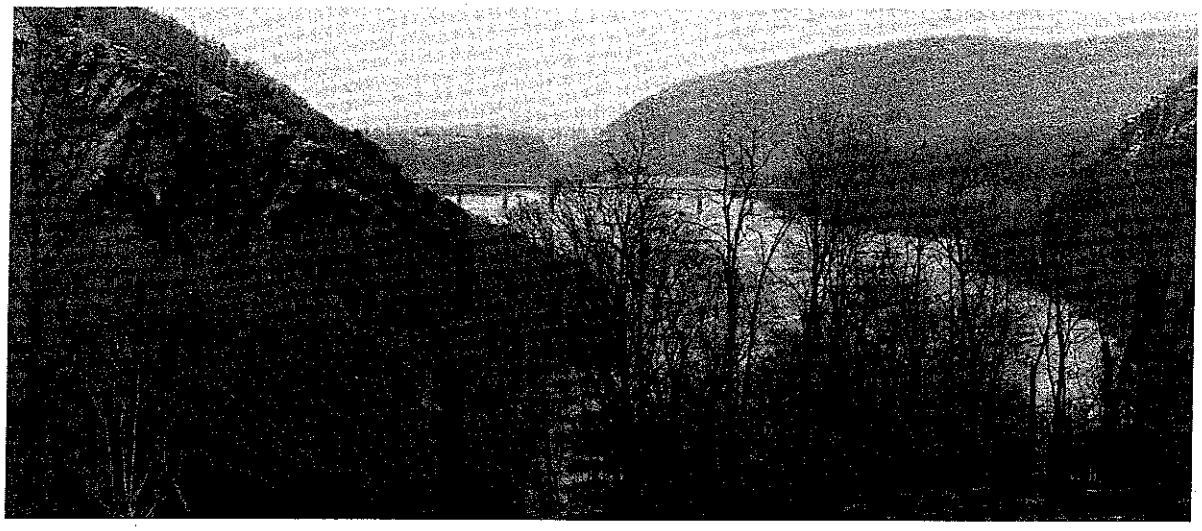
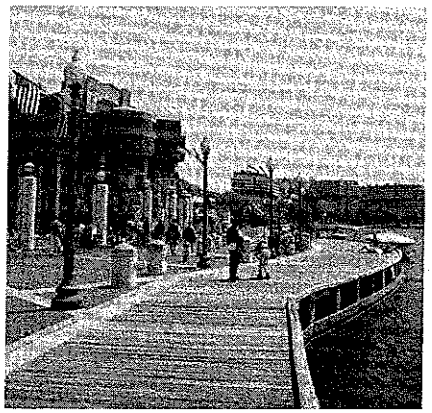
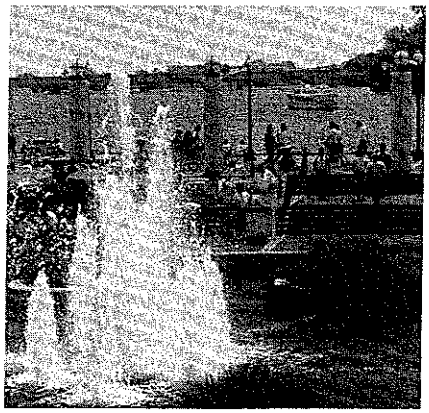
THE STRATEGY FOR IMPROVING WATER-QUALITY MONITORING IN THE UNITED STATES







FINAL REPORT
OF THE
INTERGOVERNMENTAL
TASK FORCE
ON MONITORING
WATER QUALITY

Intergovernmental Task Force
on Monitoring Water Quality

February 1995

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MAJOR CONCLUSIONS AND RECOMMENDATIONS

Major Conclusions

- Water-quality monitoring information is used to protect human health, to preserve and restore healthy ecological conditions, and to sustain a viable economy.
- Tens of thousands of public and private organizations monitor water quality for a wide variety of objectives.
- Total annual expenditures in the public and private sectors to control water pollution are tens of billions of dollars and climbing. Monitoring is necessary to judge the effectiveness of these investments.
- In the last decade, it has become clear that monitoring activities need to be improved and integrated better to meet the full range of needs more effectively and economically.
- A new monitoring approach is required to target water-pollution-control resources to priority concerns and to evaluate the effectiveness of actions taken to prevent or remediate problems. A better balance of ambient and compliance monitoring is needed.

Major Recommendations

Work Together

- Incorporate monitoring as a critical element of program planning, implementation, and evaluation
- Use collaborative teams comprised of monitoring organizations from all levels of government and the private sector to plan and implement monitoring improvements in geographic areas. Include volunteer monitoring efforts in these teams.
- Establish a National Water Quality Monitoring Council with representation from all monitoring sectors to develop guidelines for voluntary use by monitoring teams nationwide, to foster technology transfer and training, and to coordinate planning and resource sharing (Technical Appendix C).
- Link national ambient water-quality-assessment programs.

Share Data

- Agree on sets of widely useful key physical, chemical, and biological indicators to support interjurisdictional aggregations of comparable information for decisionmaking across many scales (Technical Appendixes D and E)
- Use metadata standards to document and describe information holdings and to help secondary users judge whether data are useful for their applications.
- Link information systems to provide easier access by a variety of users to available holdings.

Use Comparable Methods

- Jointly develop and adopt for common use indicator and data-element names, definitions, and formats (Technical Appendix M).
- Implement a performance-based monitoring methods system to achieve comparable data, more flexible use of monitoring methods, and more cost effective monitoring (Technical Appendixes I, N, O).
- Jointly establish reference conditions or sites for shared use in biological and ecological assessments and comparisons. Reference conditions are critically needed to establish baseline conditions against which other water bodies or habitats can be evaluated (Technical Appendixes F and G).

Monitoring Program Goals and Designs

- Design water-quality-monitoring programs and select indicators to measure progress in meeting clearly stated goals for aquatic resources, including State standards for designated uses (Technical Appendix B).
- Use flexible monitoring program designs tailored to the conditions, uses, and goals for water resources in specific area [table 2 (Final Report)].
- Use watersheds, ground-water basins, ecosystems, or other natural boundaries as planning and evaluation units for monitoring.
- Periodically evaluate monitoring efforts to ensure that they continue to meet management goals cost effectively. Use the framework presented in Technical Appendix B.

Report Findings

- Regularly interpret, assess, and report measurements and raw data for use by the public and decisionmakers.

The Strategy for Improving Water-Quality Monitoring in the United States—Summary

INTRODUCTION

The Intergovernmental Task Force on Monitoring Water Quality (ITFM) prepared this report in collaboration with representatives of all levels of government and the private sector. The report recommends a strategy for nationwide water-quality monitoring and technical monitoring improve-ments to support sound water-quality decision-making at all levels of government and in the private sector. Within the nationwide strategy, individual monitoring programs would pursue their own goals and activities, and they would be better able to use information from other sources to support their specific needs. Also, users with responsibilities that cross jurisdictions would be better able to aggregate information from other sources to improve coverage for larger areas.

Water-quality information is used to protect human health, to preserve and restore healthy ecological conditions, and to sustain a viable economy. The strategy is intended to achieve a better return on public and private investments in monitoring, environmental protection, and natural-resources manage-ment. The strategy also is designed to expand the base of information useful to a variety of users at multiple geographic scales. The collaborative process used by the ITFM already has saved millions of dollars. As the strategy is implemented, taxpayers and resource managers will get better answers to the following questions:

- What is the condition of the Nation's surface, ground, estuarine, and coastal waters?
- Where, how, and why are water-quality conditions changing over time?
- Where are the problems related to water quality? What is causing the problems?
- Are programs to prevent or remediate problems working effectively?
- Are water-quality goals and standards being met?

Answering such questions is a key issue because total expenditures in the public and private sectors on water-pollution control are tens of billions of dollars every year and climbing (U.S. Environmental Protection Agency, 1990).

Water-pollution control became a major environmental priority during the last three decades, and in response, water-quality monitoring expanded rapidly in the public and private sectors. Today, tens of thousands of public and private organizations moni-tor water quality for a wide variety of objectives.

At the same time monitoring has expanded, water-management programs have matured to encompass not only point-source, but also nonpoint-source pollution control for surface and ground waters. Point source, or "end of pipe," monitoring is different from nonpoint-source monitoring. By definition, nonpoint sources of pollution are diverse and more difficult to isolate and quantify. Monitoring to support nonpoint-source-pollution control requires a more comprehensive understanding of natural systems and the impacts of human activities, such as agriculture or urban land uses, on natural systems. Therefore, the importance of comprehensively managing water and related systems within natural geographic boundaries, such as watersheds, is now widely recognized. In the last decade, it has become clear that monitoring activities need to be improved and integrated better to meet the full range of needs more effectively and economically.

Fortunately, technology has advanced during the last 25 years. A monitoring strategy can now be supported that will answer complex questions and that targets scarce resources to priority problems within watersheds, ecosystems, and other relevant geographic settings.

Institutional and technical changes are needed to improve water-quality monitoring and to meet the full range of monitoring requirements. Monitoring needs to be incorporated as a critical element of program planning, implementation, and evaluation. The ITFM, therefore, recommends a strategy for nationwide, integrated, voluntary water-quality monitoring.

STRATEGY AND RECOMMENDATIONS

The key elements of this strategy and the associated recommendations are described below.

Goal-Oriented Monitoring and Indicators

- Design water-quality-monitoring programs to measure progress in meeting clearly stated goals for aquatic resources. These goals include public health, ecosystem, and economic objectives.

- Choose water-quality indicators jointly by participating organizations by using criteria identified by the ITFM to measure progress toward goals.

Gather and Evaluate Existing Information

- Characterize current water-quality conditions by using available information. If possible, map the conditions by using geographical information systems and include the actual locations of and reasons for impaired waters. Impaired waters are those that do not meet water quality standards. Also, map special-protection waters, which include, for example, endangered species habitats.
- Use River Reach File 3 to locate and georeference surface waters.
- After evaluating existing information, identify monitoring gaps and rank them by priority. Gaps that are lower priority and that could not be monitored within available resources need to be clearly acknowledged.

Flexible And Comprehensive Monitoring

- Use a flexible monitoring design, including public and private groups, to assess ambient waters nationwide comprehensively by using a watershed-based rotational schedule of 5 to 10 years.
- Tailor monitoring designs based on the conditions of and uses and goals for the waters.

Institutional Collaboration

- Establish closer working relations among the full range of public and private organizations that monitor and use water-quality information. The ITFM recommends the following:

- **National/Federal Programs**

- Working with representatives from all levels of government and the private sector, support the implementation of the strategy nationwide by:
  - Developing and distributing guidance.
  - Sponsoring technology transfer.
  - Jointly planning programs.
  - Identifying opportunities to collaborate and share resources.
  - Evaluating the effectiveness of federally funded programs.
- Link Federal ambient water-quality-assessment programs by:
  - Meeting at least annually to share information that results from federally funded assessment efforts and to coordinate future plans.
  - Identifying opportunities to collaborate and share resources.
  - Considering an Executive order to implement Federal aspects of the strategy.

- **State and Tribal Program**

- Alter the 305(b) period for reporting from every 2 years to every 5 years, or, if no legislative change is made, design the reporting so that States would cover their waters in a linked series of three successive reports covering 6 years. Electronic annual updates will be produced as needed.
- Through State and Tribal leadership in cooperation with representatives of Federal, local, and private monitoring organizations within their jurisdictions, establish and maintain teams that would design and implement water-quality-monitoring improvements.
- To the extent possible, build on existing collaborative mechanisms to implement the strategy.
- For planning and reporting, use river or groundwater basins, watersheds, ecosystems and other areas that have natural, rather than political, boundaries.
- Use an agreed upon initial set of key physical, chemical, and biological parameters to measure the attainment of designated uses set in State water-quality standards.
- Using guidance prepared at the national level, include as a subset of the initial parameters a set of core indicators that would support interstate and national aggregations of comparable information.

- **Watersheds and Local Jurisdictions**

- Work with and provide tools and information to watershed and other geographic area managers to facilitate assessment and management of waters and to resolve water quality problems.
- Include county and municipal representatives in the implementation of the Strategy at all stages.

- **Compliance and ambient monitoring coordination**

- Develop, test, and institutionalize methods to integrate ambient and compliance informa-tion to better support decisionmaking. Also, make ambient information more available to the compliance monitoring community.
- Made available to the public in automated systems compliance information that would generally be useful.
- Include minimum levels of quality-assurance (QA) and quality-control (QC) information.
- Begin efforts as pilot studies that involve appropriate Federal, State, or Tribal agencies and the compliance monitoring community.

- **Volunteer Monitoring**

- Include volunteer monitoring organizations as partners when planning and implementing monitoring efforts
- Develop clear guidance concerning quality assurance, procedures for documenting information, and monitoring methods.
- Provide training for volunteers on monitoring techniques, where feasible, through interagency collaboration.

Methods Comparability

- Develop and implement technical recommendations necessary to produce comparable data of known quality that can be integrated from a variety of sources across a variety of scales.
- Through a consensus process, develop and adopt standard data-element names and definitions.
- Implement a performance-based methods system (PBMS) to achieve comparable data and more flexible use of appropriate monitoring methods. An infrastructure at the national level is required to support PBMS. ITFM recommends a Methods and Data Comparability Board (MDCB; see "Implementation" section below).
- Jointly establish reference conditions for shared use in biological/ecological monitoring programs

Information Automation, Accessibility, and Utility

- Automate data and information of general interest and usefulness.
- Develop additional tools to facilitate information searches and retrieval across data bases. One such tool is a set of minimum data elements for sharing existing data.
- When existing water-quality-information systems are being modernized or when new systems are being developed, information from the new systems can be easily shared by using:
  - Common data-element definitions and formats.
  - An expanded set of recommended data elements or qualifiers (in addition to the minimum data elements) to facilitate the sharing and exchange of information.
  - Common references tables, such as taxonomic and hydrologic unit codes, and River Reach File 3 codes.
  - Metadata standards (metadata describes the content, quality, condition, and other characteristics of data. It helps secondary users to judge whether the data would be useful for other application.)
  - Facilitate the sharing of water-quality information that would be useful to secondary users, but that currently is not readily available. For example, major public-water suppliers have offered to share such information holdings.
  - Share, and where advantageous, jointly maintain ancillary data sets that are widely used for water-quality purposes, such as land use, land cover, demographics, and water use.
  - Working with the Federal Geographic Data Committee (FGDC) and other groups, use standard data sets when they are available. An example would be the River Reach File 3 that is being jointly developed and adapted as part of the FGDC's National Spatial Data Infrastructure
  - Use Internet and MOSAIC or other widely recognized standard communications and access systems when they are available.

