in the United States. Human health and environmental health are inextricably linked to our nation's water quality. As our popu lation grows and our water resources become more intensively developed, and indeed stressed, water quality becomes a more important component of our political, economic, social, and environmental decision-making. Such decision-making cannot proceed without adequate information and understanding.

The committee frames the term "assessment of water quality" in the following context. Sound decision-making requires that problem areas be identified before they reach crisis proportions, that they be evaluated carefully and fairly to improve or protect water quality, and that information be gathered and understanding be developed from analysis and interpretation of data. The committee defines "assessment" as being directed toward these goals, rather than being directed toward assuring compliance with a regulation or statute, or toward detecting the presence of known contaminants. Therefore, an essential component of an assessment should focus on cause-effect relationships.

Long-term assessment is important for several reasons. First, the physical, chemical, and biological processes that affect water quality on and below the surface of the earth are extraordinarily-complex and are not completely understood. Thus, any assessment of the state of water quality must evolve over time, as our understanding and data bases increase. It is difficult to imagine a static, one-time assessment that would have lasting value. Second, the processes affecting water quality take place over a wide range of temporal and spatial scales. For example, ground water flow rates are very small, and a "snapshot," or even several snapshots closely spaced in time, would provide relatively little information about change. Similarly, the impacts of global climatic change on water quality are likely to occur on time scales of decades. On the other hand, mixing processes in mountain streams are very rapid, so that a single sample, or even a few samples, could easily miss important events. In either case, a long-term assessment would be more likely to detect many important aspects of the status of water quality in the United States.

Currently, there is no reliable national assessment of U.S. water quality trends. Thus, a large-scale national assessment is clearly warranted. Many important water quality decisions are made at the national level, and federal taxes support many water quality activities. In addition, because of the complexity and spatial diversity of water quality issues, a national-level aggregation and integration would be invaluable in maximizing infor mation gained from local experience. Furthermore, there are, in varying degrees, inconsistencies between data sets gathered for local or regional purposes. Collecting consistent data and carefully aggregating available data would be of significant value both in identifying and evaluating national issues and in transferring information and understanding from one region or locality to another. Finally, while there is much completed and ongoing research focusing on cause-effect water quality relationships, this research tends to be directed toward small-scale (often laboratory-scale) issues. We know little about the behavior of large systems, such as entire river basins or aquifer systems. Therefore, a national assessment is a particularly timely undertaking.

COMMITTEE'S EVALUATION OF SPECIFIC PROGRAM COMPONENTS

Integration of Surface Water/Ground Water Study Units

The original GNAW program plan specified 120 separate planned surface water and ground water study areas or units. This approach had the potential for minimizing the important linkages between surface and ground water systems. During committee meetings, the committee informed the USGS that these linkages are important in determining water quality, as some results from the Lower Kansas River Basin pilot project indicate.

In recognition of the important water quality implications of surface water/ground water interaction, the USGS decided in March 1989 to redefine the study units. The study units include river basins in which the focus of attention is on surface water quality and aquifer systems in which the focus of attention is on ground water quality. The study units range from a few thousand to several tens of thousands of square miles in area. The committee is pleased to see that plans for the full program now contain 60 integrated surface water/ground water study units. The committee believes that this new approach is better and will result in an improved product. However, since the integrated study unit concept represents a new approach, it needs further development (e.g., refinement of new study unit boundaries). The USGS must also determine how the results from the integrated units will be "scaled up" to make national inferences. It may be that the integrated approach will make this task much easier.

National Coordinating Work Groups

The National Coordinating Work Groups serve as liaisons to the NAWQA program. Group members represent federal, state, and local agencies. This liaison helps to ensure that many diverse interests and needs will be considered in the NAWQA program. The coordinating groups also serve to generate local support and enthusiasm for the program. The committee's five pilot site visits confirmed these facts. Liaison committee members were generally supportive of the NAWQA program. They were enthusiastic not only about the purely scientific aspects of the program, but also about the effect of the program in fostering communication, cooperation, and understanding among agencies (federal and nonfederal).

A shortcoming in the composition of the current liaison committees is the lack of private industry representation. Given private industry's role in creating, identifying, and solving water quality problems, it should be more strongly represented on the liaison committees. Such representation would enhance the value of the liaison committees to the USGS and promote cooperation and understanding between the public and private sectors. Since the importance of private industry vis-à-vis water quality issues and problems would vary from study area to study area, industrial representation would vary according to local importance.

Retrospective Analyses

Collection and analysis of existing data are important aspects of any study. The NAWQA program includes a retrospective analysis of existing data and information as an integral part of its total study; each study unit program will perform such an analysis. These analyses are invaluable for a number of reasons. First, the USGS will collect, synthesize, archive, and assess the quality of large amounts of information that have been collected by many organizations over many years. This effort alone will be invaluable to the many users of water quality information (e.g., government agencies as well as private industry). Second, the expertise of the USGS in interpreting the existing data will be critical to understanding the hydrologic, geologic, physicochemical, and biological processes operating in each study unit. Third, the analysis of existing data may delineate water quality trends that could influence the sampling efforts of the local NAWQA projects and identify existing or potential water quality problems that need attention from agencies or private industry.

The retrospective analyses provide a first step in developing local, regional, and national water quality data bases and demonstrate the need for long-term data bases to define significant trends.

Biology

The weakness of the NAWQA program in addressing the biological aspects of water quality cannot be overstated. The committee has conveyed this during committee meetings to the USGS many times in the course of its review. Attention to biological aspects of water quality has not traditionally been one of the strong points of the USGS. The committee is concerned that the agency may not have adequate numbers of qualified personnel to implement the program on a national scale. Some committee members believe that the USGS may have to rely on other agencies (e.g., U.S. Fish and Wildlife Service) and perhaps the academic community for expertise in biology. Other committee members believe that the USGS should ultimately develop in-house expertise and facilities in this area. Special attention should be given to resolving the question of how to perform the necessary biological monitoring, such as by cooperating with the academic community and other appropriate government agencies. However, because a consensus on this issue has not been reached, it will be discussed more fully at future committee meetings.