Quality Assurance/Quality Control

- Establish, for all monitoring programs, data-quality objectives to identify the precision and accuracy of data needed to achieve the monitoring goal.
- Save time and money by ensuring that:
  - QA/QC procedures and data are appropriate to the purposes of the program.

- Procedures are followed correctly.
- Procedures are documented with the data in storage systems.

Assessment and Reporting

- Organizations will continue to assess and report their own data for their own purposes. However, increasingly, agencies need data from other sources to understand and present their issues more completely. The ITFM recommends that reports be produced by lead agencies in close collaboration with others. The contributing partners should be acknowledged in the reports.
- Regularly interpret and assess measurements and raw data. Data should be collected only when there is a specific assessment or other intended use.
- Develop additional interpretive and assessment methods and tools.
- Inform resource managers, policymakers, the general public, and others about environmental conditions and problems.
- Include the assessment techniques in the design of the monitoring program so that the data collected effectively supports the needed analysis.

Evaluation of Monitoring Activities

- Have collaborative teams from all organizations periodically evaluate their monitoring activities and programs to assure that needed information is meeting current objectives in the most effective and economical ways.
- Every 5 years evaluate progress toward implementing the ITFM's Strategy for nationwide monitoring and document updates needed to the strategy.

Research and Development

- Identify needs for new or improved monitoring techniques to support current and emerging water-management and environmental protection requirements. The ITFM's strategy is to work closely with the National Science Foundation, the National Council on Science and Technology, and similar groups to ensure that water-quality-monitoring research needs are considered in ranking national science priorities.

Training

- Promote training incorporating all organizations to:
  - Transfer technology.
  - Inform others about needed changes in monitoring planning and procedures.
  - Achieve the QA and QC necessary to assure scientifically sound information for decisionmakers.
  - Facilitate comparability of methods.

Pilot Studies

- Continue to use pilot studies to test the implementation of the ITFM proposals. The pilot studies are needed to:
  - Provide feedback to move from the strategy to tactics for implementation.
  - Provide information on implementation costs and on the savings resulting from improvements that are made.

Implementation

- Continue the concept of intergovernmental collaboration for the development and use of monitoring guidance and for technology transfer.
- Establish a National Water Quality Monitoring Council representing all levels of government and the private sector to guide the overall implementation of the strategy. Such a council is needed to:
  - Ensure that technical support and program coordination is maintained among participating organizations.
  - Evaluate periodically the effectiveness of monitoring efforts nationwide and account for regional differences, such as between arid and water-rich States.
  - Revise the strategy as needed to ensure that monitoring continues to meet changing needs.
- Establish an MDCB under the National Council to identify methods needed to achieve nationwide comparability for core information and to provide critical guidelines and collaboration to support the PBMS.
- Establish State or Tribal and, where needed, interstate monitoring and data teams to identify roles and responsibilities and to facilitate collaborative efforts. To the extent possible, use successful existing groups.

- Develop additional technical information and guidelines to support ground-water, coastal water, and wetland monitoring. Additional guidelines are needed to ensure that the special monitoring needs of these areas are fully integrated into the nationwide strategy.

Funding

- Provide some Federal resources to help support pilot studies in selected areas. The U.S. Environmental Protection Agency (USEPA) is providing a total of $500,000 to selected States's Tribes in fiscal year (FY) 1995. In addition, the U.S. Geological Survey (USGS) will include the implementation of the ITFM's Strategy as one of the priorities of the Na-tional Water Resources Research and Information System—Federal/State Cooperative Program in FY 1995 and beyond. The above funds are in addition to Federal money for monitoring already available to States and Tribes through existing mechanisms in a number of agencies, such as the USEPA 106 grants.
- Develop financial agreements among Federal agencies to facilitate the efficient transfer of resources and to maintain accountability needed for joint monitoring and data projects. Where appropriate, similar financial agreements with State or Tribal agencies and other organizations should be developed.
- Document cost savings, and other improvements that result from collaboratively planning and implementing monitoring activities.

INCENTIVES

For the nationwide strategy to succeed as a voluntary effort, significant incentives and benefits must exist for organizations that participate. The ITFM has been encouraged by the many organizations that have already provided significant staff support and have pooled resources to develop the strategy and tools for implementation. Organizations continue to express interest in joining the collaborative effort. Some of the incentives and benefits of participating are as follows:

- Agencies can significantly expand their scientific information available for making internal decisions at relatively little cost compared with collecting additional data themselves. Adequate information reduces uncertainty about the results of proposed actions and increases management effectiveness.
- Through collaboration with other organizations, agencies can achieve a better return on their monitoring investments and, in some cases, can even reduce their costs.
- By using the concepts and tools in the nationwide strategy, agencies can correct chronic problems in their own monitoring efforts and make the data they collect in the future more useful for their own applications.
- Public and private organizations that manage natural resources and protect the environment can better determine whether their policies and actions are working as intended.
- By participating in cooperative monitoring programs, government agencies and private-sector organizations can improve the credibility of the information they report to the public.

INITIAL AGENCY ACTIONS

This report provides a comprehensive blueprint for improving water-quality-monitoring efforts nationwide. However, we do not have to wait for comprehensive implementation of the strategy to make positive changes. As a result of the ITFM process and associated efforts, we have already made a difference and saved millions of dollars. This progress includes the following:

- *Information sharing and cost savings*—Two examples of this resulted from joint purchase and maintenance of information as follows:
  - Eight Federal agencies, which include the Smithsonian Institution, have expanded and are negotiating to use and maintain a common automated taxonomic code. The National Ocean and Atmospheric Administration (NOAA), the USEPA, and the USGS are currently using this taxonomic code.
  - NOAA, the USGS, the USEPA and the U.S. Fish and Wildlife Service (USFWS) have jointly purchased and are sharing remotely sensed land-cover information needed for water assessment and management. This has already saved Federal agencies at least $4 million.
- *Jointly modernize data systems*—The USEPA's STOrage and RETrieval System (STORET) and USGS' National Water Information System (NWIS–II) are using common data-element

names and reference tables that will ensure easy sharing of data. Also, the USEPA and the USGS are working with other agencies to facilitate the use of common elements in the design of new systems.

- *State monitoring teams.*—Florida, Idaho, New Jersey, and Wisconsin have held meetings with the many collectors of water information to initiate a statewide monitoring strategy. During the public review of this strategy, States including California, Michigan, Minnesota, and Arizona stated they were pursuing monitoring teams of some kind.
- *Monitoring Program Design.*—The USEPA and States used the ITFM base monitoring-program outline to develop new monitoring guidance for USEPA water-quality grants to States. The U S Army Corps of Engineers (USACE) also based their own monitoring guidance on the ITFM products; the guidance will be used at hundreds of USACE projects nationwide.
- *Reporting.*—The ITFM analytical work related to indicators is a major contribution to proposed changes in the USEPA guidelines for the States' 1996 305(b) reports. These changes will produce more comparable information among States.
- *Methods.*—The National Water-Quality Assessment (NAWQA) Program hosted an interagency workshop to compare differences in biological monitoring methods and to look for areas where consistency or comparability is needed. A report about the workshop is available.
- *Geographic Focus.*—Many States and USEPA regional offices have reorganized management and (or) monitoring programs to place emphasis on priority watersheds and to assess more waters by using a revolving watershed approach. The coordination of monitoring in these watersheds allows managers to have more current and comprehensive information on specific issues and to make better resource-management decisions.

NATIONAL WORKPLAN TO IMPLEMENT THE STRATEGY

The ITFM's recommended nationwide strategy has received wide endorsement from a variety of reviewers. It has received over 60 individual and aggregated comments from local, State, Regional, Federal, and private organizations and from individuals. Next, the ITFM and its successor, the National Water Quality Monitoring Council, are developing a workplan to implement the strategy at the national level.

The ITFM held a National Monitoring Strategy Workshop in February 1995 to draft the implementation workplan. A broad representation of the monitoring community was present. Proposed workplan elements discussed were as follows:

- Specific indicators to measure the national water goals and how to report on them jointly.
- A national monitoring design that covers waters comprehensively by using monitoring techniques appropriate to the condition, uses, and goals for the waters. ITFM tools already developed would be used to produce the design.
- Additional agency commitment to use the ITFM recommended data-element glossary.
- Plans for a workshop to demonstrate major water data bases and to discuss Internet access and other opportunities to increase data sharing.
- Pilot projects to interface ambient and compliance monitoring better. Federal, State, Tribal, local, and private monitoring entities would participate.
- A plan to address priority training needs.
- A core list of minimum metadata elements.

CONCLUSION

As the competition increases for adequate supplies of clean water, concerns about public health and the environment escalate, and more demands are placed on the water information infrastructure. These demands cannot be met effectively and economically without changing our approach to monitoring. Each organization participating in the Strategy will need to revise their monitoring activities in a series of deliberate steps over several years as staff and resources become available. As described above, benefits of the collaborative approach are already occurring, and benefits will continue to grow as the recommendations are implemented

We, the members of the Intergovernmental Task Force on Monitoring Water Quality (ITFM), with the advice and collaboration of many others in public and private monitoring organizations, present this nationwide voluntary water-quality-monitoring strategy.

We are working to implement this strategy in our organizations and with others at many geographic scales. We invite other parties to join us in implementing the strategy

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December 15, 1994

CONTENTS

FIGURES

TABLES

The Strategy for Improving Water-Quality Monitoring in the United States—Final Report of the Intergovernmental Task Force on Monitoring Water Quality

General Intent

This is the third and final report of the Intergovernmental Task Force on Monitoring Water Quality (ITFM). It proposes changes in water-quality monitoring that are needed to support sound decisionmaking at all levels of government and in the private sector. The proposed changes in water-quality monitoring are necessary to obtain a better return on public and private investments in monitoring, environmental protection, and natural-resources management. Implementing the strategy and recommendations is necessary to achieve nationwide water-quality goals to protect human health, to preserve and restore healthy ecological conditions, and to sustain a viable economy. The proposed strategy will expand the base of information useful for multiple purposes and a variety of users. In some cases, ITFM recommendations ratify and encourage ongoing efforts. In other cases, ITFM calls for fundamental changes in the ways that water-quality-monitoring programs are defined, designed, prioritized, conducted, and funded.

Background

History of the Intergovernmental Task Force on Monitoring Water Quality

The ITFM was formed in early 1992 in response to Office of Management and Budget (OMB) Memorandum No. 92–01. This memorandum set forth specific requirements to review and evaluate water-quality-monitoring activities nationwide and to recommend improvements. Also, it delegated lead-agency responsibility for water information coordination to the USGS. The OMB memorandum and the Terms of Reference of the ITFM are provided in the ITFM first-year report (Intergovernmental Task Force on Monitoring Water Quality, 1992).

The ITFM is a Federal/State or Tribal partnership that includes representatives from 20 Federal, State, Tribal, and interstate organizations. The U.S. Environmental Protection Agency (USEPA) serves as co-chair, and the U.S. Geological Survey (USGS) serve as co-chair and the executive secretariat. In addition to the 20 officially designated ITFM representatives, more than 150 individuals in Federal and State agencies participate in nine working groups to provide additional perspective and technical expertise. Private sector organizations also participate in the process through the Federal Advisory Committee on Water Data for Public Use, public meetings announced in the *Federal Register*, and an initiative to promote coordination of ambient and compliance monitoring. The work of the ITFM is sponsored by the Federal interdepartmental Water Information Coordination Program.

Previous Reports

The two preceding ITFM reports provide information that will enhance understanding of the recommendations in this final report. In December 1992, the ITFM completed its first-year report, *Ambient Water-Quality Monitoring in the United States: First Year Review, Evaluation, and Recommendations*. The report focused on the evaluation of current ambient-monitoring efforts and the opportunities for improvement. The report concluded that monitoring programs must keep pace with changing water-management programs, a collaborative strategy is needed to link the many separate monitoring programs, a genuine appreciation of the need for cooperation currently exists among monitoring agencies, and recent advances in technology provide new opportunities for interaction and cooperation. The report recommended that an integrated, voluntary, nationwide strategy should be designed and implemented to improve water-quality monitoring in this country.

The ITFM published its second year report, *Water-Quality Monitoring in the United States: 1993 Report of the Intergovernmental Task Force on Monitoring Water Quality*, in June 1994. This report documented the ITFM's recommendations for the technical "building blocks" needed to implement the strategy and presented for public review the supporting technical reports prepared by the ITFM working groups.

These technical reports, which were published as separate appendixes, address monitoring frameworks, environmental indicators, methods comparability, data management and sharing, resource assessment and reporting, and ground-water issues. Also,

the second-year report contains information about a pilot project in Wisconsin designed to test ITFM assumptions and recommendations. [See the inside front cover of this present report for information needed to order the previous reports.]