Coordination

In order to prevent needless duplication and to take advantage of other work in progress, the NAWQA program should be coordinated with ongoing programs of other agencies (e.g., EPA activities under the Safe Drinking Water Act). Coordination is always going to be a major challenge. The USGS must remain vigilant for and take advantage of, as appropriate, not only activities already in existence, but also those activities in the planning stages, such as EPA's proposed Environmental Monitoring and Assessment Program. NAWQA should also be coordinated with existing programs such as the Fish and Wildlife Service's National Contaminant Biomonitoring Program, the Great Lakes International Fish Contaminant Monitoring Program, NOAA's program on environmental quality of coastal waters, and NOAA's tissue banking program.

National Synthesis

The program documentation is vague on how the information from the study units will be "scaled up" to the national level so that a national synthesis can be accomplished. Will the national aspect of NAWQA arise simply from the fact that the 60 study units represent most of the nation? Or will the results from the individual study units be presented in some fashion such that national water quality trends will be evident and national inferences can be drawn? Is the study unit scale large enough to address national issues and yet small enough to consider local and regional considerations? These important aspects of NAWQA need additional thought and will be addressed by the committee in its final report.

Characterization of Cause-Effect Relationships and Sources

The program is unclear as to how cause-effect relationships will be approached. This is a critical issue for the NAWQA program. Is the study unit scale small enough to resolve cause-effect issues? For example, the effects of land use on both surface and ground water quality are important and must be quantified to a greater degree than is currently being done in some of the pilot studies. To what degree will simulation modeling be used to articulate and quantify cause-effect relationships? In general, the NAWQA program is vague with regard to the question of the characterization of contaminant sources. The USGS should give more attention to how it will analyze the data with respect to determining cause-effect relationships.

Temporal Considerations

There are several unique characteristics of the NAWQA program that might loosely be referred to as "temporal considerations." For a given study unit, current plans call for five years of intensive data collection followed by four years of less intensive data collection activity (the "on/off" approach). The USGS believes that the four-year off period will afford its scientists time to assimilate and interpret data collected during the five years of intensive sampling. During the off time, the USGS will also assess the efficacy of the intensive sampling program so that necessary modifications can be effected for the next sampling period. The off period may also provide time to pursue spin-off studies, perhaps funded wholly or partially by interested state, local, regional, or other federal agencies. Such studies could also be "seeded" with NAWQA funds. University researchers and their graduate students may be used during this time to help track new issues and pursue spin-off studies.

The on/off approach for data collection and evaluation is one aspect of the study design yet to be fully considered by the committee. It may be of more value to have data collection, analysis and interpretation, and experimentation proceed simultaneously, together with continuous interaction and feedback among these different elements. Without an analytical and conceptual framework, data collection may lack direction. Conversely, without appropriate and reliable data, the analyses may lack reality and therefore have little practical value. The committee intends to pursue this matter as it looks more closely at the NAWQA study design.

As previously stated, the long-term nature of the proposed program is essential. Patterns and trends will not necessarily emerge over the short term. This is especially true in ground water systems, where water quality trends evolve more slowly than in surface water systems. Since NAWQA is not to be a "plume-chasing" program, short-term monitoring of ground water systems might not produce meaningful results. The fact that a single agency with no regulatory or enforcement bias will be performing long-term monitoring helps to ensure consistency, quality control, and quality assurance. Indeed, these latter characteristics are major NAWQA program strengths.

CONCLUSIONS

The committee is convinced that a national-scale, long-term water quality assessment is in the best interest of the country. In addition, the committee believes that the USGS is well qualified to implement the proposed NAWQA program because of the agency's ability to undertake the long-term commitment necessary for a NAWQA-type program to be successful. It is also preferable that the agency to carry out this type of program be nonregulatory.

The USGS has an excellent reputation in performing its water quality data collection programs at the national, state, and local levels. This will be important when it comes to cooperation with other federal, state, and local agencies. Thus, the com mittee recommends that the NAWQA program continue to be developed by the U.S. Geological Survey. Special attention should be given to resolving the question of performing the necessary biological monitoring, such as cooperating with the academic community and other appropriate government agencies.

NEXT STEPS

As is apparent from this interim report, committee deliberations to date have concentrated on an evaluation of the conceptual framework of NAWQA and its utility. In the future, the committee's evaluations of these aspects of the program will continue with greater attention to details of the study design and anticipated interpretative products. For example, the committee plans to consider in greater detail the design for integration of ground and surface water studies within the study units, the personnel structure envisioned to perform the national synthesis, the ability of the program to identify nationally important cause-effect relationships, and the frequency of the sampling program, i.e., the on/off approach. Further aspects of program review include a consideration of the choice of chemical constituents to be determined and the analytical methods and levels of precision obtained with those methods.

Committee to Review the USGS National Water Quality Assessment Pilot Program

Richard S. Engelbrecht (Chairman), University of Illinois
K. C. Bishop, III, Chevron U.S.A., Inc., San Francisco
Sandra L. Blackstone, University of Denver College of Law
Michael E. Campana, University of New Mexico
Margaret Conditt, Procter & Gamble, Cincinnati
Robert C. Cooper, University of California
David L. Freyberg, Stanford University
James Geraghty, Geraghty & Miller, Inc., Tampa
Judith L. Meyer, University of Georgia
Donald J. O'Connor, Manhattan College
Susan Stafford, Oregon State University
James Heaney (Ex-officio), University of Florida
Kenneth Potter (Ex-officio), University of Wisconsin
Sheila D. David, NRC Staff Officer
Anita Hall, Project Secretary

Appendix B

Documents Reviewed by the Committee

1. Plan for External Evaluation of the USGS Pilot National Water Quality Assessment Program, April 29, 1987.
2. The Quality-Assurance Plan for the Pilot National Water-Quality Assessment Program by H.C. Mattraw, Jr., W.G. Wilber, & W.M. Alley, August 1989, USGS Open File Report 88-726.
3. National Water-Quality Assessment Program-National Coordinating Workgroup, Charter and report of first meeting, 1986.
4. Planning Elements, P. Leahy, 1988.
5. Concepts for a National Water-Quality Assessment Program, Draft Executive Summary, R. Hirsch, W. Alley, & W. Wilber, 1987.
6. Conceptual Design of a National Water-Quality Assessment Program, Draft, December 15, 1987, by R. Hirsch, W. Alley, & W. Wilber.
7. Water-Quality Trends in the Nation's Rivers by R. A. Smith, R. Alexandria, M. G. Wolman, March 27, 1987, Science magazine.
8. Letter to R. Engelbrecht from V. Schneider dated August 1, 1988 consisting of information on the NAWQA Program.