Definitions and Scope

The ITFM recommendations address the full range of aquatic resources, which include ground and surface waters and fresh and marine environments, in the United States. International considerations also are important but are beyond the scope of this report. Canada and Mexico, however, have been very interested in ITFM activities, and the ITFM envisions future work with agencies in other countries. To identify improvements needed to support more effective decisionmaking, the ITFM broadly defined monitoring functions. To identify the multiple elements of a complex subject clearly, the ITFM identified five major purposes for monitoring. Table 1 lists the ITFM consensus definitions for aquatic resources and monitoring functions and the purposes of water-quality monitoring. A glossary of terms used by the ITFM is provided in Technical Appendix A.

Historical Context

Control of water pollution became a major environmental priority during the last three decades, and in response, water-quality monitoring has expanded rapidly. In the 1970's, Federal and State governments began requiring the regulated community—industry, public water suppliers, municipalities, and others—to monitor water quality. The resulting data are being used to demonstrate compliance with pollution-control permits and to obtain information required to estimate pollution loading from human sources into the environment. Today, tens of thousands of public and private organizations spend hundreds of millions of dollars a year on compliance monitoring.

These important compliance-monitoring efforts focus on well-defined sources of pollution, such as industrial facilities, sewage-treatment

Table 1. Key Intergovernmental Task Force on Monitoring Water Quality definitions

	Key ITFM definitions
Aquatic resources	Surface and ground waters, estuaries, and near coastal waters. Associated aquatic communities and physical habitats, which include wetlands. Sediments
Aquatic resources data	Physical, which includes quantity. Chemical/toxicological. Biological/ecological. Associated data needed to interpret the aquatic data, including habitat, land use, demographics, contaminant discharges, and other "ancillary" information, such as atmospheric deposition
Monitoring program activities	Identifying and documenting program goals and purposes. Designing and planning monitoring programs. Coordinating and collaborating with other monitoring agencies Selecting environmental indicators Locating appropriate monitoring sites. Selecting data-collection methods Collecting field observations and samples. Analyzing samples in laboratories. Developing and operating quality-assurance programs Storing, managing, and sharing data. Interpreting and assessing data to produce useful information. Reporting and distributing monitoring results to different audiences Evaluating the effectiveness of monitoring programs.
Purposes of monitoring	Assessing status and trends (includes spatial and temporal variability). Characterizing and ranking existing and emerging problems. Designing and implementing programs and projects Evaluating program and project effectiveness. Responding to emergencies (ITFM did not address).

plants, or waste-disposal sites. The primary intent is to characterize the concentrations of water-quality constituents at their sources, or "the ends of pipes." In part, point-source concentrations of pollution were the initial focus of regulatory monitoring because knowledge of the interactions between human activities and natural systems was more limited than it is today. Point sources are easier to define and monitor compared with nonpoint sources. As a result, more money has been spent on point-source-compliance monitoring than on either nonpoint or ambient monitoring. As a further result, few ambient-monitoring programs assessed overall water quality and the causes and sources of nonpoint-source and habitat problems.

When it became widely apparent in the late 1980's that water-quality protection and management goals could not be achieved without considering point and nonpoint sources of pollution, as well as habitat degradation, the need to reshape the overall monitoring strategy became clear. Thus, the public and the private sectors have initiated several new ambient-monitoring and assessment efforts (Intergovernmental Task Force on Monitoring Water Quality, 1992). However, significant gaps remained, and until the ITFM effort, coordination among the various new programs was uneven. Today, agreement is widespread that existing data programs cannot be added together to provide all the information needed to answer the more recent complex questions about national or regional water quality (National Research Council, 1987, 1990a, b; U.S. Environmental Protection Agency, 1987; Knopman and Smith, 1992). Wide recognition of the need to improve water-quality monitoring to accomplish clearly defined objectives and to obtain better ambient and compliance information has bolstered the ITFM's efforts to develop a strategy.

Fortunately, technology has advanced during the last 25 years. Better tools and knowledge are now available, and a monitoring strategy can now be created to support the development of policies and programs that target available resources to priority problems within watersheds, ecosystems, and specific geographic areas. It is now possible to develop a monitoring strategy that will be useful for evaluating the effectiveness of resource-management and environmental protection actions. Monitoring to evaluate program effectiveness is needed not only to protect human health and ecosystems, but also to ensure that money is spent wisely. From 1972 through 1986, the total public and private costs for water-pollution abatement exceeded $500 billion (Carlin and the Environmental Law Institute, 1990), and by the end of this century, hundreds of billions of dollars more will be spent (U.S. Environmental Protection Agency, 1990).

Institutional and technical changes are needed to improve water-quality monitoring and to meet the full range of monitoring requirements. The proposed strategy provides a long-term blueprint for making the changes that are needed. As more organizations adopt the recommendations and become partners in implementing the strategy, the nationwide capability to assess water-quality conditions will grow. As a result, the information gathered from implementing the strategy will be greater than the sum of the measurements produced by individual organizations.

Water-Quality Questions

Water-quality monitoring provides an objective source of information to answer questions that support the wise management of vital water resources. Appropriate ambient and compliance monitoring provides the basis for informed management throughout the decisionmaking process (fig. 1). Adequate monitoring is needed at many scales—site, watershed, State, Tribal, regional, and national. Historically, some questions have been difficult or impossible to answer, especially at the regional and the national scales. Improved monitoring is needed to assess the quality of essentially all the Nation's water resources in a targeted way that will provide quantitative answers to the following questions:

- What is the condition of the Nation's surface, ground, estuarine, and coastal waters?
- Where, how, and why are water-quality conditions changing over time?
- Where are the problems related to water-quality? What is causing the problems?
- Are programs to prevent or remediate problems working effectively?
- Are water-quality goals and standards being met?

Uses of Water-Quality Information

Monitoring programs over the past 3 decades have provided large amounts of data; many of these data have not been analyzed to provide water-quality managers and regulators with the information needed to manage water resources relative to the questions

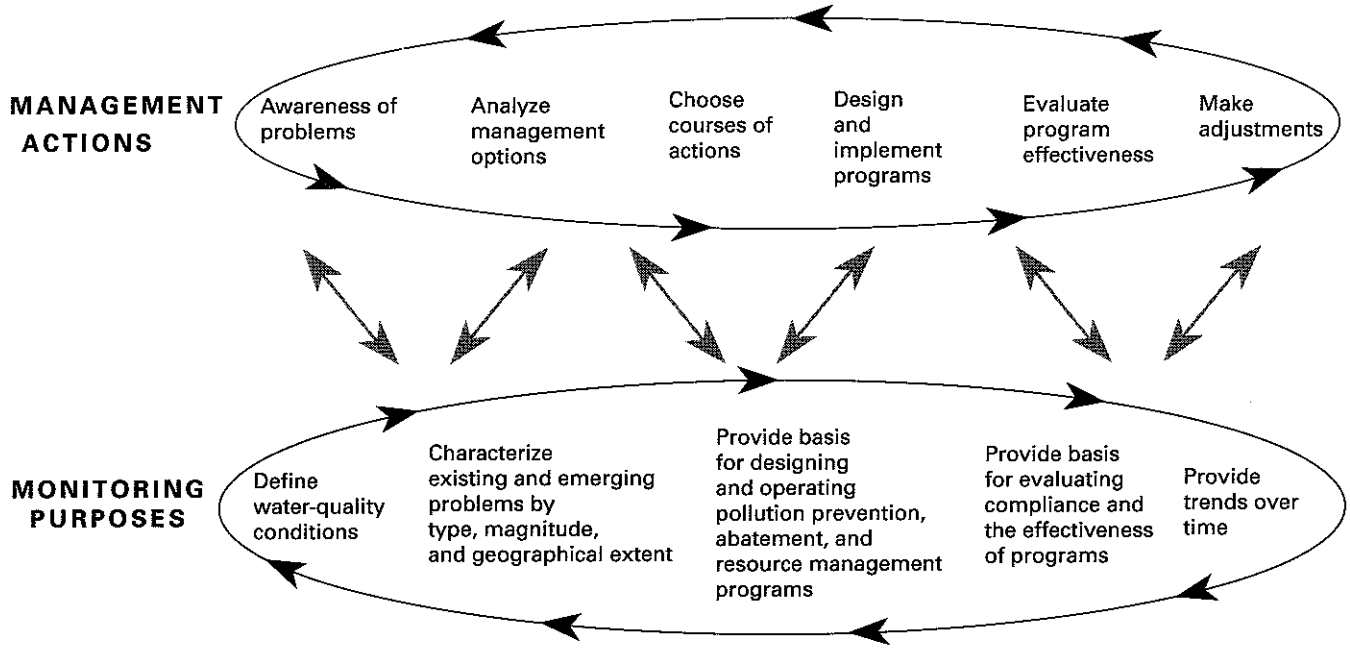


Figure 1. Relation of monitoring purposes and management actions.

listed above. One potential explanation for this lack of data analysis is a limited appreciation of the uses and the users are of water-quality information. In fact, monitoring information is used by Federal, State, and Tribal governments; legislators; regulators and natural-resources managers; private industry; scientists; academia; and the general public. Users and uses of water-quality information include the following:

- *Citizens*.—Need information to understand environmental risks, exercise environmental stewardship through responsible behavior, and support needed policy and program changes.
- *Legislators*.—Develop water-quality and related resource goals, policies, and programs and evaluate progress in achieving the goals.
- *Regulators*.—Plan, operate, and evaluate programs; protect public health, aquatic habitats, and wildlife populations; determine if water-quality standards and permit requirements are being met; and take appropriate enforcement action when necessary.
- *Resource managers*.—Develop plans and policies, support operational decisions, resolve water-use disputes, and evaluate the success of programs.
- *Municipalities and industries*.—Plan and manage water supplies and discharges; identify sites for development, preservation, and other purposes; and comply with water-quality standards and permits.
- *Environmental groups*.—Evaluate government policies and programs and identify problems that need to be addressed.
- *Scientists*.—Improve understanding of the relations among ecological, chemical, physical, biological, and hydrological processes and conditions.

Findings and Changes Needed

The ITFM members have found that there are opportunities to improve current water-quality-monitoring efforts nationwide in the public and the private sectors. Although many individual monitoring networks have been well designed to meet their own goals, data solely from these networks often will not provide a broad and comprehensive assessment of water quality at national, interstate, State, Tribal, or watershed scales. Also, data from some of the networks cannot be readily shared and integrated to help with similar assessments in related areas. The ITFM identified several kinds of problems for which changes are recommended in later sections of this report. The changes needed are summarized as follows:

- *Identify indicators to measure goals*.—It is critical that the specific purposes and goals for a

monitoring program be identified as it is being designed. This establishes a foundation for choosing indicators to measure progress toward meeting water-quality goals or to evaluate the effectiveness of programs and policies

- *Allocate monitoring resources on the basis of water-quality goals, conditions, and uses.*—The United States cannot afford to monitor all geographic locations by using the same frequency, spatial density, selection of indicators, or other design factors. A rationale is needed to target monitoring resources more effectively on the basis of the goals, conditions, and uses of the waters. For instance, monitoring designs to assess potable supplies in Arizona need to be different from designs to monitor salmon habitat in the Pacific Northwest.
- *Integrate surface- and ground-water monitoring.*—Water-quality and water-quantity information for fresh and saline surface- and ground-water resources need to be integrated. Ground- and surface-water systems are hydraulically connected. Land- and water-use and other human activities within watersheds affect water quality on the surface and underground. However, the scopes of individual monitoring programs are limited by the sponsoring organizations' missions, legislative mandates, and staffing and financial resources within single organizations. Consequently, management decisions and monitoring programs often narrowly focus on surface- or ground-water-quality considerations. Such separation hampers the effectiveness of water-quality-management programs.
- *Link compliance and ambient monitoring.*—Historically, water-quality-monitoring efforts have been oriented to support single programs. Ambient and compliance monitoring have been done in separate, often unrelated, programs. Comprehensive watershed, ecosystem, and ground- and surface-water management requires monitoring that is more complete and useful for comprehensively characterizing water conditions. It is necessary to understand pollution loading impacts on ambient conditions and the impacts of ambient characteristics on regulatory decisions and water uses. These issues are mutually dependent and need to be linked better.
- *Include ecological, biological, and toxicological information.*—Specific ecological and biological conditions and toxicological constituents of recent concern need to be monitored. Many existing water-monitoring networks were designed and implemented without direct measurements of ecological conditions and before many toxic constituents were widely recognized as being important. Although many components of ecosystem monitoring are still in the research and development phases, improved field and laboratory methods for biological measures of ecological conditions and toxicants (for example, tissue and bed-sediment analyses) and the use of biomarkers create opportunities to fill some of the gaps in monitoring programs. The new information will significantly improve ecosystem-, watershed-, and aquifer-management decisions.
- *Implement comparable methods.*—Data compatibility must be improved so that organizations can use information from multiple sources. Differences in methods used to collect and analyze water-quality samples frequently pose impediments to making full use of data from other sources. Also, organizations use different names or different definitions for the same or similar parameters. Finally, even if the methods, names, and definitions are compatible, adequate quality-assurance (QA) programs are needed to quantify the precision, accuracy, and integrity of environmental data to ensure that these data can be used for the appropriate application.
- *Make data more accessible and of known quality.*—A secondary user cannot access most water-quality data. When these data are accessible, they require considerable additional effort to understand or use. Frequently, the data are poorly documented. Consistent with the findings about comparable methods, information-management systems need to use common data-element names, definitions, and data descriptors to facilitate the use of the information.
- *Modernize information systems.*—Many existing data-storage and information systems need to be modernized. Large-scale data-base-management systems fulfilled their original purposes; by today's standards, however, they are narrowly focused to the historical requirements of the managing organizations. As the technology of data collection, analysis, storage, retrieval, and

interpretation matures, organizations need to revise their data-management systems. The revisions will permit the storage of new types of data, as well as more convenient access and use by secondary users. Modern structured systems design has only recently begun to address issues, such as identification of common data descriptors and metadata standards, that allow secondary users to evaluate whether someone else's data meets their needs. As systems are created or redesigned, the ability to transfer information easily among organizations needs to be incorporated. Also, the overall design of new systems should incorporate new querying tools, such as WAIS or MOSAIC. In addition, new systems should provide links to modern statistical, modeling, and information-presentation software.