9. Resources for the Future report "Water Quality Information for Policy Purposes: Evaluating NAWQA as a Tool for Policy Design and Assessment", September 1987.
10. Water Fact Sheet, USGS, Department of the Interior, National Water-Quality Assessment Pilot Program, 1988.
11. USDA Research Plan for Water Quality, January 1989.
12. The National Stream Quality Accounting Network (NASQAN)-Some Questions and Answers, Geological Survey Circular 719, 1975.
13. The National Hydrologic Bench-Mark Network by Ernest D. Cobb and J.E. Biesecker, U.S. Geological Survey Circular 460-D, 1971.
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Appendix C

Choice of Chemical Constituents

Table 3.2 —Major metals and trace elements targeted for analysis in tissues collected in the National Water-Quality Assessment Program and currently analyzed in existing tissue analysis programs of national scope

	Program			
Name of metal or element	National Water-Quality Assessment Program	National Status and Trends Program	National Bioaccumulation Study	National Contamitant Biomonitoring Program
	(USGS)[1]	(NOAA)[2]	(EPA)[3]	(FWS)[4]
Aluminum	+	+		
Antimony	+	+		
Arsenic	+	+		+
Barium	+			
Beryllium	+			
Cadmium	+	+		+
Chromium	+	+		
Copper	+	+		+
Iron		+		
Lead	+	+		+
Manganese		+		
Mercury	+	+	+	+
Molybdenum	+			
Nickel	+	+		
Selenium	+	+		+
Silicon		+		
Silver	+	+		
Thallium	+	+		
Tin	+	+		
Vanadium	+			
Zinc	+	+		+

[1] U.S. Geological Survey
[2] National Oceanic and Atmospheric Administration
[3] U.S. Environmental Protection Agency
[4] U.S. Fish and Wildlife Service

Table 3.3 —Synthetic organic compounds targeted for analysis in tissues collected in the National Water-Quality Assessment Program and currently analyzed in existing tissue analysis programs of national scope

	Program			
Name of metal or element	National Water-Quality Assessment Program	National Status and Trends Program	National Bioaccumulation Study	National Contamitant Biomonitoring Program
	(USGS)[1]	(NOAA)[2]	(EPA)[3]	(FWS)[4]
Polynuclear aromatic hydrocarbons				
Acenaphthene	+	+		
Anthracene	+	+		
Benz (a) anthracene	+	+		
Benzo (a) pyre	+	+		
Benzo (e) pyrene		+		
Biphenyl	+	+	+	
Chrysene	+	+		
Dibenz (a,h) anthracene	+	+		
2, 6-Dimethylnaph thalene		+		
Fluor anthene	+	+		
Fluorene	+	+		
1-Methylnaphthalene		+		
2-Methylnaphthalene		+		
1-Methylphenanthrene		+		
Naphthalene	+	+		
Perylene		+		
Phenanthrene	+	+		
Pyrene	+	+		
Organochlorine insecticides				
Aldrin	+	+		+
Butachlor	+		+	
Chlorbenzilate	+		+	
Chlordane, cis	+	+	+	+
Chlordane, trans	+		+	+

	Program			
Name of metal or element	National Water-Quality Assessment Program	National Status and Trends Program	National Bioaccumulation Study	National Contamitant Biomonitoring Program
	(USGS)[1]	(NOAA)[2]	(EPA)[3]	(FWS)[4]
Organochlorine insecticides				
Chlorpyrifos	+		+	+
o,p'-DDD	+	+		+
p,p'-DDD	+	+		+
c,p'-DDE	+	+		
p,p'-DDE	+	+	+	+
o,p'-DDT	+	+		
o,p'-DDT	+	+		
Dicofol (Keltbane)	+		+	+
Dieldrin	+	+	+	+
Diethylhexylphthalate (DEHP)	+		+	+
Diphenyldisulfide	+		+	+
Endrin	+		+	+
Heptachlor	+	+	+	+
Heptachlor epoxide	+	+	+	+
Hexachlorobenzene (HCB)	+	+	+	+
Hexachlorocyclohexanes (BHC) including Lindane	+	+	+	+
Isopropalin	+		+	+
Kepone	+		+	+
Mercury, organic	+		+	+
Methoxychlor	+		+	+
Mirex	+	+	+	+
n-alkanes	+		+	+
Nitrofen	+		+	+
Nonachlor, cis	+		+	+
Nonachlor, trans	+	+	+	+
Octachlorostyrene	+		+	+
Oxychlordane	+		+	+

	Program			
Name of metal or element	National Water-Quality Assessment Program	National Status and Trends Program	National Bioaccumulation Study	National Contamitant Biomonitoring Program
	(USGS)[1]	(NOAA)[2]	(EPA)[3]	(FWS)[4]
Organochlorine insecticides				
Pentachloroanisole	+		+	+
Pentachlorobenzene	+		+	+
Pentachloronitrobenzene (PCNB)	+		+	+
Pentachlorophenol (PCP)	+		+	+
Perthane	+		+	+
1,2,4,5-Tetrachlorobenzene	+		+	+
1,2,3,4-Tetrachlorobenzene	+		+	+
1,2,3,5-Tetrachlorobenzene	+		+	+
Toxaphene				+
1,2,3-Trichlorobenzene	+		+	+
1,2,4-Trichlorobenzene	+		+	+
1,3,5-Trichlorobenzene	+		+	+
Triohloronate	+		+	+
Trifluralin	+		+	+
Triphenyl phosphate	+		+	+
Polychlorinated biphenyls				
Monochlorobiphenyls	+			
Dichlorobiphenyls	+	+	+	
Trichlorobiphenyls	+	+	+	
Tetrachlorobiphenyls	+	+	+	