- *Assess data and report results.*—It is no longer enough to collect and store data. Basic data need to be routinely interpreted, assessed, and reported because most users rely on available interpreted information rather than raw data. Also, routine interpretation helps to reveal inadequacies in monitoring-program design or implementation so that timely adjustments can be made.
- *Identify research needs.*—Applied research and development are needed in several areas. These needs include methods for collecting and using ancillary data, modeling complex hydrogeologic systems and ecosystems, measuring and assessing ecological health, and sampling and analyzing toxic constituents (such as trace elements, pesticides, other organic chemicals) at affordable costs. Also, methods are needed to design and operate monitoring for nonpoint sources of pollution and highly variable wet-weather runoff that are difficult to quantify. Technology is needed to improve monitoring instrumentation, which includes sensor development. Achieving the watershed-management and ecosystem-protection goals will require sustained interagency support for applied interdisciplinary technology development and research to address these and other knowledge gaps.
- *Cost effectiveness.*—Resources for monitoring water quality need to be applied more effectively to produce more useful results. Many of the recommendations discussed later in this report are intended to improve resource sharing among monitoring organizations or to expand the base of information that can serve multiple uses.

To respond to these findings, the ITFM proposes a comprehensive nationwide strategy for water-quality monitoring and resource assessment. Implementation of the following strategy and recommendations by all levels of government and the private sector will make information available in a timely manner to support management decisions and to measure progress towards meeting water-quality goals. The intent is to set in motion a process that makes it advantageous for all data collectors to embrace the proposed changes in monitoring water quality voluntarily and to make the resulting information more useful.

Nationwide Strategy for Improving Water-Quality Monitoring

Major recommendations that have resulted from the ITFM's 3-year evaluation of water monitoring in the United States are presented below. Some recommendations are based on longstanding coordinating mechanisms that work, given the existing constraints. Other recommendations propose voluntary intergovernmental and private sector collaboration that takes into consideration specific Federal, State, Tribal, regional, local, and watershed and private interests. Simply put, these recommendations present a nationwide strategy that would improve the ability to monitor, assess, and manage the Nation's water resources at all geographic scales.

Goal-Oriented Monitoring and Indicators

The ITFM, as well as the public, endorses the USEPA Office of Water's proposed nationwide water goals. These goals are to protect and enhance public health, to conserve and enhance ecosystems, to meet State water-quality standards, to improve ambient conditions, and to prevent or reduce pollutant loadings. In addition, the quantity and quality of water needed to sustain a viable economy must be provided.

Specific environmental indicators will measure whether or not the goals are being achieved. The ITFM defines an environmental indicator as "a measurable feature which singly or in combination provides managerial and scientifically useful evidence of environmental and ecosystem quality or reliable

evidence of trends in quality." Environmental indicators need to be measured by using available technology that is scientifically valid for assessing or documenting ecosystem quality. They also need to provide information upon which resource managers can base decisions and communicate results to the public. Environmental indicators encompass a broad suite of measures that include tools for assessment of physical, chemical/toxicological, and biological/ecological conditions and processes at several scales. Water-quality indicators must explicitly measure the identified goals and relate to State standards. The ITFM has developed some preliminary guidance that includes criteria to assist organizations in selecting indicators for specific goals (see Technical Appendixes D and E). The development of such guidance is continuing in conjunction with the USEPA's 305(b) consistency workgroup, which includes 22 States, 3 Tribes, and other Federal agencies. At the national level, Federal agencies are developing indicators in concert with actions mandated in each Federal agency through the Government Performance Results Act of 1993.

Gathering and Evaluating Existing Information Gaps and Priorities

Before significant improvements in water-quality monitoring are implemented, existing monitoring efforts and information need to be identified and evaluated. This evaluation can be structured by attempting to characterize current surface- and ground-water-quality conditions by using available information. Geographic information systems (GIS) can be very helpful in conducting such evaluations and presenting maps and analyses of the spatial relations among the associated information on water bodies. The actual locations of impaired water bodies and the reasons for the impairments should be included if information permits. In addition, special protection areas and waters that are not impaired should be mapped. Special protection waters include endangered species habitats, and impaired waters are those that do not meet water-quality standards. A useful tool for locating and georeferencing surface waters is the USEPA's computerized River Reach File 3 (RF3), which was originally developed by using USGS topographic maps. It is now being adapted for use as a future Federal Information Processing Standard. After mapping and evaluating existing information, monitoring gaps can be identified and ranked by priority. Ranking by priority is important because monitoring gaps that are lower priority and that can not be monitored within available resources can be explicitly acknowledged. Once the initial information is properly structured in a GIS system, new information can be added as it becomes available. Also, the information can be used more easily for many management purposes.

Flexible and Comprehensive Monitoring

To provide adequate and cost-effective information for resource management and environmental protection, comprehensive assessments of the Nation's ambient water resources are needed; such a comprehensive assessment would use basins rotating in and out of 5- to 10-year cycles in which feasible monitoring designs and monitoring techniques are targeted to the condition of and goals for the water. Ambient-monitoring resources should be targeted at the State or Tribal scale and, as needed, at the regional and the watershed scales and depend on water-quality conditions, designated uses, and goals for the water. The most intense and frequent monitoring should focus on threatened or impaired water bodies. Outstanding natural water resources, endangered species habitats, sole-source aquifers, and other water bodies that are identified for special management and protection should be monitored comprehensively, but less frequently than impaired waters, in periodic cycles every few years. If detrimental changes are detected, however, then more intensive monitoring would be needed. Waters that have been assessed and determined to meet their designated uses and that are not impaired or threatened should be monitored less intensively on a rotational screening basis every 5- to 10-years to confirm that new problems have not emerged. Temporal frequency, spatial density, suites of parameters or indicators, and other design factors should be tailored to the conditions, uses, and goals for the water that is monitored (table 2).

To initiate the flexible and comprehensive monitoring approach described above, Federal, State, and Tribal agencies would need to use key existing information to categorize the surface and ground waters in their jurisdictions by using the criteria discussed above and shown in table 2. At first, the waters would be assigned to categories on the basis of the information currently available and aggregated into an overall assessment by using GIS. By using the approach recommended, confirmation or adjustments could be made to the characterization

Table 2. Targeted monitoring strategy

[Monitoring data from all partners can be used in any category. Site selection design can range from probalistic to targeted in any category]

Management focus for resource	Categories of water	Flexible monitoring designs
Maintenance	Meets or exceeds standards and objectives.	Long-term. Low frequency or rotational. Low/moderate density. Screening by using a comprehensive site of indicators.
Special protection	Outstanding natural resource waters; habitat of endangered species; ecological reference conditions; sole-source aquifers	Long-term periodic frequency Moderate spatial density. Comprehensive suite of indicators.
Remediation and restoration	Do not meet standards and objectives. Or may not meet in the future unless action is taken	Shorter term. High frequency High density. Indicators tailored to specific problems.

of the waters as a result of monitoring programs that would be designed for each water resource on the basis of conditions, uses, and goals. The design would include physical, chemical/toxicological, biological/ecological, habitat, and ancillary information and would incorporate monitoring efforts from local municipalities, private industry, and all levels of government. Within the selected indicators, a core set of comparable indicators would be chosen by mutual agreement and obtained for local use and for aggregation in regional and national assessments. Water for which information is insufficient to define the water-quality condition will need to be sampled in a stratified manner that reflects potential sources of pollutants from anthropogenic activities, climate, hydrogeologic setting, and goals for the water. During the 5- to 10-year cycles, the waters would be comprehensively assessed by using flexible monitoring designs (table 2). Information that results from the monitoring would be routinely interpreted, assessed, and reported by the responsible agencies to the public and decisionmakers. In addition, at the national level, the USEPA would aggregate information from States, Tribes, and others to produce the assessment report required by Section 305(b) of the Clean Water Act. Because the current Clean Water Act mandates a 305(b) report every 2 years, this recommendation would be implemented by linking a series of three reports that would cover all States and Tribal waters in 6 years. If legislative changes are made, then the USEPA would report to Congress every 5 years. The 305(b) report and other national and regional assessments would incorporate the suite of comparable core parameters collected and made available by States, Tribes, and other participating groups. On the basis of the results of the monitoring and assessments, the Federal, State, and Tribal agencies would adjust the category of each water resource and refine the monitoring design, as appropriate.

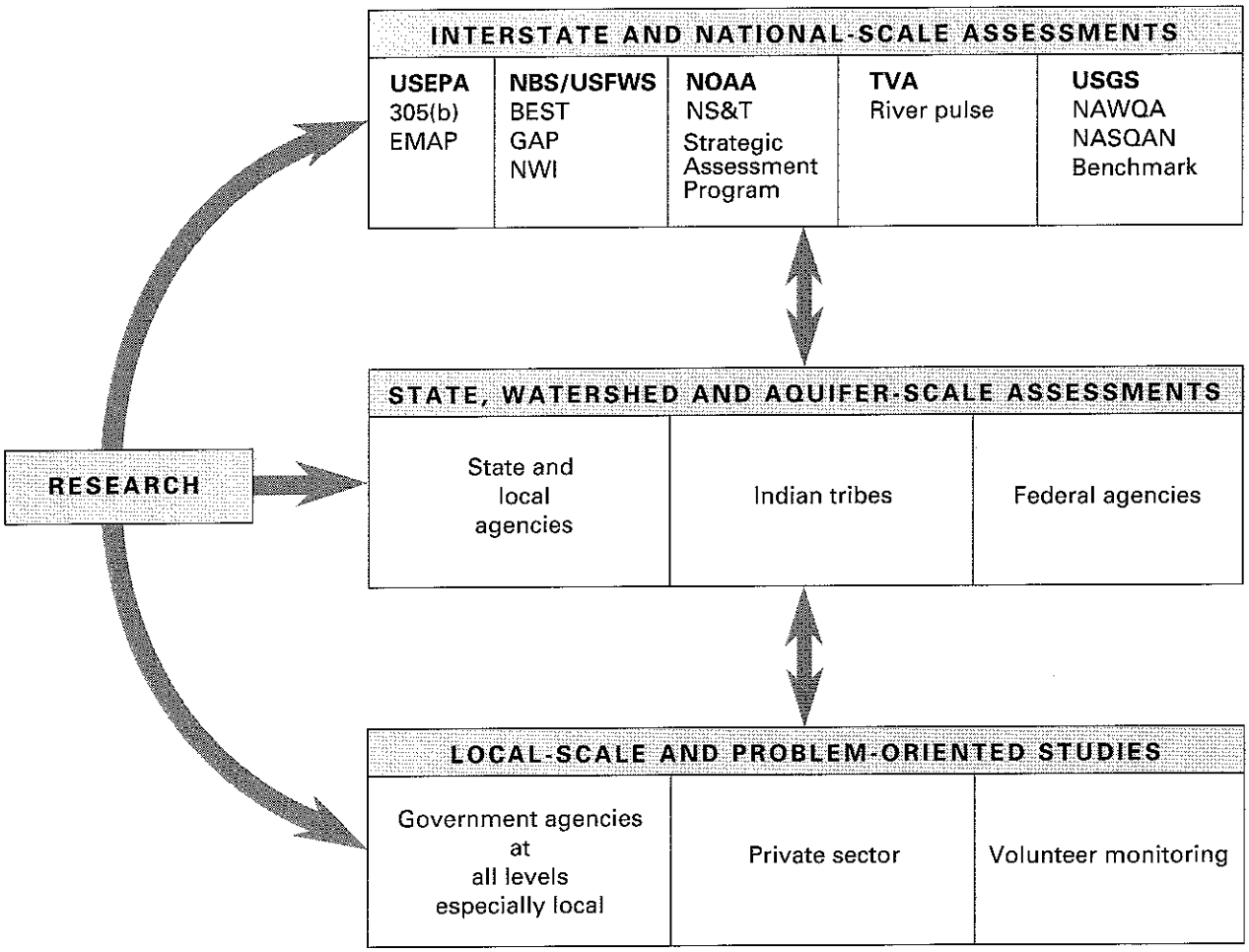
Institutional Collaboration

Thousands of organizations operate water-quality-monitoring programs and projects nationwide. Collaboration is necessary because few single organizations can afford to collect all the information needed for informed decisionmaking. The strategy to integrate these diverse institutional efforts is to establish collaborative partnerships of multiorganizational teams at national, interstate, State or Tribal, and watershed levels. These teams should include municipal, private, and volunteer monitoring groups. Formal mechanisms are needed at the national and the State or Tribal levels to ensure effective planning and coordination for monitoring efforts. At the watershed and the interstate levels, planning and coordination mechanisms need to be flexible enough to adapt to changing situations and resource limitations (fig. 2).

Federal Programs

Like other monitoring efforts, Federal programs are designed to meet mission-specific objectives. [See the first year report (Intergovernmental Task Force on Monitoring Water Quality, 1992, Appendix B) for a description of relevant Federal programs]. Collectively, they could convey a reasonably complete nationwide or regional story about

water quality. As part of the nationwide strategy, the ITFM proposes that national monitoring programs collaborate to provide a strong ambient-water-quality framework within which States, Tribes, and watersheds could contribute their geographically specific information. Non-Federal organizations should be involved in collaborating with and advising Federal programs and be able to access Federal information easily. Federal programs should among themselves identify common physical, chemical, and biological indicators, reference conditions, and comparable core parameters to share and report together. Major Federal information systems should be linked through shared reference tables, minimum data elements, common data-element definitions and names, and information-transfer software, such as



EXPLANATION

BEST	Biomonitoring of Environmental Status and Trends
EMAP	Environmental Monitoring and Assessment Program
GAP	Gap Analysis Program
NASQAN	National Stream Quality Accounting Network
NAWQA	National Water-Quality Assessment
NBS	National Biological Service
NOAA	National Oceanic and Atmospheric Administration
NS&T	National Status and Trends Programs
NWI	National Wetland Inventory
TVA	Tennessee Valley Authority
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
305(b)	National Water Quality Inventory (Clean Water Act)

Figure 2. Key monitoring relations.