	Program			
Name of metal or element	National Water-Quality Assessment Program	National Status and Trends Program	National Bioaccumulation Study	National Contamitant Biomonitoring Program
	(USGS)[1]	(NOAA)[2]	(EPA)[3]	(FWS)[4]
Polychlorinated hiphenyls				
Pentachlorobiphenyls	+	+	+	
Hexachlorobiphenyls	+	+	+	
Hepatachlorobiphenyls	+	+	+	
Octachlorobiphenyls	+	+	+	
Nonachlorobiphenyls	+	+	+	
Decachlorobiphenlys			+	
3,4,3',4'-Tetrachlorobiphenyl			+	
3,4,5,3',4'-Pentachlorobiphenyl			+	
3,4,5,3',4',5'-Hexachlorobiphenyl			+	
Total PCBs	+		+	
Arcclor 1242				+
Arcclor 1248				+
Arcclor 1254				+
Aroclor 1260				+
Chlorinated Dioxins and Furans				
2,3,7,8-TCDD			+	
1,2,3,7,8-PeDD			+	
1,2,3,6,7,8-HxDD			+	
1,2,3,7,8,9-HxDD			+	
1,2,3,7,8-HxDD			+	
1,2,3,4,6,7,8-HpDD			+	
2,3,7,8-TCDF			+	
1,2,3,7,8-PeDF			+	
2,3,4,7,8-PeDF			+	
1,2,3,6,7,8-HxDF			+	
1,2,3,7,8,9-HxDF			+	
1,2,3,4,7,8-HxDF			+	
2,3,4,6,7,8-HxDF			+	
1,2,3,4,6,7,8-HxDF			+	
1,2,3,4,7,8,9-HxDF			+	

[1] U.S. Geological Survey

[2] National Oceanic and Atmospheric Administration

[3] U.S. Environmental Protection Agency

[4] U.S. Fish and Wildlife Service

Table 3.4 Semi-volatile, methylene-chloride extractable target compounds to be determined in the <2 millimeter fraction of selected bed-material samples from the surface-water part of the National Water-Quality Assessment Program. (U.S. Geological Survey National Water Quality Laboratory Schedule 1386 for total recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
4-Chloro-3-methylphenol	59-50-7	34455	600
2-Chlorophenol	95-57-8	34589	200
2, 4-Dichlorophenol	120-83-2	34604	200
2, 4-Dimethylphenol	105-67-9	34609	200
4, 6-Dinitro-2-methylphenol	534-52-1	34660	600
2, 4 Dinitrophenol	51-28-5	34619	600
2-Nitrophenol	88-75-5	34594	200
4-Nitrophenol	100-02-7	34649	600
Pentachlorophenol	87-86-5	39061	600
Phenol	08-95-2	34695	200
2, 4, 6-Trichlorophenol	88-06-2	34624	600
Acenaphthene	83-32-9	34208	200
Acenaphthylene	208-96-8	34203	200
Anthracene	120-12-7	34223	200
Benzo (a) anthracene	56-55-3	34529	200
Benzo (b) flouranthene	205-99-2	34233	400
Benzo (k) flouranthene	207-08-9	34245	400
Benzo (g,h,i) perylene	191-24-2	34524	400
Benzo (a) pyrene	50-32-8	34250	400
4-Bromophenyl phenyl ether	101-55-3	34639	200
Butyl benzyl phthalate	85-68-7	34295	200
bis (2-Chloroethoxy) methane	111-91-1	34281	200
bis (2-Chloroethyl) ether	111-44-4	34276	200
bis (2-Chloroisopropyl) ether	180-60-1	34286	200

Table 3.5 Target organochlorine compounds to be determined in the <2 millimeter fraction of selected bed-material samples from the surface-water part of the National Water-Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule 1325 for total-recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
Aldrin	309-00-2	39333	0.01
	5103-74-2		
Chlordane	5103-71-9	39351	1.00
DDD	72-54-8	39363	0.10
DDE	72-55-9	39368	0.10
DDT	50-29-3	39373	0.10
Dieldrin	60-57-1	39383	0.10
Endosulfan	115-29-7	39389	0.10
Endrin	72-20-8	39393	1.00
Gross PCBs		39519	1.00
Gross PCNs		39251	1.00
Heptachlor	76-44-8	39413	0.10
Heptachlor epoxide	1024-57-3	39423	0.10
Lindane	58-89-9	39343	0.10
Methoxychlor	72-43-5	39481	0.10
Mirex	2385-85-5	39758	0.10
Perthane	72-56-0	81886	1.00
Toxaphene	8001-35-2	39403	10.00

Table 3.6 Target acid-extractable organic compounds to be determined in selected surface-water samples of the National Water-Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule 1393 for total-recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
4-Chloro-3-methylphenol	59-50-7	34452	30.0
2-Chlorophenol	95-57-8	34586	5.0
2, 4-Dichlorophenol	120-83-2	34601	5.0
2, 4-Dimethylphenol	105-67-9	34606	5.0
2, 4-Dinitrophenol	51-28-5	34616	20.0
4, 6-Dinitro-2-methylphenol	534-52-1	34657	30.0
2-Nitrophenol	88-75-5	34591	5.0
4-Nitrophenol	100-02-7	34646	30.0
Pentachlorophenol	87-86-5	39032	30.0
Phenol	108-95-2	34694	5.0
2, 4, 6-Trichlorophenol	88-06-2	34621	20.0