Internet or MOSAIC. Federal agencies with national status and trends programs or major water-resources responsibilities are shown in figure 3.

The ITFM strategy includes an annual meeting of all managers of Federal water-status and water-trends programs to report on the previous year's monitoring results, to coordinate the future workplan, and to collaborate on nationwide products. In addition, the ITFM recommends that an advisory group be formed to support the major Federal ambient-assessment programs, such as the USGS's National Water-Quality Assessment (NAWQA) Program and the National Stream Quality Accounting Network (NASQAN), the USEPA's Environmental Monitoring and Assessment Program (EMAP), the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program (NS&T), and the National Biological Service's (NBS) Biomonitoring of Environmental Status and Trends (BEST) Program. This advisory group would foster better integration of Federal programs and more effective use of available resources. It would include members from all levels of government and the private sector. Currently, some Federal programs have their own advisory committees to support program-specific issues that require additional attention. As needed, these should continue as working groups of the assessment advisory group.

The Administration should consider issuing an Executive order to provide guidance to Federal agencies about their activities and participation. Active Federal leadership is needed to support such nationwide efforts as developing standards and guidelines, sharing data, leveraging program resources, facilitating technology transfer, and building consensus.

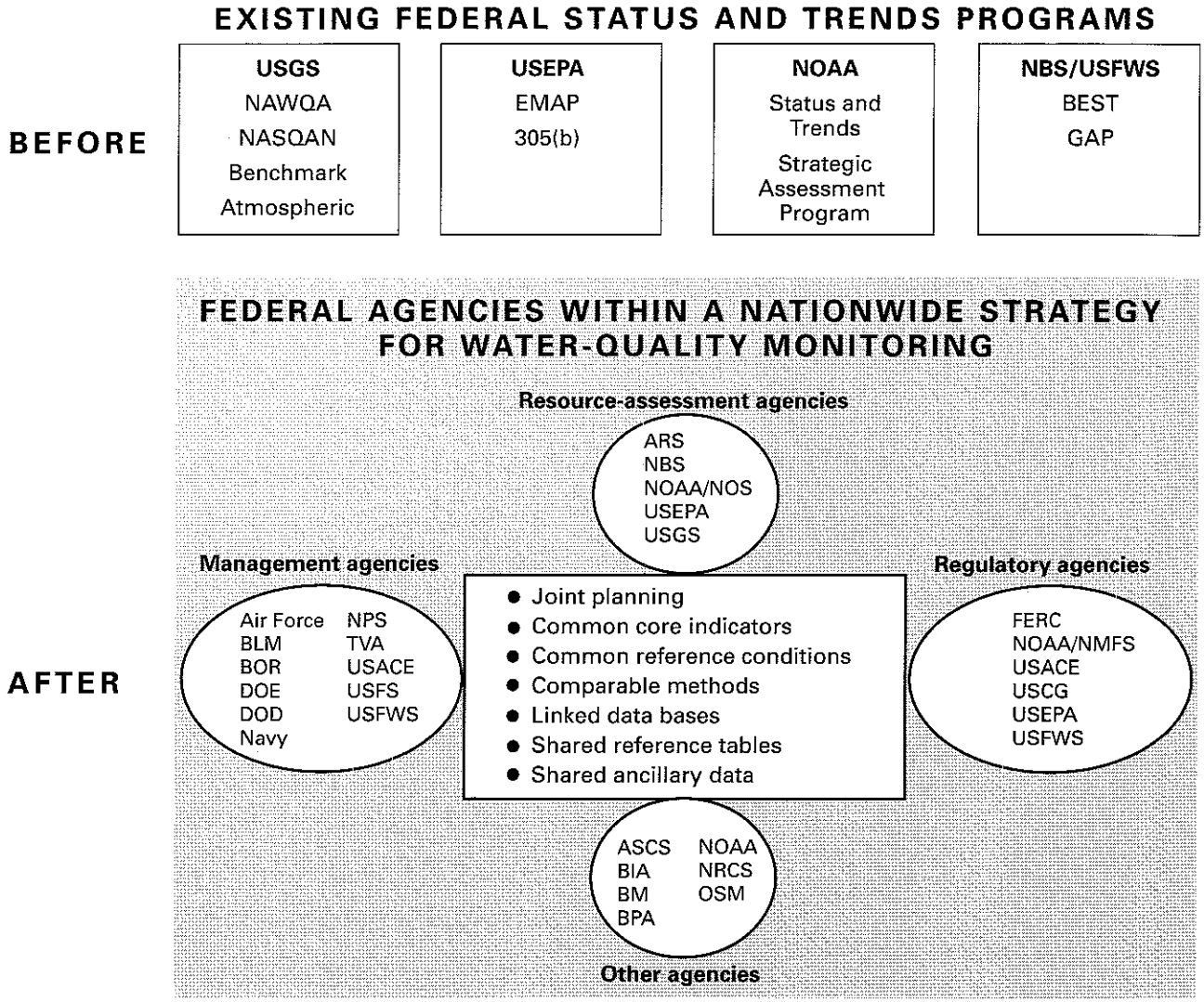
State and Tribal Programs

States and Tribes report water-quality status to the USEPA in the biennial 305(b) reports. USEPA has identified two concerns about its national report aggregated from the State reports. First, the data from the States and the Tribes are often not comparable and make a consistent aggregation of data at larger scales, especially the interstate and the national, difficult. Second, States and Tribes assess considerably less than all their water resources in any 2-year reporting period, in part, because many State budgets for monitoring programs have decreased over the years.

The ITFM recommendations of a 6-year cycle for the 305(b) report (5 years vs. current 2 years if legislative changes are made) and increased State comparability of assessment and collection methods would answer the concerns. In addition, some State and Tribal programs now are using program designs that allow them to monitor their water resources over a longer time period, say 5 to 10 years, often targeting their limited resbiological indicators, reference conditions, and compa
rable core parameters to share and report together. Major Federal information systems should be linked ources to address specific issues. In other words, some States and Tribes are already using revolving watershed assessments and priority systems similar to the approach endorsed by the ITFM.

The ITFM recommends that a redesign of State and Tribal monitoring programs begin with evaluating, synthesizing, and mapping existing information that would actively involve many different monitoring partners in a collaborative effort. This collaborative effort would include the following:

- *Delineate the area.*—The boundaries of water areas need to be determined. Depending on the objective of the program, the boundaries may be political or natural, such as hydrologic systems or ecosystems. Whichever method is chosen, GIS overlays of the boundaries should be available.
- *Map the waters.*—Key information about the chosen areas, which includes locating impaired waters, special protection waters, and unimpaired waters, as previously described, needs to be portrayed. The ITFM recommends using the RF3 as a uniform way to identify waters. The RF3 is a computer-mapping system that includes codes for surface waters, the direction of flow, and stream-reach locations. The USGS's Regional Aquifer System Analysis is the best source of information on major ground-water aquifers
- *Map scientific knowledge and human influences.*—Scientific information and human influences need to be overlaid on the basic map of surface and ground waters. Several examples are listed as follows:
  - Natural and political boundaries, which include watersheds, municipalities, counties, and States.
  - Surface-water characteristics, which include water bodies, hydrography, hydrologic characteristics, biological communities, and waste-water treatment plants.



EXPLANATION

ARS . . . . . Agricultural Research Service
ASCS . . . Agriculture Stabilization and Conservation Service
BEST . . . . Biomonitoring of Environmental Status and Trends
BIA . . . . . Bureau of Indian Affairs
BLM . . . . Bureau of Land Management
BM . . . . . Bureau of Mines
BOR . . . . Bureau of Reclamation
BPA . . . . Bonneville Power Administration
DOD . . . . U.S. Department of Defense
DOE . . . . U.S. Department of Energy
EMAP . . . Environmental Monitoring and Assessment Program
FERC . . . . . Federal Energy Regulatory Commission
GAP . . . . Gap Analysis Program
NAWQA . . National Water-Quality Assessment
NASQAN . . . National Stream Quality Accounting
NBS . . . . . National Biological Service
NMFS . . . . National Marine Fisheries Service
NOAA . . . National Oceanic and Atmospheric Administration
NOS . . . . . National Ocean Service
NPS . . . . . National Park Service
NRCS . . . . Natural Resources Conservation Service
OSM . . . . Office of Surface Mining
REMAP . . . Regional Environmental Monitoring and Assessment Program
TVA . . . . . Tennessee Valley Authority
USACE . . . U.S. Army Corps of Engineers
USCG . . . . U.S. Coast Guard
USEPA . . . U.S. Environmental Protection Agency
USFS . . . . U.S. Forest Service
USFWS . . . U.S. Fish and Wildlife Service
USGS . . . . U.S. Geological Survey
305(b) . . . National Water Quality Inventory (Clean Water Act)

Figure 3. Federal agencies and National Status and Trends Programs.

- Human infrastructures and activities, such as land use or water intake and effluent discharge facilities and nonpoint sources.
- Ground-water characteristics, which include vertical and lateral extent and hydraulic properties of aquifers and confined units, waste-injection sites, and landfills.
- Natural characteristics, such as soils, geology, altitude, dominant vegetation, and precipitation values.

- *Map the desired goals for the waters.*—The goals that residents wish their waters to meet should be shown as overlays on a multilayer map. These goals will include the water-quality standards that States and Tribes set for their waters and also may include specific additional goals that, for instance, a watershed team may desire.

The ITFM recommends that comprehensive assessments of State or Tribal water resources be conducted by using criteria shown in table 2. In this design, States and Tribes would first characterize their waters with available information and knowledge. Then, on a 5- to 10-year rotating basis or other design (at the discretion of the State or Tribe), they would comprehensively assess their water resources by using different monitoring intensities and techniques according to the conditions of the water bodies and other factors, as described above. Volunteer and private sector monitoring can be integrated into any of the three program priorities, and data from Federal, State, Tribal, local, and private assessments could be shared in all categories. Statistical monitoring designs, as well as targeted and intensive surveys, also can be integrated.

State and Tribal Teams

The ITFM recommends the establishment of collaborative teams at the State or Tribal level that would include representatives of all the major monitoring sectors active in the jurisdictions. The primary responsibility for promoting collaborative water-monitoring and assessment programs should reside with a national monitoring council and with the State or Tribal teams. In some places, the establishment or use of existing monitoring teams may be appropriate. For example, each State or Tribal team also should include, as needed, representatives from Federal, regional, and local agencies, and other institutions, such as universities, industrial organizations, and volunteer monitoring groups that collect and analyze surface and ground-water information within the State or Tribal geographic area.

The State or Tribal and regional teams would have several principal functions. They would clarify roles and responsibilities and facilitate communication and collaboration among Federal, State, Tribal, interstate, local, and private water-monitoring and assessment programs that participate in the strategy. They would identify major issues or programs that joint efforts could address most effectively. Also, the teams would tailor the national guidelines to meet regional needs and encourage their adoption by participating agencies and institutions.

Watershed Managers

Managers of local watershed resources need aggregated data from a variety of sources to guide their policies and activities. To help meet this need, the ITFM recommends that a National Water-Quality Monitoring Council develop a guidance document that summarizes where existing data can be found. Some organizations are already addressing this need. The U.S. Forest Service (1994) and the U.S. Environmental Protection Agency (1991) have written watershed-assessment handbooks; the U.S. Forest Service (USFS) handbook describes ecosystem management for forested watersheds. The Soil Conservation Service (1994) has prepared a handbook on monitoring water-quality conditions that are related to agricultural activities. The American Society for Testing and Materials (ASTM) is developing a standard for water-quality monitoring in conjunction with the ITFM. As part of the nationwide strategy, the proposed National Water-Quality Monitoring Council will work with agencies, private and volunteer organizations, and academia to produce a handbook for monitoring and assessing water-quality watersheds that is applicable for nationwide use.

The ITFM encourages agencies at all governmental levels to develop and evaluate monitoring and assessment programs by using the frameworks for monitoring program design that are described in Technical Appendixes B and L. The ITFM also promotes the coordination of new and existing ambient- and compliance-monitoring programs to provide needed information within watersheds and other geographic areas of concern for all potential data users. Each monitoring program is specific to its geographic location and purpose. At the same time, each is a part of the nationwide monitoring

effort to generate information on surface- or groundwater conditions, which is the basis for regional and nationwide descriptions of water quality. Unless each monitoring program develops comparable information on mutually selected core indicators, the regional and the nationwide descriptions will be difficult to assemble, and comparison of conditions among locations will be difficult.

Compliance and Ambient Monitoring

Ambient information is critical to compliance efforts, and compliance information about pollution locations and loads is needed to interpret ambient data. Compatible compliance information about pollution loads is vital to assessing the relative contributions of point and nonpoint sources of pollution for watershed management. In many cases, the compliance community performs some ambient monitoring, most of which is for compliance-monitoring purposes. For example, water suppliers monitor source-water supplies to determine the treatment needed for drinking water. During its third year, the ITFM began working with organizations that represent the regulated community to define how these programs can more effectively work together.

The regulated community—industry, public water suppliers, municipalities, and others—provides much of the money spent for water-quality monitoring, most of which is spent for compliance-monitoring purposes. Much of the compliance and ambient data generated by the regulated community, however, is unavailable for other uses because of differing designs and goals in collecting the data and also because no one has asked for it in a systematic way beyond its narrow compliance context. Also, these same data are not likely to be available in the future until capture and storage of the data become easier. Because of its unavailability and because it was collected for different purposes, often using different methods and quality assurance/quality control (QA/QC), data from the regulated community have been used infrequently in ambient-assessment studies.

The ITFM monitoring strategy is to form partnerships among compliance monitors and ambient monitors to make applicable data from both communities more usable and accessible. The goal is to find opportunities that are mutually beneficial and more efficient to gather data and develop more useful and comprehensive interpretive products. Because of the different purposes for which data is collected, it may not always be possible to integrate ambient and compliance information. However, some integration will be beneficial, particularly in the area of source-water monitoring for drinking water. It also will be useful to determine natural seasonal variability, to separate natural from anthropogenic causes, and to identify spacial variability.

Potential areas of cooperation include developing a data-storage system that is easily accessible, that is easy to use for data entry and retrieval, and that can store generally useful compliance data. For example, water suppliers' data could go into the new USEPA Public Water Supply System, ambient data collected by dischargers could go into the modernized USEPA's STOrage and RETrievel System (STORET) system, or interfaces could be built between facility data systems and national or State data systems.

In return, agencies would work with the regulated community to:

- Consider adjusting the frequency and parameter coverage of required compliance monitoring in accord with geographic water-quality conditions.
- Design ambient monitoring at locations selected to provide users of raw water with timely water-quality information.
- Develop jointly and use comparable protocols and QA guidelines for ambient- and compliance-monitoring activities so that data can be aggregated for differing objectives.
- Include the regulated community in training programs as instructors and attendees.
- Use the water-quality information more effectively to make key resource decisions.

Closer cooperation on monitoring can help the compliance-monitoring community and State or Tribal environmental agencies identify more cost-effective ways to protect the environment. For example, Florida is considering ways to allow a reduction in compliance monitoring at wells after water companies have achieved an effective well-head-protection program that minimizes the likelihood of contamination in the aquifer.

To enhance the integration of compliance- and ambient-monitoring information for decision-making, the ITFM, under the leadership of the USEPA and the USGS, plans to initiate pilot projects in selected NAWQA Program study units and other key watersheds. The general approach for the pilot project will involve defining the areas of

study, identifying the water-quality information needs and objectives for the area, determining the limitations of existing compliance and ambient programs to meet those needs, implementing actions to overcome the impediments encountered and to provide the necessary information, evaluating the strengths and weaknesses of actions taken, and collaborating to improve the balance between compliance and ambient information.

Examples of questions that could be addressed in these projects include the following:

- What contaminants are important for monitoring in the selected watersheds and aquifers? What are their sources? How frequently does an area need to be sampled to address key management issues and concerns?
- What are the sources, transport, fate, and effects of selected contaminants in important stream reaches or in the watershed as a whole?
- Does the information collected during the project provide a clear framework for key management and control decisions by the key stakeholders in the watershed?
- How do pollutant loadings affect the biological condition of the waters?

Volunteer Monitoring

Nationwide, participants in more than 500 volunteer monitoring programs are collecting a great variety of water-quality information. These programs involve more than 340,000 volunteers of all ages and backgrounds in almost every State. Volunteers monitor all types of water bodies and collect physical, chemical, biological, and habitat data.

In general, volunteers monitor for one or both of the following purposes:

- To provide an opportunity when the community, youth, land owners, and planners can become educated about local water-resources characteristics and problems, and a sense of stewardship is fostered for those natural resources.
- To provide data for Federal, State, Tribal, and local water-quality agencies and private organizations for use in watershed planning, assessment, and reporting and water-quality manage-ment Volunteers collect data from water that otherwise may not be assessed, and they increase the amount of water-quality information available to decisionmakers at all levels of government. Uses of volunteer data include delineating and characterizing watersheds, screening for water-quality problems, some compliance monitoring if rigorous quality assurance documentation is provided, and measuring baseline conditions and trends.

Because volunteer monitoring organizations can be strong partners in the nationwide monitoring strategy, the ITFM recommends integrating volunteer monitoring into existing and planned monitoring programs. To improve the quality and utility of volunteer efforts, the ITFM recommends the following:

- Links between volunteer monitoring programs and water-quality and planning agencies should be established at all levels of government to encourage cooperative planning, training, and data exchange between volunteer groups and agencies. These links may include State or Tribal associations or councils of volunteer program coordinators and agency representatives, agency-sponsored volunteer programs, and sharing and collaboration in such areas as volunteer training, data management, and resource sharing.
- Nationally consistent quality-assurance guidance should be developed for volunteer monitoring groups to help volunteer programs document their methods and quality-assurance protocols. This national guidance can be adapted to meet individual State, regional, Tribal, or local data requirements. The USEPA is currently leading such an effort that involves other Federal, State, Tribal, and volunteer organizations. Such documentation has the following benefits:
  - Enhances credibility and replicability of volunteer methods.
  - Allows volunteer collection and analytical methods, site selection, and other volunteer program design characteristics to be understood by potential data users.
  - Allows volunteer data to be compared with those of other programs.
  - Encourages volunteer programs to practice sound quality-assurance methods.
- Standard volunteer monitoring field methods should be developed. Use of these methods cannot be mandatory because of differing needs, goals, capabilities, and resources of volunteer programs. However, their development and availability will provide a common baseline for many programs, thereby improving comparability among the programs.

- Nationwide training on laboratory, field, and quality-assurance methods for volunteers should be promoted. Such training helps encourage consistency in methods, increases the level of quality assurance for volunteer information, and promotes the exchange of ideas and the development of advanced methods.
- The incorporation of proper documentation of volunteer data into water-quality-data systems should be promoted to facilitate data sharing and use of volunteer data. Documentation in water-data systems of volunteer collection methods, analytical approaches, and quality-assurance protocols helps potential data users understand the limitations and strengths of volunteer data, thereby increasing confidence in its use.
- Volunteer participation should be provided for on State, Tribal, watershed, aquifer, and regional water-monitoring teams. Volunteer programs will provide these teams with unique links to academic organizations, advocacy groups, civic associations, government, and private enterprise. Team members, including volunteers, will serve to integrate monitoring efforts to meet local, regional, and nationwide information needs.

Methods Comparability

One of the biggest barriers to sharing water-monitoring data is that agencies often use methods that are not comparable to obtain data (collect and analyze samples) for the same variable. This means that data from these agencies cannot be combined to allow scientists and the public to assess water-quality conditions.

To assess similar conditions objectively across a variety of scales up to and including national assessments, monitoring data produced by different organizations should be comparable, of known quality, available for integration with information from a variety of sources, and easily aggregated spatially and temporally. The ITFM recommends several actions to improve data compatibility. First, partners in the strategy must adopt common parameter/indicator names and definitions. This is fundamental to achieving compatible data. The ITFM has begun a Data-Element Glossary that will support data compatibility and facilitate information sharing (Technical Appendix M). Partners in the strategy should begin by adopting the initial set of common names and definitions and then expand that set as rapidly as possible.

In addition, the ITFM strategy proposes a performance-based methods system (PBMS) for the field and laboratory (Technical Appendixes I, N, O). The PBMS accommodates the use of different methods for measuring the same constituent provided that all methods produce the same results for the same sample within a specified level of confidence. Analytical reference materials also can be an important component of a PBMS. This approach is technically practical and allows implementation of improved, and sometimes more economical, sampling and analytical techniques over time. The PBMS will require institutional support at the national level; therefore, the ITFM recommends an Intergovernmental Methods and Data Comparability Board (MDCB; Technical Appendix H).

The ITFM recommends the use of reference conditions in biological and ecological assessments (Technical Appendixes F and G). Reference conditions allow the comparison of observed water-quality characteristics to appropriate baseline conditions; they also can be used to calibrate a method for a specific ecoregion or habitat. As a way to specify reference conditions, the ITFM recommends using the concept of ecoregional reference sites. An ecoregion is a homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables. Such regions help define the potential designated-use classifications of specific water bodies. In theory, reference conditions are single measurements or sets of selected measurements of unimpaired water bodies that are characteristic of an ecoregion and (or) habitat. In practice, reference conditions represent conditions (biological, physical, chemical) exhibited at either a single site or an aggregation of sites that represent the least impacted (by anthropogenic disturbances and pollution) reference sites or the reasonably attainable condition at the least impacted reference sites.

Information Automation, Accessibility, and Utility

The vast amount of water-quality information collected by public and private entities is not often easily accessible to users outside the collecting organization. The principal barriers to data and information

interactions of surface waters. The ITFM recognized these differences and accordingly established a special focus group for ground-water monitoring to ensure that ITFM proposals, such as the framework for monitoring programs (Technical Appendix B), address specific ground-water needs. Additional results of the deliberations of the Ground Water Focus Group are presented in Technical Appendix L, and their work is continuing to address indicators for ground-water monitoring.

Project on Biological Integrity of Surface Waters

As an initial step in implementing the nationwide monitoring strategy, the ITFM proposes that existing information about the biological conditions of streams and rivers be gathered and evaluated. In addition to supporting the goal to conserve and enhance ecosystems, this biological evaluation would initiate the implementation of technical concepts and institutional collaboration integral to the strategy. Most water-monitoring networks were designed and implemented at a time when detection and control of chemical pollutants in water was of paramount importance. Now, however, the need for aquatic biological information is more widely recognized.

In addition, the biological evaluation would integrate information from different organizations, show data gaps, and test recommendations designed to improve information compatibility. Because of differences in monitoring purposes, various Federal, State, and Tribal programs produce data that vary in parameters, spatial density, frequency of collection, analysis methods, and level of QA.

Further actions following the initial data gathering would need to be implemented through a series of iterations of data collection, data interpretation, and voluntary refocusing over an extended time period. The NBS is a key agency to participate in this project.

Training

One of the key implementation issues is that training must be available to all Federal, regional, State, Tribal, local, private, and volunteer personnel involved in water monitoring. Training would be the cornerstone to promoting the use of the monitoring framework, the correct use of environmental indicators, the application of comparable methods of sample collection techniques and analytical methods, the storage and sharing of environmental data, and the use of new methods to interpret and report results.

Training programs are now available in such organizations as the USGS, the USEPA, the U.S. Army Corps of Engineers (USACE), the Tennessee Valley Authority (TVA), the U.S. Department of Agriculture, associations, societies, and the Water Resources Research Institutes and academic organizations. A collaborative effort is needed to conduct water-monitoring and data-management training. Training should include monitoring and data management for water quality. Training would be tailored to selected audiences, which would include managers who use water-quality information for decisionmaking, research scientists, field and laboratory technicians, and interested members of public, volunteer, and private organizations. An interagency training team should be formed at the national level to coordinate an inventory of training programs now available from public agencies, academic institutions, and private organizations and the development of a list of training needs and the number of trainees anticipated, training materials, and plans to meet identified training for different sectors.

Participating agencies should make training available at various locations across the country on a continuing basis; the training would use formal and informal formats as appropriate. The collaborative training plans should include a QA program to measure the effectiveness of training efforts and should include a complete review every 5 years. Training may not be fully implemented for several years because of the massive effort that will be required to organize and operate a coordinated nationwide training effort.

It also is important to broaden training into collaboration and education. Many groups, such as the Nature Conservancy, the Ecological Society of America, and the Association of Environmental Engineering Professors, were involved in commenting on or were suggested as collaborators for implementation of the strategy for nationwide monitoring.

Pilot Studies

Before some ITFM proposals are implemented nationwide, additional pilot studies are needed. Groups working at the national level need feedback to move from strategy to tactics for implementation.

communication that recognizes the particular style, format, media, and content considerations appropriate to each audience. As a corollary activity, mechanisms are needed to ensure the best uses of the technical information derived from assessment activities

Interpretations of results from national programs and the integration of results from State and regional programs should lead to similar conclusions about the conditions of our Nation's water. The only differences in interpretations should be in the areal extent of coverage (presumably broader coverage for the national programs) and the degree of resolution (presumably finer resolution for the regional, State, and Tribal programs). Both types of programs are critical components in the nationwide strategy.

Improved mechanisms for performing and sharing top/down and bottom/up interpretation, assessment, and aggregation of water-resources information will make it possible to produce information products more quickly after resource assessments are completed. However, complex review and approval procedures within many agencies can cause significant delays in releasing those products to their intended audiences. Implementation of an effective national strategy must address issues of timeliness and audience identification for reporting, integrating information across disciplines, comparing data analyses and interpretations, and providing mechanisms for information aggregation (see Technical Appendixes J and K).

Modeling is an assessment tool that uses data, helps identify data needs, and allows management decisions to be made on the basis of predictions. Implementation of the ITFM strategy should include use of modeling.

Evaluation of Monitoring Activities

Collaborative teams at all levels should periodically evaluate their monitoring activities to confirm that they are meeting their objectives in the most effective and economical manner. The successor to the ITFM should produce a report every 5 years to evaluate water-quality-monitoring activities and to document progress in implementing the nationwide strategy and making appropriate adjustments. This report should include a summary of water-monitoring activities over the previous 5 years, an evaluation of the applicability of the monitoring program, and the Nation's ability to obtain and share information needed to evaluate water quality. The report should present successes at the national and the watershed scales and should identify continuing barriers to understanding water-quality conditions. This report should not address the status of water-quality conditions; existing Federal, regional, State, and Tribal agencies have that responsibility. However, greater collaboration and information sharing should enhance the individual reports.

Ground-Water and Other Specific Water-Resource Considerations

Selected categories of aquatic resources should receive specific attention when water-quality-monitoring programs are planned and implemented. These categories include ground water, wetlands, lakes, and coastal water. For these categories, additional guidance and recommendations are needed to supplement the general information provided throughout this report. The ITFM has addressed some of the monitoring issues specific to ground water, and the results are discussed below. However, additional work needs to be done on the other three categories. Focus groups of appropriate experts are needed to develop guidelines and to make recommendations for these three resource categories.