Table 3.7 Target organophosphorus insecticides to be determined in selected surface-water samples of the National Water-Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule 1319 for total-recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
Chlorpyrifos		38932	0.01
Diazinon	333-41-5	39570	0.01
Ethion	563-12-2	39398	0.01
Malathion	121-75-5	39530	0.01
Methyl parathion	298-00-0	39600	0.01
Methyl trithion	953-17-3	39790	0.01
Parathion	56-38-2	39540	0.01
Trithion	786-19-6	39786	0.01

Table 3.8 Target carbamate pesticides to be determined in selected ground-water samples of the National Water Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule SH13 for total recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
Aldicarb	115-06-3		0.5
Aldicarb sulfane	1646-88-4		0.5
Aldicarb sulfoxide	1648-87-3		0.5
Carbaryl	63-25-2	39750	0.5
Carbofuran	1563-66-2		0.5
3-Hydroxycarbofuran			0.5
Methiocarb	2032-65-7		0.5
Methomyl	16752-77-5	39051	0.5
1-Napthol			0.5
Oxanyl	23135-22-0		0.5
Propham	122-42-9	39052	0.5
Propoxur (Baygon)	114-26-1		0.5

Table 3.9 Target triazine and other nitrogen-containing herbicides to be determined in selected surface-and ground-water samples from the National Water-Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule 1389 for total recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
Alachlor	15972-60-8	77825	0.1
Ametryn	834-12-8	82184	0.1
Atrazine	1912-24-9	39630	0.1
Bromacil*	314-40-9		
Burylate*	2008-41-5		
Carboxin*	5234-68-4		
Cyanazine	21725-46-2	81757	0.1
Cycloate*	1134-23-2		
Diphenamid*	957-51-7		
Hexazinone*	51235-04-2		
Metolachlor	51218-45-2	39356	0.1
Metribuzin	21087-64-9	81408	0.1
Prometon	1610-18-0	39056	0.1
Prometryn	7287-19-6	39057	0.1
Propazine	139-40-2	39024	0.1
Simazine	122-34-9	39055	0.1
Simetryn	1014-70-6	39054	0.1
Terbacil*	5902-51-2		
Trifluralin	1582-09-8		

* Under development

Table 3.10 Target chlorophenoxy acid herbicides to be determined in selected surface-and ground-water samples of the National Water-Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule 0079 for total recoverable compounds) [Reporting level is in micrograms per liter]

Compound	CAS No.	WATSTORE Code	Reporting Level
2, 4-D	94-75-7	39730	0.01
Dicamba	1918-00-9	82052	0.01
2, 4-DP	120-36-5	82183	0.01
Picloram	1918-02-1	39720	0.01
Silvex	93-72-1	39760	0.01
2, 4 5-T	93-76-5	39740	0.01

Table 3.11 Target volatile organic compounds to be determined in selected surface- and ground-water samples of the pilot National Water-Quality Assessment Program. (U.S. Geological Survey National Water-Quality Laboratory Schedule 1390 for total recoverable compounds) [Reporting level is in micrograms per liter]

Compound	WATSTORE Code	Reporting Level
Bromodichloromethane	32101	0.2
Carbon tetrachloride	32102	0.2
1,2-Dichloroethane	32103	0.2
Bromoform	32104	0.2
Dibromochloromethane	32105	0.2
Chloroform	32106	0.2
Toluene	34010	0.2
Benzene	34030	0.2
Chlorobenzene	34301	0.2
Chloroethane	34311	0.2
Ethylbenzene	34371	0.2
Bromomethane	34413	0.2
Chloromethane	34418	0.2
Methylene chloride	34423	0.2
Tetrachloroethene	34475	0.2
Trichlorofluoromethane	34488	0.2
1,1-Dichloroethane	34496	0.2
1,1-Dichloroethene	34501	0.2
1,1,1-Trichloroethane	34506	0.2
1,1,1-Trichloroethene	34511	0.2
1,1,2,2-Tetrachloroethane	34516	0.2
1,2-Dichlorobenzene	34536	0.2
1,2-Dichloropropane	34541	0.2
1,2-Trans-dichloroethene	34546	0.2
1,2,4-Trichlorobenzene	34551	0.2
1,3-Dichlorobenzene	34566	0.2
1,4-dichlorobenzene	34571	0.2
2-Chloroethylvinyl ether	34576	0.2
Dichlorodifluoromethane	34668	0.2
1,3-Trans-dichloropropene	34699	0.2
1,3-Cis-dichloropropene	34704	0.2
1,2-Dibromoethane	39082	0.2
Vinyl chloride	39175	0.2
Trichlorethene	39180	0.2
Hexachlorobutadiene	39702	0.2
1,2-Cis-dichloroethene	77093	0.2
Styrene	77128	0.2

Compound	WATSTORE Code	Reporting Level
P-xylene	77133	0.2
M-xylene	77134	0.2
O-xylene	77135	0.2
1, 1-Dichloropropene	77168	0.2
1, 3-Dichloropropane	77173	0.2
1, 2, 4-Trimethylbenzene	77222	0.2
Isopropyl benzene	77223	0.2
N-propylbenzene	77224	0.2
1, 3, 5-Trimethylbenzene	77226	0.2
O-chlorotoluene	77275	0.2
P-chlorotoluene	77277	0.2
Bromochloromethane	77297	0.2
N-butylbenzene	77342	0.2
Sec-butylbenzene	77350	0.2
Tert-butylbenzene	77353	0.2
1, 2, 3-Trichloropropane	77443	0.2
1, 1, 1, 2-tetrachloroethane	77562	0.2
1, 2, 3-Trichlorobenzene	77613	0.2
Bromobenzene	81555	0.2
1, 2-Dibromo-3-chloropropane	82625	0.2
Napthalene	91203	0.2
P-isopropyl toluene	———	0.2
2, 2-Dichloropropene	———	0.2

Appendix D

Members, USGS National Coordinating Work Group

Carroll Curtis
Project Director
Environmental Monitoring
and Data
Council of Environmental
Quality
722 Jackson Place, N.W.
Washington, D.C. 20503