Historically, ambient-water-quality considerations have focused on surface-waters. The original goals of the Clean Water Act primarily targeted State-designated uses for surface waters. Surface and ground waters are, however, hydraulically connected. Geochemical processes are reflected in the quality of ground water and can profoundly affect surface-water quality and aquatic biota because approximately 40 percent of flowing surface water comes from ground water.

Water-quality-monitoring programs must consider differences in spatial, temporal, and other characteristics between ground- and surface-water resources. Ground water normally is not easily accessed for monitoring, and suitable wells must be located or drilled (except in special circumstances). Further, ground water has distinct three-dimensional distributions within geologic formations of rock and soil that are often in units that have very different physical, chemical, and biological characteristics. In particular, water flows in aquifers at extremely slow rates compared with surface-water-flow rates. For example, ground water may move fractions of an inch per day, or even per year, while streams and rivers frequently move miles per day. As a result of these and other differences, ground-water interactions with the biosphere and lithosphere differ significantly from the

interactions of surface waters. The ITFM recognized these differences and accordingly established a special focus group for ground-water monitoring to ensure that ITFM proposals, such as the framework for monitoring programs (Technical Appendix B), address specific ground-water needs. Additional results of the deliberations of the Ground Water Focus Group are presented in Technical Appendix L, and their work is continuing to address indicators for ground-water monitoring.

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In addition, the biological evaluation would integrate information from different organizations, show data gaps, and test recommendations designed to improve information compatibility. Because of differences in monitoring purposes, various Federal, State, and Tribal programs produce data that vary in parameters, spatial density, frequency of collection, analysis methods, and level of QA.

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Training programs are now available in such organizations as the USGS, the USEPA, the U.S. Army Corps of Engineers (USACE), the Tennessee Valley Authority (TVA), the U.S. Department of Agriculture, associations, societies, and the Water Resources Research Institutes and academic organizations. A collaborative effort is needed to conduct water-monitoring and data-management training. Training should include monitoring and data management for water quality. Training would be tailored to selected audiences, which would include managers who use water-quality information for decisionmaking, research scientists, field and laboratory technicians, and interested members of public, volunteer, and private organizations. An interagency training team should be formed at the national level to coordinate an inventory of training programs now available from public agencies, academic institutions, and private organizations and the development of a list of training needs and the number of trainees anticipated, training materials, and plans to meet identified training for different sectors.

Participating agencies should make training available at various locations across the country on a continuing basis; the training would use formal and informal formats as appropriate. The collaborative training plans should include a QA program to measure the effectiveness of training efforts and should include a complete review every 5 years. Training may not be fully implemented for several years because of the massive effort that will be required to organize and operate a coordinated nationwide training effort.

It also is important to broaden training into collaboration and education. Many groups, such as the Nature Conservancy, the Ecological Society of America, and the Association of Environmental Engineering Professors, were involved in commenting on or were suggested as collaborators for implementation of the strategy for nationwide monitoring.

Pilot Studies

Before some ITFM proposals are implemented nationwide, additional pilot studies are needed. Groups working at the national level need feedback to move from strategy to tactics for implementation.

More tailored guidance is needed to ensure that the flexibility required in different areas of the country is accommodated. In addition, information on implementation costs and on the savings that result from improvements also are needed. Although the ITFM believes that many improvements to monitoring can be accomplished within available resources, such improvements must be thoughtfully planned and coordinated. When program updates or new monitoring efforts are funded, the ITFM recommendations can be more readily accommodated However, special care must be taken to ensure that attempts to implement aspects of the strategy by using available monitoring resources do not adversely impact existing monitoring that now supports critical objectives.

Incentives

Because of its voluntary nature, the strategy proposed by ITFM must offer tangible benefits to encourage organizations that monitor or fund water-quality activities to participate in the strategy. The major incentives for participation are discussed below:

- By improving water-quality information nationwide, public and private organizations can increase the effectiveness of natural-resources management and environmental protection efforts and can document the benefits of actions taken This will answer the water-quality questions listed at the beginning of this report that Federal agencies are often asked by Congress and that agencies at all scales are asked by the public. Multiple agencies with varied expertise and responsibilities working together on the same problem will have the information necessary to achieve comprehensive ecosystem management for aquatic and related terrestrial resources. Managers will be able to make more effective decisions and to consider policies and programs more comprehensively. Disagreements among agencies about water-quality conditions and assessment results will be fewer, and it will be possible to base more decisions on objective information rather than on opinion. State, Tribal, and local agencies with enforcement responsibilities will have a better technical basis for taking regulatory action. The regulated community will have more complete knowledge to ensure that actions required of them will correct environmental problems. Better, more comprehensive information will improve the connection between public programs and the conditions they are supposed to address.
- Because data collection will be coordinated, use of available resources will be more effective, and efforts will not be duplicated. Monitoring programs that evolve from a coordinated effort among major data-collecting agencies in an area will provide more complete coverage in space, time, and parameters. The resulting information will better support decisionmaking for complex contemporary problems and allow for joint monitoring and assessment of water-quantity and water-quality and surface- and ground-water issues. Partnerships among agencies responsible for compliance- and ambient-monitoring programs will be able to design programs that complement each other. These coordinated and collaborative programs produce a consistent distributed data set that is jointly supported by many agencies and that includes agreed-upon data-quality-control measurements. The coordination and collaboration also will identify the ancillary data, as well as the scale and accuracy, that is needed.
- Participants in the ITFM strategy will have tools to monitor water quality more effectively Examples of these tools include:
  - Common format for designing monitoring programs.
  - Comparable use of indicators.
  - Comparable performance-based methods used for field and laboratory work.
  - Consistent QA/QC activities that produce data of known quality.
  - Metadata collected and recorded to aid with interpretations.
  - Ancillary data needs identified, located, and shared.
  - Compatible data-storage system
  - Software that encourages data sharing.
  - Methods for data analysis.
  - Examples and guidelines for publishing and speaking to many types of audiences
  - Formats for evaluating the effectiveness of monitoring programs.
- Valuable services will be provided for participants in the strategy. The services will

include guidance and advice on new pollutants, new research methods, and interagency questions. The ITFM will be able to review and advise on newly designed monitoring programs, as well as on agency and organization collaboration among existing ones.

- The training program to promote the use of guidelines and recommendations will be available to all participants and will bring together talents, skills, and knowledge from Federal, State, Tribal, watershed, local, and private representatives and volunteers.
- The credibility of water-quality information will improve as many organizations produce the information and agree on its assessment and presentation

Implementation

An institutional infrastructure is needed to support the implementation of the strategy. The infrastructure should include a national collaboration forum and formal or informal State and Tribal implementation teams. If State or Tribal entities identify the need for regional or watershed-level implementation teams, then regional teams also should be used to carry out the strategy. It is important to the success of the strategy that existing collaborative mechanisms be used to the extent possible. Maximum flexibility is needed at the interstate, the regional, and the watershed levels to assure effective implementation. Figure 4 shows an overview of the proposed organizational framework.

National Water-Quality Monitoring Council

A National Water-Quality Monitoring Council will be established to carry forward national aspects of the strategy. The National Council would develop guidance and tools to provide technical support and serve as a forum for collaborative program planning. The viewpoints of business, academia, and volunteers are critical to the successful implementation of the strategy. Membership on the National Council would include the private sector, volunteer monitoring organizations, and government agencies at all levels—Federal, State, Tribal, interstate, and local. Non-Federal representation would be drawn from various geographic areas of the country to cover the full range of natural, social, and economic settings. The National Council would operate as part of the Water Information Coordination Program (WICP), which is required by OMB Memorandum No. 92–01. A draft charter for the proposed National Council is presented in Technical Appendix C.

The National Council would assume broad responsibility for promoting implementation of the nationwide monitoring strategy and the ITFM recommendations that would improve monitoring and resource assessments in the United States. In principle, the National Council would facilitate monitoring and assessment programs to fulfill their intended initial purpose and support national compatibility and information sharing where purposes overlap. The National Council would be concerned with water monitoring, which has been broadly defined to include measuring the physical, chemical/toxicological, and biological/ecological characteristics of surface and ground waters, including freshwater, marine, and wetlands, as well as associated data that involve habitat, land use, demographics, weather, and atmospheric deposition. The National Council would coordinate its activities with the ongoing work of the Federal Geographic Data Committee (FGDC), which is authorized by OMB Circular A–16. The National Council would be concerned with the monitoring of streams, rivers, lakes, estuaries, wetlands, coastal and ground waters, sewer and industrial outflows, and public drinking-water sources (not finished water). It would consider the following monitoring purposes, which are implemented by individual monitoring agencies: to assess status and trends, to identify and rank existing and emerging problems, to design and implement programs, to determine whether goals and standards are being met, to assure regulatory compliance, to facilitate responses to emergencies, to support hydrologic research, and to help target monitoring, prevention, and remediation resources.

The National Council would issue voluntary guidelines to promote consistency. These guidelines would address the comparability of field and laboratory methods, recommended minimum sets of parameters for specific monitoring purposes, environmental indicators, QA programs, metadata requirements, data management and sharing, and reader-friendly formats for reporting information to decisionmakers and the public.

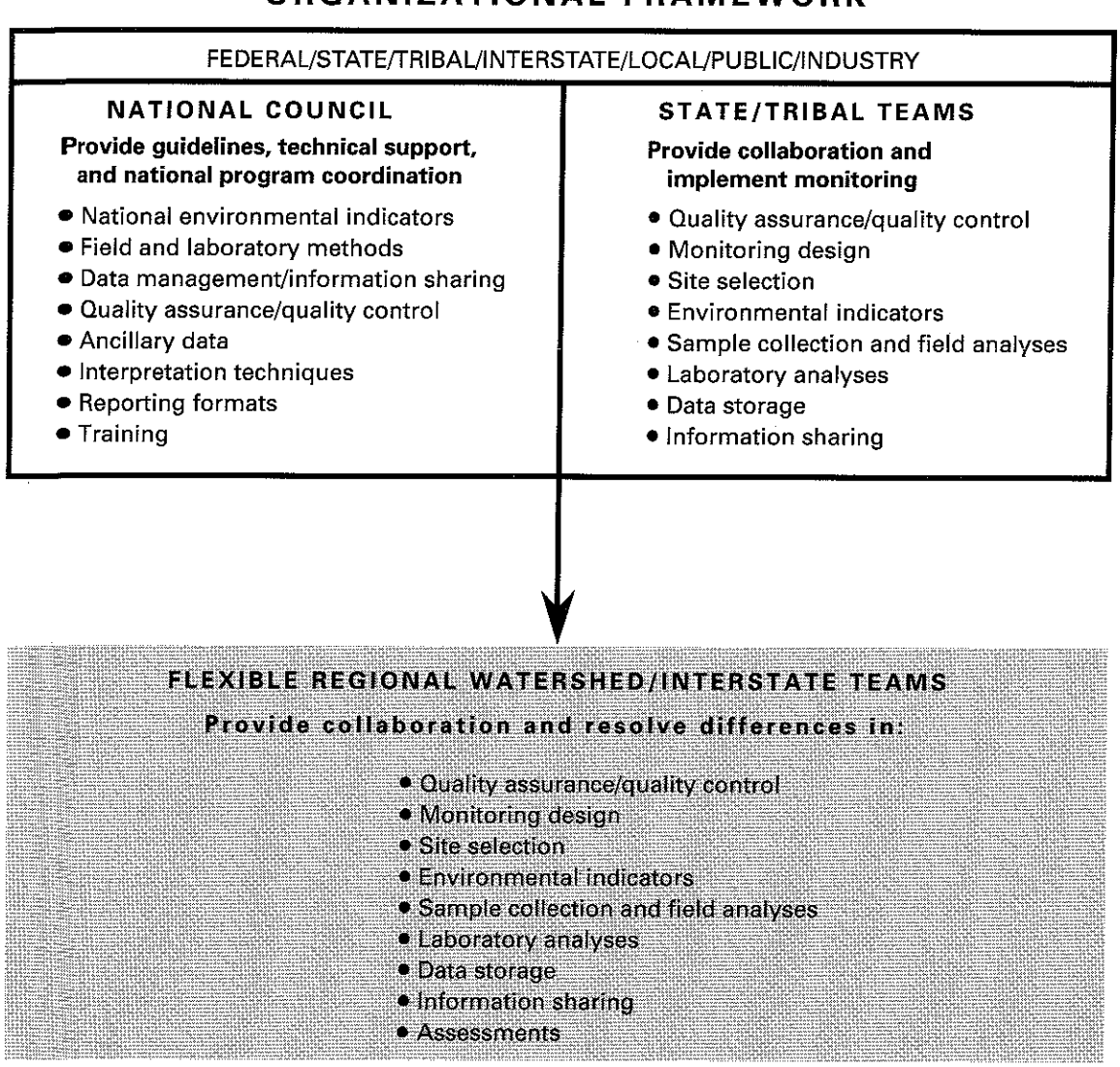

Figure 4. Organizational framework for implementing the strategy.

These guidelines would build on the progress achieved by the ITFM and other groups, should yield significant improvements in the nationwide consistency of data-collection activities, and should provide comparable methods and results when reporting and sharing data. The National Council would encourage the voluntary adoption of these guidelines by relevant federally funded State, Tribal, public, and private organizations operating watershed monitoring and assessment programs and other monitoring efforts. Through its relations with State and Tribal teams, it also would promote adoption of these guidelines by cooperating State, Tribal, regional, and local agencies, as well as private and volunteer organizations. The National Council would coordinate the development of a nationwide training effort to help ensure that appropriate individuals acquire the knowledge and skills needed to carry out monitoring and assessment responsibilities.

To facilitate implementation of the Strategy, the ITFM recommends that the Administration consider issuing an Executive order that provides guidance and requirements for Federal agencies with water-quality-monitoring responsibilities.

Methods and Data Comparability Board

To provide the national infrastructure necessary to implement methods comparability, the ITFM recommends that an MDCB be established under the auspices of the National Council. The mission of

the MDCB would be to promote and coordinate the collection of monitoring data of known quality by using comparable field techniques and analytical chemical and biological measurement methods, where objectives are similar, through the voluntary participation of the monitoring community. A draft charter for the MDCB is provided in Technical Appendix H

The scope of the MDCB would be to provide a framework and a forum to identify interagency priorities for parameters that most need comparable methods, to take actions that improve the scientific validity of water-quality data, to establish comparable approaches among agencies for collecting water-quality-monitoring information, to provide a forum for advancing state-of-the-technology water-quality methods and practices, and to assist all levels of government in collecting monitoring information in a comparable and coordinated manner. The MDCB would work closely with other organizations that promote methods comparability, such as the ASTM and the USEPA's Environmental Monitoring Management Council.

Environmental Indicators Guidance Committee

To develop necessary guidance for indicators, the ITFM recommends establishing an Environmental Indicators Guidance Committee that would carry on the activities of the ITFM's Environmental Indicators Task Group work in conjunction with the MDCB. The National Council and this Committee should develop guidelines for the selection and reporting of environmental indicators and criteria for determining reference conditions to assess water-quality and related ecological systems. Also, the National Council and this Committee should adopt recommended data elements for water-quality-data systems and the minimum elements to facilitate the sharing of environmental indicator information.

Data-Elements Glossary

The ITFM's Data Management and Information Sharing (DMIS) Task Group has prepared a Data-Elements Glossary to support data collection, interpretation, presentation, and sharing (Technical Appendix M). The full glossary of recommended data elements represents the base data requirement proposed for implementation as agencies develop new water-quality-data systems. The DMIS Task Group also has identified minimum data elements that are needed to share water-quality data effectively among existing systems. The minimum data elements would be incorporated in user interfaces of data systems maintained by participating agencies. Finally, the DMIS Task Group has identified core water-quality-data sets, such as ecoregions, hydrologic units, river reaches, land use/land cover, taxonomic codes, and aquifer names, that will be maintained by one organization or a consortium of organizations and shared by all ITFM organizations. The next steps will involve reaching an agreement on minimum data sets and common data-exchange formats. Modern technology can now provide the means to achieve data sharing and efficiencies not thought possible just a few years ago.

The ITFM recommends that the National Council promote a coordinated effort of data-management-system enhancement or development with the objective of creating linked multiagency information systems with common standards. Agencies would not develop a common system, but rather a linked series of key systems that would coordinate their designs to facilitate the storage of data at many locations and still be able to share information effectively. This coordinated design would involve the sharing of data models and, in some cases, data-base structures; environmental data and associated QA information would be maintained in a data manage-ment system operated by the Federal, State, Tribal, or local agency or private organization responsible for collecting the data. The design also would include an interface whose components would be used by all participating organizations. The interface would include the ability to query the various data bases by using the minimum data elements of the DMIS Task Group. The coordinated design also should include a series of standard reports and (or) an exchange format. This effort would likely need a multiagency consortium to design, develop, test, implement, and maintain the linked systems.

Funding

Some Federal resources must be provided to help support pilot studies in selected areas. The USEPA is planning to provide $500,000 to selected States during FY 1995. The USEPA worked with the ITFM and the States to determine how the monies can best be used to achieve targeted comprehensive monitor-ing to measure progress toward the nationwide goals. Much of the money will be used to georeference State waters to RF3. USEPA also targeted $2 million to Tribal monitoring programs. In addition, the USGS will identify the implementation of the ITFM strategy

as one of the priorities of the National Water Resources Research and Information System—Federal/State Cooperative Program in Fiscal Year 1995 and beyond. Through the Cooperative Program, agencies at State, Tribal, and local levels of government are partners with USGS in data collection and special studies of mutual interest on a 50/50 cost-sharing basis. This priority will provide an edge for ITFM pilot studies and future water-quality-monitoring-design efforts that compete for Federal matching funds. In FY 1995, the appropriated Federal matching funds in the Cooperative Program will exceed $60 million. The above funds are in addition to Federal monies already available to States and Tribes for monitoring through existing mechanisms in a number of agencies including the USEPA Section 106 grants.

Better environmental protection and resource-management decisionmaking, which are the results of better monitoring, will result in cost savings. By improving and using more complete water-quality-monitoring results, decisionmakers can target scarce financial and other resources to priority problems, evaluate the effectiveness of actions taken, make needed adjustments, and avoid costly mistakes. Many of the recommendations can be jointly funded within existing budgets by the participating agencies. In some cases, financial agreements will be developed among agencies to support mutually beneficial monitoring projects. In other cases, basic agreements exist and are being used. Because the strategy will be implemented over time and almost all the recommendations are intended for future monitoring, major adjustments in funding are not required in the short term. By leveraging technical capability and cost sharing, agencies can make better use of existing expertise and funding resources nationwide. It is noteworthy, however, that the early successes of the ITFM are due, in large part, to the energy and enthusiasm of the members and contributions from participating agencies for specific projects. A modest amount of short-term funding to support the administrative infrastructures for the groups that are implementing the strategy may be needed. Such support would ensure that the process of collaboration continues, thereby allowing the Nation to realize the expected long-term benefits and efficiencies. This would allow all participants to achieve a higher return for their existing and future investments. As changes are made, the savings will be used to support improvements in other functions. The result will be more cost-effective monitoring and a significant expansion and improvement in the information that can be used for decisionmaking. As the strategy is implemented and participating agencies jointly develop and implement detailed plans, specific information on cost savings and costs for implementation should be documented and reported. After available funds are used effectively, then participating agencies will need to address resource requirements for future actions.

Initial Agency Actions to Improve Monitoring

Benefits from the ITFM 's strategy and recommendations are already being identified. Member agencies have taken significant steps to improve water-quality monitoring and to achieve cost savings now and in the future. The progress to date includes actions that foster different aspects of the strategy. Selected examples are presented below.

Eight Federal agencies, which include the Smithsonian Institute, the Agricultural Research Service (ARS), the National Marine Fisheries Service (NMFS), the National Resources Conservation Service (NRCS), the NBS, NOAA's National Ocean Data Center, the USEPA, and the USGS, are taking an important step forward to improving consistency among Federal data-storage systems that contain biological information. These agencies are developing joint agreements to maintain and use the same reference table for taxonomic codes. The codes would be related to the same taxonomic identifiers and hierarchy in the participating agencies' automated information systems. NOAA, the USEPA, and the USGS have agreed to use these codes. This major advance will reduce costs and facilitate data sharing among the systems. It is the first time that more than two agencies have agreed to support and use the same taxonomic codes.

Five Federal environmental monitoring programs in the USEPA, the NBS, the USGS, and NOAA have formed a partnership with the USGS's Earth Resources Observation Systems (EROS) Data Center to facilitate the development of comprehensive land-characteristics information for the United States. The Multi-Resolution Land Characteristics Consortium is generating land-cover data for the conterminous United States and is developing a land-characteristics data base that meets the diverse needs of the participating programs. Cost savings for purchasing the data are $4 million, and large additional savings will result from the joint image-processing and data management.

Regarding modernizing or creating new Federal information systems, the USEPA is modernizing STORET, and the USGS is modernizing its system (NWIS–II). For many years, much water-quality information collected by the USGS has been loaded into STORET. During this modernization phase, the agencies are working closely together to implement common data-element names and reference tables that will make it easier to exchange and aggregate data. In addition, the USGS has worked with the NBS to facilitate the compatible development of their information system. Such initiatives will make it easier for States and others to aggregate information from Federal systems. Also, success-ful efforts to make Federal systems compatible will encourage the non-Federal sector to adopt the common data-element names and reference tables. Significant cost savings nationwide over long periods of time and a larger, more useful environmental information base will result from such compatibility.

With leadership from the USEPA, the ITFM created the Master Directory of Water Quality and Ancillary Data that includes printed texts, data, and indexes of data holdings (U.S. Environmental Protection Agency, 1993). The Master Directory is available on diskette, CD–ROM, and Internet. The Master Directory greatly simplifies users' access to relevant information and reduces costs by using modern information-transfer technology.

The ITFM has initiated pilot studies in three member States to help develop and test concepts. Federal, State, and local agencies are participating in these initiatives. Arizona is focusing on data management and information sharing. Florida is developing a statewide network that integrates surface- and groundwater monitoring in the Suwannee River Basin. Wisconsin is comparing monitoring methods used by Federal and State agencies and evaluating the differences in the results; the ultimate goal is to improve the comparability of data for Wisconsin so that data can be aggregated for a variety of applications.

The ITFM sponsored 10 regional meetings during summer 1993 to review its proposals and recommendations and to discuss monitoring opportunities and problems in the Federal regions. Additional meetings and review activities to contribute final comments and facilitate regional collaboration were held in 1994. In addition, Florida, Idaho, New Jersey, and Wisconsin have held statewide monitoring meetings that have included monitoring organizations and information users. The purpose of these meetings is to begin the design of statewide monitoring strategies. During the review of this strategy, other States, which included California, Michigan, Minnesota, and Arizona, stated they were pursuing collaborative monitoring teams of some kind.

In the area of monitoring program design, the USEPA, the States, and the Tribes are using the ITFM monitoring program framework as the basis for developing monitoring guidance for the USEPA Section 106 grants to States and Tribes. The use of the program throughout the Nation will significantly improve the usefulness of water-quality information and the cost effectiveness of the programs (Technical Appendix B). Federal agencies also are redesigning monitoring programs to parallel the ITFM program concepts more closely. For example, the USGS is redesigning NASQAN to implement such monitoring concepts, as well as to respond to budget constraints. The USACE is developing guidance documents for its water-quality-monitoring program that closely parallels the ITFM recommendations. This guidance will address water-quality-monitoring activities at hundreds of USACE projects nationwide.

The ITFM analytical work related to indicators is a major contribution to proposed changes to the USEPA guidelines for the States' 1996 305(b) reports. These changes are being made in consultation with representatives from Federal, State, Tribal, and interstate agencies that conduct environmental monitoring and assessment activities. The changes to the guidelines will produce more comparable information and will help link the information collected more directly to water-quality goals nationwide.

Regarding the establishment of ecological reference sites and conditions, representatives from States, USGS/NAWQA, and USEPA/EMAP are working together to identify and use reference conditions characteristic of waters and associated habitats that meet desired goals. The resulting reference conditions are needed as baselines against which to compare and assess the biological integrity of aquatic systems generally. All levels of government and the private sector will be able to use the information generated from the reference sites and conditions to make more effective regulatory and resource-management decisions.

The USGS, through the NAWQA Program, hosted an interagency workshop on the biological methods used to assess the quality of streams and rivers (U.S. Geological Survey, 1994). The purposes of the workshop were to promote better communication among Federal agencies and to facilitate

data exchange and interagency collaboration. The workshop focused on community assessment methods for fish, invertebrates, and algae; characterization of physical habitats; and chemical analyses of biological tissues. The 45 biologists who attended the workshop evaluated similarities and differences among biological monitoring protocols and identified opportunities for collaboration and research, improving data compatibility, and sharing information.

Conclusion

Implementation of the recommendations and strategy in this report will result in an adequate water-information base to achieve natural-resource-management and environmental protection goals in the public and the private sectors. Identified changes are already being made, but implementation of the full strategy cannot be achieved quickly. Each participating organization will need to revise its monitoring activities in a series of deliberate steps over several years as money and time become available. However, because benefits from the changes are incremental, improvement of water-quality monitoring has begun as described in the preceding section.

As the competition for adequate supplies of clean water increases, concerns about public health and the environment escalate, and geographically targeted watershed-management programs increase, more demands will be placed on the water-quality-information infrastructure. These demands cannot be met effectively and economically without changing our approach to monitoring. The agencies that participated on the ITFM believe that the implementation of this strategy for nationwide water-quality monitoring will provide sound answers to the fundamental questions posed in the introduction to this report.

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ACRONYMS USED IN THIS REPORT

ARS	Agricultural Research Service
ASCS	Agricultural Stabilization and Conservation Service
ASTM	American Society for Testing and Materials
BEST	Biomonitoring of Environmental Status and Trends Program
BIA	Bureau of Indian Affairs
BM	Bureau of Mines
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
BPA	Bonnevile Power Administration
CD–ROM	Compact Disc–Read Only Memory
DMIS	Data Management and Information System
DOE	U.S. Department of Energy
DOD	U.S. Department of Defense
EMAP	Environmental Monitoring and Assessment Program (USEPA)
EROS	Earth Resources Observation System
FERC	Federal Energy Regulatory Commission
FGDC	Federal Geographic Data Committee
FY	Fiscal Year
GAP	Gap Analysis Program (NBS)
GIS	geographic information system
ITFM	Intergovernmental Task Force on Monitoring Water Quality
M–92–01	Office of Management and Budget Memorandum No. 92–01
MDCB	Methods and Data Comparability Board
MOSAIC	A software package for Local World Wide Web on the X-Window system
NASQAN	National Stream Quality Accounting Network (USGS)
NAWQA	National Water-Quality Assessment (USGS)
NBS	National Biological Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NS&T	National Status and Trends Program (NOAA)
NWI	National Wetlands Inventory (USFWS)
NWIS–II	National Water Information System (USGS)
OMB	Office of Management and Budget
OSM	Office of Surface Mining
PBMS	performance-based methods system
QA/QC	Quality Assurance/Quality Control
RF3	River Reach File 3
STORET	STOrage and RETrieval System (USEPA)
TVA	Tennessee Valley Authority
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAIS	wide-area information server
WICP	Water Information Coordination Program