Lewis Dodgion
Chief, Division of
Environmental Protection
Department of Conservation
and Natural Resources
Carson City, NV 89701

Judith A. Duncan
Lab Chief, State
Environmental Laboratory
Oklahoma State Department
of Health
P.O. Box 53551
Oklahoma City, OK 73152

Earl E. Eiker
Chief, Hydraulics and
Hydrology Division
HQ USACE (DAEN-ECE-H)
Room 2114, Pulaski Building
20 Massachusetts Avenue
Washington, D.C. 203 14-1 000

Donald C. Haney
State Geologist and Director
Kentucky Geological Survey
University of Kentucky
228 Mining and Mineral
Resources Building
Lexington, KY 40506-o 107

Ronald Hoffer
Office of Ground Water
Protection
U.S. Environmental
Protection Agency
Room 811, East Tower
(WH-550G)
401 M Street, S.W.
Washington, D.C. 20460

Dick Hofman
Deputy Director
New Jersey State Department
of Environmental
Protection
Division of Water Resources
P.O. Box CN-029
Trenton, NJ 08625

U. Gale Hutton
Nebraska Division of Water
Quality
P.O. Box 94877
Lincoln, NB 68509

Leon Hyatt
Chief, Hydrology Branch
U.S. Bureau of Reclamation
P.O. Box 25007
D-750
Denver, CO 80225

Carol Jolly
Water Quality Program
Manager
Washington Department of
Ecology
MS PV-11
Olympis, WA 98504

Gyula Kovach
Manager, .Bureau of Water
Protection
Kansas Department of
Health and
Environment
Forbes Field, Building 740
Topeka, KS 66620

James N. Krider
National Environmental
Engineer
Soil Conservation Service
Room 612B, South Building
Washington, D.C. 200 13

Richard Lanyon
Assistant Director of
Research and Development
Metropolitan Water
Reclamation District of
Greater Chicago
1000 East Erie
Chicago, IL 60611

Carl Meyers
Deputy Director of
Assessment and
Watershed Protection
U.S. Environmental
Protection Agency
(WH-553)
401 M Street, S.W.
Washington, D.C. 20460

Robert B. Raschke
Western Representative
National Association of
Conservation Districts
9150 West Jewel1 Avenue
Suite 113
Lakewood, CO 80226

Gray R. Reynolds
Director of Watershed and
Air Management
USDA-Forest Service
Room 1210 RP-E
Washington, D.C. 20013-6090

Andrew Robertson
Chief, Ocean Assessments
Division
NOAA/NOS/N/OMA3
Rockwell Building
Room 652
11400 Rockville Pike
Rockville, MD 20852

Kenneth D. Schmidt
Ground Water Quality
Consultant
Kenneth D. Schmidt &
Associates
600 West Shaw Avenue
Suite 250
Fresno, CA 93704

Russ Susag
Director of Environmental
Regulatory Affairs
P.O. Box 33331
Building 21-21-06
St. Paul, MN 55133

Hugo F. Thomas
Department of
Environmental Protection
State Office Building
165 Capitol Avenue
Hartford, CT 06106

Peter Tinsley
Maryland Department of the
Environment
Water Management
Administration
2500 Broening Highway
Baltimore, MD 21224

Appendix E

Representatives of State and Federal Agencies Interviewed by the Committee at their February 16-17, 1989 Meeting

FEBRUARY 16, 1989

Steve Cordle, U.S. Environmental Protection Agency

Dixie Bounds, Department of the Interior

Dave Buelow, U.S. Army, Corps of Engineers

Chuck Evans, Association for State-Interstate Water Pollution Control Agencies

Steve Glomb, U.S. Environmental Protection Agency

Ron Hoffer, U.S. Environmental Protection Agency

Dirk C. Hoffman, Interstate Conference on Water Policy

Claire Jacobi, Office of Management and Budget

Joel Kaplan, Office of Management and Budget

Jim Krider, Soil Conservation Service

Kermit N. Larson, U.S. Forest Service

Jay Messer, U.S. Environmental Protection Agency

Bruce Newton, U.S. Environmental Protection Agency

Andy Robertson, National Oceanic and Atomospheric Administration

Don Steffeck, U.S. Fish & Wildlife Service

Peter Tinsley, Maryland Department of the Environment

FEBRUARY 17, 1989

William Alley, U.S. Geological Survey

Paul Beauchemin, U.S. Geological Survey

Pete Bermel, U.S. Geological Survey

Dixie Bounds, Department of the Interior

Margaret Carpenter, Department of the Interior

Phil Cohen, U.S. Geological Survey

Jonathan Deason, Department of the Interior

Robert Hirsch, U.S. Geological Survey

Joel Kaplan, Office of Management and Budget

Patrick Leahy, U.S. Geological Survey

Malka Pattison, Department of the Interior

John Scheffer, U.S. Geological Survey

Verne Schneider, U.S. Geological Survey

Carl Shapiro, U.S. Geological Survey

Harlan Watson, Department of the Interior

William Wilber, U.S. Geological Survey

Appendix F

Biographical Sketches of Committee Members

Richard S. Engelbrecht, Chairman, received an A.B. from Indiana University; M.S. and Sc.D. from the Massachusetts Institute of Technology. He has been on the faculty of the University of Illinois at Urbana-Champaign since 1954. He is currently professor of environmental engineering and is distinguished in the fields of water-pollution research and water-quality control. Dr. Engelbrecht is a member of the National Academy of Engineering and in 1986 was the National Research Council's chairman of the Committee on Recycling, Reuse, and Conservation in Water Management for Arid Areas. He was also chairman of the WSTB's colloquium on NAWQA and was a founding member of the National Research Council's Water Science and Technology Board.

K. C. Bishop received his B.S. degree in chemistry from the University of California at Santa Barbara and his Ph.D. from Yale University in 1973 for his work on the metal catalyzed rearrangements of small ringed hydrocarbons. After postdoctoral work at Stanford, he joined Chevron Research Company in 1974. His research projects were primarily in the area of catalysts and sulfur control. In 1981 he moved to the Environmental Health Protection staff of Chevron Chemical Company. In this position he organized Chevron's program for hazardous waste site cleanup, instituted RCRA's ground water requirements, and coordinated pesticide ground water issues. He has recently become the Government Affairs office policy coordinator for environment and health issues including ground water, pesticides, community right to know, and emergency response at Chevron.

Sandra Blackstone received a B.A. from the University of Vermont, a J.D. from the University of Denver College of Law and Ph.D. in mineral economics from Colorado School of Mines. She is currently professor of Natural Resources Law at the University of Denver College of Law. Her research interests are natural resources law and economics, mining law, environmental law, oil and gas law, public land law, regulatory policy, energy policy and economics, international, mineral development and trade policy. Dr. Blackstone has served on the NRC Board on Mineral and Energy Resources.

Michael E. Campana received a B.S. from College of William and Mary in 1970, a M.S. from University of Arizona in 1973 and a Ph.D. from University of Arizona in 1975. His professional interests include the delineation of regional/local subsurface flow systems using integrated hydraulic environmental isotropic and hydrogeochemical data, watershed hydro-geology, geothermal hydrogeology, hydrogeologic aspects of high-level radioactive waste disposal, determination of fluid age distributions in hydrologic systems and education in hydro-geology and hydrology. Dr. Campana was formerly with the Water Resources Center at the Desert Research Institute, Reno, Nevada. He is currently Professor, Department of Geology at the University of New Mexico.

Margaret Conditt received a Ph.D. in Analytical Chemistry from the University of Colorado in 1984. Since that time she has worked with Procter and Gamble on GC/MS method development and analysis of herbicides (Alar) in foods, tracking of detergent constituents in waters and wastewaters, and reducing the impact of consumer product solid waste upon the environment. Prior to graduate school, she worked for the USGS in water quality analysis. Her research interests are in environmental analytical chemistry and the impact of industry on the environment.

Robert C. Cooper received his Ph.D. in microbiology from Michigan State University in 1958. His professional experience includes being assistant professor to associate professor of public health, School of Public Health from 1958-1974. Presently Dr. Cooper is professor, environmental health science and Director, Sanitary engineering and Environmental Health Research Lab, University of California, Richmond. His research interests include microbiological aspects of water quality; water quality and human health.

David L. Freyberg received a Ph.D. in hydrology, hydraulics and hydromechanics from Stanford University in 1981. His teaching experience has encompassed stochastic hydrology; watershed hydrology; soil moisture and ground water; hydrologic modeling; water resources development and introductory fluid mechanics. Prior to 1980 Dr. Freyberg was a project engineer and project manager in the water resources management department at Anderson-Nichols and Co., Inc., Boston. Currently, he is Professor, Department of Civil Engineering at Stanford University.

James Geraghty received a B.S. in 1949 from City College and a M.S. from New York University in 1953. His professional experience includes geologist, Water Resources Division, Ground Water Branch, U.S. Geological Survey, 1949-1955; ground water geologist, Leggette, Brashears & Graham, 1955-1957; ground water geologist, Port Washington, 1957-1974 and Tampa, 1975-1978, Annapolis, 1978-1982. His research interests are ground water geology and hydrology. Mr. Geraghty is a principal in the ground water consulting firm of Geraghty & Miller, Inc.

Judy L. Meyer is currently professor of zoology and ecology at the University of Georgia. She received her M.S. in zoology from the University of Hawaii and her Ph.D. in ecology from Cornell University in 1978. Her professional experience includes two years as a research associate, Oceanography Department, University of Hawaii, and she has been on the faculty at the University of Georgia since 1977. Dr. Meyer's research interests include limnology and aquatic ecology, terrestrial-aquatic ecosystem interactions, element cycling, and food webs in streams.

Donald O'Connor received a BCE from Manhattan College in 1944; MCE from Polytechnic Institute of Brooklyn in 1947, and Eng. Sc.D. from New York University in 1956. Dr. O'Connor presently divides his time between being a Professor at Manhattan College and a consultant for Hydroqual, Inc. in New Jersey. He has participated in various projects for governmental agencies, industry and private consulting engineers in the area of water quality analysis and management and was co-founder of consulting engineering firm, Hydroqual, Inc., in New Jersey. His area of expertise is mathematical analysis of water quality of natural systems. Dr. O'Connor is a member of the WSTB and the National Academy of Engineering.

Susan Stafford is currently at the Department of Forest Science, Oregon State University, forest biometrician. Dr. Stafford consults with Forest Science researchers on the design of experiments in forest ecology, forest genetics and on the collecting, handling, and analysis of data. She is also data manager for the H.J. Andrews Experimental Forest and Director and creator of the Forest Science Data Bank at OSU. Dr. Stafford received her Ph.D. in applied statistics in 1979 from SUNY College of Environmental Science and Forestry.

EX OFFICIO MEMBERS

James Heaney, received his Ph.D. in civil engineering from Northwestern University in 1968 with an emphasis on water resources engineering, operations research, and urban and regional planning. He is presently professor of environmental engineering sciences at the University of Florida, Gainesville. He is also director of Florida Water Resources Research Center. Dr. Heaney is a registered professional engineer with the State of Florida. He is a member of the American Society of Civil Engineers, American Water Resources Association, and Association of Environmental Engineering Professors. Dr. Heaney has been a member of the WSTB since 1986.

Kenneth W. Potter, received his B.S. (geology) from Louisiana State University in 1976 and his Ph.D. (geography and environmental engineering) from The Johns Hopkins University. Presently he is Professor of civil and environmental engineering at the University of Wisconsin-Madison, where he teaches courses in hydrology and water resources. His current research interests include drainage basin hydrology, particularly with respect to extreme events. Dr. Potter has recently been appointed as a member of the WSTB and has served on various NRC committees.

Appendix G

Draft Memorandum of Agreement Between the USGS and the U.S. Fish & Wildlife Service, October 18, 1989

MEMORANDUM OF AGREEMENT

Between the U.S. Geological Survey and the U.S. Fish and Wildlife Service

I. Purpose

The purpose of this agreement is to provide the terms and conditions under which the U.S. Fish and Wildlife Service (FWS) will cooperate with the U.S. Geological Survey (USGS) in the National Water-Quality Assessment (NAWQA) Program. The program is presently in a pilot phase, and a decision will be made in fiscal year (FY) 1990 whether to proceed to full implementation in FY 1991.

II. Background

Both the USGS and the FWS are involved in measuring the levels of chemical constituents in water and sediment and in evaluating the impacts of observed constituents on the biological health of rivers. For example, the USGS through its NAWQA Program is describing the conditions and trends in ambient water quality, whereas the FWS, through its National Contaminant Biomonitoring Program, is focusing on the conditions and trends of contaminant levels in fish and wildlife. The FWS also evaluates the effects of contaminants on fish and wildlife using a variety of other bioassessment methodologies through its research and operations activities.

The USGS is currently completing the pilot phase of the NAWQA Program. In consultation with the National Academy of Sciences, the FWS, and other Federal and State agencies, the USGS has developed and is testing protocols for conducting ecological surveys and for collecting and analyzing plant and animal tissues for trace elements and synthetic organic compounds. Both of these biological protocols will be integral components of a fully implemented NAWQA Program. The bio logical component of NAWQA will be enhanced by incorporating the expertise of biologists from the FWS and other federal and state agencies and universities.

III. Scope of Work

Where it is mutually agreed upon, FWS involvement in a fully implemented NAWQA Program would include:

- Participation on regional and study unit teams in the planning and conduct of ecological surveys, the collection and analyses of plant and animal tissues for trace elements and synthetic organic compounds, and other activities as appropriate;
- Assistance in preparing regional and national syntheses of water-quality information and reports;
- Assistance in contracting and quality assuring analyses of tissues for concentrations of trace elements and synthetic organic contaminants;
- Assistance in development and testing of new biological field methods that are appropriate to the spatial and time scales of the NAWQA Program; and
- Participation on technical advisory committee(s) that will be convened as needed to make recommendations to the USGS on: (1) emerging regional and/or national water-quality issues that should be addressed by the program, (2) issues about the design of the program that remain unresolved at the end of the pilot program and/or that evolve over time, and (3) methods development activities that should be pursued. Participants on the advisory committee(s) will consist of representatives from universities, other federal and state agencies, and private industry appropriate to the issue(s) of concern.

IV. Agreements

A. Both parties agree to:

- Cooperate in the joint development and preparation of annual work plans for each study unit that will outline the scope, magnitude, timing, costs, and prioritization of activities. Regional and headquarters personnel from both agencies will assemble these plans into an annual national work plan which will be the basis for renewing this agreement (see section VI) and for monitoring progress.
- Meet at least semiannually to review the progress of work and to discuss the scope and financing of activities in the next planning cycle.

B. FWS agrees to:

- Make available scientific and technical personnel, supplies, and equipment to accomplish activities designated in the study unit work plans.
- Collaborate with the USGS in (1) project planning, (2) collecting, analyzing, and interpreting data, and (3) summarizing technical information and preparing reports.
- Present periodic reports of progress and accomplishments to the USGS, including:

  - A written report including data, interpretations, and findings at the close of each activity specified in the unit work plans.
  - Quarterly progress reports that indicate the status of activities directed toward meeting goals established by the study unit work plans.
  - Provisional data specifically requested by USGS.

C. USGS agrees to:

- Indicate the total amount of funds and full-time equivalent positions that will be provided to support FWS work detailed in the study unit work plans. This committment, will be made by July 1 to permit the FWS to plan for the allocation of resources to conduct the agreed upon activities. The committment may be subject to change depending on the actual appropriations to the USGS for NAWQA.

V. Implementation

The approach for conducting the biological component of NAWQA will involve formation of teams of biologists in each of the USGS regions that will: (1) provide assistance and oversight to each of th study unit project teams in preparing work plans and in the collection and interpretation of biological data, and (2) monitor the status of biological activities in each of the study units through a quarterly reporting process that documents progress, accomplishments, and problems.

The FWS Regions will designate at least one person to work with each of the USGS regional teams of biologists. The designated FWS individuals will participate in the preparation of work plans for each study-unit investigation and will be responsible for coordinating those elements of the plan that are FWS responsibilities.

Study unit work plans and status reports will be assembled by the USGS and FWS at the regional and national levels and distributed to the authorized representatives (see section IX) for appropriate action. Authorized representatives, or their designees, will meet at least semiannually to review the progress of activities covered under this agreement.

VI. Renewal

This agreement may be renewed annually, if agreeable to both agencies. Renewal of the agreement shall be based on an annual national work plan assembled from the individual study unit work plans. The annual national work plan will be completed by July I to allow either agency time for contingency planning.

VII. Termination

Either party may terminate this agreement by giving written notice of termination to the other party not less than ninety (90) days in advance of the effective ending date.

VIII. Publications

Publications documenting cooperative efforts may be prepared by either agency, or jointly, provided that both agencies have an opportunity to review manuscripts prior to publication. Should differences of viewpoint occur, an effort will be made to reconcile them. However, this shall not prohibit either agency from publishing the data, provided it assumes sole responsibility and gives credit to the other agency.

IX. Authorized Representatives

USGS:	Philip Cohen
	Chief Hydrologist
	Water Resources Division
	409 National Center
	Reston, Virginia 22092
FWS:	Ralph O. Morgenweck
	Assistant Director
	Fish and Wildlife Enhancement
	Room 3024, Main Interior Building
	Washington, D.C. 20240

X. Financial

FWS will submit billings using the On-Line Payment and Collection System citing agency location code 14-08-0001. The interagency agreement number (To be provided) also must be referenced on all billings.

XI. Approval

Approved and Accepted for USGS	Approved and Accepted for FWS
By:	
Dallas L. Peck Director	John F. Turner Director
Date:	Date: